Study of Ambient Air Quality at Avonmouth

8 August 2014 – 10 December 2014

Report – AAM/TR/2015/01

We are The Environment Agency. It's our job to look after your environment and make it **a better place** – for you, and for future generations.

Your environment is the air you breathe, the water you drink and the ground you walk on. Working with business, Government and society as a whole, we are making your environment cleaner and healthier.

The Environment Agency. Out there, making your environment a better place.

Published by:

Environment Agency
Horizon house, Deanery Road
Bristol BS1 5AH
Tel: 0117 934 4000
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

Address for Enquiries:

Ambient Air Monitoring Team
Environment Agency
Lutra House,
PO Box 519
Preston
PR5 8GD

Tel: 01772 714324
Email: AAMTEAM@environment-agency.gov.uk

Executive Summary

This report provides the results from a study of ambient air quality in the vicinity of Avonmouth Docks, in Bristol. The Environment Agency's Ambient Air Monitoring Team (in National Monitoring Services) carried out the study between 8 August 2014 and 10 December 2014 (125 days) on behalf of the Wessex area.

The report presents the measured levels of particulate (TSP and PM_{10}) and compares these levels with the objectives of the UK Air Quality Strategy (AQS), where applicable.

The report also provides analysis of measured levels of total suspended particulate (TSP), PM_{10}, $PM_{2.5}$ sulphur and heavy metals, collected between 4 September 2014 and 10 December 2014 (98 days) by TRL Ltd near Portview Road, Bristol, on behalf of the Bristol City Council.

Rainfall data provided by the Bristol Port Company has been used to consider the impact of this variable on particulate concentrations.

Comparison of the PM_{10} and $PM_{2.5}$ data with the relevant AQS objectives indicated that the current standards would not be expected to exceed at the MMF and TRL monitoring sites.

Comparison of PM_{10} and $PM_{2.5}$ concentrations with the Air Quality Index indicated that the concentrations were in the low banding for $\geq$98% of the monitoring period respectively.

PM_{10} concentrations at the MMF and TRL monitoring sites are shown to be in a similar range to those measured at the AURN monitoring station at Bristol St Pauls, but they are generally higher.

Directional analysis suggests that the MMF and TRL monitoring sites are seeing elevated contributions from different localised sources of particulate.

Consideration of rainfall data suggest that lower PM_{10} concentrations were seen when there was higher rainfall.

Sulphur samples showed monthly mean concentrations ranging from 0.5 - 2.3µg/m^3 with a higher monthly mean seen in September, which was identified as a drier month than October and November.

The measurement of heavy metal concentrations showed concentrations that were below the 2012 UK averages. Although the period of sampling only covers a few months, the levels did not suggest that there would be exceedances of relevant health based guidelines if metal concentrations remained at these levels.

Complaints of dust were reported over the monitoring period when the wind was from a south westerly direction across the docks and coal conveyor. There is also one incident where the wind was from the north east, from the direction of the A4 and M5.

The ongoing monitoring by Bristol City Council, investigation in to reported complaints of dust and cooperation of site operators will help to keep particulate emissions at acceptable levels.

Contents

1 Introduction

This report provides the results from a study of ambient air quality in the vicinity of Avonmouth Docks, in Bristol. The Environment Agency's Ambient Air Monitoring Team (in National Monitoring Services) carried out the study between 8 August 2014 and 10 December 2014 (125 days) on behalf of the Wessex area.

The report presents the measured levels of particulate (TSP and PM_{10}) and compares these levels with the objectives of the UK Air Quality Strategy (AQS), where applicable.

The report also provides analysis of total suspended particulate (TSP), PM_{10}, $PM_{2.5}$ sulphur and heavy metals data, collected between 4 September 2014 and 10 December 2014 (98 days) by TRL Ltd (formerly Transport Research Laboratory) near Portview Road, Bristol, on behalf of the Bristol City Council.

Rainfall data provided by the Bristol Port Company has been used to consider the impact of this variable on particulate concentrations.

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 identify specific sources causing an appreciable impact on air quality
- To quantify the impact of nearby industrial sites on local air quality
- To identify and understand the conditions that give rise to episodes of poor air quality
- To compare Environment Agency data with that collected at the TRL monitoring site

2 Monitoring Location

The Ambient Air Monitoring team deployed its mobile monitoring facility (MMF5) at Avonmouth Docks (Figure 2.1). Particulate data from the TRL monitoring site has also been analysed for the period corresponding to the MMF study. The TRL monitoring site was located off of Port view Road.

A number of industrial activities were located near the monitoring stations including Sims Metal Management Ltd which is located to the north of the MMF Figure 2.2.

Figure 2.1: Map of monitoring locations

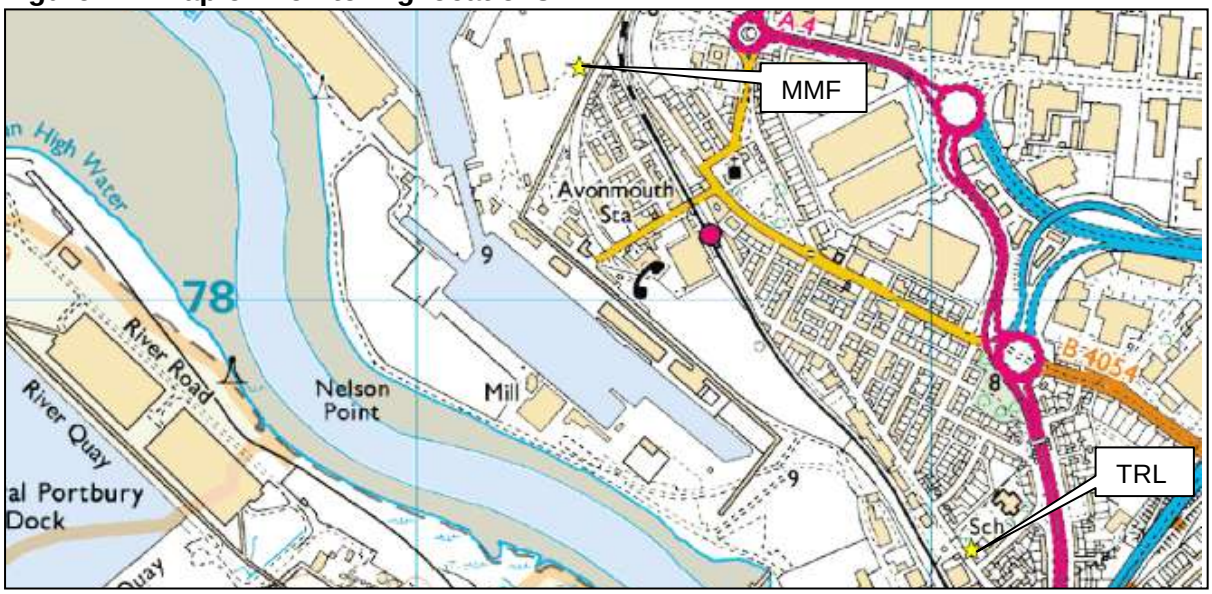
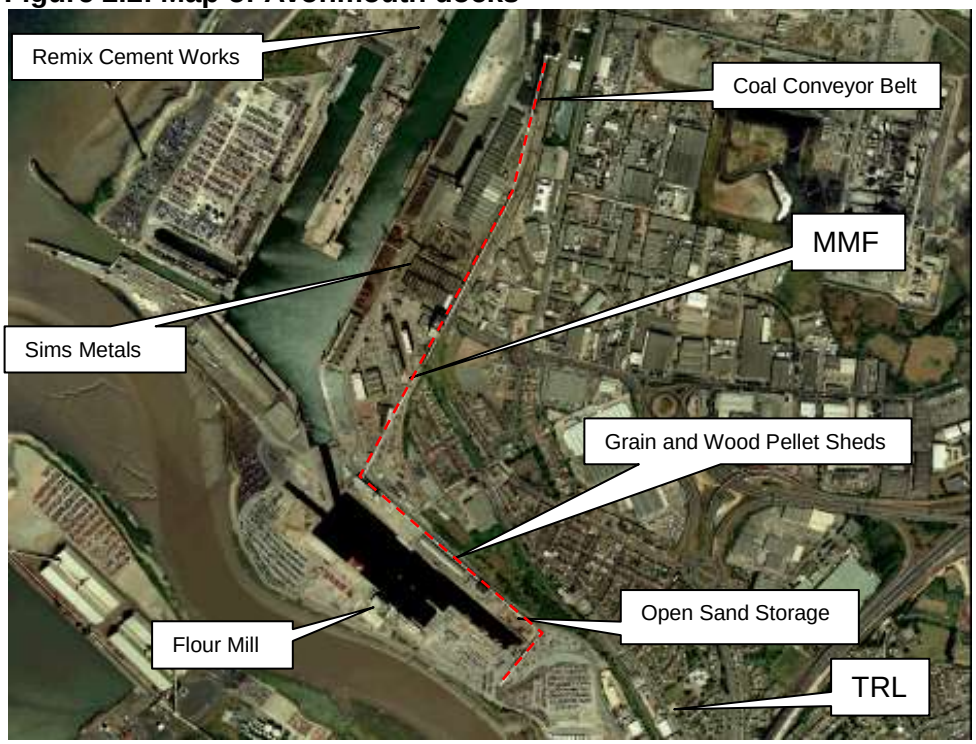


Figure 2.2: Map of Avonmouth docks



3 Monitoring Results

3.1 Meteorology

Wind speed and direction measurements were collected at both the MMF and TRL site during the study period. At both monitoring sites the sensor was mounted on a mast extending from the top of the trailer giving an overall height above ground of 8m.

It is advisable that a met mast should be located over 100m from any buildings of greater or comparable height, so as to reduce any influence that surrounding buildings may have had on the wind distribution; this was achieved at both monitoring locations.

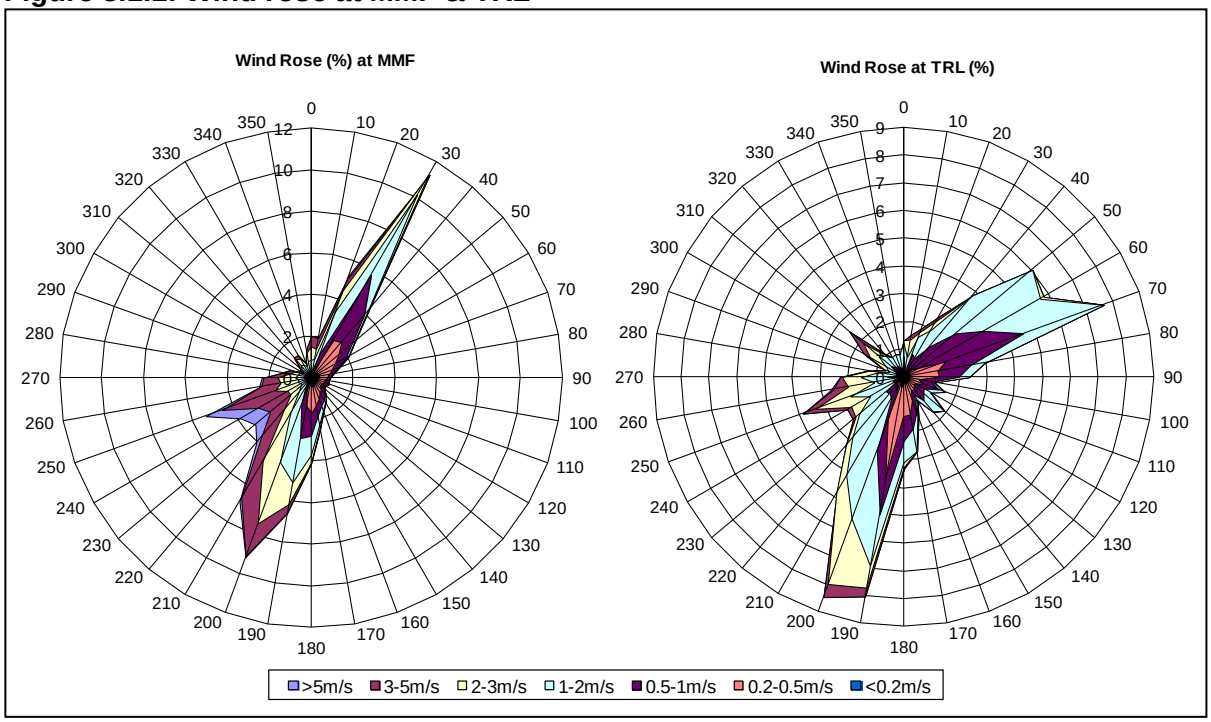
When setting up the instrument measuring wind direction at the beginning of the study, the mast was rotated such that the vane pointed in a known direction and this was used as the datum from which other directions were determined by the sensor. An uncertainty of ±5° on the wind direction is introduced 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 TRL data was identified as being out of alignment by 8^{o} for this report the data has been altered by -8^{o}.

The frequency distribution of wind direction at the MMF and TRL monitoring locations is shown in Figure 3.1.1.

The plot shows that at the MMF the wind was dominant from directions between 20° - 40° and 170° - 270° with wind coming from these sectors 21% and 51% of the time respectively.

The plot shows that at the TRL site the wind was dominant from directions between 50° - 80° and 190° - 260° with wind coming from these sectors 22% and 36% of the time respectively.

Figure 3.1.1: Wind rose at MMF & TRL



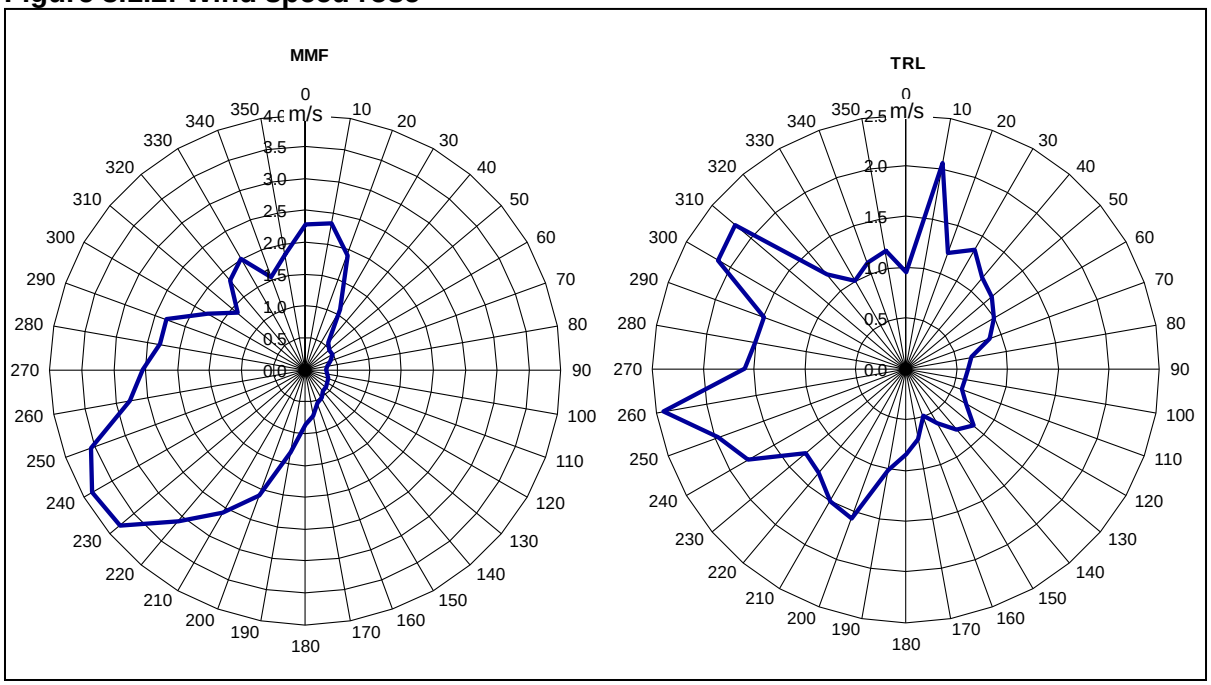
The wind speed frequencies at the MMF and the TRL site are summarised in Table 3.1.1. The tables show that a higher percentage of wind speeds ranged between 0.5-3m/s at the TRL monitoring site (93%).

Table 3.1.1 Summary of wind speed frequencies

Wind Speed (m/s)	Frequency of wind speed (%)	
	MMF	TRL
<0.2	6.80	2.80
0.2 - 0.5	15.0	18.8
0.5 - 1	16.8	22.9
1 - 2	23.3	38.3
2 - 3	18.3	12.8
3 - 5	15.9	4.30
>5	4.00	0.10
Total	**100**	**100**

A plot of mean wind speed (m/s) against wind direction for the MMF and the TRL site is shown in Figure 3.1.2. The maximum mean wind speed at the MMF was greater than 3.5m/s and came from the wind directions between 230º - 250º. The maximum mean wind speed at the TRL site was greater than 2m/s and came from the wind directions between 10º, 250º - 260º and 300º - 310º.

Figure 3.1.2: Wind speed rose

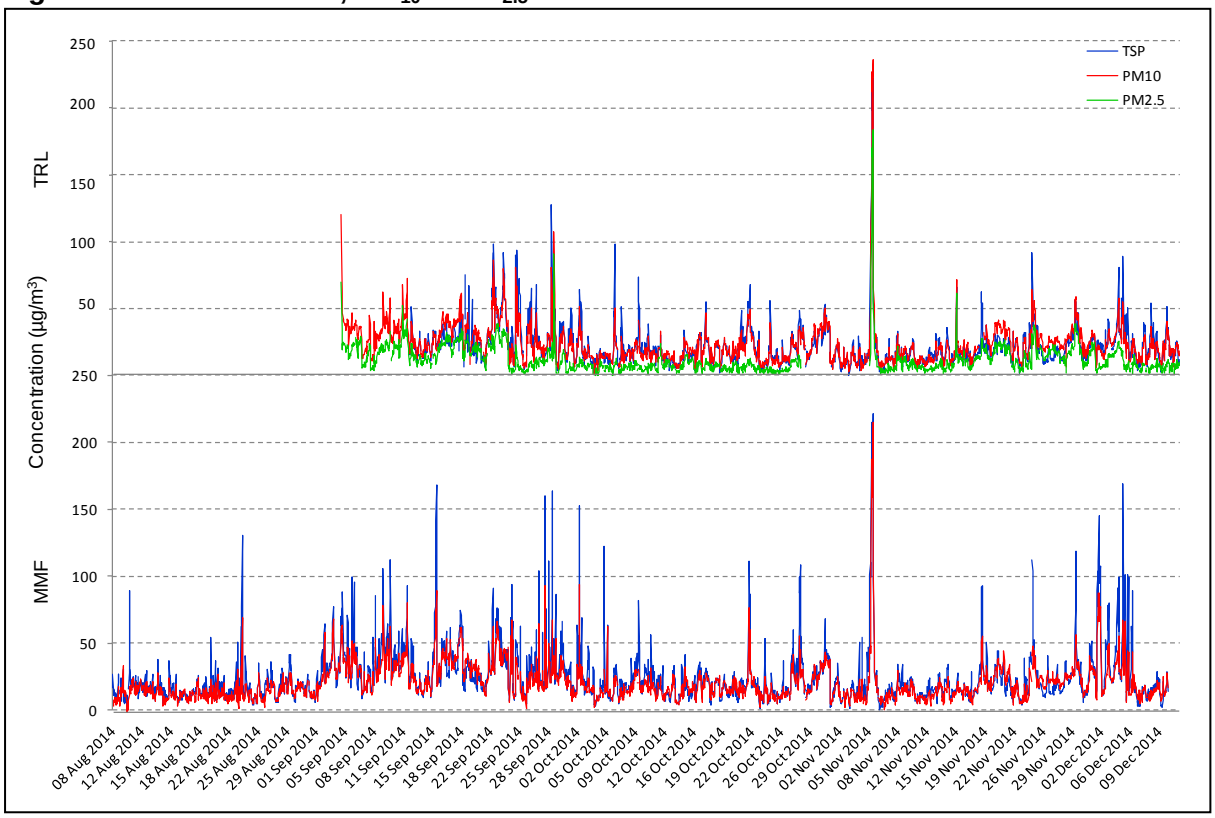


3.2 Particulate (TSP, PM_{10} & $PM_{2.5}$)

Between 8 August 2014 and 10 December 2014 (125 days) airborne TSP and PM_{10} concentrations at MMF were measured (at a height of 2m above ground) using TEOM instruments. Airborne TSP, PM_{10} and $PM_{2.5}$ concentrations at the TRL monitoring site were measured between 4 September 2014 and 10 December 2014 (98 days) using TEOM instruments. Details of the instrumentation and methodology are given in Appendix C.

Successful data collection at the MMF for both TSP and PM_{10} over the period was 99%. Successful data collection of TSP, PM_{10} and $PM_{2.5}$ at the TRL monitoring site over the period was 91%, 99% and 98% respectively. A time series plot of 1-hour TSP and PM_{10} concentrations over the monitoring period for the MMF and TSP, PM_{10} and $PM_{2.5}$ concentrations for the TRL monitoring site are shown in Figure 3.2.1. PM_{10} & $PM_{2.5}$ concentrations have been adjusted using Kings College London (KCL) volatile correction model (VCM); the adjustment causes an increase in PM_{10} & $PM_{2.5}$ concentrations. There is not an adjustment factor available for the TSP data.

Figure 3.2.1: 1-hour TSP, PM_{10} & $PM_{2.5}$ mean concentrations



Particulate concentrations have been monitored at Bristol St Paul's (BSP) monitoring station (GR 359492, 173925) since 2007 as part of Defra's Automatic Urban and Rural Network (AURN). The monitoring location is classed as an urban background site.

Figure 3.2.2 shows the 24 hour PM_{10} concentrations between the 8 August 2014 – 11 December 2014 at the MMF, TRL and BSP monitoring locations.

Figure 3.2.2: PM_{10} 24-hour mean concentrations

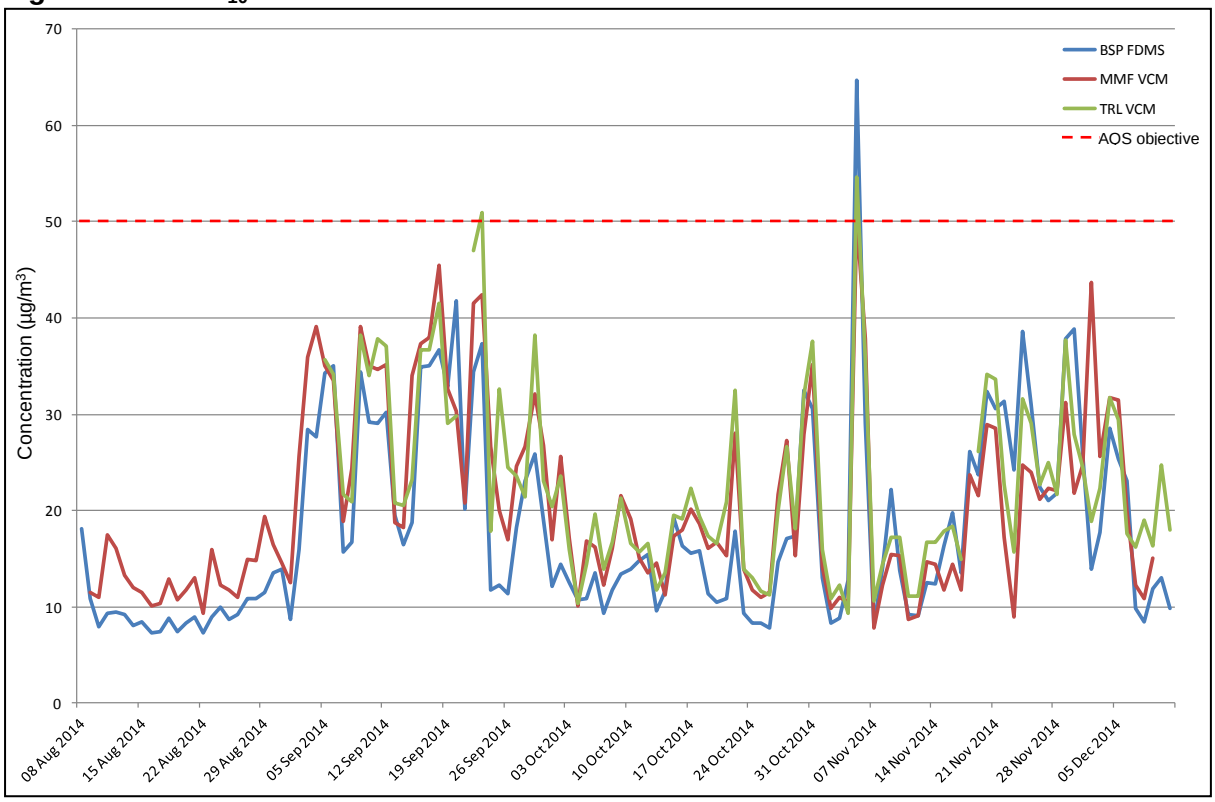


Figure 3.2.2 shows a similar trend in PM_{10} concentrations at all three monitoring locations. The mean PM_{10} concentration over the monitoring period at the MMF and TRL and BSP sites were 20.6µg/m^3, 23.4µg/m^3 and 18.1µg/m^3 respectively. Considering the distribution of the data and the mean values for the three monitoring locations, the lowest PM_{10} concentrations were seen at BSP, suggesting that there are different/additional source(s) of PM_{10} near the MMF and TRL monitoring locations.

3.2.1 Comparison with Air Quality Strategy (AQS) Objectives

It has been shown that particulate measurements using a TEOM instrument are not equivalent to the reference method for particulate matter and therefore not strictly comparable to the AQS Objectives. This should be taken into consideration when examining data which is close to breaching standards.

PM_{10} data collected with a TEOM instrument can be adjusted using the King's College London (KCL) Volatile Correction Model (VCM). The VCM uses FDMS instrument data from sites within 100km distance of the MMF in order to adjust the PM_{10} measurements to be comparable with the reference method. Further explanation can be found in Appendix C.

There is not currently a validated correction factor for TSP or $PM_{2.5}$ TEOM data, and therefore the data is not comparable to the AQS Objective values. KCL has developed a VCM for $PM_{2.5}$ that does go some way toward estimating the volatile fraction of the particulate lost on the TEOM. Although not strictly equivalent to the reference method it does give a better estimation of total particulate $PM_{2.5}$ than uncorrected TEOM data and therefore has been used in this study. Further explanation can be found in Appendix C.

FDMS data acquired from the VCM has been used to correct the PM_{10} & $PM_{2.5}$ TEOM data from the MMF and TRL monitoring sites. TEOM concentrations that incorporate FDMS data

are quoted as µg/m^3, where as those that have not been multiplied by these factors are quoted as µg/m^3[TEOM]. The FDMS data that has been used to run the PM_{10} VCM & $PM_{2.5}$ VCM in this study is unratified. This should be taken into consideration when examining any data which is breaching standards.

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

The mean PM_{10} concentration over the monitoring period at the MMF and TRL sites were 20.6µg/m^3 and 23.4µg/m^3 respectively. 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 sites.

Figure 3.2.3 shows the 24-hour (midnight-midnight) mean PM_{10} concentrations (µg/m^3) at the MMF and the TRL monitoring sites.

Figure 3.2.3 PM_{10} 24-hour (midnight-midnight) mean concentrations

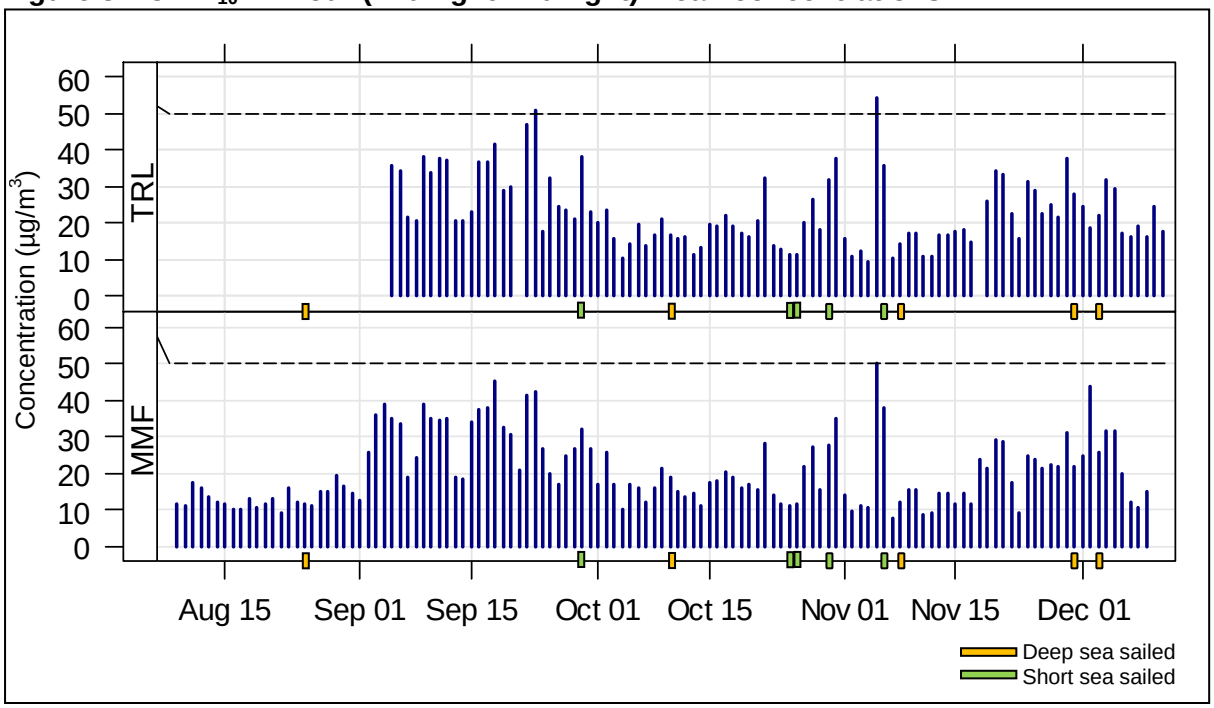


Figure 3.2.3 shows that the PM_{10} 24-hour (midnight-midnight) mean concentration at the MMF was greater than 50µg/m^3 on one occasion during the monitoring period, on the 5th November, the maximum concentration being 50.3µg/m^3. If the assumption is made that the conditions during the monitoring period were representative of a typical year, then over a year the 50µg/m^3 level for 24-hour (midnight-midnight) mean concentrations might be exceeded on 3 occasions and thus the AQS for 24-Hour (midnight-midnight) mean PM_{10} concentrations would not be expected to exceeded at the monitoring site.

The 24-hour (midnight-midnight) mean concentration at the TRL site was greater than 50µg/m^3 on two occasions during the monitoring period, including the 5th of November. If the assumption is made that the conditions during the monitoring period were representative of a typical year, then over a year the 24-hour (midnight-midnight) mean concentration may be exceeded at the TRL site on seven occasions and thus the AQS for 24-Hour (midnight-

midnight) mean PM_{10} concentrations would not be expected to exceeded at the monitoring site.

The AQS objective for $PM_{2.5}$, limits the annual mean concentration to 25µg/m^3. The mean $PM_{2.5}$ concentration over the monitoring period at the TRL site was 12.1µg/m. 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 for $PM_{2.5}$ would not be expected to exceed at the TRL monitoring site.

Elevated particulate concentrations are offten seen on the 5th of November, and can be explained by the additional particulate emitted from bonfires and firework displays on this day. The BSP monitoring site also exceeded the 24-hour (midnight-midnight) mean AQS objective on one occasion during the monitoring period, on the 5th of November, the maximum concentration being 64.7µg/m^3. Figure 3.2.4 shows the 1-hour mean concentrations (µg/m^3) on the 5th November at the three monitoring locations. The plot shows that the elevation in PM_{10} concentrations occured in the evening, at a time where PM_{10} concentrations would typically be lower following daytime industrial activity and traffic.

Figure 3.2.4: PM_{10} 1-hour mean concentrations, 5 November 2014

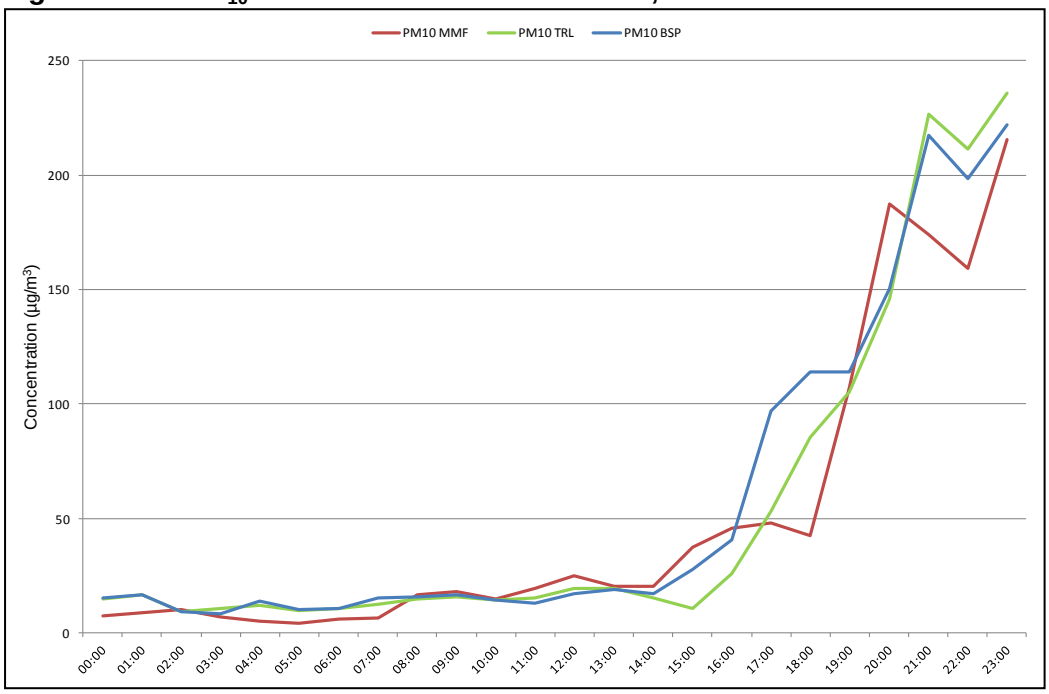
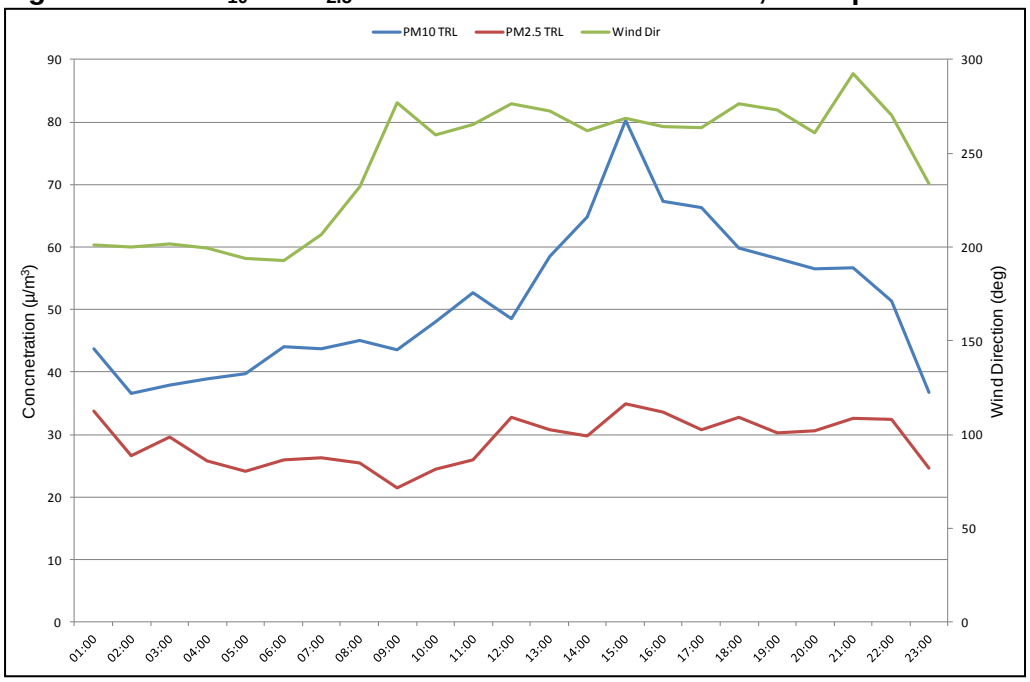


Figure 3.2.5 shows the PM_{10} and $PM_{2.5}$ 1-hour mean concentrations (µg/m^3) on the 23rd September at the TRL monitoring location. The figure shows an elevation in PM_{10} concentrations between 10:00 – 22:00 that does not occur in the $PM_{2.5}$ fraction. The wind was coming from between 262^o -293^o during this period, from the direction of the coal conveyor and docks.

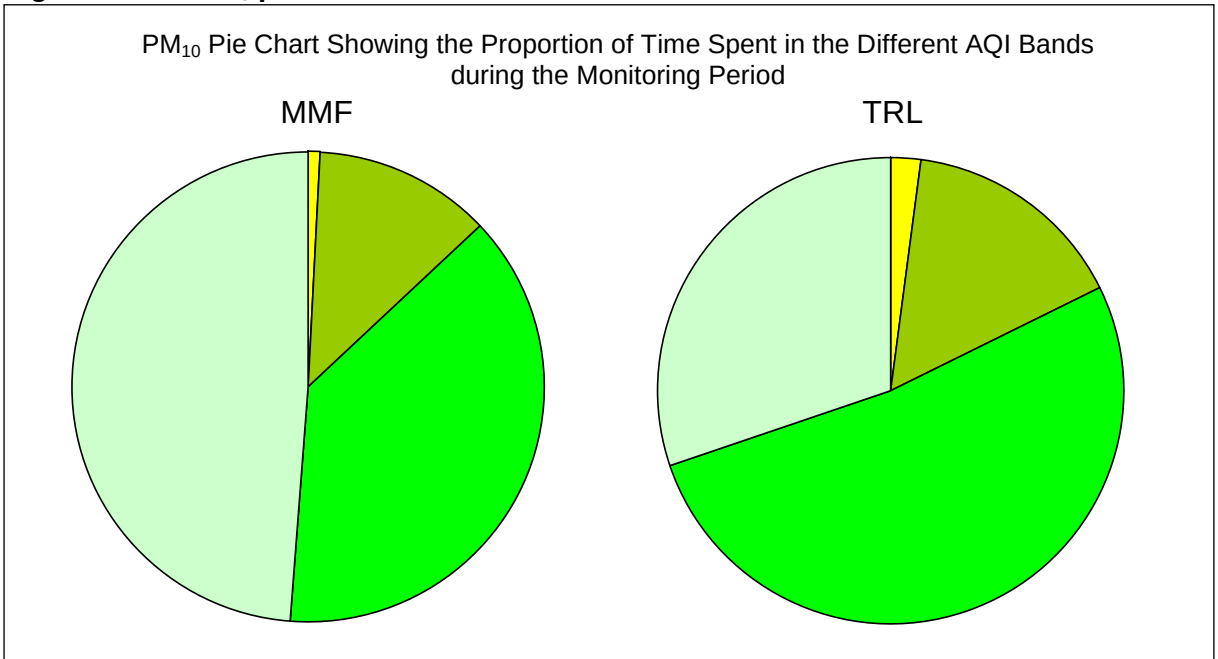
Figure 3.2.5: PM_{10} & $PM_{2.5}$ 1-Hour mean concentrations, 23 September 2014 at TRL



3.2.2 Comparison with Air Quality Index

In the United Kingdom a daily Air Quality Index has been developed. The system uses an index numbered 1-10 (low – high pollution), to provide more detail on a daily basis about air pollution levels to the general population and those at higher risk from air pollution.

Figure 3.2.6: PM_{10} pie chart for MMF and TRL site



Index Band µg/m³ (%)	1 Low 0-16	2 Low 17-33	3 Low 34-49	4 Moderate 50-58	5 Moderate 59-66	6 Moderate 67-74	7 High 75-83	8 High 84-91	9 High 92-99	10 Very High ≥ 100
MMF	48.8	38.2	12.2	0.8						
TRL	30.2	52.1	15.6	2.1						

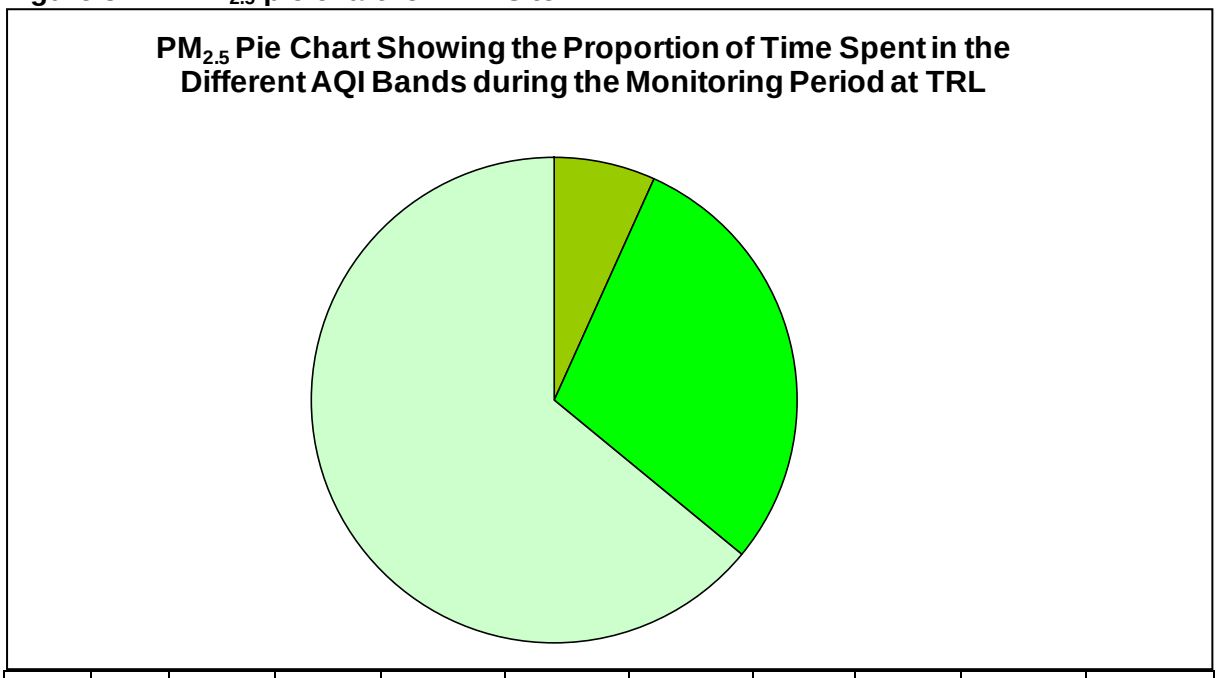
Figure 3.2.6 and 3.2.7 looks at the daily PM_{10} and $PM_{2.5}$ concentrations (ug/m^3) in relation to the Air Quality Index banding.

Figure 3.2.6 shows that at the MMF the daily PM_{10} concentrations fell within the lower AQI bands, for 99% of the monitoring period. The results fell within the moderate banding for <1% of the monitoring period.

The TRL site showed that daily PM_{10} concentrations fell within the lower AQI bands, for 98% of the monitoring period. The results fell within the moderate banding for 2% of the monitoring period.

Figure 3.2.7 shows that the daily $PM_{2.5}$ concentrations fell within the lower AQI bands throughout the monitoring period.

Figure 3.2.7: $PM_{2.5}$ pie chart for TRL site



Index Band µg/m^3	1 Low 0-11	2 Low 12-23	3 Low 24-34	4 Moderate 35-41	5 Moderate 42-46	6 Moderate 47-52	7 High 53-58	8 High 59-64	9 High 65-69	10 Very High ≥ 70
%	48.8	38.2	12.2							

3.2.3 Detailed Consideration of PM_{10} Pollution Events

The periods where PM_{10} 1-hour concentrations (ug/m^3) increased significantly above the average level have been considered as separate pollution events and have been examined in greater depth. For the purposes of this study the highest five recorded events at each site were individually considered and the association between recorded PM_{10} levels and the wind direction and wind speed at that time examined. The results are summarised in Table 3.2.1 and 3.2.2.

Table 3.2.1: Summary of PM_{10} pollution events at MMF

Pollution Event	Date	Time	Maximum 1-Hour Concentration (µg/m^3)	Wind Direction (degrees)	Wind Speed (m/s)
1	05/Nov/2014	23:00	215	148	0.2
2	06/Nov/2014	00:00	215	149	0.4
3	02/Oct/2014	13:00	93.7	322	1.2
4	28/Sep/2014	12:00	93.1	0	2.7
5	15/Sep/2014	18:00	89.4	19	2.1

Table 3.2.1 shows that high levels of PM_{10} were recorded at the monitoring site when the wind was coming from between 322º - 19º in the direction of Sims Metal Management Ltd. The wind was between 148^o – 149^o on the 5/6 November. The events occurred at wind speeds of 0.2 – 2.7 m/s. Excluding the events over bonfire night, the pollution events occurred between 13:00 - 18:00.

Table 3.2.2: Summary of PM_{10} pollution events at TRL

Pollution Event	Date	Time	Maximum 1-Hour Concentration (µg/m^3)	Wind Direction (degrees)	Wind Speed (m/s)
1	05/Nov/2014	23:00	236	209	0.4
2	06/Nov/2014	00:00	229	185	0.2
3	04/Sep/2014	14:00	120	24	1.0
4	29/Sep/2014	13:00	108	250	1.0
5	22/Sep/2014	11:00	86.7	304	1.1

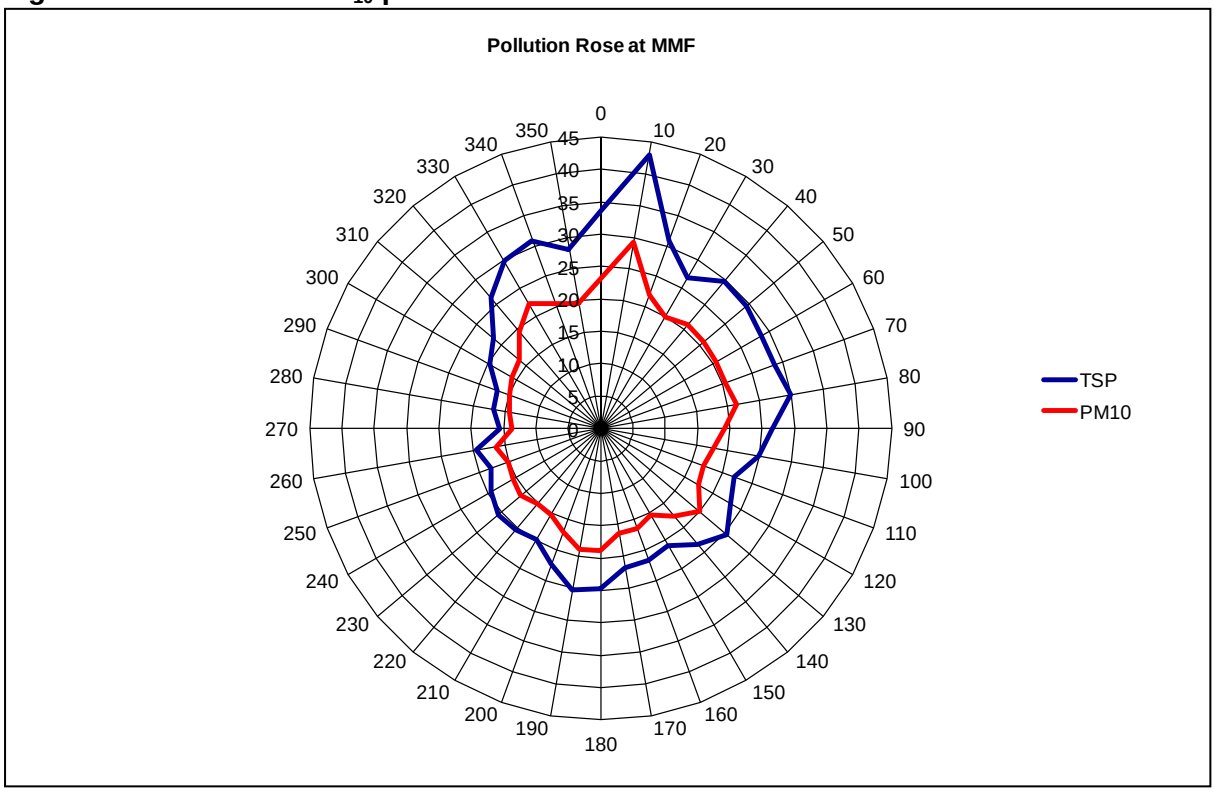
Table 3.2.2 shows that high levels of PM_{10} were recorded at the TRL monitoring site when the wind was coming from between 250º - 24º and 185^o -209^o over bonfire night at low wind speeds of 0.2 – 1.1 m/s. Excluding bonfire night the pollution events occurred between 11:00 - 14:00.

3.2.4 Directional Analysis

A radial plot of mean TSP and PM_{10} concentrations (µg/m^3[TEOM]) against wind direction, recorded at MMF are shown in Figure 3.2.8.

Figure 3.2.8 shows that the highest average TSP and PM_{10} concentrations are seen for wind sectors 0^o – 20^o in the direction of Sims Metal Management Ltd, with average concentrations greater than 30µg/m^3[TEOM] and 20µg/m^3[TEOM] respectively.

Figure 3.2.8: TSP and PM_{10} pollution rose at MMF site



A radial plot of mean TSP, PM_{10} and $PM_{2.5}$ concentrations (µg/m^3[TEOM]) against wind direction, recorded at the TRL monitoring site are shown in Figure 3.2.9.

Figure 3.2.9: TSP, PM_{10} & $PM_{2.5}$ pollution rose at TRL site

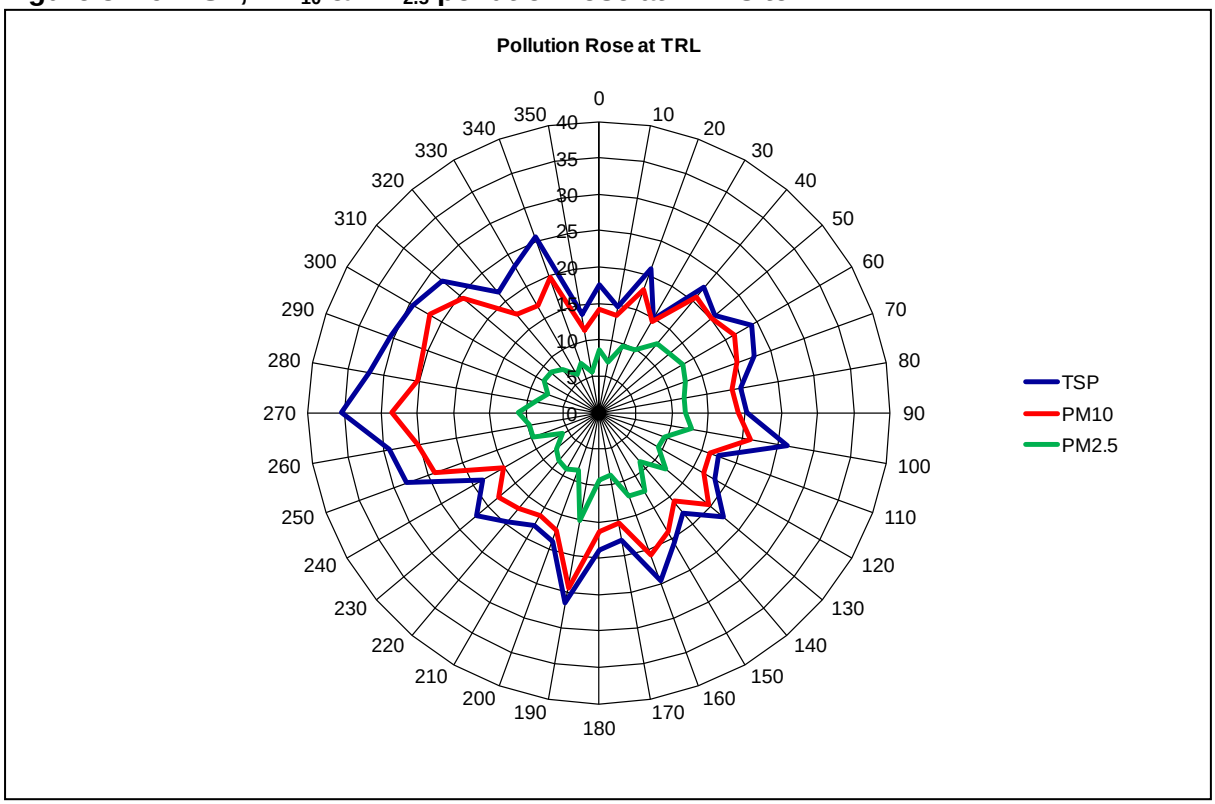
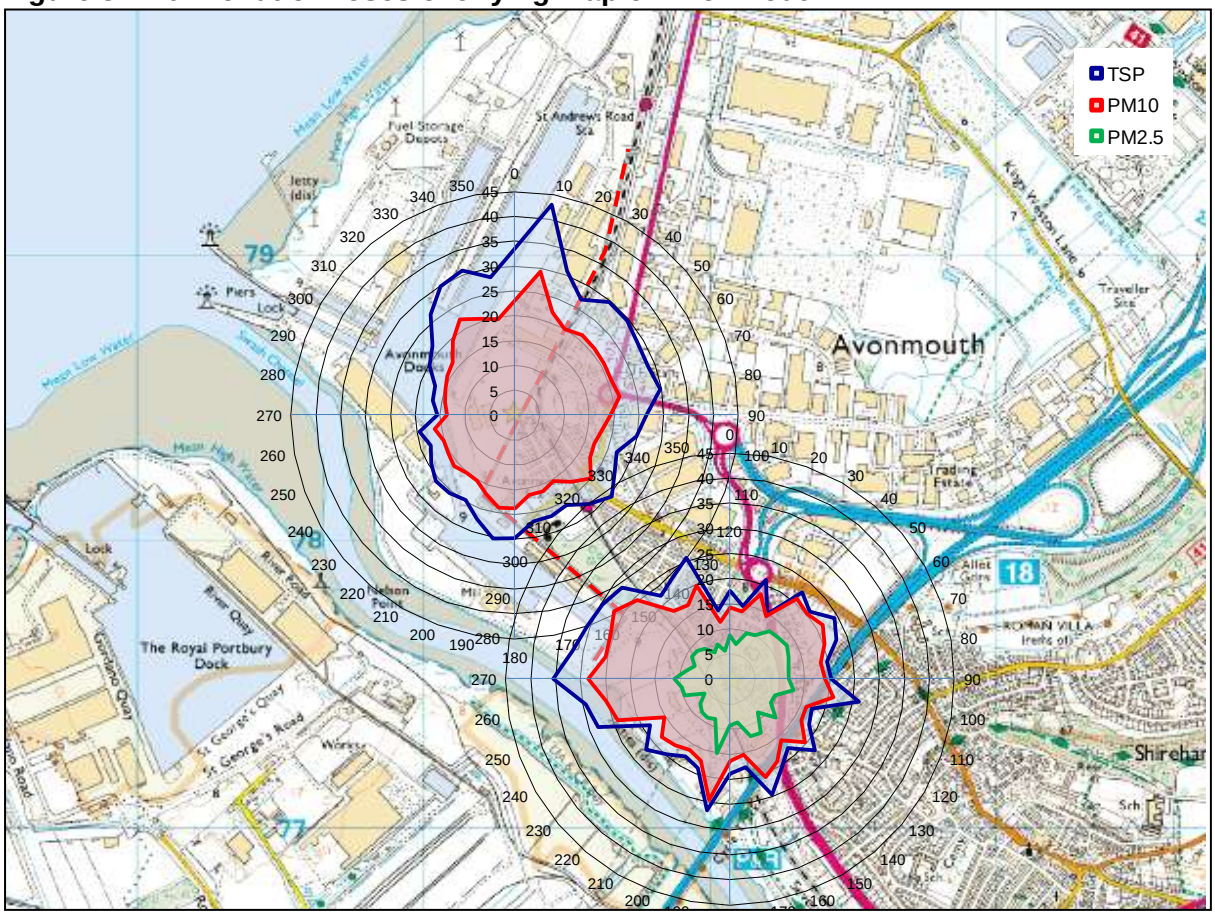


Figure 3.2.9 shows that the highest average TSP and PM_{10} concentrations are seen for wind sectors 250° - 310°, but not $PM_{2.5}$ with average concentrations greater than 25µg/m^3[TEOM] and 20 µg/m^3[TEOM]. This suggests that the source from this direction is from the re suspension of particulate from the direction of the coal conveyor and docks.

Elevated $PM_{2.5}$ concentrations were seen for wind directions 30° - 100° with average concentrations >10µg/m^3[TEOM]. Similar elevations are seen in the PM_{10} and TSP fractions suggesting that the particulate from this direction is from a traffic source.

Figure 3.2.10 shows the mean pollution roses from the MMF and TRL monitoring locations overlying a map of the Avonmouth area, which can be used to pinpoint potential sources of particulate affecting the two locations. The plot suggest that different localised sources are affecting the two monitoring locations, with elevated TSP and PM_{10} levels at the MMF site from the direction of Sims Metal Management Ltd, woodchip store, remix cement works and coal conveyor belt. Elevated TSP and PM_{10} concentrations are seen from the direction of the grain and wood pellet sheds, open sand storage, flour mill and coal conveyor belt at the TRL monitoring site. Elevated TSP, PM_{10} and $PM_{2.5}$ concentrations are seen from the direction of the A4 and M5.

Figure 3.2.10: Pollution roses overlying map of Avonmouth



An array of plots showing the contribution to TSP and PM_{10} loading (µg/m^3[TEOM]) at the MMF monitoring site for different percentiles is shown in Figure 3.2.11 and 3.2.12 respectively. An explanation of percentile analysis is given in Appendix D.

Figure 3.2.11: TSP percentile rose at MMF

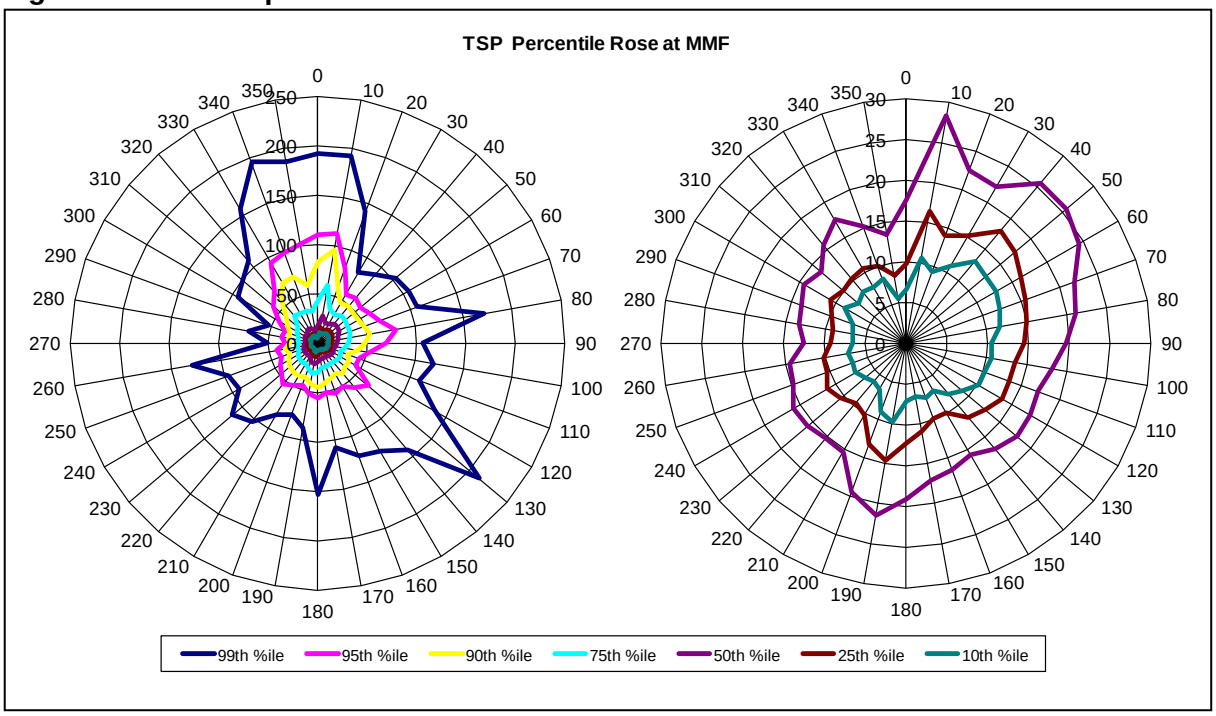
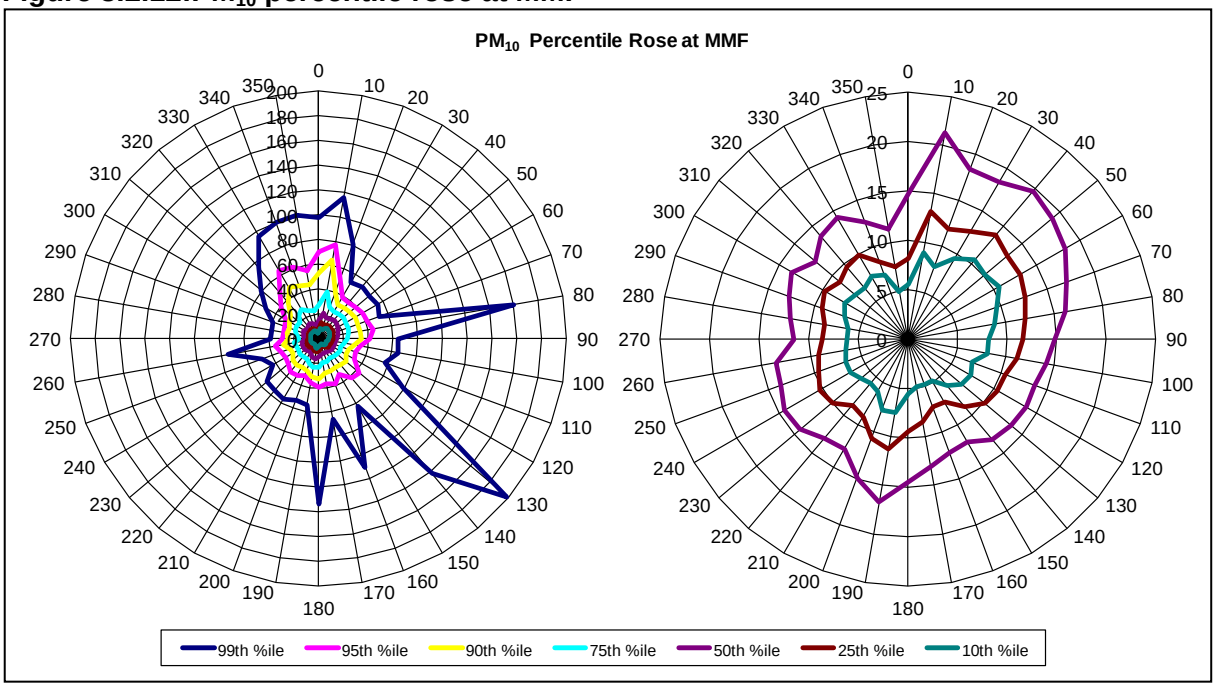


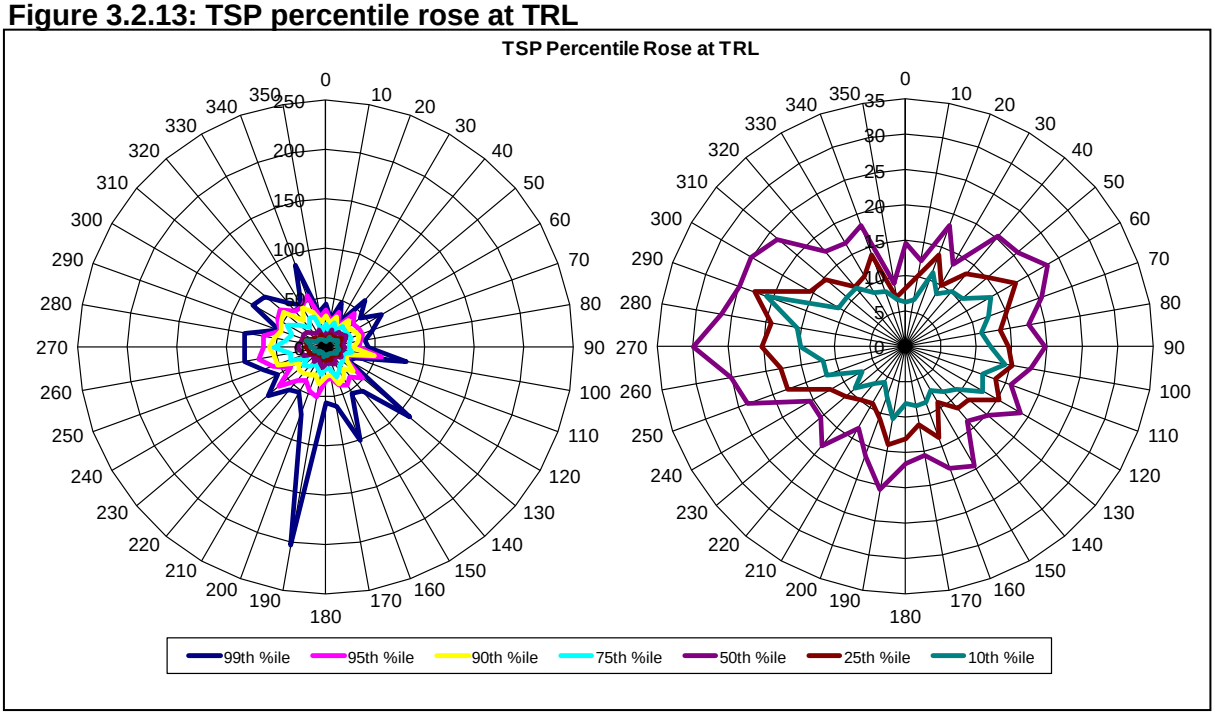
Figure 3.2.12:PM_{10} percentile rose at MMF



Figures 3.2.11 and 3.2.12 show that there are elevated concentrations in the higher and lower concentrations from wind direction 10^{o} suggesting that there is a relatively continuous source of particulate from this wind direction. Elevated TSP and PM_{10} concentrations are seen in the higher percentiles for wind sectors 300^{o} - 360^{o} suggesting an intermittent source of particulate from these wind directions. There is an elevation in TSP and PM_{10} concentrations in the lower percentiles for wind direction 20^{o} – 120^{o}, suggesting that there is a relatively continuous source of particulate from these wind directions, but does not lead to very high PM_{10} concentrations. An elevation in TSP and PM_{10} concentrations seen in the 99th

percentile for wind directions 80° - 160° can be linked to a single event of high particulate concentrations on the 5th November.

Figure 3.2.13: TSP percentile rose at TRL



An array of plots showing the contribution to TSP, PM_{10} and $PM_{2.5}$ loading (µg/m^3[TEOM]) at the TRL monitoring site for different percentiles is shown in Figure 3.2.13, 3.2.14 and 3.2.15 respectively.

Figure 3.2.14: PM_{10} percentile rose at TRL

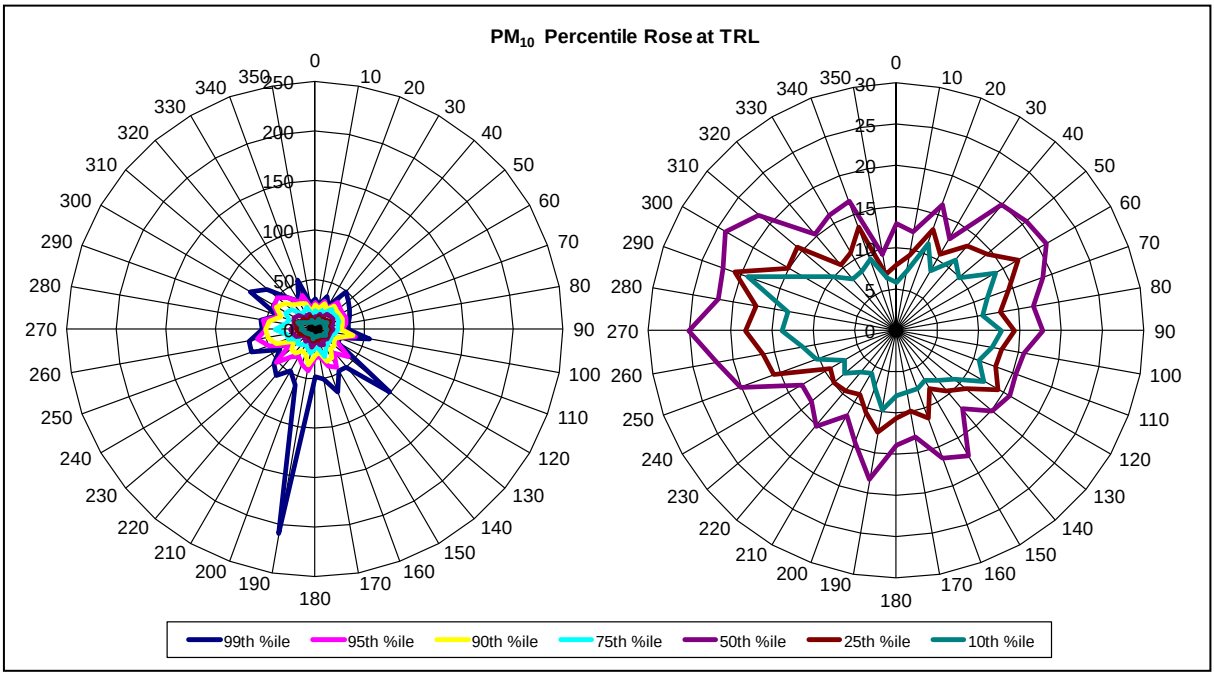
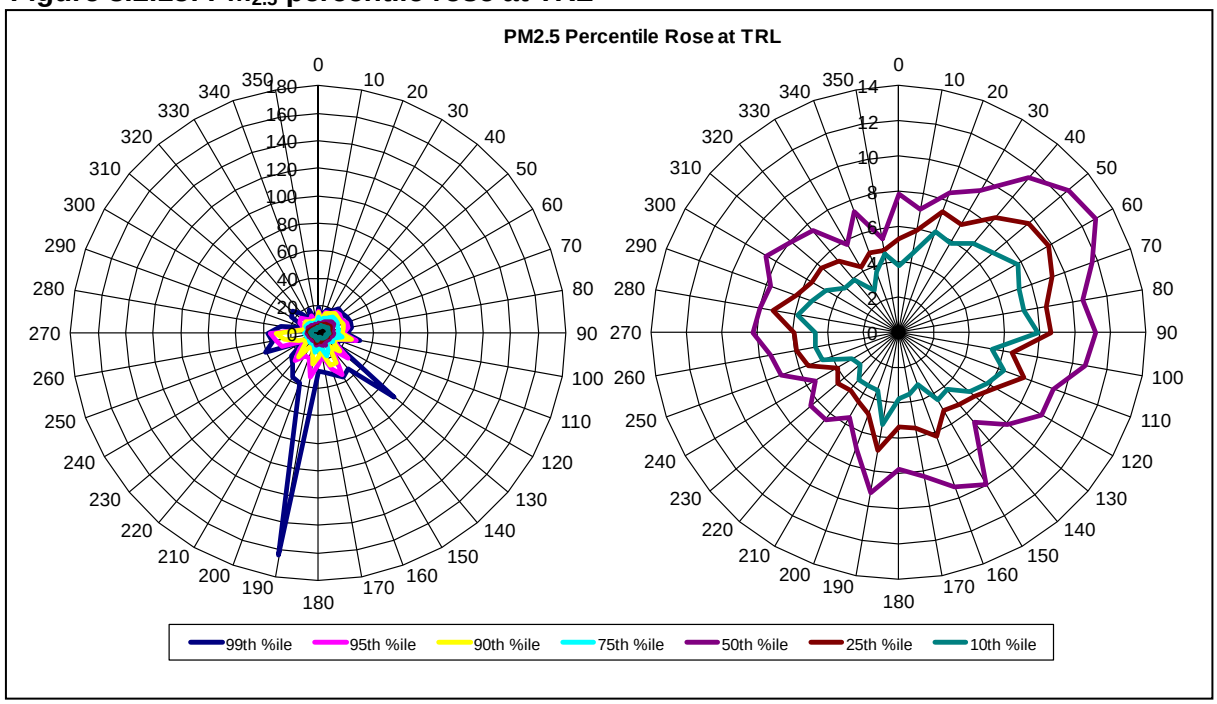


Figure 3.2.15: $PM_{2.5}$ percentile rose at TRL



The percentile roses for the TRL site show elevated TSP and PM_{10} concentrations in the higher and lower percentiles for wind directions 240° - 340° suggesting a relatively continuous source from this wind direction, this is also visible in the $PM_{2.5}$ plot, to a lesser amount. There is also elevated PM_{10} and $PM_{2.5}$ concentrations for wind directions 30° – 110° suggesting a relatively continuous source(s) from these directions. Peaks in the 99th percentile can also be seen for wind direction 120° – 240° that can be linked to elevated particulate levels on the 5th November.

Figure 3.2.16 shows the variation in 5 minute TSP and PM_{10} concentrations (µg/m^3[TEOM]) with wind speed, seen for varying wind directions at the MMF monitoring location. The data is plotted in polar coordinates. The area of the map represents the wind speed, for varying wind directions.

Figure 3.2.16: Polar plots at MMF site

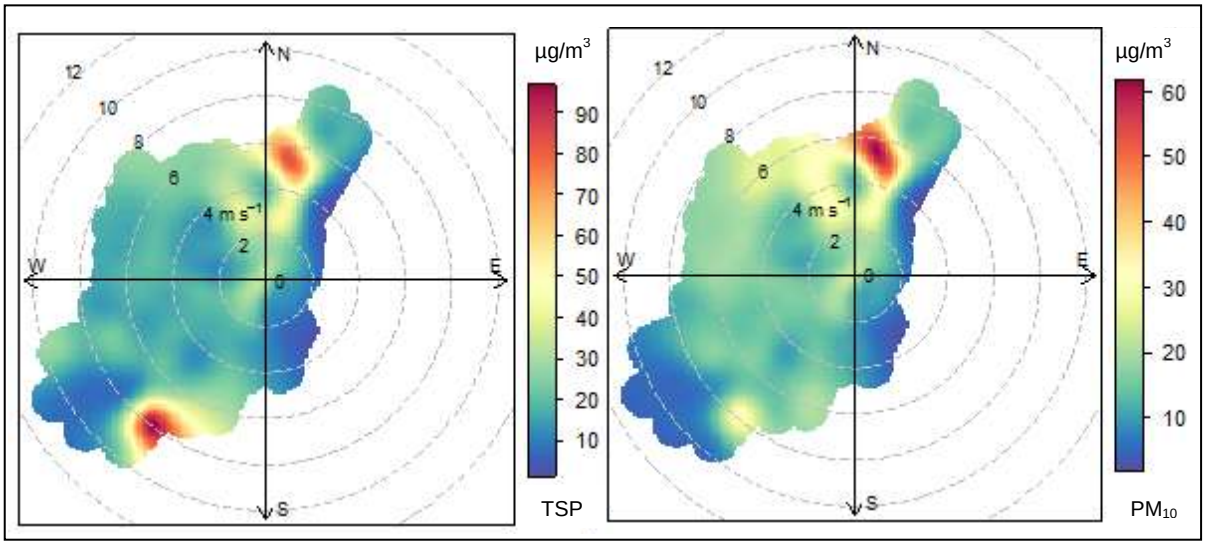
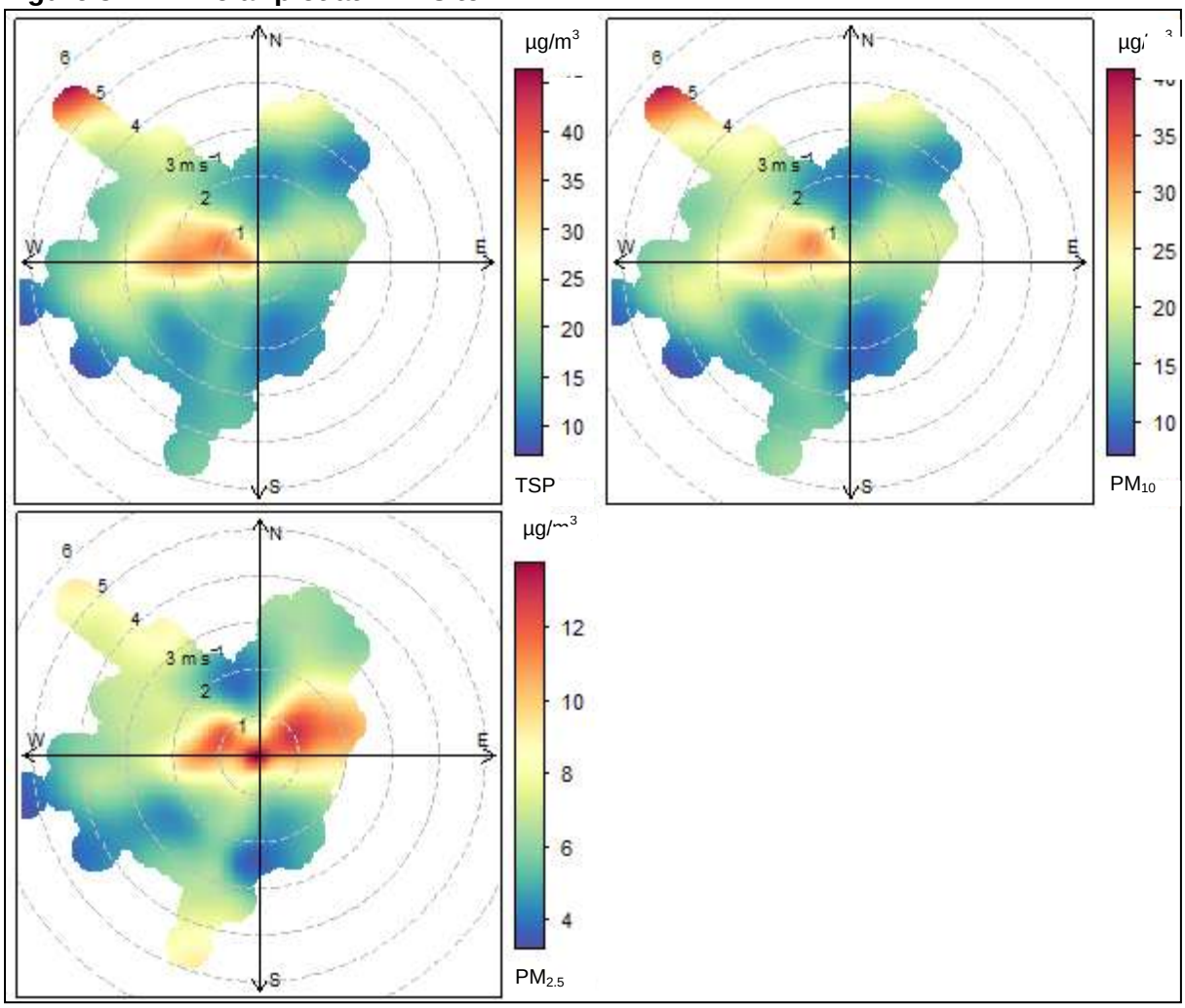


Figure 3.2.16 shows higher particulate concentrations with increasing wind speed for wind directions to the north, suggesting a source of re suspended particulate from this direction. There is also a source of particulate at higher wind speeds from the south west.

Figure 3.2.17 shows the variation in 1 hour TSP, PM_{10} and $PM_{2.5}$ concentrations ($\mu g/m^3$[TEOM]) with wind speed, seen for varying wind directions at the TRL monitoring location.

Figure 3.2.17 shows a source of particulate at higher wind speeds for wind directions from the north west. Increasing TSP and PM_{10} concentrations are seen with increasing wind speed for wind directions from the west, suggesting that elevated PM_{10} concentrations are affected by re-suspension of PM_{10}. $PM_{2.5}$ concentrations are higher at lower wind speeds, suggesting that levels are affected by a localised source that is dispersed at higher wind speeds.

Figure 3.2.17: Polar plot at TRL site



3.2.5 Diurnal and Weekday Variation

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 3.2.18 and 3.2.19 show the average levels of TSP, PM_{10} and $PM_{2.5}$ at the MMF and TRL site respectively, for each hour of the day shown for each 45° wind direction sector.

Figure 3.2.18 shows a strong single diurnal peak for wind sectors 315^o – 45^o between 06:00 – 21:00 and to a lesser extent for wind sectors 225^o – 315^o suggesting that daytime activities on site(s) are contributing to elevated particulate concentrations. Wind sectors 45^o – 180^o display a double peak pattern suggesting that traffic may be influencing particulate concentrations from these wind directions.

Figure 3.2.18: TSP and PM_{10} diurnal plot at MMF

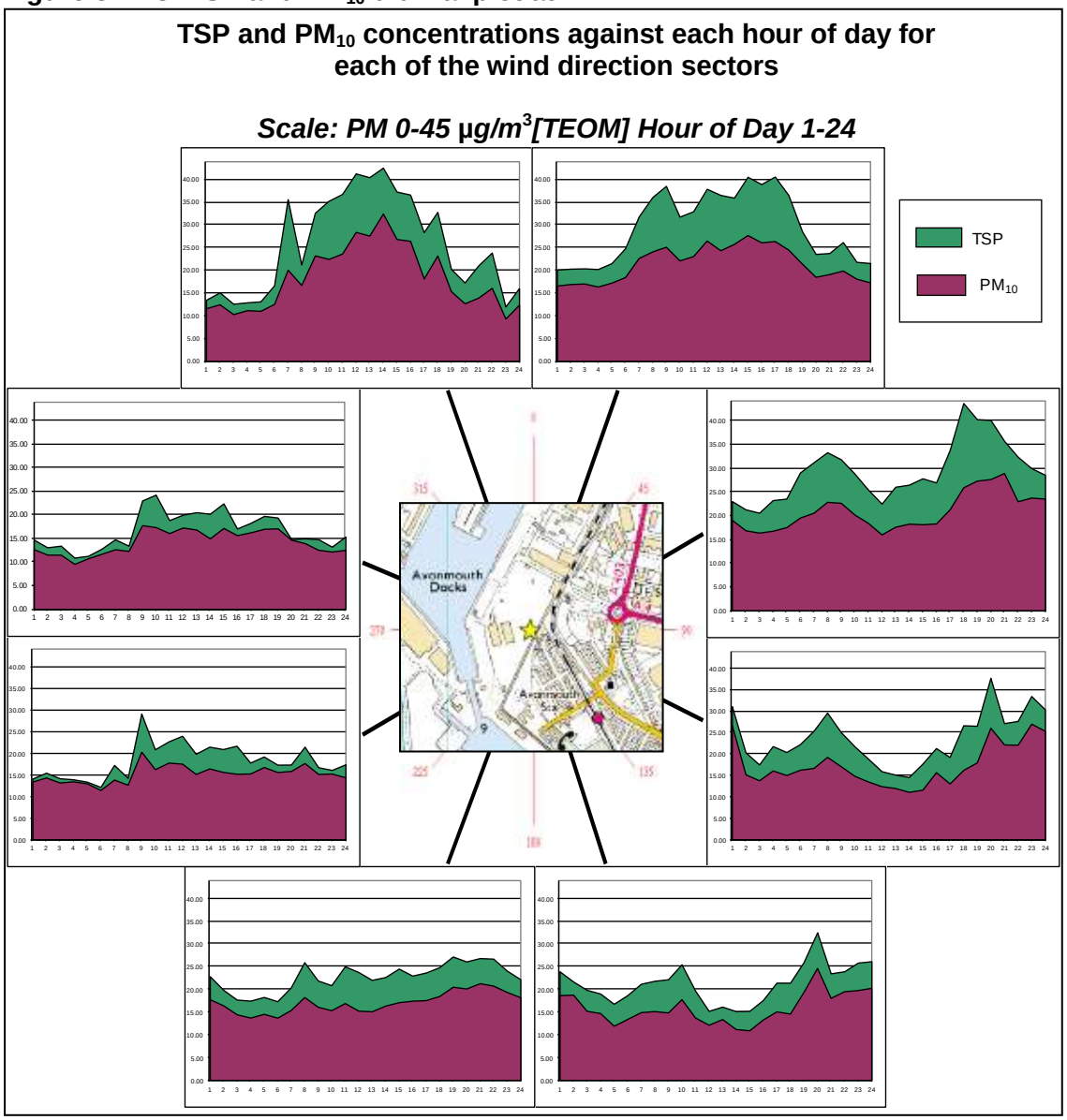


Figure 3.2.19 shows a single diurnal peak for wind sectors 225^{o} – 360^{o} with high levels until midnight for wind sectors 225^{o} – 315^{o} suggesting that daytime activities are contributing to elevated particulate concentrations. Wind sectors 135^{o} – 180^{o} display a double peak pattern suggesting that traffic may be influencing particulate concentrations from these wind directions.

Figure 3.2.19: TSP, PM_{10} and diurnal plot at TRL

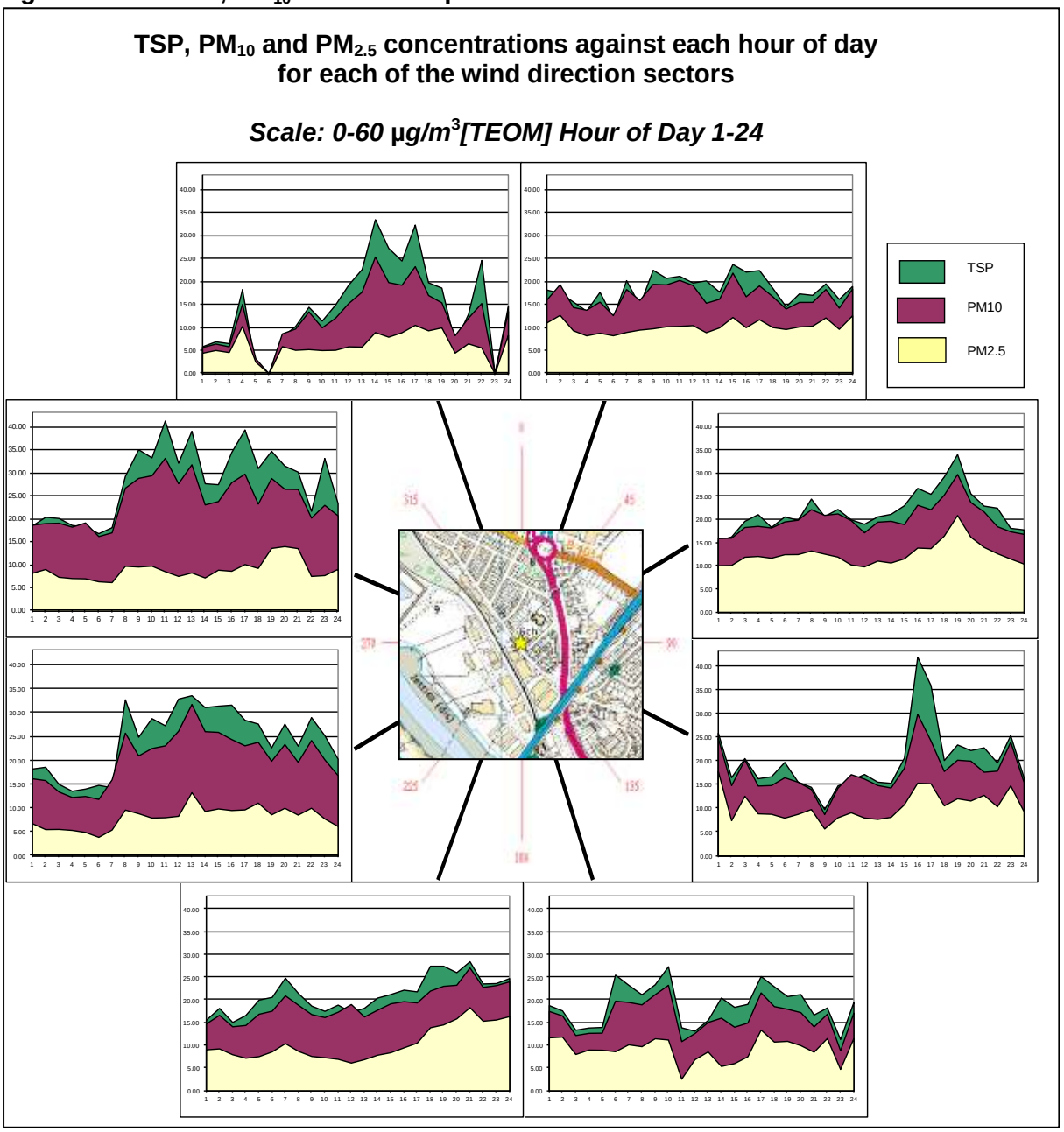


Figure 3.2.20 and 3.2.21 show the diurnal, weekday and monthly variation of mean TSP, PM_{10} and $PM_{2.5}$ concentrations at the MMF and TRL monitoring sites for all wind directions.

Figure 3.2.20 showed lower particulate concentrations on weekends for wind directions 0° – 90° and 180° – 315° suggesting that particulate concentrations were elevated during the working week. Concentrations were still elevated on Saturdays for the remaining wind directions, suggesting that activities were still contributing to elevated concentrations on Saturdays for these wind directions.

Figure 3.2.20: TSP and PM_{10} weekday plot at MMF

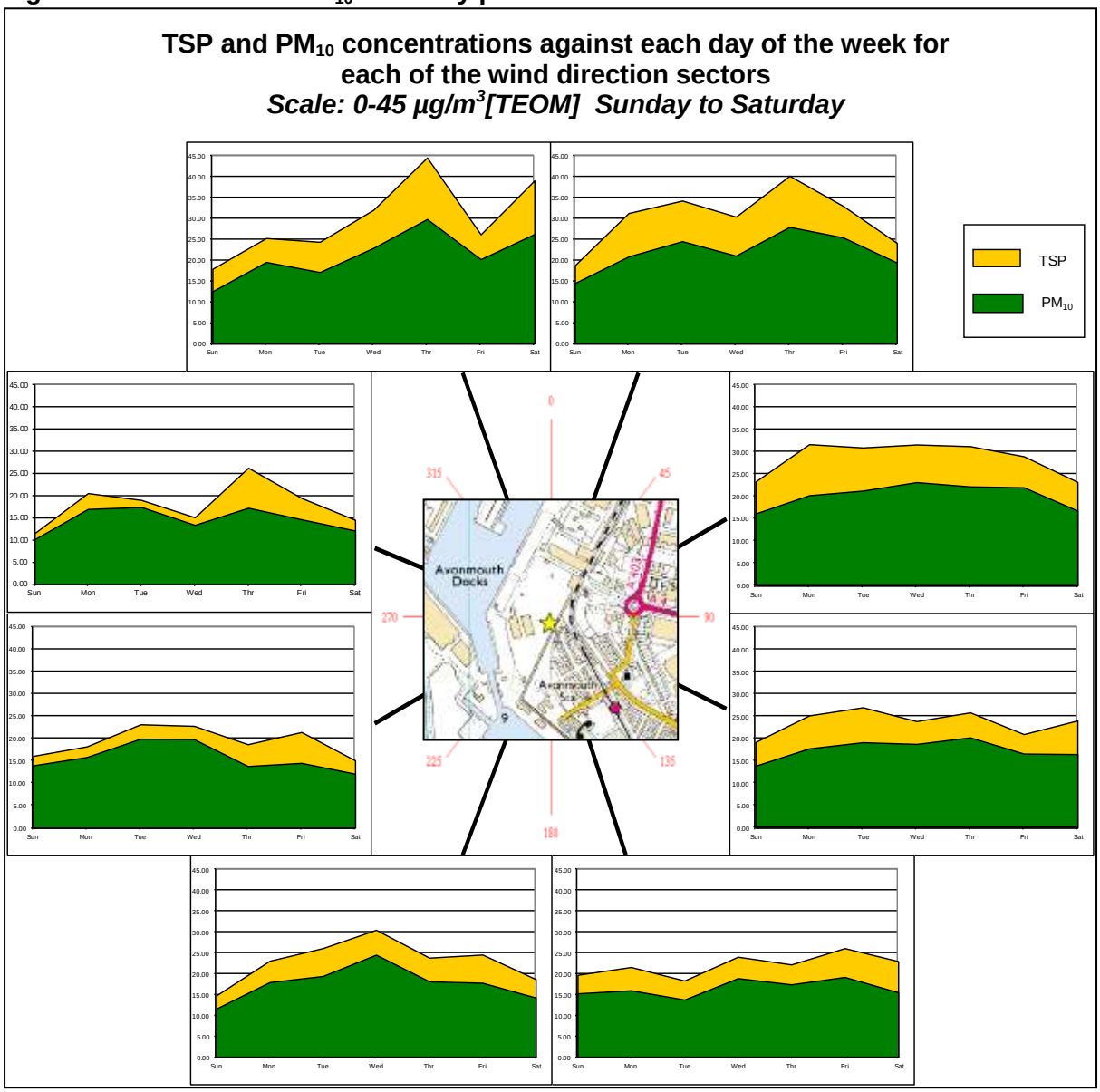
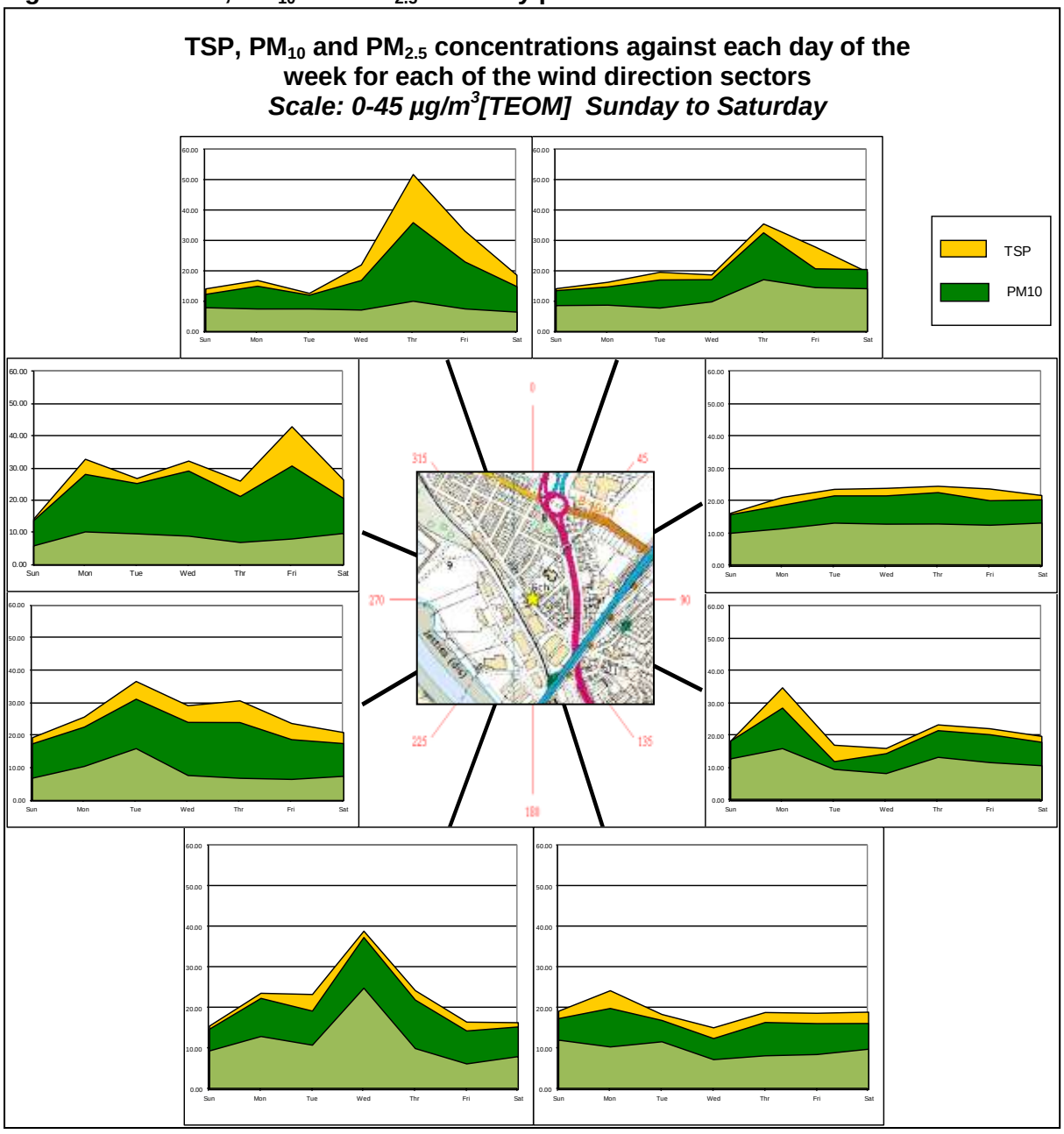


Figure 3.2.21 showed lower particulate concentrations on weekends for wind directions 180° – 270° suggesting that particulate concentrations were elevated during the working week. Concentrations were still elevated on Saturdays for wind directions 270° – 360°, suggesting that particulate sources were still contributing to elevated concentrations on Saturdays for these wind directions.

Figure 3.2.21: TSP, PM_{10} and $PM_{2.5}$ weekday plot at TRL



3.2.6 Comparison with Rainfall Data

During the monitoring period, between 8 August 2014 and 10 December 2014 (125 days) 1 minute rainfall data was collected on the south pier of Avonmouth docks by the Bristol Port Company. Figure 3.2.22 compares the 24-hour mean PM_{10} concentrations at the MMF and 24-hour total rainfall. The plot generally shows higher PM_{10} concentrations during dryer periods e.g. in September, where the monthly mean PM_{10} concentration was 30µg/m^3, and

lower PM_{10} concentrations when there is higher total rainfall e.g. October and November where monthly mean PM_{10} concentrations were 17.8µg/m^3 and 18.8µg/m^3 respectively.

Figure 3.2.22: 24-hour mean PM_{10} concentrations & 24-hour total rainfall

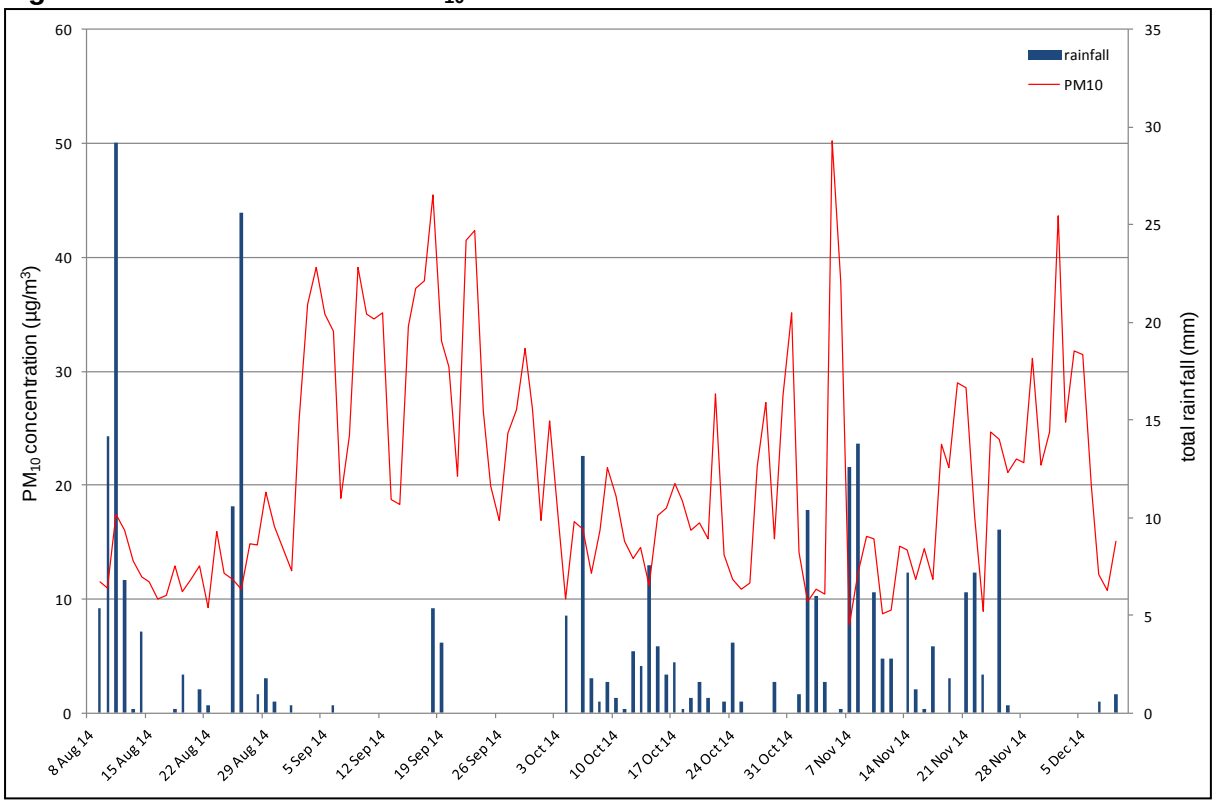


Figure 3.2.23: 24-hour mean PM_{10} histogram

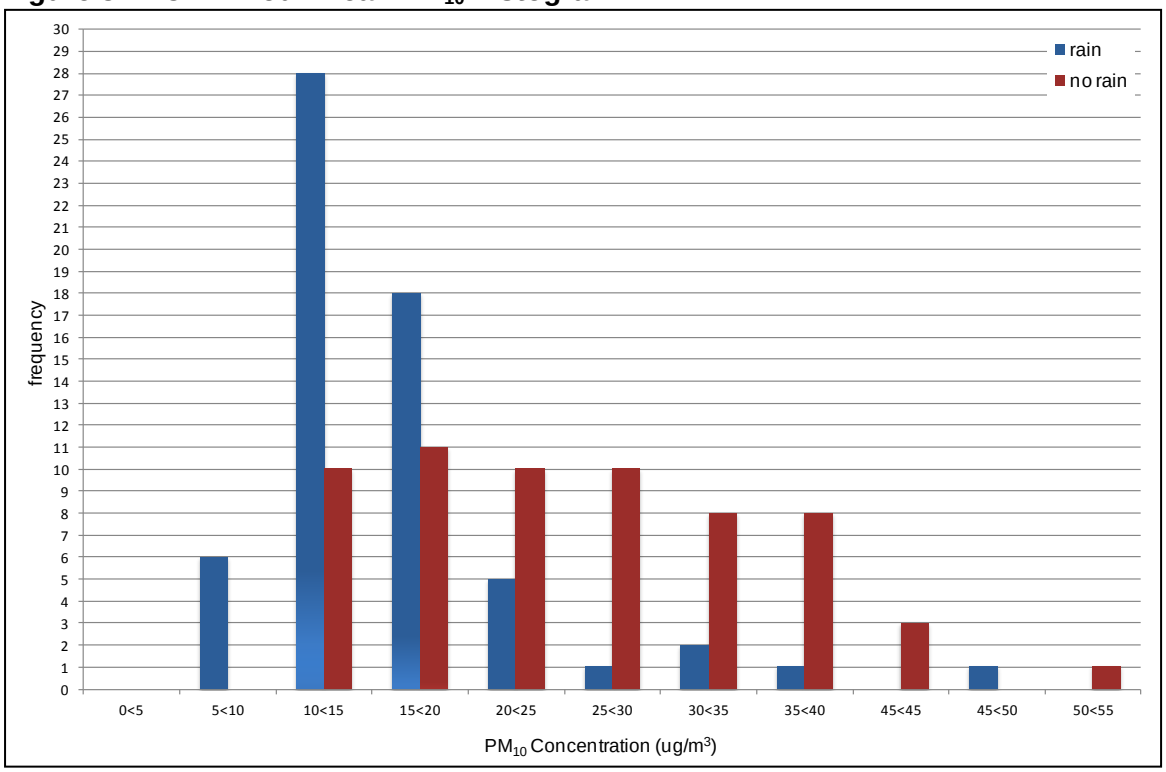


Figure 3.2.23 shows a PM_{10} frequency histogram plotted for days when rainfall was recorded (62 days) and when no rainfall was recorded (61 days). The plot shows that there are more days where the 24-hour mean PM_{10} concentrations are below 20µg/m^3 (84%) on days where rainfall was recorded, than on days where there was no rain (34%).

3.2.7 Conclusion

Comparison of the PM_{10} data with the AQS objective for the 24-hour (midnight-midnight) mean suggested that the standard would not be expected to exceeded at the MMF and TRL monitoring site.

The mean PM_{10} concentration over the monitoring period at the MMF and TRL monitoring site was 20.6µg/m^3 and 23.4µg/m^3 respectively. If the assumption is made that the conditions during the monitoring period was representative of a typical year, then the results would indicate that the AQS annual mean objective of 40µg/m^3 would not be expected to exceeded at the MMF or TRL monitoring sites.

The mean $PM_{2.5}$ concentration over the monitoring period at the TRL site was 12.1µg/m. 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 for $PM_{2.5}$ would not be expected to exceed at the TRL monitoring site.

Comparison of PM_{10} concentrations with the Air Quality Index at the MMF and the TRL site indicated that the 24-hour (midnight-midnight) mean was in the low banding for 99% and 98% of the monitoring period respectively. $PM_{2.5}$ concentrations at the TRL site were in the lower banding throughout the monitoring period. Both sites showed the highest elevated particulate concentrations on the 5th of November, bonfire night.

Pollution rose analysis indicates that the highest average TSP and PM_{10} concentrations measured at the MMF were from a wind direction between 0^o – 20^o in the direction of Sims Metal Management Ltd.

Pollution rose analysis at the TRL site indicates that the highest average TSP and PM_{10} concentrations measured at the monitoring site were from a wind direction between 250^o - 310^o. Elevated $PM_{2.5}$ concentrations were seen for wind directions 30^o - 100^o.

Percentile rose analysis at the MMF site suggested a relatively continuous source from 10^o and an intermittent source between 300^o - 360^o contributing to elevated particulate concentrations.

Percentile rose analysis at the TRL site suggested a relatively continuous source for wind directions 240^o - 340^o contributing to elevated TSP and PM_{10} concentrations. A relatively continuous source is also seen for wind directions 30^o - 110^o.

The elevated concentrations on bonfire night are evident in the 99th percentile at both monitoring locations.

Wind speed variation analysis at the MMF showed elevated particulate concentrations with increasing wind speeds for wind directions from the north in the direction of Sims Metal Management Ltd.

Wind speed variation analysis at the TRL site showed elevated particulate concentrations at high wind speeds for wind directions from the north west and Increasing TSP and PM_{10} concentrations, with increasing wind speed for wind directions from the west

Diurnal and weekday analysis at the MMF showed the influence of industrial activity between 06:00 – 21:00 for wind sectors 315^o – 45^o, with lower concentrations on Sundays. The influence of traffic emissions were seen for wind sectors 45^o – 180^o, with lower concentrations on Sundays.

Diurnal and weekday analysis at the TRL site showed the influence of industrial activity for wind sectors 225^o – 315^o, with concentrations lower on weekends. The influence of traffic emissions were seen for wind sectors 135^o – 180^o.

Comparing PM_{10} concentrations at the MMF with rainfall data suggest that rainfall could lower PM_{10} concentrations.

3.3 Sulphur and Heavy Metals

During the monitoring period, between 8 August 2014 and 10 December 2014 (125 days) monthly particulate samples were being collected and analysed for sulphur and a suite of heavy metals near Portview Road, Bristol. The monitoring was carried out by TRL, on behalf of the Bristol City Council. The sulphur samples were collected using TEOM instruments and the heavy metal samples were collected using a Partisol2000 instrument. Table 3.3.1 and Table 3.3.2 show the sampling periods for the sulphur and heavy metal samples respectively.

Table 3.3.1: Sulphur sampling periods

	Start	End	Sample Volume (m^3)		
			TSP	PM_{10}	$PM_{2.5}$
Sample 1	04/Sep/2014	29/Sep/2014	107	107	108
Sample 2	29/Sep/2014	05/Nov/2014	159	160	160
Sample 3	05/Nov/2014	28/Nov/2014	98	99	99

Table 3.3.2: Heavy metals sampling periods

	Start	End
Sample 1	09/Sep/2014	29/Sep/2014
Sample 2	29/Sep/2014	05/Nov/2014

3.3.1 Sulphur

The sulphur samples were analysed from particulate mass collected on monthly filters (13mm diameter) on the same TEOM instruments used to measure TSP, PM_{10} and $PM_{2.5}$ concentrations at the TRL monitoring site. The monthly TSP, PM_{10} and $PM_{2.5}$ filters were combusted at high temperature, and the mass of sulphur (µg) estimated from the SO_2 released by combustion. For each sample the blank mass was subtracted from the sample mass.

Table 3.3.3: Sulphur concentrations

	Concentration (ug/m^3)		
	TSP	PM_{10}	$PM_{2.5}$
Sample 1	2.2	2.3	2.2
Sample 2	0.5	0.6	0.5
Sample 3	0.6	0.7	0.6

Table 3.3.3 shows that the sulphur deposited on the filter was within the $PM_{2.5}$ fraction with all three PM size fractions showing similar sulphur concentrations. Higher Sulphur concentrations were measured in the first sample between 4 September 2014 – 29 September. September was identified as a drier month than October and November, with a higher monthly mean PM_{10} concentration of 30µg/m^3.

3.3.2 Heavy Metals

A suite of heavy metal results were calculated from particulate mass collected on filters (46mm diameter) using a Partisol2000 instrument and batched in to monthly samples. The sample and blank filters were analysed using the analytical technique of Inductively Coupled Plasma Mass Spectrometry (ICP-MS), with results reported in µg.

For each sample, the mass of the metals has been divided by the volume of air which passed over the filter to estimate the concentration of each heavy metal. For each metal species the blank mass was subtracted from the sample mass. Any values that are reported as being below the limit of detection are assumed to be at the limit of detection. Table 3.3.4 shows the calculated concentrations for the two samples collected and also reports the UK annual mean metal concentrations in 2012, calculated from all sites in the UK Heavy Metals Monitoring Network.

Table 3.3.4 Heavy metal concentrations

Metal Species	Concentration (ng/m^3)			
	Sample 1	Sample 2	Average	2012 UK Annual Mean
Arsenic (As)	0.65	0.42	0.53	0.63
Cadmium (Cd)	0.22	0.01	0.11	0.31
Cobalt (Co)	0.01	0.11	0.06	0.30
Cromium (Cr)	0.05	1.84	0.95	5.17
Copper (Cu)	1.55	4.45	3.00	15.9
Mercury (Hg)	0.01	0.01	0.01	0.05
Magnesium (Mn)	5.03	3.74	4.39	11.6
Nickel (Ni)	0.63	1.21	0.92	3.65
Lead (Pb)	5.58	2.42	4.00	11.2
Antimony (Sb)	3.73	1.10	2.42	
Thallium (Tl)	0.01	0.24	0.12	
Vanadium (V)	1.40	1.01	1.21	1.25
Zinc (Zn)	0.01	5.49	2.75	48.9
Totals	18.90	22.06	20.48	

Table 3.3.4 shows that there is variation in the two samples collected with all of the average concentrations calculated from the two samples falling below the UK annual means.

Table 3.3.5 summaries the different health based guidelines relevant to the suite of heavy metals that have been measured. Although comparison with the guidelines requires a longer period of monitoring, we have compared the guidelines with our heavy metal results for interest.

Comparison of the results with the relevant guidelines does not suggest that the metal concentrations measured would fail to comply.

For chromium, the value reported is total chromium (chromium II, III and VI). It is estimated that 20% of total chromium in particulate matter is typically present in the form of chromium VI. An estimated average concentration of chromium VI over the monitoring period is therefore 0.19ng/m^3 which is just below the long term EAL for chromium VI. This guideline value represents a level in ambient air at which no or minimal effects on human health are likely to occur.

Table 3.3.5: Summary of health based guidelines

Metal Species	AQS Annual Average	WHO Annual Average	Long Term EAL	WHO continuous lifetime exposure	WHO excess lifetime risk*	EPAQS Long term EAL Cr(VI)	EPAQS Annual average
As			3ng/m^3		0.66ng/m^3		
Cd			5ng/m^3	0.3µg/m^3			
Cr						0.2ng/m^3	
Cu			10µg/m^3				
Hg		1µg/m^3					
Mn		0.15µg/m^3					
Ni					2.5ng/m^3		20ng/m^3
Pb	0.25µg/m^3	0.5µg/m^3					
Sb			5µg/m^3				
V			5µg/m^3				

* WHO excess lifetime risk of cancer of 1 in 1million

3.3.3 Conclusion

The three sets of sulphur samples suggest that the sulphur measured at the monitoring site was carried in the $PM_{2.5}$ size fraction. The highest sulphur monthly mean concentration was seen for the sample collected in September, when there was low rainfall and higher monthly mean PM_{10} concentration of 30µg/m^3.

The two metals samples showed metal concentrations that were below their 2012 UK averages. Although the period of sampling only covers a few months, the levels did not suggest that there would be exceedances of relevant health based guidelines if metal concentrations remained at these levels.

3.4 Consideration of complaints data

Table 3.4.1: Incident details & MMF data

NIRS No.	Date	Time	WD	WS	PM_{10} (µg/m^3 TEOM)
NIRS 01272945	31 Aug 2014	16:00	233	5.0	22.4
NIRS 01269314	18 Aug 2014	11:03	247	2.4	10.7
NIRS 01275239	8 Sep 2014	10:33	28	0.9	15.1
NIRS 01281181	25 Sep 2014	09:00	221	2.9	25.8
NIRS 01288968	23 Oct 2014	10:32	207	2.8	13.3
NIRS 01299658	6 Dec 2014	14:45	221	2.0	17.7

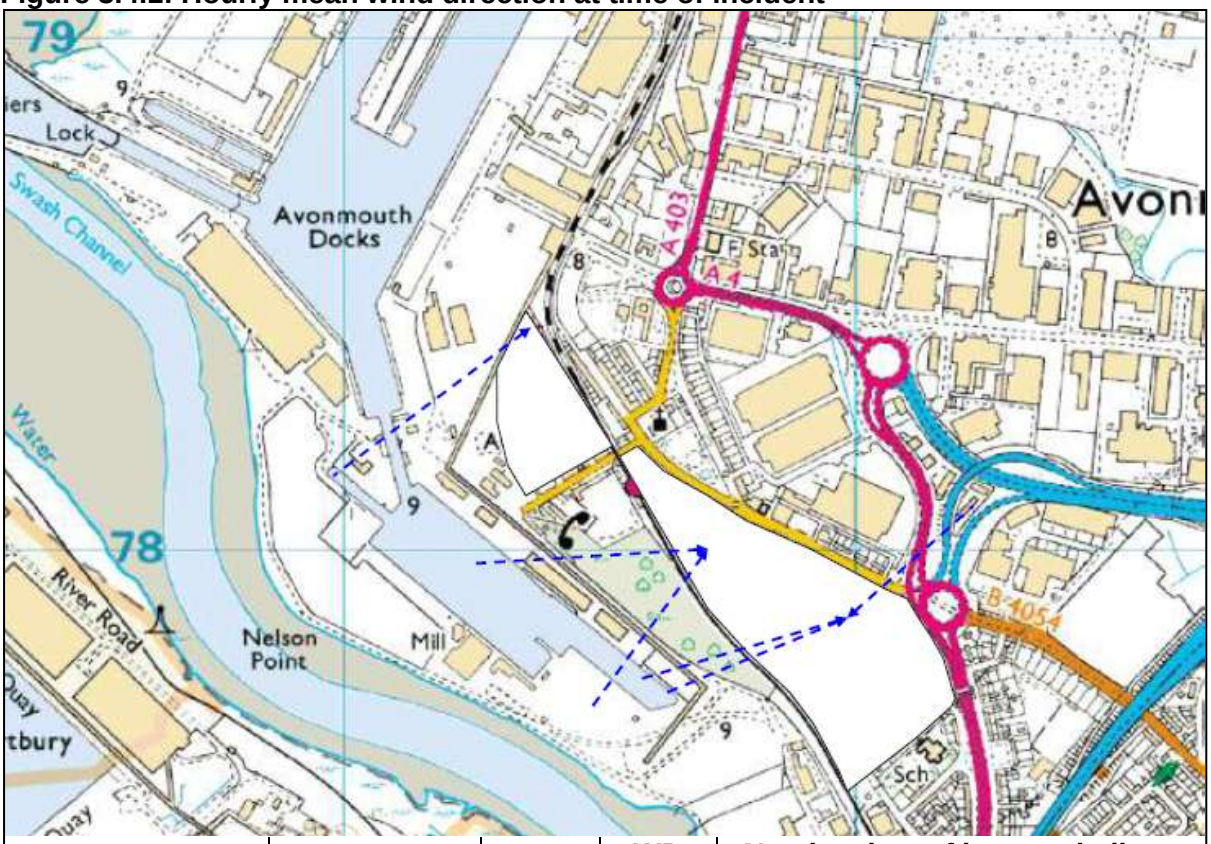
During the monitoring period the Environment Agency received six complaints of dust. Table 3.4.1 and 3.4.2 show the incident details and the hourly average results recorded at the MMF and TRL sites respectively.

Table 3.4.2: Incident details & TRL data

NIRS No.	Date	Time	WD	WS	PM_{10} ($\mu g/m^3$ TEOM)
NIRS 01272945	31 Aug 2014	16:00			
NIRS 01269314	18 Aug 2014	11:03			
NIRS 01275239	8 Sep 2014	10:33	46	1.0	37.0
NIRS 01281181	25 Sep 2014	09:00	253	2.3	43.0
NIRS 01288968	23 Oct 2014	10:32	216	1.8	15.6
NIRS 01299658	6 Dec 2014	14:45	267	0.8	26.3

Using the data in tables 3.4.1 & 3.4.2 Figure 3.4.1 provides a visual representation of the hourly mean wind directions at the time that the complaints of dust were recorded. Assuming that the wind direction has not greatly altered over a few hours Figure 3.4.1 provides a suggestion of which direction the particulate may have arrived.

Figure 3.4.1: Hourly mean wind direction at time of incident



NIRS No.	Date	Time	WD Used	Nearby sites of interest in line with WD
NIRS 01272945	31 Aug 2014	16:00	233	Coal conveyor| Remix Dry mortar
NIRS 01269314	18 Aug 2014	11:03	247	Coal conveyor | Cemex
NIRS 01275239	8 Sep 2014	10:33	46	Residential | A4 | M5
NIRS 01281181	25 Sep 2014	09:00	253	Coal conveyor | Cemex
NIRS 01288968	23 Oct 2014	10:32	216	Coal conveyor
NIRS 01299658	6 Dec 2014	14:45	267	Coal conveyor| Tarmac

Figure 3.4.1 suggests that complaints of dust were reported over the monitoring period when the wind was from a south westerly direction across the docks and coal conveyor. There is also one incident where the wind was from the north east, from the direction of the A4 and M5, this may also relate to a fire that was reported in the area nearby on the 8th September.

4 Summary

Comparison of the PM_{10} data with the AQS objective for the 24-hour (midnight-midnight) mean indicated that the current standard would not be expected to exceeded at the MMF and TRL monitoring sites.

The mean PM_{10} concentrations over the monitoring period at the MMF and TRL monitoring site were 20.6µg/m^3 and 23.4µg/m^3 respectively. 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 of 40µg/m^3 would not be expected to exceed at the monitoring sites.

The mean $PM_{2.5}$ concentration over the monitoring period at the TRL site was 12.1µg/m. 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 for $PM_{2.5}$ would not be expected to exceed at the TRL monitoring site.

Comparison of PM_{10} concentrations with the Air Quality Index at the MMF and the TRL site indicated that the PM_{10} concentrations were in the low banding for 99% and 98% of the monitoring period respectively. $PM_{2.5}$ concentrations at the TRL site were in the lower banding throughout the monitoring period.

PM_{10} concentrations at the MMF and TRL monitoring sites are shown to be in a similar range to those measured at the AURN monitoring station at Bristol St Pauls, but they are generally higher.

Directional analysis suggests that the MMF and TRL monitoring sites are seeing elevated contributions from different localised sources of particulate.

Directional analysis at the MMF site indicated elevated sources when the wind is blowing from the north, from the direction of Sims Metal Management Ltd. The particulate source is relatively continuous from this direction and shows elevated particulate concentrations with increasing wind speed. The source of particulate from the north shows elevated concentrations during the working day.

Directional analysis at the TRL site show elevated sources of particulate from the north west from the direction of the coal conveyor and docks and a relatively continuous source from the east-north east in the direction of the A4 and M5. The particulate concentrations from the north west increase in the morning and appear to remain high until midnight.

Consideration of rainfall data suggest that lower PM_{10} concentrations were seen when there was higher rainfall.

Sulphur samples showed monthly mean concentrations ranging from 0.5 - 2.3µg/m^3 with a higher monthly mean seen in September, which was identified as a drier month than October and November.

The measurement of heavy metal concentrations showed concentrations that were below the 2012 UK averages. Although the period of sampling only covers a few months, the levels did not suggest that there would be exceedances of relevant health based guidelines if metal concentrations remained at these levels.

Complaints of dust were reported over the monitoring period when the wind was from a south westerly direction across the docks and coal conveyor. There is also one incident where the wind was from the north east, from the direction of the A4 and M5.

Bristol City Council is to continue monitoring air quality in the Avonmouth ward. The capture of a longer period of monitoring data will allow for a greater understanding of seasonal variation in particulate concentrations and provide a more appropriate data set for comparison with the annual PM_{10} and $PM_{2.5}$ AQS objectives.

Ongoing investigation in to wind direction measurements complaints of dust incidents are reported can help to identify potential sources of dust.

Ongoing discussion with site operators at Avonmouth Docks can help to identify how activities can be managed in a way that can help keep particulate emissions at acceptable levels.

5 References

1. Department for Environment, Food and Rural Affairs (July 2007), *The Air Quality Strategy for England, Scotland, Wales and Northern Ireland,* (HMSO)
2. Department for Environment, Food and Rural Affairs (2009), Panel on Air Quality Standards, *Guidelines for Metals and Metalloids in Ambient Air for the Protection of Human Health*,(HMSO)
3. Environment Agency (2011), *H1 Annex F- Air Emissions*,(HMSO)
4. National Physical laboratory (2013), *Annual report for 2012 on the UK Heavy Metals Monitoring Network*, (HMSO)
5. World Health Organisation (2000), *Air quality guidelines for Europe, 2nd edition*. WHO Regional Publications European Series, No 91 Copenhagen

Appendix A Mobile Monitoring Facilities

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 Thames Wharf study was MMF7. The pollutants that can be measured using MMF5 are:

- particles (PM_{10} & $PM_{2.5}$)

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,

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 five 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 Particulate Matter

Airborne particulate matter can be found in a wide range of particle sizes (nm-µm) and chemical constituents. Total suspended particulate (TSP) PM_{10} and $PM_{2.5}$ levels have been monitored in this study. Total suspended particulate is defined as the total amount of particulates suspended in air. 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 TSP, PM_{10} and $PM_{2.5}$ is restricted to its physical characteristic and no particular chemical composition is implied (The size-selective samplers used to collect small particles preferentially are designed to collect 50% of 10µm aerodynamic diameter particles, more than 95% of 5µm particles, and less than 5% of 20µm particles). 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 2001 were[(1)]:

- Road transport; nationally, road transport contributed around 27% of primary PM_{10} and 38% of primary $PM_{2.5}$ emissions, however, the contribution can be much higher in urban areas.
- Industrial processes; including a range of different industrial processes leading to the release of dust as well as construction, mining and quarrying activities. Nationally, it is estimated that these processes accounted for around 27% of primary PM_{10} emissions and 21% of primary $PM_{2.5}$ emissions.
- Domestic coal burning; traditionally the major source of airborne particles, but its decline has reduced the contribution to around 17% nationally for primary PM_{10} and 16% for primary $PM_{2.5}$ emissions, and mostly in a small number of specific locations. Electrical supply industry power generation; is estimated to have been responsible for 9.8% of primary PM_{10} emissions and 8.6% of primary $PM_{2.5}$ emissions.

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 TSP, PM_{10} & $PM_{2.5}$ concentration is a Rupprecht & Patashnick (R&P) Tapered Element Oscillating Microbalance (TEOM). It provides measurements in real time and stores them as 15-minute averages.TSP, PM_{10} and $PM_{2.5}$ fractions were measured using separate TEOM systems with specific PM_{10} and $PM_{2.5}$ filter inlets. The system measures PM concentration by continuously determining the particle mass deposited on a filter. The filter is attached to a hollow tapered element that vibrates at its natural frequency of oscillation (***f***). As particles collect on the filter, the frequency changes by an amount inversely proportional to the square root of the mass deposited (**m**).

$$\mathbf{m} = \mathbf{k}/f^2$$

Where k is a constant determined during calibration of the instrument.

The flow rate through the system is controlled using thermal mass flow controllers and automatically measured so that the mass concentration can be calculated. The analyser consists of a sample inlet head that has an airflow of 16.67 litres per minute. The action of the air through the head selects particles of aerodynamic diameter less than 10μm. After the air has passed through the head the flow is divided using a flow splitter to direct 3 litres per minute through the filter cartridge.

It is a requirement of the TEOM instrument that the filter is kept at a constant temperature of 50^{o}C. This can lead to a difference between mass concentrations determined using a TEOM and co-located gravimetric filter samplers, for which the collection filters are unheated and therefore at ambient temperature. The effect of this difference is variable depending on the nature of the particulate being measured. It is considered most probable that the discrepancy is a consequence of evaporation of semi-volatile secondary particles such as ammonium nitrate and some organic compounds. Therefore, care must be taken when predicting the secondary particle contribution to the total mass concentration.

The Airborne Particles Expert Group (APEG now the Air Quality Expert Group) have published a report which concluded that at concentrations around 50μm/m^3 the TEOM tends to under-read compared with a gravimetric sampler by between 15 and 30%. However, this effect is not constant, and varies depending upon the mass concentration, the distance from a specific source, and the environmental conditions. Further studies have been commissioned by DETR to investigate these effects, and to provide a more robust relationship between the TEOM and the European transfer gravimetric reference method.

The air quality objectives are based upon measurements carried out using the European transfer reference method or equivalent. Therefore a potential inconsistency between measurements of PM_{10} concentrations made using a TEOM analyser and the objectives – for example, a daily mean concentration of 45μg/m^3 measured using a TEOM analyser could

be underestimating the gravimetric concentration by 15$\mu m/m^3$ or more. It is therefore necessary to apply a correction factor when assessing TEOM measured concentrations against the objectives.

Recent findings have suggested that the correction factor of 1.3 originally recommended by the NQAS guidance for use with PM_{10} and $PM_{2.5}$ data is not equivalent to the reference method for particulate matter and therefore not strictly comparable to the European Daughter Directive Limit Values.

King's College London on behalf of Defra have developed a volatile correction model (VCM) which can be used to correct PM_{10} TEOM measurements for the loss of volatile components caused by the high sampling temperature, with corrected measurements being comparable to the gravimetric reference equivalent. The VCM works by using volatile particulate measurements from nearby Filter dynamics measurement system (FDMS) within a radius of 130km, this allows for the loss of volatiles from the TEOM measurements to be calculated and added to the measurements obtained from the TEOM.

Reference Equivalent PM_{10} = TEOM – 1.87 FDMS purge

FDMS Purge is usually a negative value due to the loss of volatiles. It can be measured at a remote site, allowing for the possibility of using one FDMS to correct many TEOM instruments within suitable distance.

The model provides adequate coverage for the whole of the UK, except Scotland and Northern Ireland.

KCL has developed a VCM for $PM_{2.5}$ that does go some way toward estimating the volatile fraction of the particulate lost on the TEOM. Although not strictly equivalent to the reference method it does give a better estimation of total particulate $PM_{2.5}$ than uncorrected TEOM data and therefore has been used in this study.

The manufacture's specification states that the TEOM is accurate to within 4 $\mu g/m^3$.

This instrument is used extensively in the UK automatic monitoring networks and has been designated as an equivalent method for the determination of 24-hour average PM_{10} concentrations by the USEPA.

References

1. Air Quality Expert Group, June 2005, Report on Particulate Matter in the United Kingdom, Defra, p.416.
2. DETR – May 2000 - Pollutant Specific Guidance.

Appendix D 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 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.

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

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

BetterSolutions.com

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 does not 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 are 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.

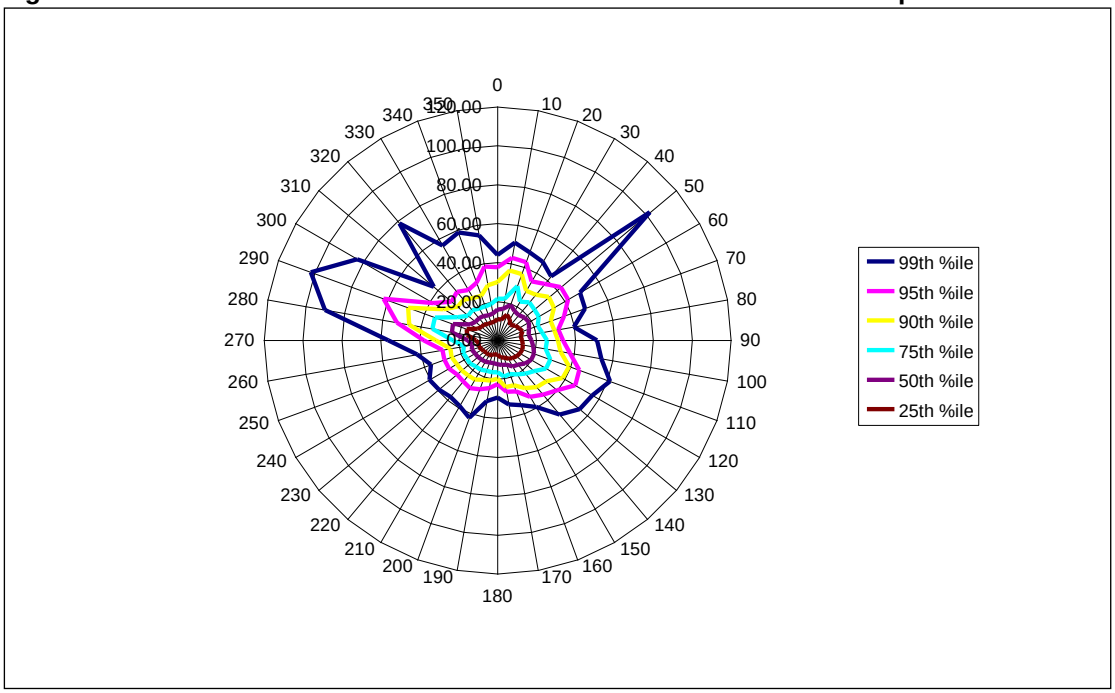


Figure 2 - shows a bias at 260° that is only evident in the 99th percentile.

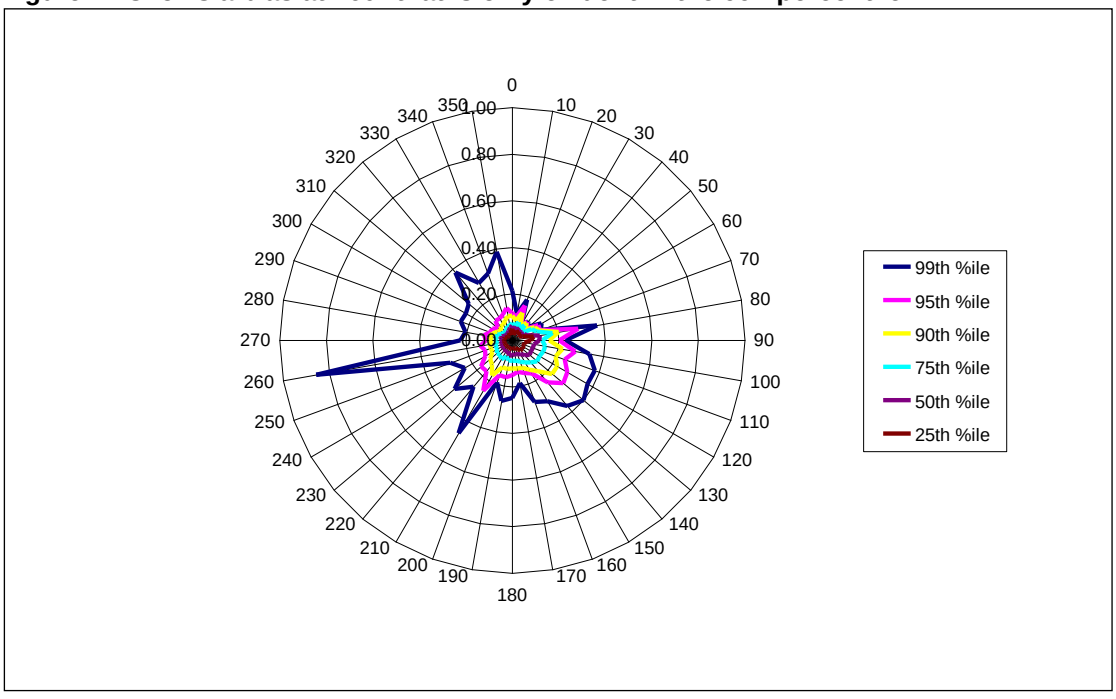
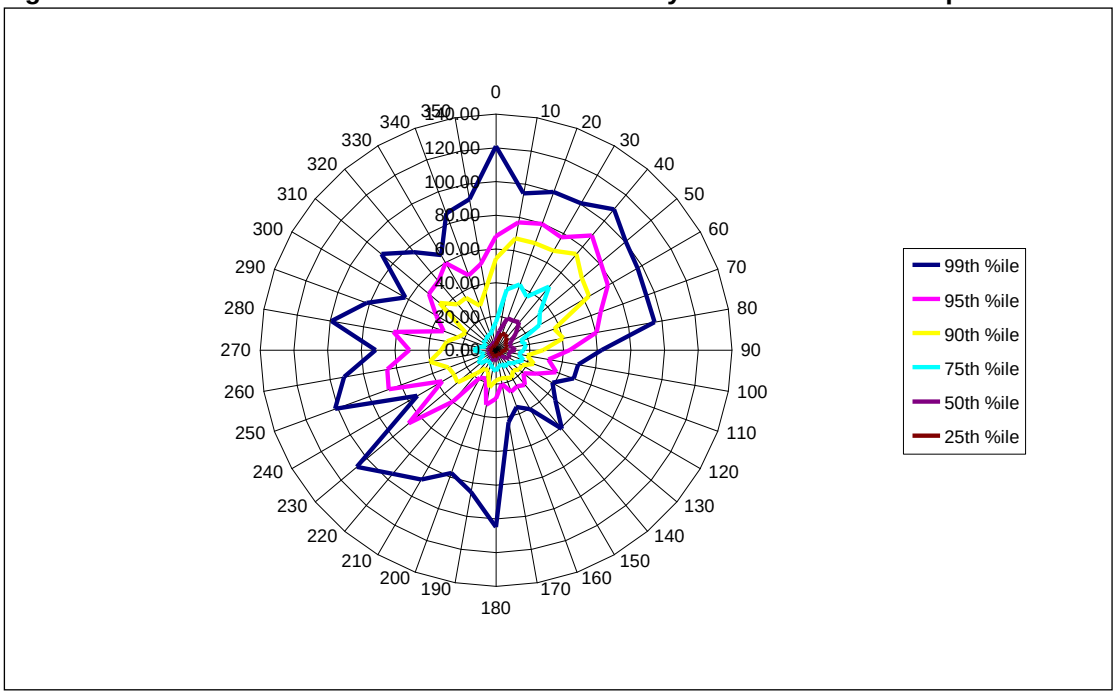


Figure 3 - shows a bias between 20° – 50° that is only evident in the lower percentiles.



Appendix E Abbreviations

AQS – Air Quality Strategy

BSP – Bristol St Pauls

FDMS – Filter Dynamics Measurement System

ICPMS – Inductively Coupled Plasma Mass Spectrometry

KCL – Kings College London

MMF – Mobile monitoring facility

PM_{10} – Particulate matter with aerodynamic diameter <10µm

$PM_{2.5}$ – Particulate matter with aerodynamic diameter <2.5µm

TEOM – Tapered Element Oscillating Microbalance

TSP – Total suspended particulate

VCM – Volatile correction model

Would you like to find out more about us, or about your environment?

Then call us on

03708 506 506 (Mon-Fri 8-6)

Calls to 03 numbers cost the same as calls to standard geographic numbers (i.e. numbers beginning with 01 or 02).

email

enquiries@environment-agency.gov.uk

or visit our website

www.environment-agency.gov.uk

incident hotline 0800 80 70 60 (24hrs)
floodline 0845 988 1188

Environment first: Are you viewing this on screen? Please consider the environment and only print if absolutely necessary. If you are reading a paper copy, please don't forget to reuse and recycle if possible.