AIR QUALITY IN HELSBY

2021 Annual Report

Report for: Peel NRE Limited

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EXECUTIVE SUMMARY

This report provides details and results of the air quality monitoring programme that took place at Helsby, Cheshire from 1st January to 31st December 2021.

The work was carried out by Ricardo Energy and Environment on behalf of Peel NRE Limited. The monitoring programme includes measurements of particulates (PM_{10} and $PM_{2.5}$), heavy metals, and Toxic Organic Micro Pollutants (dioxins, furans, dioxin like polychlorinated biphenyls, and polycyclic aromatic hydrocarbons), to assess their concentrations against the relevant air quality objectives.

Hourly PM_{10} and $PM_{2.5}$ monitoring was carried out using a Fine Dust Analysis System (FIDAS). The data capture rate for PM in 2021 was 87%. The annual means measured in 2021 for PM_{10} and $PM_{2.5}$ were 11.4 μgm^{-3} and 7.1 μgm^{-3}, respectively. The annual mean AQS objectives are >40 μgm^{-3} for PM_{10} and >20 μgm^{-3} for $PM_{2.5}$, therefore, the annual means are below the limit values. The 24-hour mean PM_{10} limit is 50 μgm^{-3} which may not be exceeded more than 35 times per year to meet the objective. There were no exceedances of this limit in 2021, therefore the objective was met.

Monthly collated filter samples of PM_{10} were analysed for a number of heavy metals. The mean values were compared to the UK AQS Objective for lead and Ambient Air Directive target values or Environment Assessment Levels for other compounds where applicable. All heavy metal concentrations were below the target values in 2021.

Dioxins, furans, dioxin like polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) were extracted from samples collected and collated every three months from a High-Volume sampler. Benzo(a)pyrene (B[a]P) is used as a marker for PAHs in ambient air. The mean concentrations of B[a]P in 2021 was 0.06 ngm^{-3}, which is well below the annual mean European target value of 1 ngm^{-3} and the UK objective of 0.25 ngm^{-3}.

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1. INTRODUCTION

This report produced on behalf of Peel NRE Limited, relates to the period 1st January 2021 to 31st December 2021 during which time air quality monitoring of dioxins, furans, particulates, PAHs and heavy metals were undertaken in Helsby, Cheshire.

The monitoring, commissioned on behalf of Peel NRE, followed on from an original contract with the Bioenergy Infrastructure Group (B.I.G) acting on behalf of Ince Bio Power Ltd. The original contract, which was completed in July 2020, was to monitor pollutants prior to and post construction and commissioning of a new biomass renewable energy power plant in Cheshire (Plot 9, Ince Resource Recovery Park). Further information on the air quality monitoring which took place during this initial survey can be found in a report located on the Protos website.[1]

Monitoring continued without a break following the initial survey and will be ongoing to provide members of the local and wider community with air quality data on an annual basis. It will also provide monitoring required by businesses operating at Protos to ensure compliance with planning conditions.

During the period 1st January 2021 to 31st December 2021, activity on site at Protos included:

- Operational biomass energy plant on plot 9a.
- Operational timber recycling facility on plot 3.
- Construction of an energy from waste facility on plot 8 including import of fill material to create working platform, installation of site office and welfare complex, piling works for main building foundations across the site, commencement of erection of structural steel and precast concrete structures.
- Construction of two sub-stations on land adjacent to plot 12 connecting facilities at Protos with an 11KV and 33KV network.
- Ground preparation works through the importation of naturally occurring construction fill materials
- Phase 2 infrastructure works including earthworks and piling to facilitate construction of internal estate roads and construction of two bridges and creation of ecological areas.
- Ongoing estate management including habitat and tree management

For more information on any of these activities, please visit www.protos.co.uk/community or email community@protos.co.uk

2. MONITORING SITE AND METHODS

2.1 MONITORING STATION

The monitoring station was set up in 2016 on land owned by Helsby Parish Council adjacent to an office building accessed from Mountain View, Helsby. The site was previously used by Ince Bio Power Ltd and will continue to be used for the purposes of ongoing monitoring for current and future facilities located at Protos.

Protos is an energy and resource site of 54ha, currently under development by Peel NRE. During 2021 two plots within Protos were fully occupied at the site and two further sites under construction. Figure 1 shows the location of the monitoring station (blue marker) with respect to the Protos development (as shown by the red line), the operational Ince Bio Power Plant and Ince Park Renewables Ltd (orange markers) and sites under construction (red markers).

This plan will be updated each year to show facilities at Protos which have been under construction, under commissioning, or operational during the reporting year.

[1] https://www.protos.co.uk/media-centre/community-downloads/#air-quality-documents.

Figure 1 Location of Helsby monitoring station (blue marker) and the Protos development. Operational facilities within the Protos development are shown as orange markers and facilities under construction are shown as red markers.

2.2 POLLUTANTS MONITORED

The monitoring station set up in Helsby is shown in Figure 2. The following sections provide an overview of the pollutants that Ricardo Energy & Environment were contracted to measure at the site in Helsby throughout 2020, firstly by B.I.G., then since July 3rd 2020, by Peel NRE. In addition, hourly meteorological data from Liverpool John Lennon Airport (located 9 km NW of the monitoring station) were sourced from the NOAA Integrated Surface Databased [1] and accessed using the worldmet R package [2].

Figure 2 Monitoring station located on land adjacent to RSK offices accessed from Mountain View in Helsby.

2.2.1 Particulate Matter

Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. The terms PM_{10} and $PM_{2.5}$ are used to describe particles with an effective size with a median aerodynamic diameter of 10 and 2.5 µm respectively. These are of greatest concern with regard to human health, as they are small enough to penetrate deep into the lungs. They can cause inflammation and a worsening of the condition of people with heart and lung diseases. In addition, they may carry surface absorbed carcinogenic compounds into the lungs. Particles with a median aerodynamic diameter greater than 10 µm are less likely to travel as far into the respiratory system. These larger particles are also removed more readily from the air by sedimentation.

The main source of airborne particulate matter in the UK is combustion (industrial, commercial and residential fuel use). Other large sources include production processes, agriculture and road transport. PM and its precursors can also be transported long distances, and transboundary pollution from the continent can result in increased PM in the UK.

PM_{10} and $PM_{2.5}$ were measured using an MCERTS approved Fine Dust Analysis System (FIDAS). The FIDAS analyser utilises an LED to determine particle numbers and particle size distribution through light scattering of individual particles.

The output is recorded and stored every 10 seconds and averaged to 15 minute average values by an on-site data logger. This logger is connected to a modem to download the data to Ricardo Energy & Environment. The data are then converted to concentration units and averaged to hourly mean concentrations. Data were processed according to the rigorous quality assurance and quality control procedures used by Ricardo Energy & Environment, and ratified every six months, to produce the final dataset reported here.

2.2.2 Heavy Metals

Heavy metals are toxic metallic elements that can result in adverse health effects. Anthropogenic sources of heavy metals include emissions from industrial processes and fuel combustion.

A Partisol 2025 sampler was used to collect particulates in the PM_{10} fraction on a weekly schedule. The weekly filters were collated into monthly samples and sent to an analytical laboratory to be analysed for heavy metals using including: Arsenic, Cadmium, Cobalt, Chromium, Mercury, Manganese, Nickel, Lead, Antimony, Thallium, Vanadium, Zinc, via UKAS accredited procedures, and Chromium VI (not accredited).

2.2.3 Toxic Organic Micro Pollutants (TOMPs)

Toxic Organic Micro Pollutants include a range of persistent organic pollutants (POPs), such as polychlorinated-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs). Exposure to POPs can have an adverse impact on human health and the environment. The main source of POPs in recent years in the UK are unintentional by-products from the incomplete combustion of fuels.

A High Volume sampler was used to collect samples for analysis of dioxins, furans, dioxin like PCBs and PAHs. Samples were collected every 2 weeks and collated into 3 monthly samples (Table 1). Sample blanks were also obtained and analysed and found to be within acceptable limits. The method used for the analytical measurement complies with US EPA 1613B for the PCBs, dioxins and furans, and EPA-TO-13A for PAHs.

Table 1 Start and end dates of 3-monthly periods for TOMPs sampling in 2021.

Period	Start Date	End Date
Period 1	19/01/2021	24/03/2021
Period 2	24/03/2021	16/06/2021
Period 3	16/06/2021	22/09/2021
Period 4	22/09/2021	29/12/2021

2.3 AIR QUALITY LIMIT VALUES

Table 2 shows the current UK objectives (included in the Air Quality Standards Regulations [3] and subsequent Amendments for the purpose of Local Air Quality Management), for the pollutants monitored at Helsby for this report. These regulations are based on those in the European Commission Directive on Ambient Air Quality and Cleaner Air for Europe [4], [5] (referred to as the Air Quality Directive) when the UK was a member of the European Union. Since Brexit, the UK is no longer tied to the EU limits, however, current objectives in the UK have been adopted from those stated in the Air Quality Directive, as shown in Table 2.

Where target analytes do not have a UK objective limit value, Ambient Air Directive (AAD) target values or Environmental Assessment Levels (EALS) used for Environmental Permit Risk assessments [6] were adopted for the purpose of this study, as shown in Table 3.

Table 2 UK and European air quality objectives for pollutants measured at Helsby.

Pollutant	UK Objective	European Objective	Measured as
PM_{10}	50 μgm^{-3} not to be exceeded more than 35 times a year	50 μgm^{-3} not to be exceeded more than 35 times a year	24 hour mean
PM_{10}	40 μgm^{-3}	40 μgm^{-3}	annual mean
$PM_{2.5}$	20 μgm^{-3}	20 μgm^{-3}	annual mean
Polycyclic Aromatic Hydrocarbons (PAH)	0.25 ngm^{-3} B[a]P	1 ngm^{-3} B[a]P	annual mean
Lead	0.25 μgm^{-3}	0.5 μgm^{-3}	annual mean

Table 3 UK and European air quality objectives for pollutants measured at Helsby.

Pollutant	Adopted limit (ngm^{-3})	Standard	Measured as
Arsenic (As)	6	AAD Target Value	annual mean
Cadmium (Cd)	5	AAD Target Value	annual mean
Copper (Cu)	10000	Environmental Assessment levels	annual mean
Mercury (Hg)	250	Environmental Assessment levels	annual mean
Manganese (Mn)	150	Environmental Assessment levels	annual mean
Nickel (Ni)	20	AAD Target Value	annual mean
Antimony (Sb)	5000	Environmental Assessment levels	annual mean

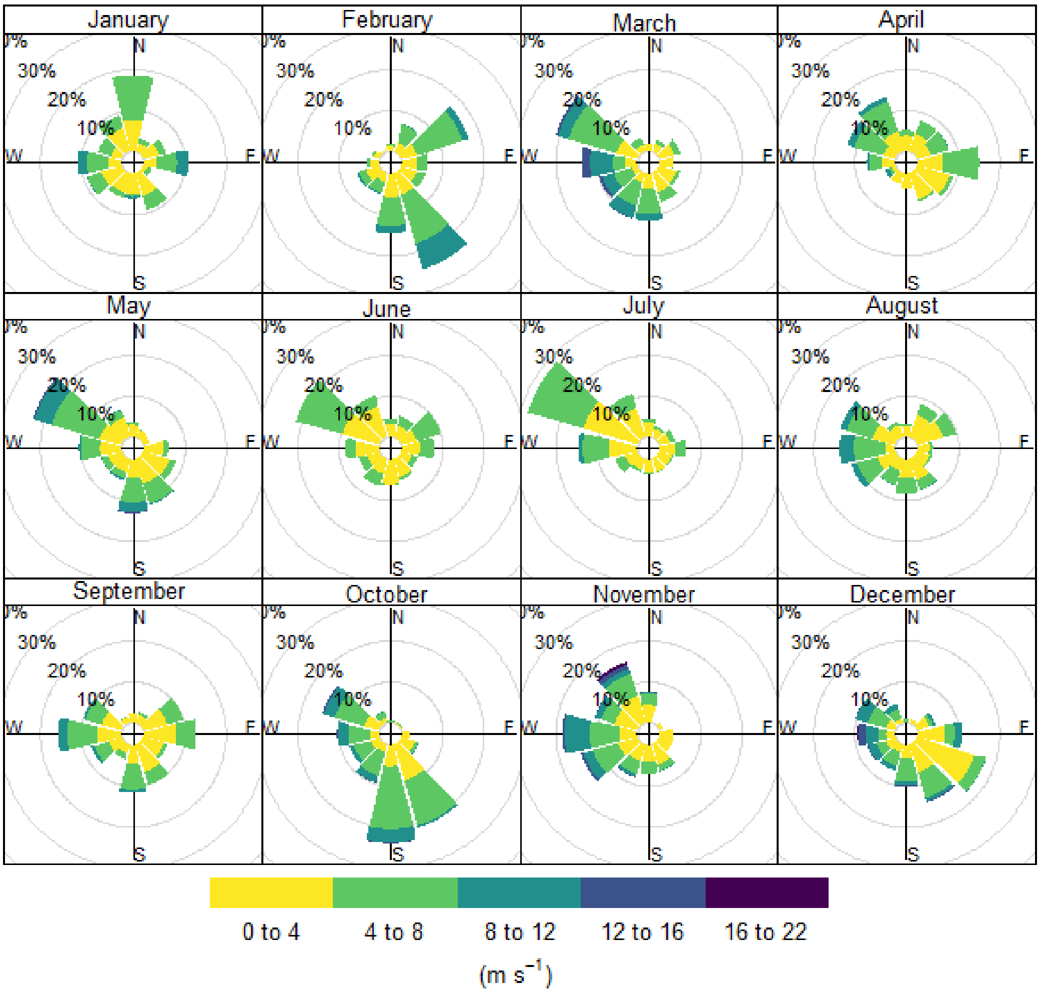
3. RESULTS AND DISCUSSION

The pollutant data measured at Helsby during 2021 have been analysed and where applicable, measurements have also been assessed with respect to current Air Quality Objectives.

3.1 METEOROLOGICAL CONDITIONS

Figure 3 shows the distribution of wind speed and wind direction (wind rose) for each month at Liverpool John Lennon Airport. The “spokes” show the direction the wind is coming from, a longer spoke means a higher frequency of wind from that direction and the colours represent the wind speed (purple= high winds, yellow = calm winds). Between March and July, the wind direction was predominantly from a north-westerly direction. In late November Storm Arwen arrived from a northerly direction resulting in high winds and unsettled weather.

Figure 3 Monthly wind roses in 2021 for Liverpool John Lennon Airport. Data source: NOAA Integrated Surface Database (ISD) [1].



3.2 PM DATA ANALYSIS

3.2.1 Summary Statistics

Table 4 shows a summary of the PM data for 2021. The period mean concentrations are below the annual mean air quality objectives for PM_{10} and $PM_{2.5}$. There were no exceedances of the PM_{10} daily mean objective during 2021, therefore the objective was met. The data capture rates in 2021 for both PM fractions is 87%.

Table 4 Summary statistics and exceedances for particulate matter measured at Helsby in 2021.

Statistic	PM_{10}	$PM_{2.5}$
Annual Mean (µgm^{-3})	11.4	7.1
Hourly Maximum (µgm^{-3})	74.1	51.7
Daily Maximum (µgm^{-3})	46.1	39.7
Data Capture rate (%)	86.9	86.9
Period mean > annual mean objective	No	No
Exceedances (daily mean > 50 µgm^{-3})	0	0

3.2.2 AQ Index Distribution

The plots below illustrate the distribution of AQ index values for Helsby for PM_{10} and $PM_{2.5}$. The AQIs are based on the daily mean for PM and each plot shows the number of days that concentrations measured are in each index. The index ranges from 1 to 10 and separated into four different bands: 1-3 = Low, 4-6 = Moderate, 7-9 = High, and 10 = Very High. Further information on the AQ Index is available in Table A1 in the appendix and from UK-Air [7]. During 2021, there were no days recorded when the PM_{10} AQI went above the "Low" banding (Index 1-3). For $PM_{2.5}$ there was one day in 2021 when the AQI was in the "Moderate" banding (Index 4), with the rest recorded as "Low".

Figure 4 Distribution of AQI for PM_{10}.

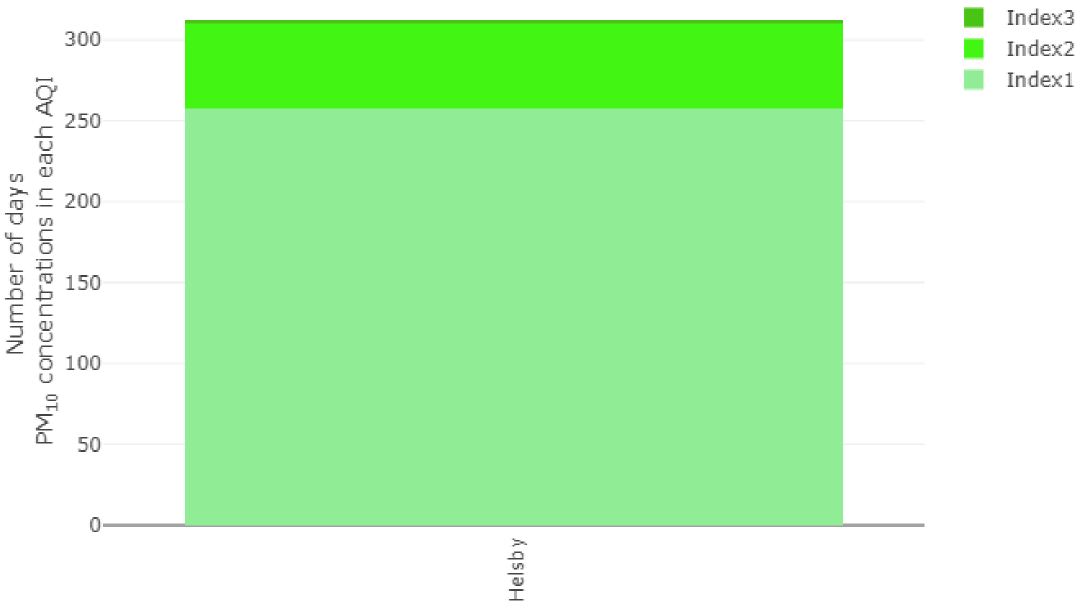
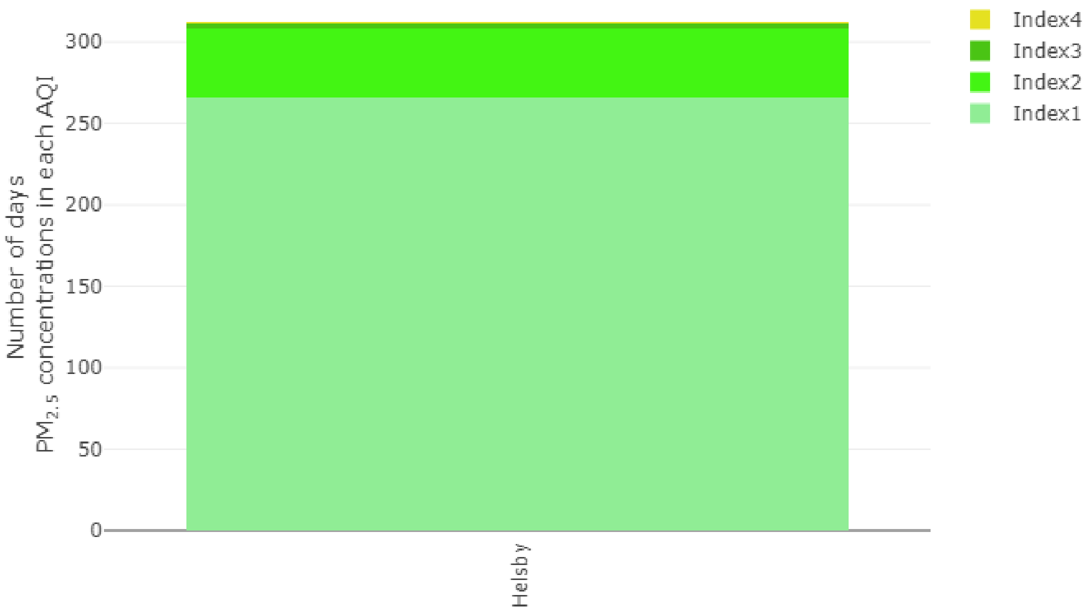


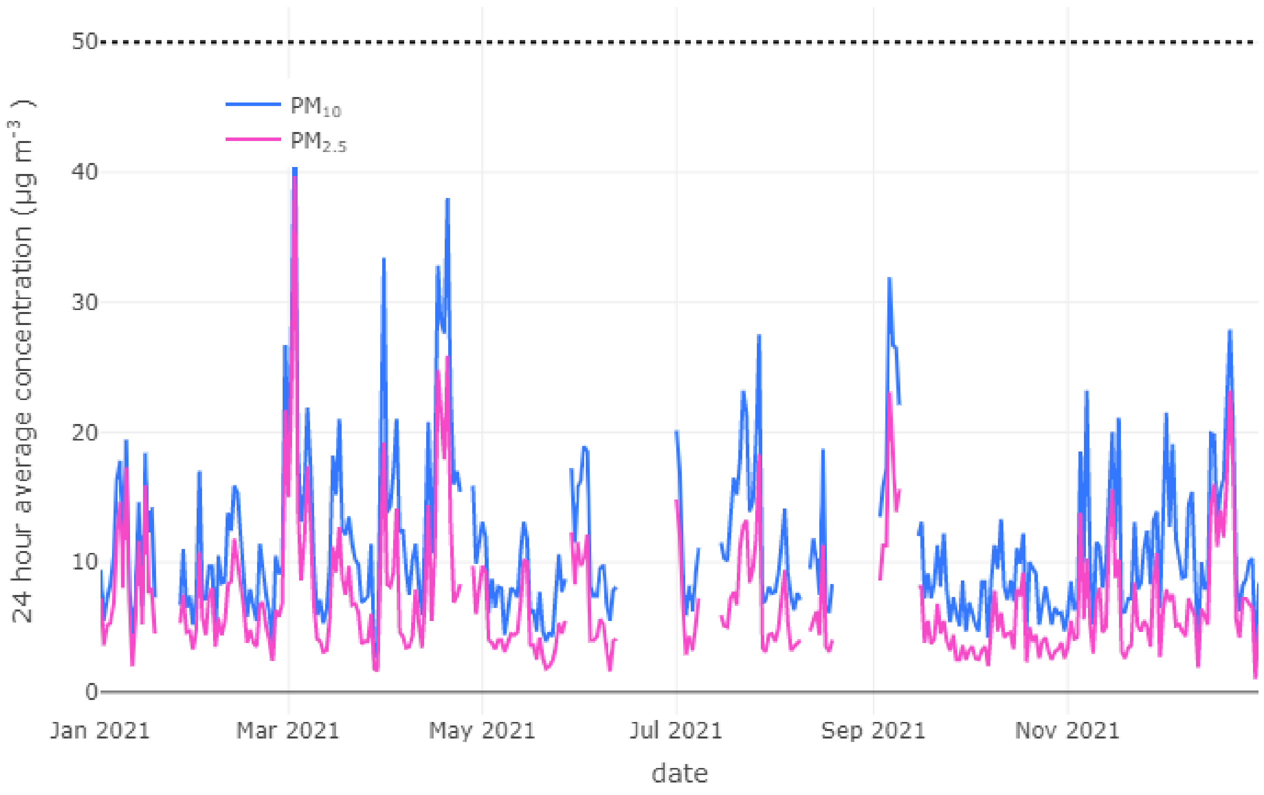
Figure 5 Distribution of AQI for $PM_{2.5}$.



3.2.3 Time Series

Figure 6 shows the 24 hour averaged time series of PM_{10} and $PM_{2.5}$ measured at Helsby during 2021.

Figure 6 24 hour average PM_{10} and $PM_{2.5}$ concentrations measured at Helsby during 2021. The dashed line represents the PM_{10} 24 hour objective.



3.2.4 Time Variations

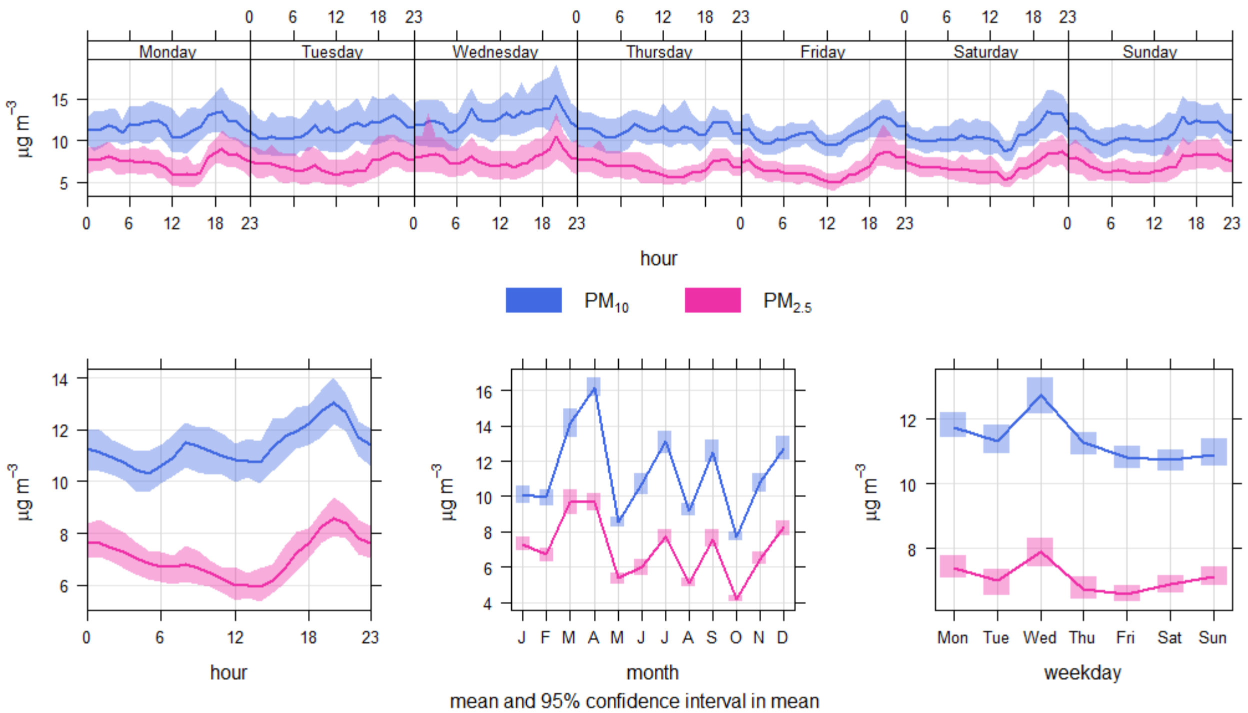
As PM_{10} and $PM_{2.5}$ are continuously measured on an hourly time period, the variability over short and long time periods can be assessed. Figure 7 shows the daily, weekly, and monthly variability in concentrations for 2021.

Seasonal: Variations in the PM concentrations across seasons can be seen in the "month" plot in Figure 7. PM concentrations were elevated over winter/spring during 2021. There is likely to be an increase in emissions from residential heating during these colder months. This, coupled with low dispersion under cold/stable conditions can result in elevated levels of PM. Long range transport of pollutants can also result in an increase in PM in the UK. Despite the national lockdown being in place, the highest PM levels were still observed in April 2021. As shown in (Figure 3) there were a high proportion of easterly winds measured at the nearby Liverpool John Lennon Airport during April. Air masses arriving from the east can transport pollutants from the continent resulting in an increase in PM.

Weekly: The weekly cycles for PM_{10} and $PM_{2.5}$ are very similar with the highest concentrations typically observed mid-week, which may be related to local traffic.

Diurnal: The diurnal cycle, as seen in the "hour" plot in Figure 7 shows a minimum in PM_{10} and $PM_{2.5}$ around noon, and peaks in the morning and evening.

Figure 7 Temporal variations in PM10 and PM2.5 concentrations measured at Helsby during 2021.



3.2.5 Calendar Plots

The plots in Figure 8 and 9 show daily variation in concentrations by pollutant for each month in 2021. The colours shown for each day relate to the concentration. The highest daily mean PM_{10} and $PM_{2.5}$ concentrations were observed from 3rd March, with average daily concentrations of 46.1 µgm^{-3} and 39.7 µgm^{-3}, respectively. The wind direction on 3rd March was from an easterly/south easterly direction. Southern and easterly winds can often bring polluted air from the continent and dust from the Sahara Desert to the UK, which may result in elevated levels of pollutants observed in the UK. “Moderate” pollution was observed across most of England on this day.

Figure 8 Calendar plot for PM_{10} measured at Helsby during 2021.

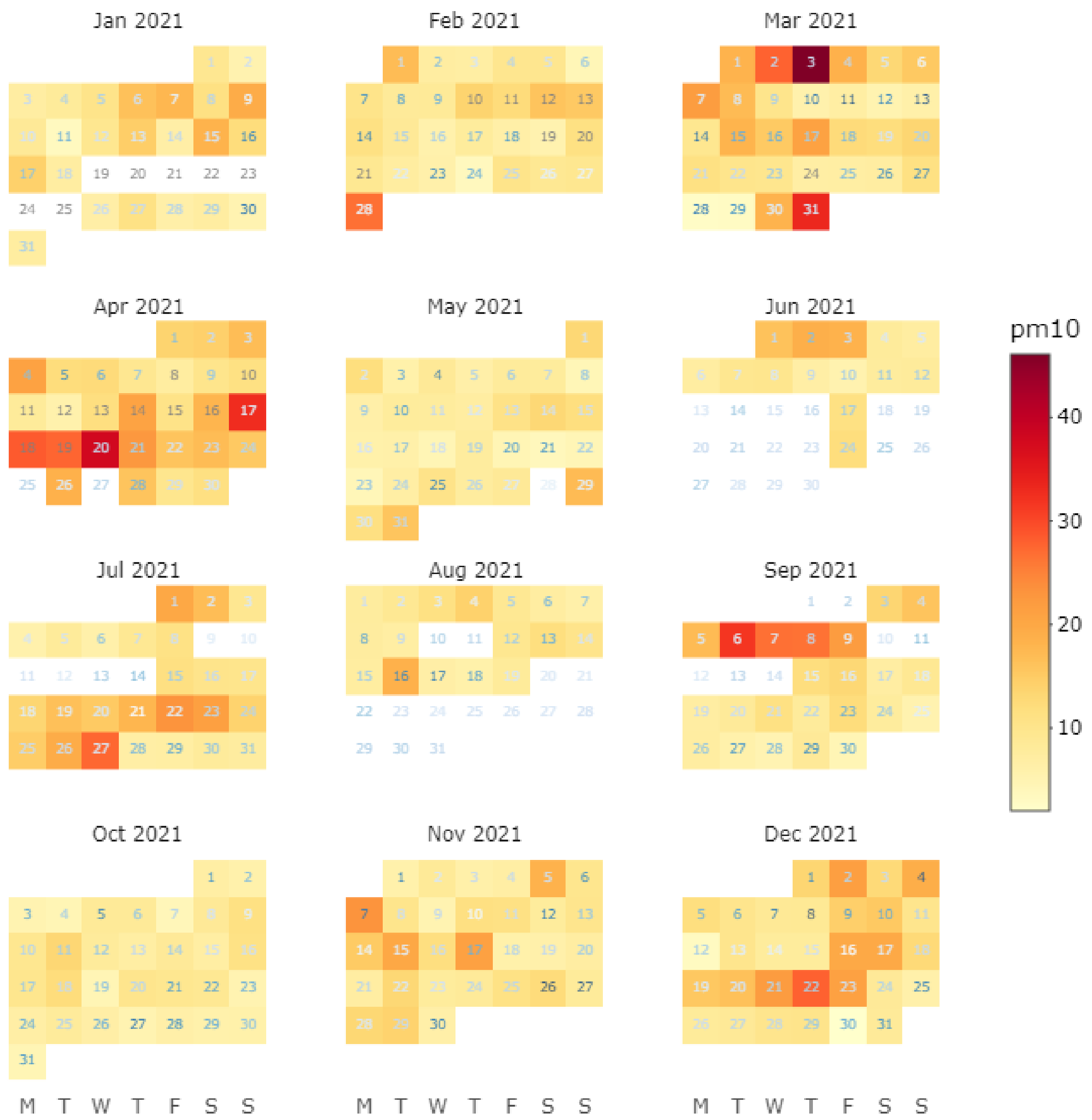
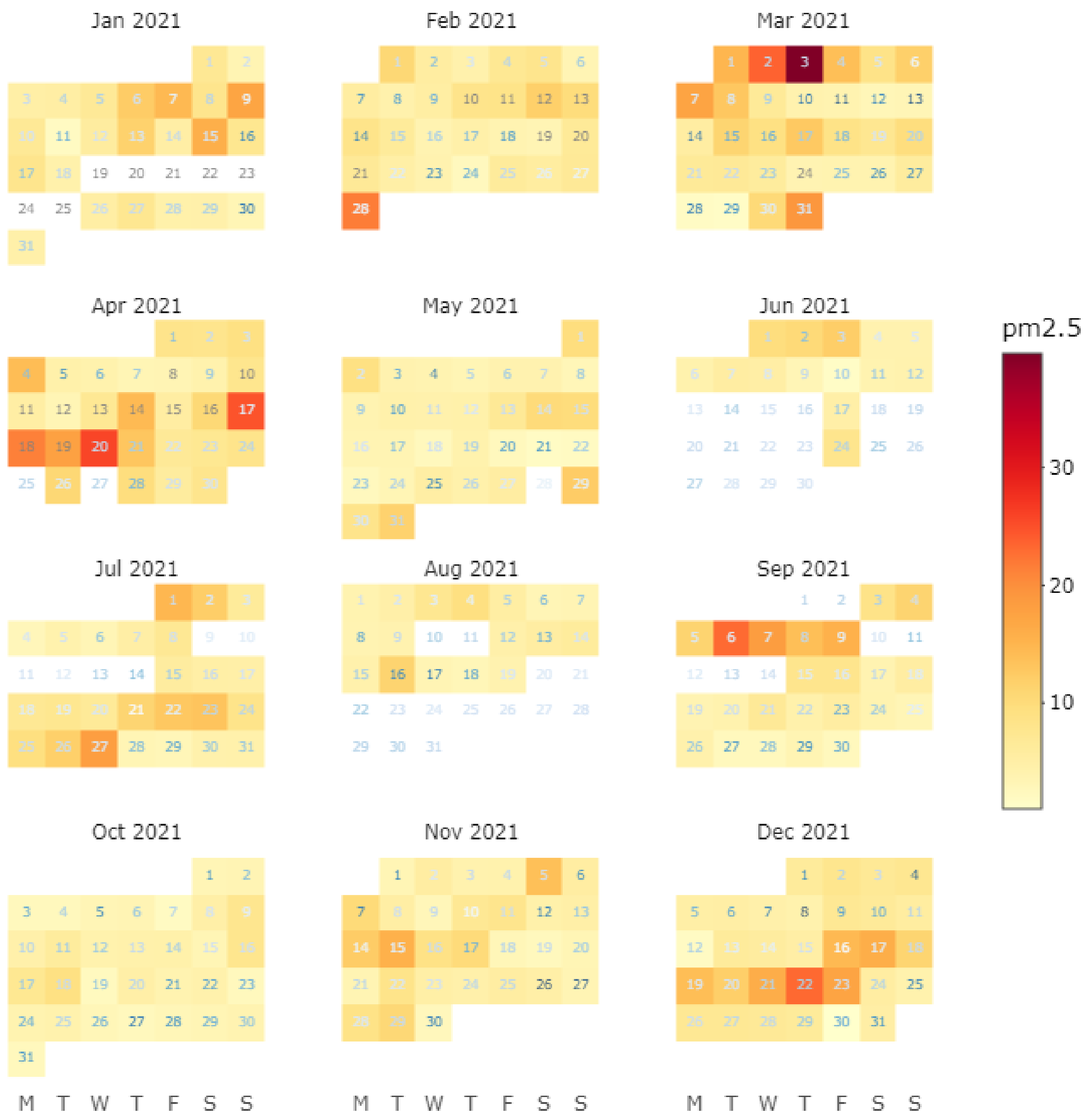


Figure 9 Calendar plot for $PM_{2.5}$ measured at Helsby during 2021.



3.2.6 Polar Plots

To investigate possible sources of PM in 2021, meteorological data measured at Liverpool John Lennon Airport was used to assess the hourly mean PM_{10} and $PM_{2.5}$ concentrations with wind speed and wind direction.

Figure 10 and Figure 11 show bivariate polar plots or "pollution roses" of PM_{10} and $PM_{2.5}$, respectively. The plots indicate how the PM concentration varies with wind direction and wind speed, with blue colours representing lower PM levels, and red colours higher PM levels.

PM_{10}: In 2021, the highest concentrations of PM_{10} were observed when the wind was from the northwest under high (>10 ms^{-1}) wind speeds, and from the southwest and northeast under calmer wind speeds (< 7 ms^{-1}). The high PM_{10} at high wind speeds may be related to pollution from the M56 and farther afield – potentially including the Protos site. Elevated PM_{10} at low wind speeds is typically associated with local sources.

The polar plot for 2021 is different to 2020, when the highest PM_{10} levels were observed when the wind was from the southwest under high (>10 ms^{-1}) wind speeds.

$PM_{2.5}$: For $PM_{2.5}$ the highest concentrations were observed from the southwest and northeast under calmer wind speeds. There is some indication of higher $PM_{2.5}$ from the northwest under high wind speeds but is less prominent than for PM_{10}.

Figure 10 Bivariate polar plot of PM_{10} for 2021.

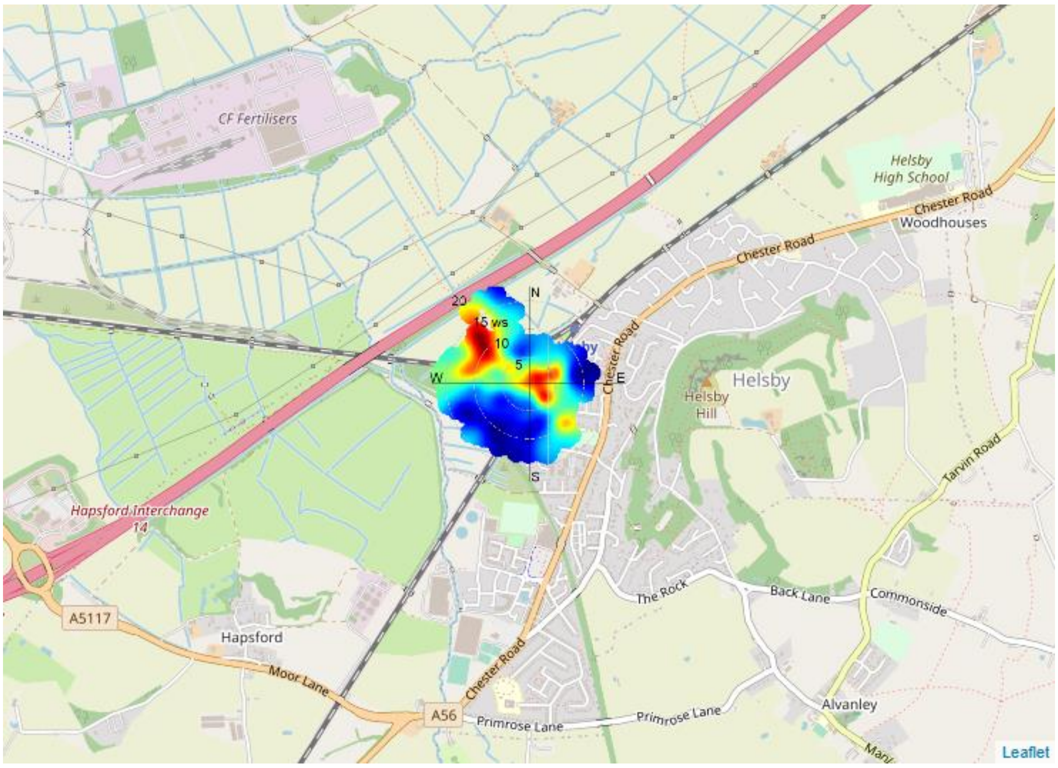
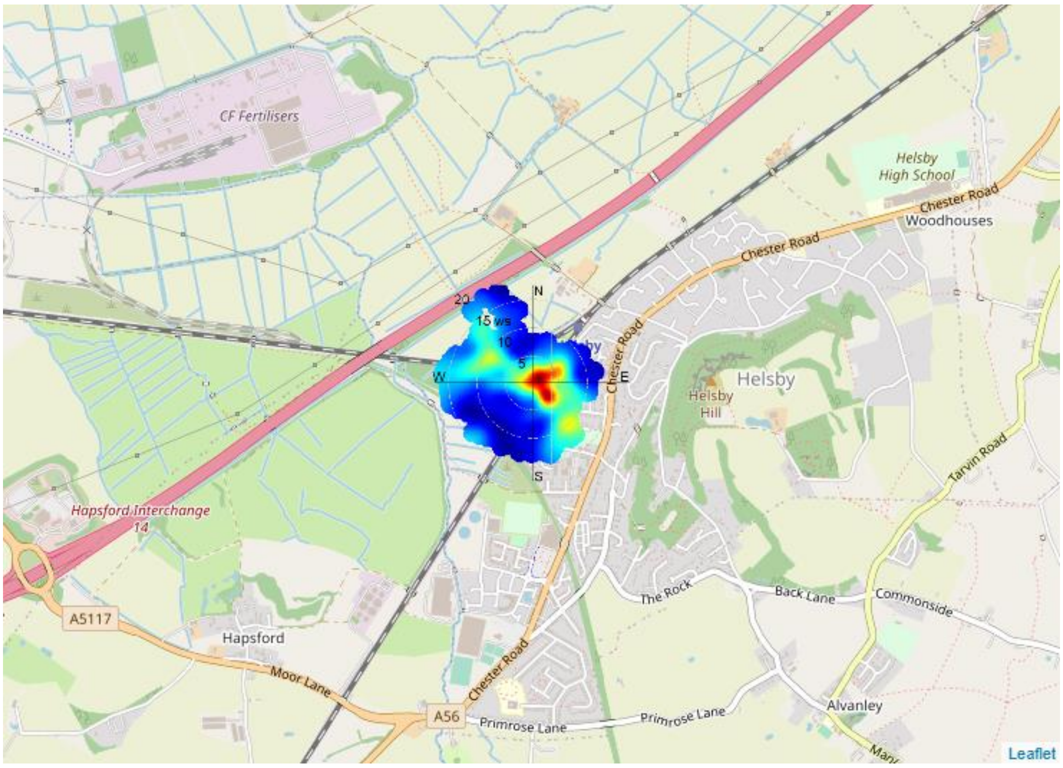


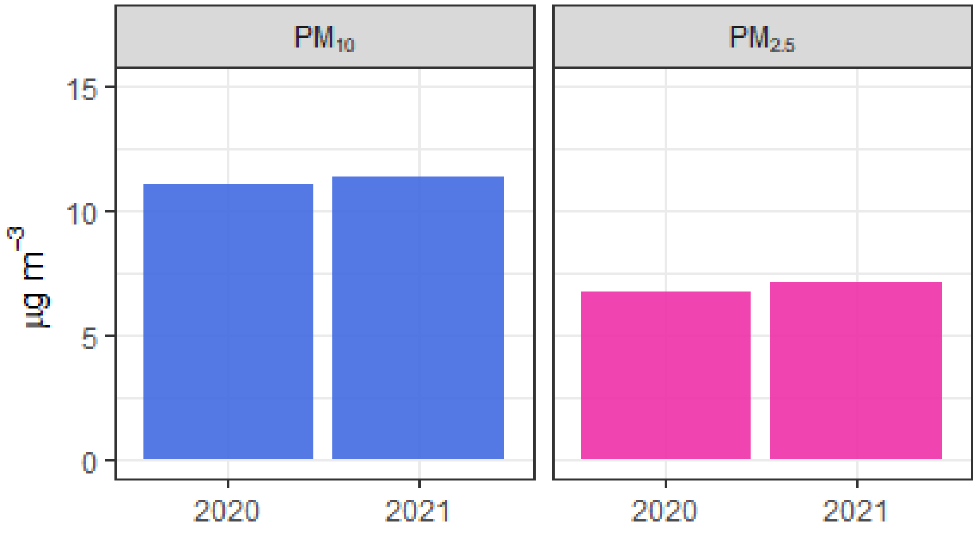
Figure 11 Bivariate polar plot of $PM_{2.5}$ for 2021.



3.2.7 Annual Variation

Figure 12 shows the annual mean PM_{10} and $PM_{2.5}$ concentrations measured at Helsby in 2020 and 2021. The concentrations vary very little across the two years, for both PM_{10} and $PM_{2.5}$. The measured concentrations are well below the annual mean air quality objectives for PM_{10} and $PM_{2.5}$ in 2020 and 2021.

Figure 12 PM_{10} and $PM_{2.5}$ annual mean concentrations from 2020 to 2021.



3.3 HEAVY METALS ANALYSIS

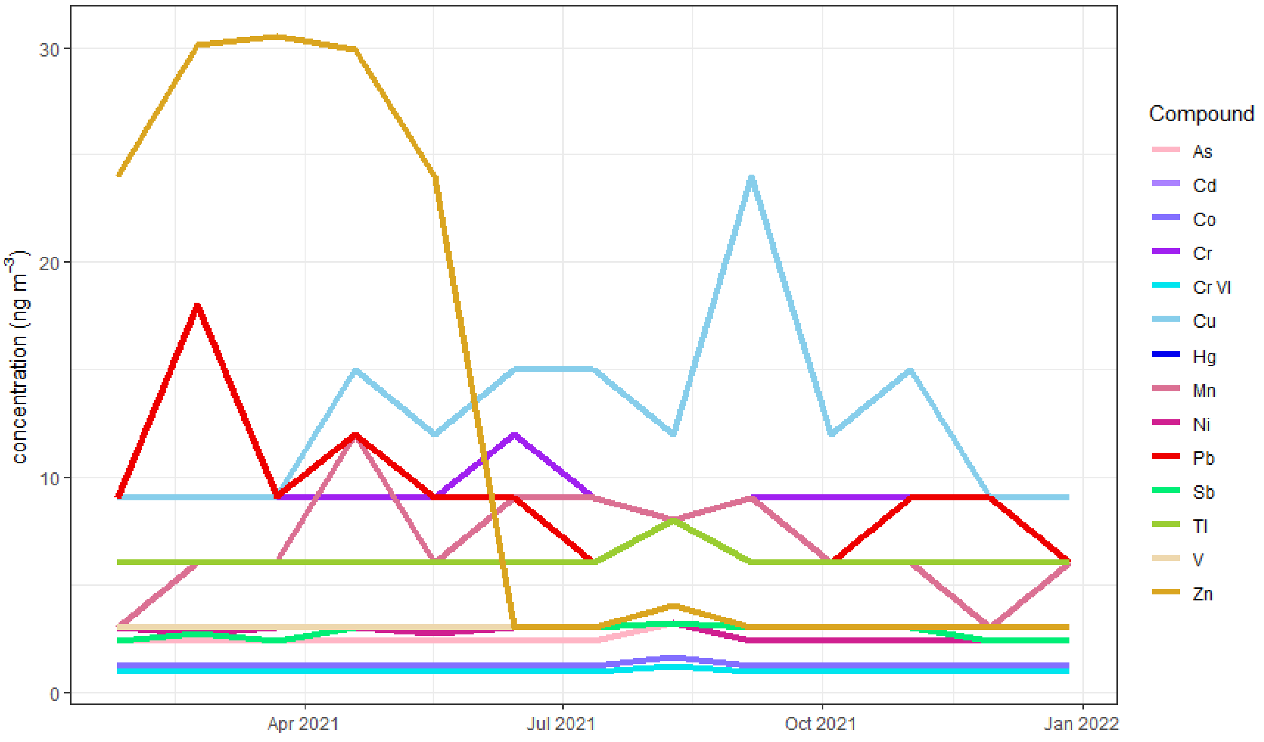
Annual averages for heavy metal concentrations measured during 2021 are given in Table 5. Where no regulations apply, Ambient Air Directive target values or Environment Assessment Levels outlined in Table 3 have been used where available. Annual averages with and without measurements below detectable limits are provided. During 2021, all heavy metal concentrations measured were below the target values.

Table 5 Summary statistics for heavy metals during 2021.

Adopted limits ($ng.m^{-3}$)	As 6	Cd 5	Co -	Cr -	Cu 10000	Hg 250	Mn 150	Ni 20	Pb 250	Sb 5000	Tl -	V -	Zn -	Cr VI -
Annual Average	2.5	3.1	1.2	9.2	13	3.1	6.8	2.7	8.9	2.8	6.2	3.1	13	0.92
% of limit	41	62			0.1	1.2	4.6	14	3.6	0.1				
Annual Average (without < LOD)				9.2	13		6.8	2.8	8.9	2.9		3.1	28	
% of limit (without < LOD)					0.1		4.6	14	3.6	0.1				

Figure 13 shows a time series of the metal concentrations for each month, during 2021. Data from the analysis of the monthly samples are provided in Table in the Appendix. In Figure 13 it is observed that zinc concentrations drop rapidly between May and June 2021 and remain below detectable limits for the rest of the year (see Table C3 in Appendix C). There is no obvious correlation between the change in zinc concentrations and the wind conditions, therefore no conclusion can be drawn at this point. Whether the zinc concentrations remain below the limit of detection in 2022 will be investigated in the next annual report.

Figure 13 Heavy metal concentrations measured at Helsby during 2021. Points shown at mid-point of 4-week period.



3.4 PAH ANALYSIS

Table 6 shows the period mean of the measured PAHs in PM_{10} calculated from the 3-monthly samples in 2021. All compounds sampled were above the LOD. Benzo(a)pyrene (B[a]P) is used as a marker for assessment of PAHs against UK and European objectives. The annual mean concentration of B[a]P in 2021 was 0.06 ngm^{-3}, which is well below the European target value of 1 ngm^{-3} and below the stricter UK objective of 0.25 ngm^{-3}. To assess the use of B[a]P as a marker for PAHs, additional PAHs are required to be measured as per the Fourth Daughter Directive (DD4). These additional compounds should include at a minimum: benz[a]anthracene, benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, indeno[1,2,3-cd]pyrene and dibenz[a,h]anthracene. All these compounds were measured at Helsby, along with other PAHs. Please note, however, that the naphthalene concentrations reported are highly uncertain due to potential breakthrough on the sampling media at the flow rates used.

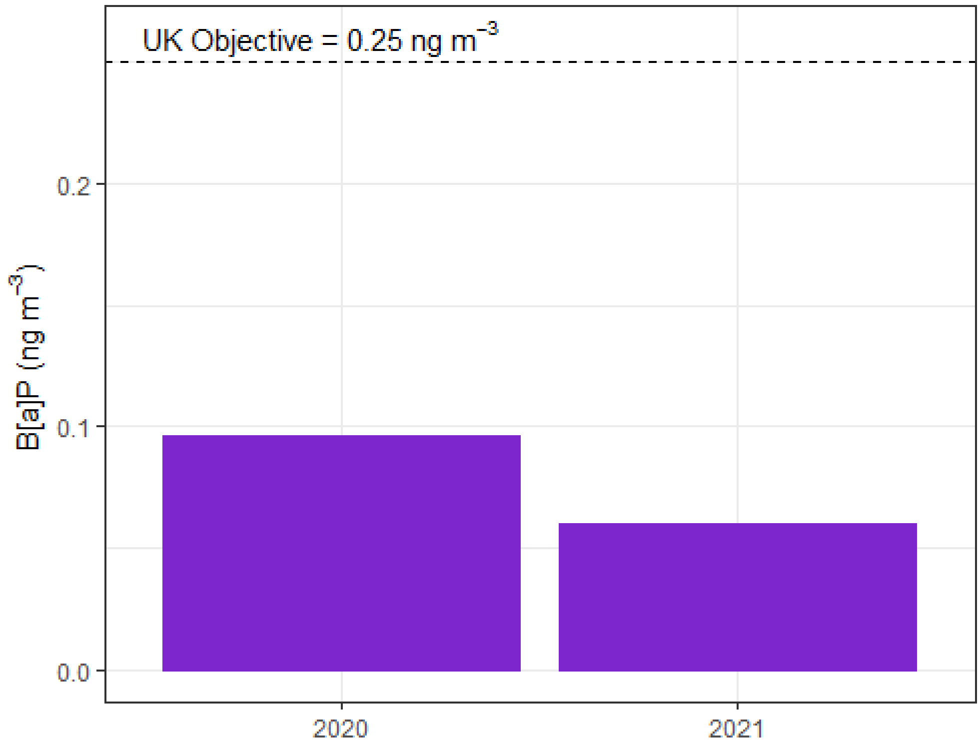
Table 6: Summary statistics for PAHs during 2021. Benzo(a)pyrene is used for assessment of PAHs against air quality objectives.

Compound	Annual Mean (ngm^{-3})
Naphthalene	0.17
Acenaphthylene	0.016
Acenaphthene	0.18
Fluorene	0.77
Phenanthrene	3.9
Anthracene	0.13
Fluoranthene	0.88

Compound	Annual Mean (ngm^{-3})
Pyrene	0.57
Benzo(a)anthracene	0.069
Chrysene	0.14
Benzo(b)fluoranthene	0.15
Benzo(k)fluoranthene	0.053
Benzo(a)pyrene	0.06
Indeno(1,2,3-cd)pyrene	0.1
Dibenzo(ah)anthracene	0.014
Benzo(ghi)perylene	0.12
Benzo(j)fluoranthene	0.064
Dibenzo(ac)anthracene	0.012

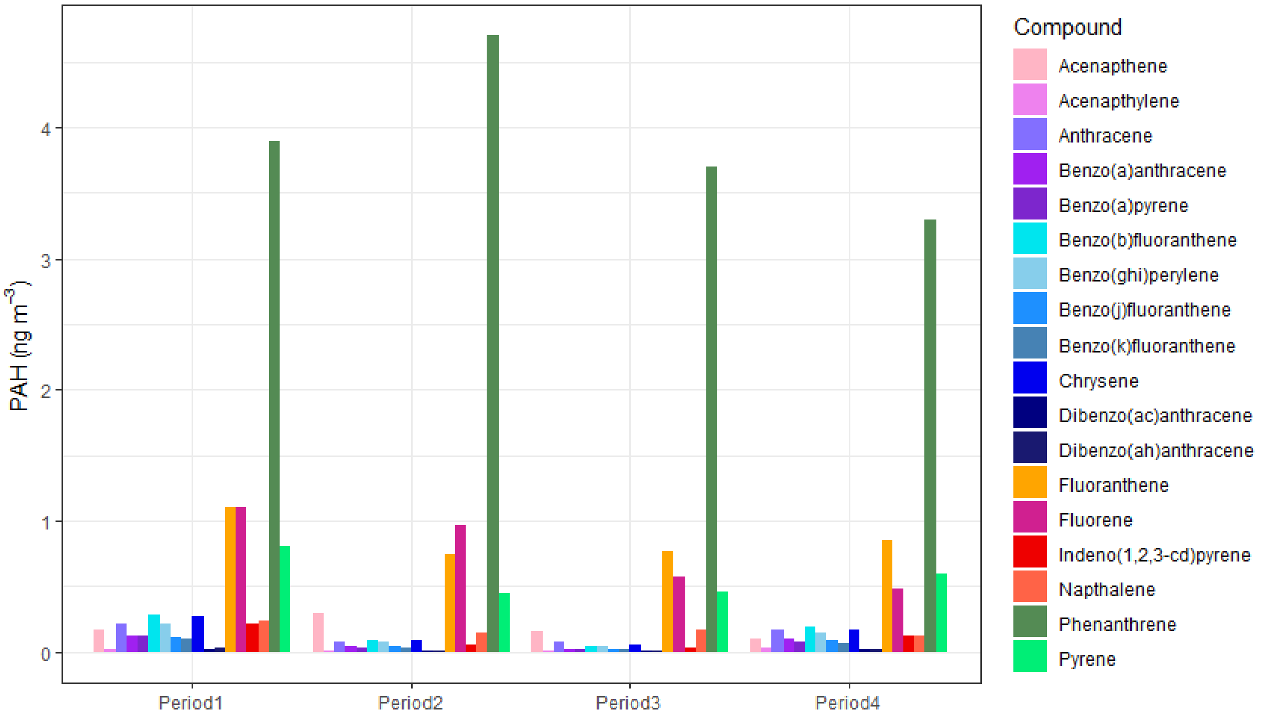
Figure 14 shows a comparison of annual mean B[a]P concentration between 2020 and 2021. The analysis shows that B[a]P decreased on average in 2021 when compared to 2020. In both years the measured concentrations were well below the UK objective of 0.25 ngm^{-3}. The decrease observed may just be due to year-on-year variability and no conclusions can be drawn at this point. This plot will be updated with more data in future years.

Figure 14: Annual mean B[a]P concentrations for 2020 and 2021. The dashed line represents the UK objective limit for B[a]P (0.25 ngm^{-3}).



Concentrations of PAHs for each of the four periods in 2021 are shown in Figure 15. The data for each period are provided in Table C2 in Appendix A3.

Figure 15: PAH concentrations measured at Helsby during 2021.



3.5 DIOXINS, FURANS AND PCB ANALYSIS

The TOMPs data (Dioxins, Furans and PCBs) for Helsby have been converted to Toxic Equivalency using the World Health Organization Toxic Equivalency Factors (see Appendix A2). The annual mean concentrations for each set of compounds measured at Helsby are provided in the tables below.

Table 7: Summary statistics for Dioxins at Helsby during 2021.

Compound	Annual Mean (fgm^{-3} TEF)
2378 Tetra CDD	0.68
12378 Penta CDD	2.8
123478 Hexa CDD	0.2
123678 Hexa CDD	0.81
123789 Hexa CDD	0.48
1234678 Hepta CDD	0.43
OCDD Octa CDD	0.0095

Table 8: Summary statistics for Furans at Helsby during 2021.

Compound	Annual Mean (fgm^{-3} TEF)
2378 Tetra CDF	0.55
12378 Penta CDF	0.23

Compound	Annual Mean (fgm^{-3} TEF)
23478 Penta CDF	4.8
123478 Hexa CDF	0.72
123678 Hexa CDF	0.78
234678 Hexa CDF	0.83
123789 Hexa CDF	0.29
1234678 Hepta CDF	0.28
1234789 Hepta CDF	0.031
OCDF Octa CDF	0.0014

Table 9: Summary statistics for PCBs at Helsby during 2021.

Compound	Annual Mean (fgm^{-3} TEF)
CB-81	0.0041
PCB-77	0.011
PCB-123	0.0096
PCB-118	0.15
PCB-114	0.00088
PCB-105	0.0039
PCB-126	1.6
PCB-167	0.0003
PCB-156	0.0014
PCB-157	0.00036
PCB-169	0.01
PCB-189	0.00025

Bar plots showing the concentrations of Dioxins, Furans and PCBs measured at Helsby for each of the four periods in 2021 are shown in Figure 16 to Figure 18, below. The data for each period and compound are provided in Table C3 in Appendix A3.

Figure 16: Dioxin concentrations measured at Helsby during 2021.

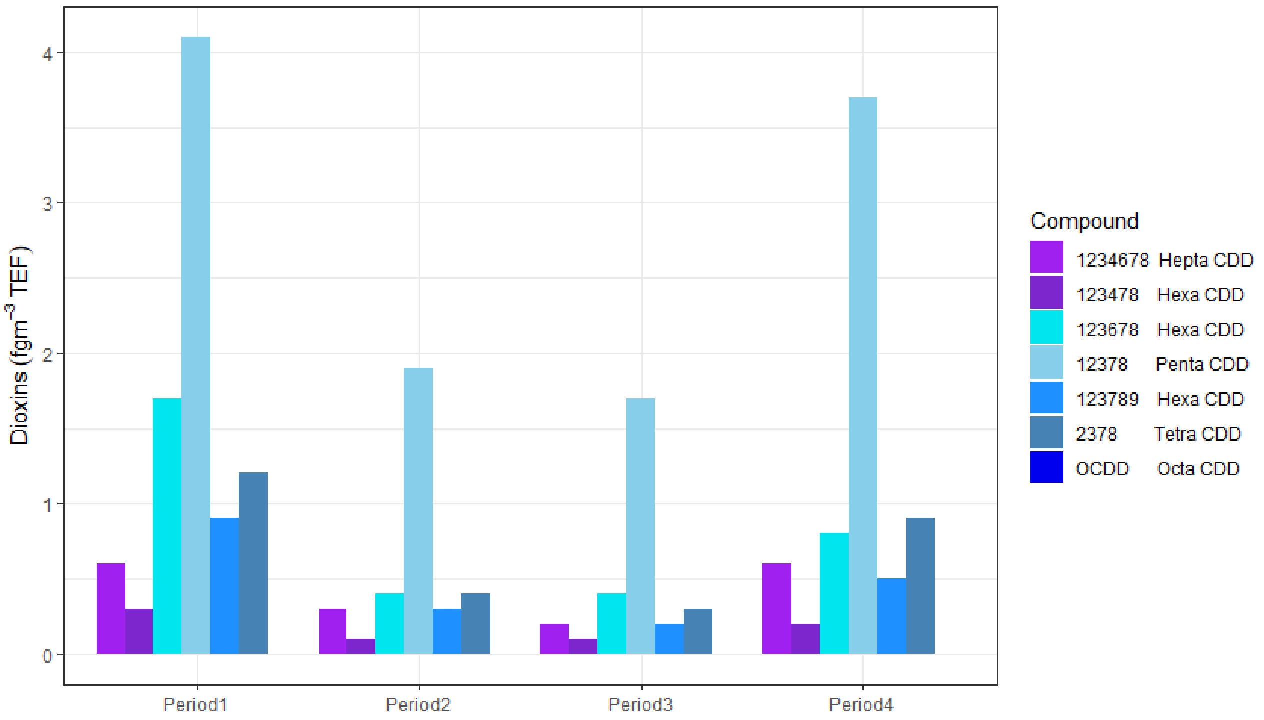


Figure 17: Furan concentrations measured at Helsby during 2021.

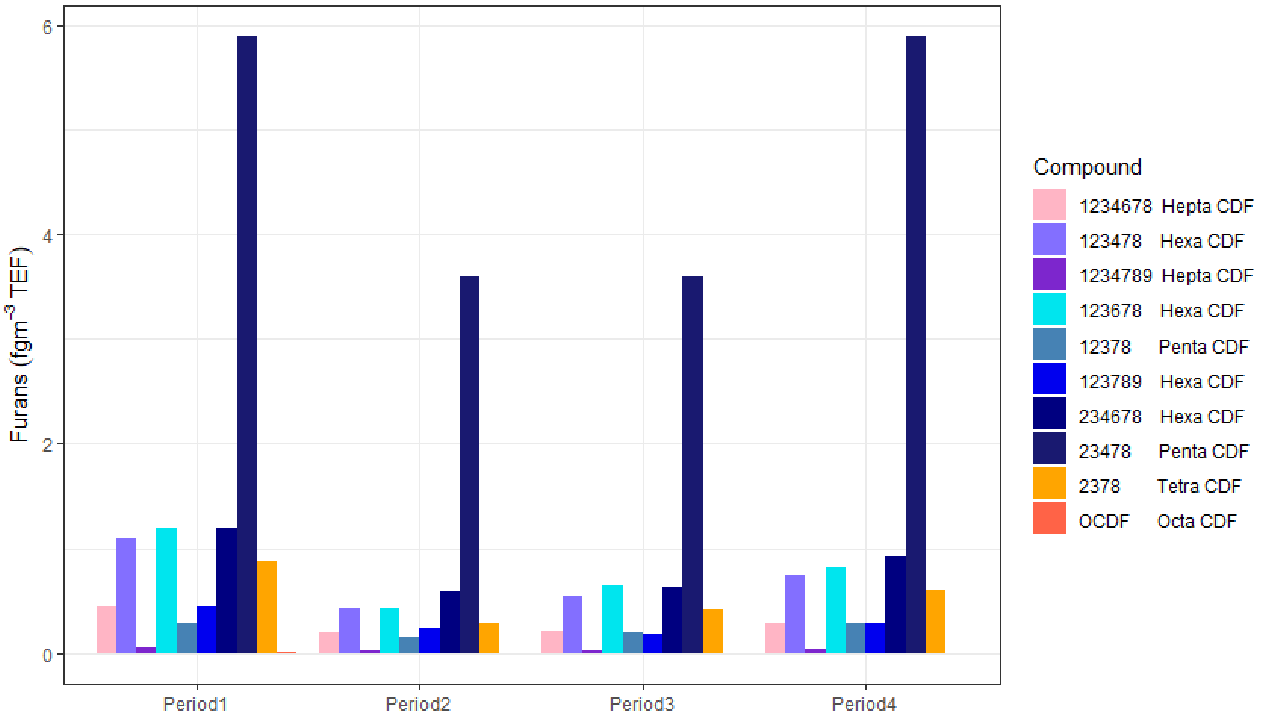
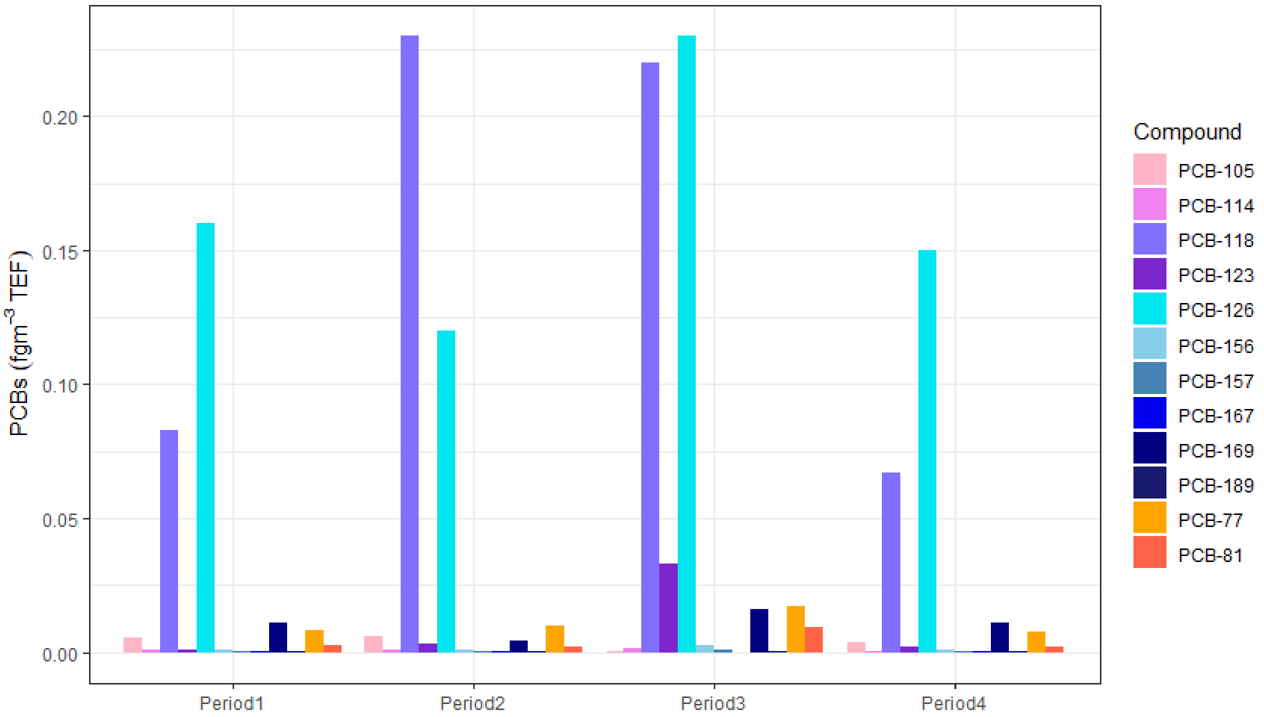


Figure 18: PCB concentrations measured at Helsby during 2021. Note, for PCB-126 actual concentrations are x10.



4. CONCLUSIONS

This report provides the results from the analysis of the pollutant data measured at the site in Helsby in 2021.

The results show that both PM_{10} and $PM_{2.5}$ annual means in 2021, were well below the annual mean AQS objective of 40 μgm^{-3} for PM_{10} and 20 μgm^{-3} for $PM_{2.5}$. There were no exceedances of the 24-hour PM_{10} limit of 50 μmg^{-3}.

Variations in hourly PM_{10} and $PM_{2.5}$ concentrations with wind speed and direction were assessed to investigate sources of particulates. Higher concentrations of PM_{10} were associated with high winds from the northwest, whereas for $PM_{2.5}$, the highest concentrations were observed under low wind speeds.

Filter samples of PM_{10} were collected every month and heavy metal concentrations extracted - all annual mean concentrations were below their associated target value.

Samples were collected and collated every 3 months for analysis of dioxins, furans, PCBs, and PAHs. The annual mean concentrations of Benzo(a)pyrene (B[a]P), which is used as a marker compound for PAHs, was 0.06 ngm^{-3} in 2021, which is below the European (1 ng^{-3}) and UK (0.25 ngm^{-3}) objectives.

5. REFERENCES

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APPENDICES

Appendix 1 Air Pollution Bandings

Table A1 *Description of air pollution bandings*

Banding	Index	Accompanying health messages for at-risk individuals
Low	1,2,3	Enjoy your usual outdoor activities.
Moderate	4,5,6	Adults and children with lung problems, and adults with heart problems, who experience symptoms, should consider reducing strenuous physical activity, particularly outdoors.
High	7,8,9	Adults and children with lung problems, and adults with heart problems, should reduce strenuous physical exertion, particularly outdoors, and particularly if they experience symptoms. People with asthma may find they need to use their reliever inhaler more often. Older people should also reduce physical exertion.
Very High	10	Adults and children with lung problems, adults with heart problems, and older people, should avoid strenuous physical activity. People with asthma may find they need to use their reliever inhaler more often.

Appendix 2 Toxic Equivalency Factors

The International Toxic Equivalent (ITEQ) values for individual congeners are calculated for each sample using the WHO schemes. The factors are provided in Table B2. Where an isomer has a result less than the LOD a value equivalent to the LOD is used to determine the ITEQ. Therefore, these values represent a worst case assessment. Additional total ITEQ values are also calculated, assuming that where a result is less than the limit of detection then the ITEQ contribution is zero.

Table A2 Toxic equivalency factors for TOMPs

Compound	WHO TEF	Compound	WHO TEF
DIOXINS		**PCBs**	
2378 Tetra CDD	1	PCB-81	0.0003
12378 Penta CDD	1	PCB-77	0.0001
123478 Hexa CDD	0.1	PCB-123	0.00003
123678 Hexa CDD	0.1	PCB-118	0.00003
123789 Hexa CDD	0.1	PCB-114	0.00003
1234678 Hepta CDD	0.01	PCB-105	0.00003
OCDD Octa CDD	0.0001	PCB-126	0.1
FURANS		PCB-167	0.00003
2378 Tetra CDF	0.1	PCB-156	0.00003
12378 Penta CDF	0.05	PCB-157	0.00003
23478 Penta CDF	0.5	PCB-169	0.003
123478 Hexa CDF	0.1	PCB-189	0.00003
123678 Hexa CDF	0.1		
234678 Hexa CDF	0.1		
123789 Hexa CDF	0.1		
1234678 Hepta CDF	0.01		
1234789 Hepta CDF	0.01		
OCDF Octa CDF	0.0001		

Appendix 3 Datasets

Tables C1 to C3 provide the analysis of heavy, metals, PAHs, Dioxins, Furans and PCBs, for each period during 2021.

Table C1 Analysis of heavy metals for each period. *Values with the prefix "<" denote data where the values were below the limit of detection.*

start	end	Report ID	As	Cd	Co	Cr	Cu	Hg	Mn	Ni	Pb	Sb	Tl	V	Zn	Cr VI
11/01/2021	08/02/2021	ASC/49770.001	<2.40	<2.99	<1.20	8.98	8.98	<2.99	2.99	2.99	8.98	<2.40	<5.99	2.99	23.95	<0.90
08/02/2021	08/03/2021	ASC/49770.002	<2.41	<3.01	<1.20	9.02	9.02	<3.01	6.01	2.71	18.04	2.71	<6.01	3.01	30.07	<0.90
08/03/2021	05/04/2021	ASC/49770.003	<2.44	<3.05	<1.22	9.14	9.14	<3.05	6.09	3.05	9.14	2.44	<6.09	3.05	30.47	<0.91
05/04/2021	03/05/2021	ASC/49770.004	<2.40	<2.99	<1.20	8.98	14.97	<2.99	11.98	2.99	11.98	2.99	<5.99	2.99	29.94	<0.90
03/05/2021	31/05/2021	ASC/49770.005	<2.40	<2.99	<1.20	8.98	11.98	<2.99	5.99	2.70	8.98	2.99	<5.99	2.99	23.96	<0.90
31/05/2021	28/06/2021	ASC/51023.001	<2.40	<3.00	<1.20	11.98	14.98	<3.00	8.99	3.00	8.99	3.00	<5.99	3.00	<3.00	<0.90
28/06/2021	26/07/2021	ASC/51023.002	<2.40	<3.00	<1.20	8.99	14.98	<3.00	8.99	3.00	5.99	3.00	<5.99	3.00	<3.00	<0.90
26/07/2021	23/08/2021	ASC/53087.001	<3.19	<3.99	<1.60	7.99	11.98	<3.99	7.99	<3.19	7.99	<3.19	<7.99	3.99	<3.99	<1.20
23/08/2021	20/09/2021	ASC/53087.002	<2.40	<3.00	<1.20	8.99	23.97	<3.00	8.99	2.40	5.99	3.00	<5.99	3.00	<3.00	<0.90
20/09/2021	18/10/2021	ASC/53087.003	<2.40	<3.00	<1.20	8.99	11.98	<3.00	5.99	2.40	5.99	3.00	<5.99	3.00	<3.00	<0.90
18/10/2021	15/11/2021	ASC/53087.004	<2.40	<2.99	<1.20	8.98	14.97	<2.99	5.99	<2.40	8.98	2.99	<5.99	2.99	<2.99	<0.90
15/11/2021	13/12/2021	ASC/53087.005	<2.40	<2.99	<1.20	8.98	8.98	<2.99	2.99	<2.40	8.98	<2.40	<5.99	2.99	<2.99	<0.90
13/12/2021	10/01/2022	ASC/53087.006	<2.40	<3.00	<1.20	8.99	8.99	<3.00	5.99	<2.40	5.99	<2.40	<5.99	3.00	<3.00	<0.90

Table C2 Analysis of PAHs for each period.

Compound	Period 1	Period 2	Period 3	Period 4
Naphthalene	0.240	0.155	0.174	0.122
Acenaphthylene	0.018	0.010	0.008	0.027
Acenaphthene	0.173	0.299	0.161	0.099
Fluorene	1.082	0.961	0.569	0.479
Phenanthrene	3.858	4.735	3.686	3.271
Anthracene	0.216	0.074	0.077	0.166
Fluoranthene	1.133	0.749	0.767	0.853
Pyrene	0.797	0.444	0.456	0.600
Benzo(a)anthracene	0.121	0.036	0.019	0.102
Chrysene	0.269	0.083	0.049	0.165
Benzo(b)fluoranthene	0.283	0.083	0.044	0.186
Benzo(k)fluoranthene	0.098	0.030	0.015	0.067
Benzo(a)pyrene	0.119	0.030	0.014	0.077
Indeno(1,2,3-cd)pyrene	0.207	0.056	0.029	0.122
Dibenzo(ah)anthracene	0.029	0.006	0.003	0.016
Benzo(ghi)perylene	0.223	0.073	0.037	0.154
Benzo(j)fluoranthene	0.108	0.040	0.016	0.092
Dibenzo(ac)anthracene	0.022	0.006	0.003	0.015

Table C3 Analysis of Dioxins, Furans and PCBs, for each period.

Compound	Period 1	Period 2	Period 3	Period 4
DIOXINS				
2378 Tetra CDD	1.18	0.36	0.29	0.89
12378 Penta CDD	4.07	1.86	1.71	3.7
123478 Hexa CDD	0.34	0.12	0.11	0.25
123678 Hexa CDD	1.7	0.35	0.4	0.8
123789 Hexa CDD	0.92	0.27	0.23	0.49
1234678 Hepta CDD	0.64	0.31	0.21	0.57
OCDD Octa CDD	0.013	0.008	0.004	0.013
FURANS				
2378 Tetra CDF	0.88	0.29	0.41	0.6
12378 Penta CDF	0.28	0.16	0.19	0.29
23478 Penta CDF	5.89	3.6	3.64	5.93
123478 Hexa CDF	1.14	0.43	0.55	0.75
123678 Hexa CDF	1.22	0.43	0.65	0.82
234678 Hexa CDF	1.19	0.59	0.63	0.92
123789 Hexa CDF	0.44	0.24	0.18	0.29
1234678 Hepta CDF	0.44	0.19	0.21	0.29

Compound	Period 1	Period 2	Period 3	Period 4
1234789 Hepta CDF	0.047	0.023	0.023	0.033
OCDF Octa CDF	0.0019	0.0012	0.0013	0.0012
PCBs				
PCB-81	0.0024	0.0022	0.0096	0.0023
PCB-77	0.0085	0.0098	0.0172	0.0076
PCB-123	0.00077	0.0029	0.0326	0.0019
PCB-118	0.083	0.23	0.22	0.067
PCB-114	0.00072	0.00075	0.0017	0.00032
PCB-105	0.0053	0.0061	0.00053	0.0036
PCB-126	1.62	1.16	2.28	1.5
PCB-167	0.00029	0.00049	0.0000027	0.00042
PCB-156	0.001	0.001	0.0027	0.00089
PCB-157	0.00022	0.00024	0.00069	0.00027
PCB-169	0.011	0.0044	0.016	0.011
PCB-189	0.00028	0.00015	0.00037	0.00021

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