Air Quality in Helsby

Report for Bioenergy Infrastructure Group
ED60804

ED 60804 | Issue Number 1 | Date 18/09/2020

Customer:

Bioenergy Infrastructure Group

Customer reference:

ED60804

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18 September 2020

Ricardo Energy & Environment reference:

Ref: ED60804- Issue Number 1

Executive summary

This report provides details of the monitoring survey that took place at Helsby, Cheshire over two 12-month periods, prior to and post the commissioning of the nearby Ince Bio Power site. Phase 1 of the monitoring covered the period from 19th October 2016 to 18th October 2017, and Phase 2 from 3rd July 2019 to 2nd July 2020. The work was carried out by Ricardo Energy and Environment on behalf of CoGen Ltd acting on behalf of Ince Bio Power Ltd London Gateway.

The aim of the survey was to monitor 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, and a comparison of results between Phase 1 and Phase 2.

Hourly PM_{10} and $PM_{2.5}$ monitoring was carried out using a Fine Dust Analysis System (FIDAS). Data capture rates for Phase 1 and Phase 2 were 96 and 87% respectively. The period means for PM_{10} and $PM_{2.5}$ were 12.9 μgm^{-3} and 8.4 μgm^{-3} for Phase 1, and 11.5 μgm^{-3} and 6.9 μgm^{-3} for Phase 2. The annual mean AQS objective is 40 μgm^{-3} for PM_{10} and 25 μgm^{-3} for $PM_{2.5}$, therefore, the period means are below the limit values for both phases. 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 only two exceedances of the 50 μgm^{-3} during Phase 1 and none during Phase 2, therefore this 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 for both phases.

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 Phase 1 and Phase 2 were 0.064 ngm^{-3} and 0.069 ngm^{-3}, respectively, which are well below the annual mean European target value of 1 ngm^{-3} and the UK objective of 0.25 ngm^{-3} .

Differences were observed in the concentrations of the pollutants measured between the two phases. Some pollutants increased and others decreased, however there is no clear indication as to whether this is due to a change in emissions from different sources, or the result of meteorological variations.

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1 Introduction

The objective of this project was to undertake air quality monitoring of dioxins, furans, particulates, PAHs and heavy metals on behalf of Bioenergy Infrastructure Group (B.I.G) acting on behalf of Ince Bio Power Ltd. The contract was originally let by CoGen Ltd, however the contract was novated to B.I.G in advance of the second phase of monitoring. The monitoring was required prior to and post construction and commissioning of a new biomass renewable energy power plant in Cheshire (Plot 9, Ince Resource Recovery Park).

The monitoring took place in two phases: Phase 1 monitoring was for 12 months from 19th October 2016 to 18th October 2017, prior to the commissioning of the Ince Bio Power site and Phase 2 monitoring was undertaken post commissioning of the site, from 3rd July 2019 to 2nd July 2020.

2 Monitoring Site and Methods

2.1 Monitoring Station

A monitoring station was set up in the grounds of the Eccies Social Club in Helsby, although the club closed during the monitoring regime and repurposed as an office building. Figure 1 shows the location of the monitoring station with respect to the Ince Bio Power Plant in Cheshire. The monitoring station set up is shown in Figure 2.

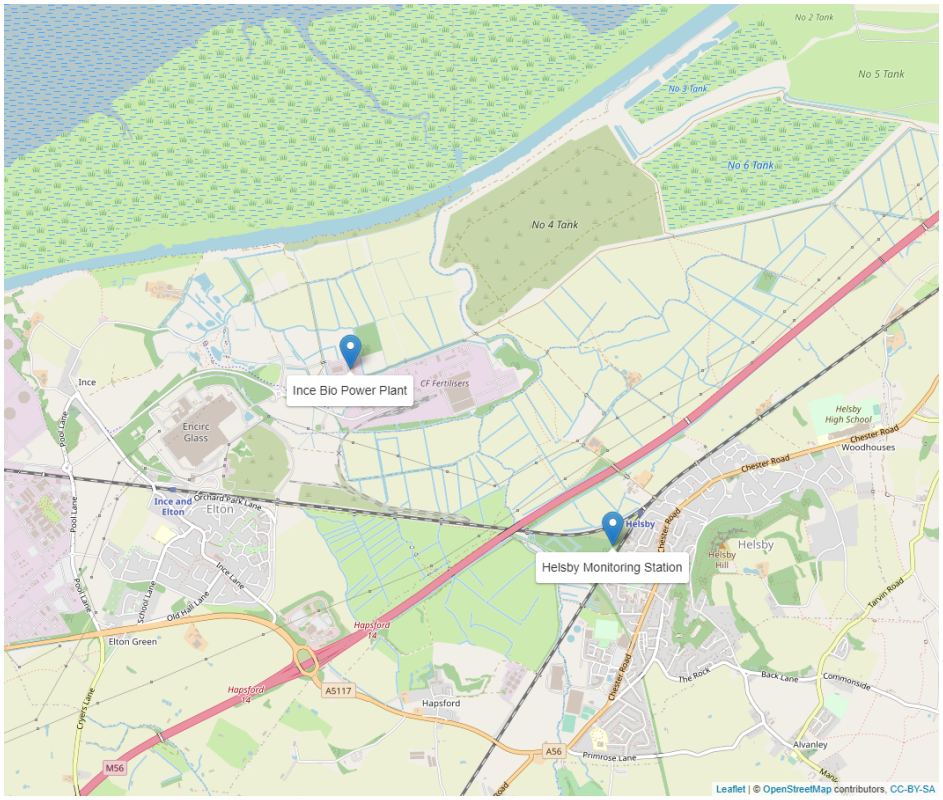

Figure 1: Location of monitoring station and Ince Bio Power Station.

Figure 2: Monitoring station in the grounds of the Eccies Social Club in Helsby, Cheshire.

2.2 Pollutants Monitored

Table 1 provides an overview of the pollutants that Ricardo Energy & Environment were contracted to measure at the site in Helsby, over the two phases.

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 (NOAA 2020) and accessed using the worldmet R package (Carslaw 2020).

Table 1: Period of measurement for pollutants during Phase 1 and Phase 2.

	Measurement	Start date	End date	Days
Phase 1	PM_{10}, $PM_{2.5}$	19/10/2016	18/10/2017	364
	Metals and CrVI	19/10/2016	18/10/2017	364
	Toxic Organic Micro Pollutants	19/10/2016	18/10/2017	364
Phase 2	PM_{10}, $PM_{2.5}$	03/07/2019	02/07/2020	365
	Metals and CrVI	27/06/2019	24/07/2020	393
	Toxic Organic Micro Pollutants	03/07/2019	02/07/2020	365

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. Larger particles, meanwhile, are not readily inhaled, and are removed relatively efficiently 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.
An annual mean limit value of 0.5 μgm^{-3} for lead in the PM_{10} particulate fraction of ambient air was defined in the Air Quality Directive (2008/50/EC). Following this, target values for arsenic (6 ngm^{-3}), cadmium (5 ngm^{-3}), and nickel (20 ngm^{-3}), were set out in the Fourth Daughter Directive (2004/107/EC).

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 2). The method used for the analytical measurement complies with BS EN 1948-3:2006 for dioxins and BS EN 1948-4:2006 for dioxin like PCBs.

Table 2: Start and end dates of 3-monthly periods for TOMPs sampling.

Phase 1	Start	End	Phase 2	Start	End
Period 1	19/10/2016	11/01/2016	Period 1	03/07/2019	08/10/2019
Period 2	11/01/2016	04/04/2017	Period 2	08/10/2019	04/12/2019
Period 3	04/04/2017	29/06/2017	Period 3	04/12/2019	25/03/2020
Period 4	29/06/2017	18/10/2017	Period 4	25/03/2020	18/06/2020

2.3 Air Quality Limit Values

Table 3 shows the current UK objectives (included in the Air Quality Regulations and subsequent Amendments for the purpose of Local Air Quality Management), and European air quality objectives, for the pollutants monitored at Helsby for this report.

Table 3: 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
	40 μgm^{-3}	40 μgm^{-3}	annual mean
$PM_{2.5}$	25 μgm^{-3}	25 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

3 Results and Discussion

The pollutant data measured at Helsby have been analysed to determine any potential impacts from the commissioning of the Ince Bio Power plant. Where applicable, measurements have also been assessed with respect to current Air Quality Objectives.

3.1 Comparison with Air Quality Objectives

Measurements from the two phases have been summarised and, where applicable, compared to National and European Air quality objectives.

Table 4 shows a summary of the PM data for Phase 1 and Phase 2. In both phases, period mean concentrations are below the annual mean air quality objectives for PM_{10} and $PM_{2.5}$. There were two exceedances of the PM_{10} daily mean objective during Phase 1, which is below the permitted 35 exceedances, therefore the objective was met. There were no exceedances of daily mean PM_{10} during Phase 2. It should be noted that when comparing site measurements against the air quality objectives, data capture should meet or exceed 90% across a calendar year. For Phase 2 the data capture rate was 87% for PM_{10} and $PM_{2.5}$, therefore the comparison with objectives is only indicative.

Table 4: Summary statistics and exceedances for PM_{10} and $PM_{2.5}$ for Phase 1 and Phase 2

	Phase 1		Phase 2	
Statistic	**PM_{10}**	**$PM_{2.5}$**	**PM_{10}**	**$PM_{2.5}$**
Mean (μgm^{-3})	12.9	8.4	11.5	6.9
Hourly Maximum (μgm^{-3})	88.8	62.7	125.9	110.1
Daily Maximum (μgm^{-3})	55.5	48.4	41.6	34.9
Data Capture rate (%)	96	96	87	87
Period mean > annual mean objective	No	No	No	No
Exceedances (daily mean > 50 μgm^{-3})	2	NA	0	NA

Summary statistics for heavy metal concentrations measured during Phase 1 and Phase 2 are given in Table 5. Where no regulations apply, Ambient Air Directive (AAD) target values or Environment Assessment Levels from the Environment Agency have been used where available. Period averages with and without measurements below detectable limits are provided. During both Phase 1 and Phase 2, all heavy metal concentrations measured were below the target values.

Table 5: Summary statistics for heavy metals during Phase 1 and Phase 2.

ngm^{-3}	As	Cd	Co	Cr	Cu	Hg	Mn	Ni	Pb	Sb	Tl	V	Zn	Cr VI
Adopted limits	**6[a]**	**5[a]**	**NA**	**NA**	**10000[c]**	**250[c]**	**150[c]**	**20[a]**	**250[b]**	**5000[c]**	**NA**	**NA**	**NA**	**NA**
Phase 1														
Period Average	2.91	3.52	1.41	9.36	14.68	3.52	5.97	3.44	13.45	3.51	6.00	4.95	20.57	1.22
% of limit	48%	70%			0.1%	1.4%	4.0%	17%	5.4%	0.1%				
Period Average (without < LOD)	3.06			9.36	14.68		5.97	3.55	13.45	3.46		4.53	20.57	
% of limit (without < LOD)	51%				0.1%		4.0%	18%	5.4%	0.1%				
Phase 2														
Period Average	3.31	3.90	1.56	11.03	16.86	3.90	6.61	4.10	14.42	5.33	7.79	6.06	17.75	1.17
% of limit	55%	78%			0.2%	1.6%	4.4%	20%	5.8%	0.1%				55%
Period Average (without < LOD)	3.32			11.03	16.86		6.61	4.02	15.48	5.56		6.06	21.21	
% of limit (without < LOD)	55%				0.2%		4.4%	20%	6.2%	0.1%				

[a]Ambient Air Directive (AAD)
[b]UK AQS Objective
[c]Environmental Assessment levels

Table 6 shows the period mean of the measured PAHs in PM_{10} were calculated from the 3-monthly samples for each phase. 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 Phase 1 was 0.064 ngm^{-3} and 0.069 ngm^{-3} during Phase 2. which are 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.

Table 6: Summary statistics for PAHs during Phase 1 and Phase 2. Benzo(a)pyrene (highlighted in red text) is used for assessment of PAHs against air quality objectives.

Compound	Phase 1 Period Mean (ngm^{-3})	Phase 2 Period Mean (ngm^{-3})
Napthalene	0.153	0.067
Acenapthylene	0.033	0.073
Acenapthene	0.114	0.226
Fluorene	0.323	0.264
Phenanthrene	2.920	0.728
Anthracene	0.091	0.055
Fluoranthene	0.748	0.463
Pyrene	0.515	0.431
Benzo(a)anthracene*	0.094	0.091
Chrysene	0.206	0.112
Benzo(b+j)fluoranthene*	0.198	0.067
Benzo(k)fluoranthene*	0.048	0.035
Benzo(a)pyrene*	0.064	0.069
Indeno(1,2,3-cd)pyrene*	0.083	0.052
Dibenzo(ah/ac)anthracene*	0.024	0.007
Benzo(ghi)perylene	0.112	0.040
Sum of all PAHs	5.7	3.3
Sum of PAHs (DD4)	0.5	0.6

*Compounds included in the sum of PAHs (DD4)

The TOMPs data for Helsby have been converted to Toxic Equivalency using the World Health Organization Toxic Equivalency Factors (Table A1). The same factors were used to calculate the values at the Hazelrigg Station[1] located in the North West of England (which is part of the national monitoring network), for comparison. Table 7 reports the period mean for each compound measured at Helsby and Hazelrigg.

For the majority of the dioxins and furans, the concentrations measured at Helsby, during both phases, were higher than the concentrations at Hazlerigg (based on a mean concentration from Dec 2015 to Jan 2017). PCBs on the other hand were much lower at Helsby, however, many PCBs measured at Hazlerigg were below the limit of detection (LoD).

[1] https://uk-air.defra.gov.uk/networks/site-info?uka_id=UKA00507&search=View+Site+Information&action=site

Table 7: Summary statistics for Dioxins, Furans and PCBs at Helsby during Phase 1 and Phase 2. Also shown for comparison are measurements Hazelrigg (from Dec 2015 to Jan 2017). Values with the prefix "<" denote period means where all values were below the limit of detection.

	Period Mean (fgTEF.m^{-3})		
Compound	**Helsby Phase 1**	**Helsby Phase 2**	**Hazelrigg**
DIOXINS			
2378 Tetra CDD	2.23	0.94	3.200
12378 Penta CDD	8.03	4.98	<0.220
123478 Hexa CDD	0.58	0.32	<0.440
123678 Hexa CDD	0.69	0.82	0.530
123789 Hexa CDD	0.70	0.60	0.880
1234678 Hepta CDD	1.33	0.68	<0.040
OCDD Octa CDD	0.024	0.017	0.017
FURANS			
2378 Tetra CDF	0.98	1.04	3.200
12378 Penta CDF	0.50	0.51	<0.220
23478 Penta CDF	8.00	8.23	<2.200
123478 Hexa CDF	1.82	1.74	<0.440
123678 Hexa CDF	1.24	1.36	<0.440
234678 Hexa CDF	2.44	2.41	<0.440
123789 Hexa CDF	1.04	0.86	<0.440
1234678 Hepta CDF	0.47	0.48	<0.040
1234789 Hepta CDF	0.13	0.10	<0.040
OCDF Octa CDF	0.004	0.004	<0.0004
PCBs			
PCB-81	0.0183	0.0052	<0.004
PCB-77	0.0305	0.0075	0.009
PCB-123	0.0031	0.0010	0.688
PCB-118	0.0183	0.0154	<0.020
PCB-114	0.0012	0.0005	<0.020
PCB-105	0.0067	0.0050	<0.020
PCB-126	4.60	1.47	1.185
PCB-167	0.0021	0.0007	<0.020
PCB-156	0.0043	0.0010	<0.020
PCB-157	0.0017	0.0004	<0.020
PCB-169	0.1308	0.0279	<0.044
PCB-189	0.0022	0.0003	<0.020

3.2 Data Analysis

3.2.1 Time Series

Below are time series plots of concentrations of pollutants during Phase 1 and Phase 2. PM_{10} and $PM_{2.5}$ show daily mean concentrations, whilst for heavy metals the data is presented as concentrations during each 4-weekly period, and for TOMPs as 3-monthly concentrations.

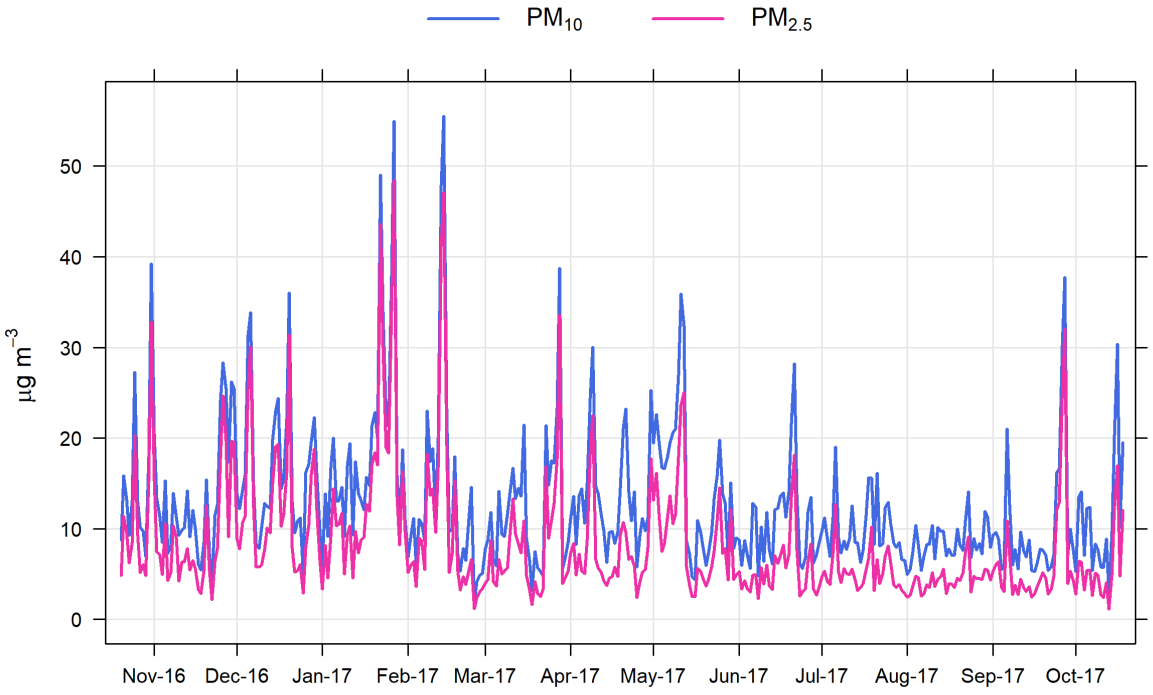

Figure 3: Daily average PM_{10} and $PM_{2.5}$ concentrations measured at Helsby during Phase1.

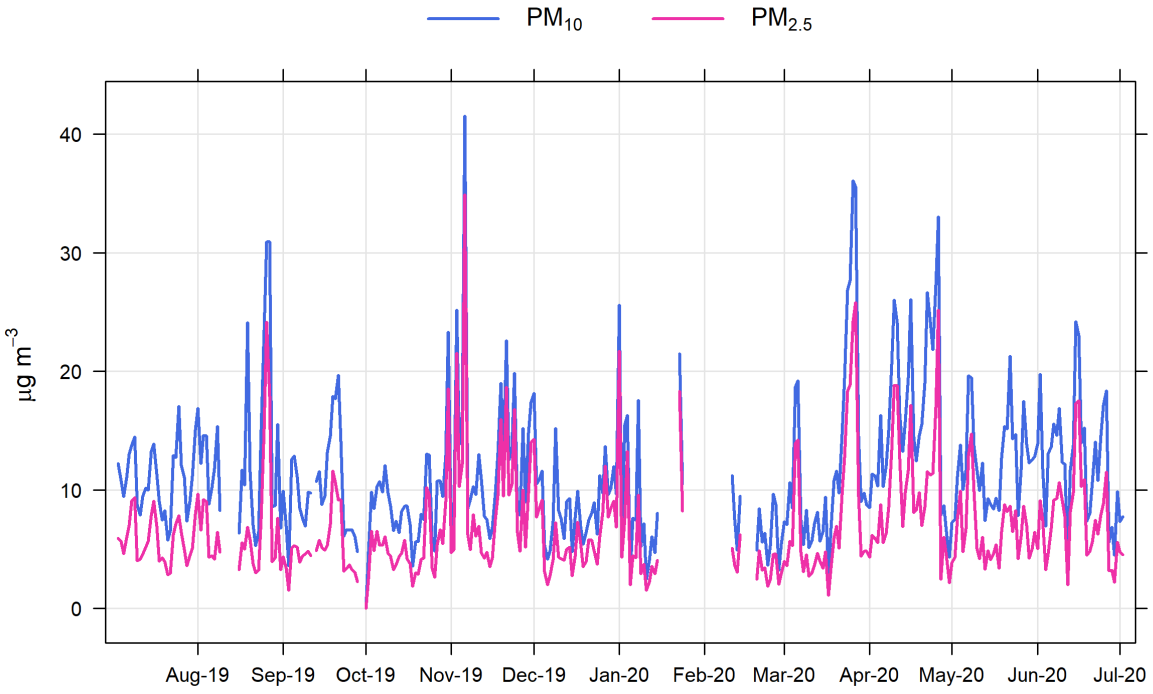

Figure 4: Daily average PM_{10} and $PM_{2.5}$ concentrations measured at Helsby during Phase 2.

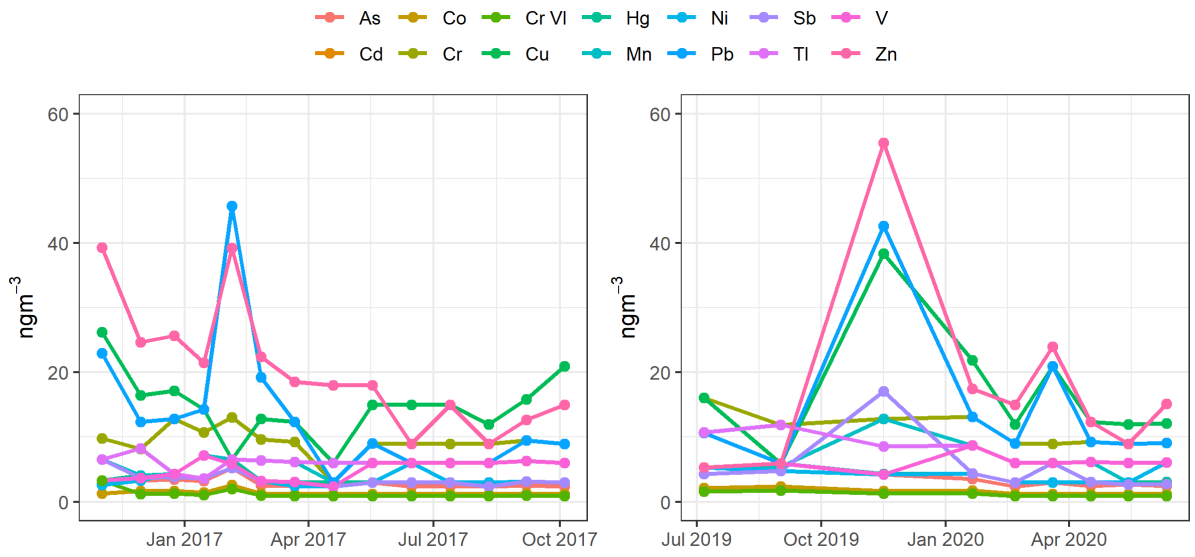

Figure 5: Heavy metal concentrations measured at Helsby during Phase 1 and Phase 2. Points shown at mid-point of 4-week period.

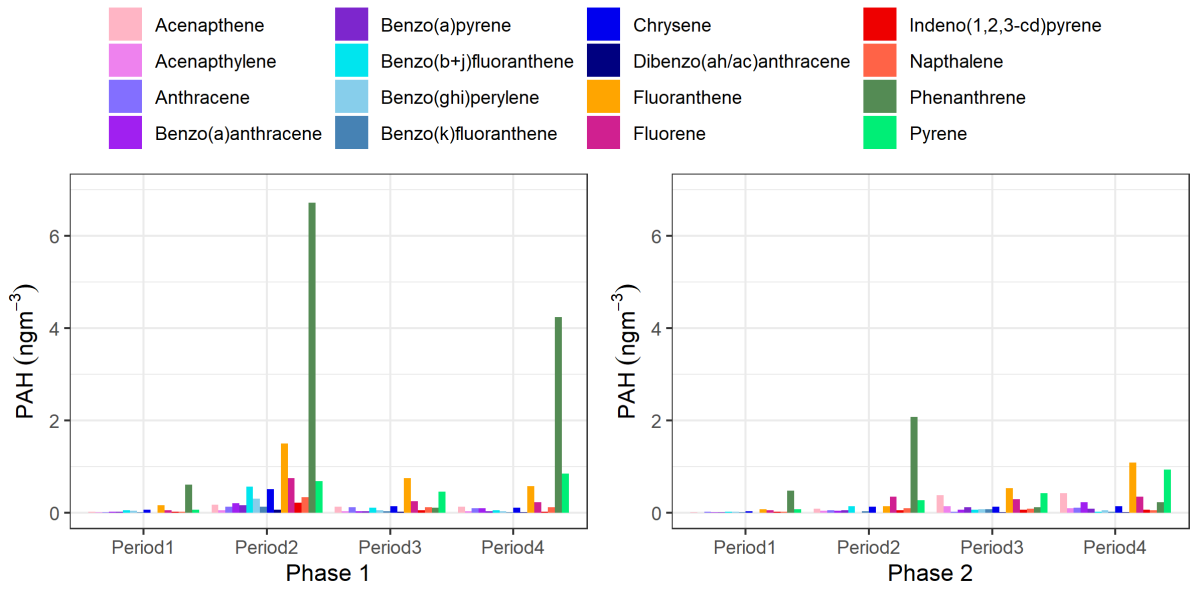

Figure 6: PAH concentrations measured at Helsby during Phase 1 and Phase 2

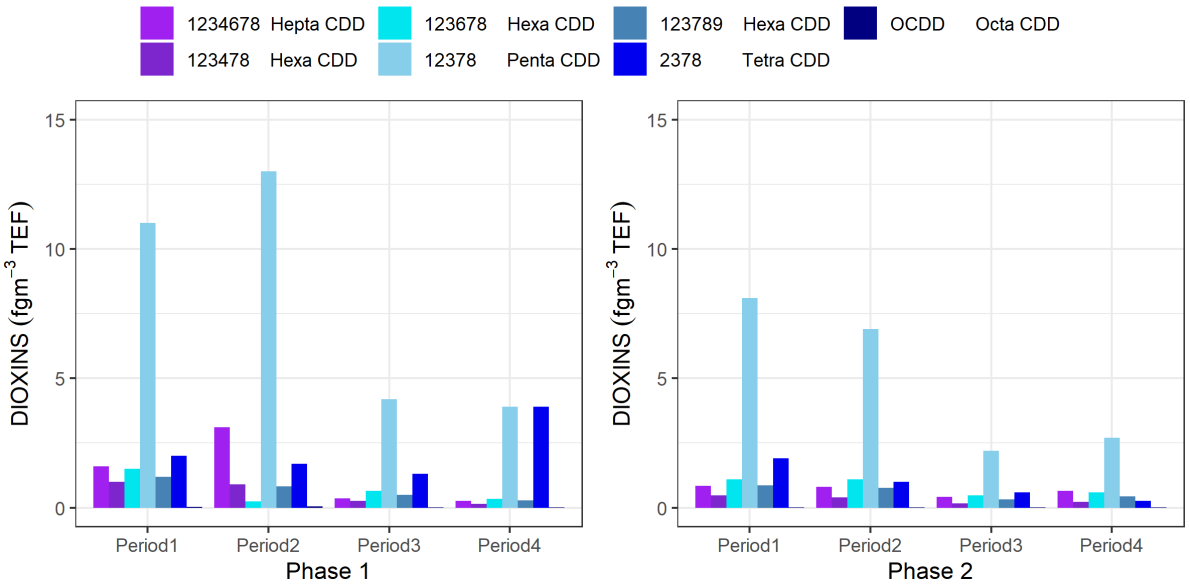

Figure 7: Dioxin concentrations measured at Helsby during Phase 1 and Phase 2

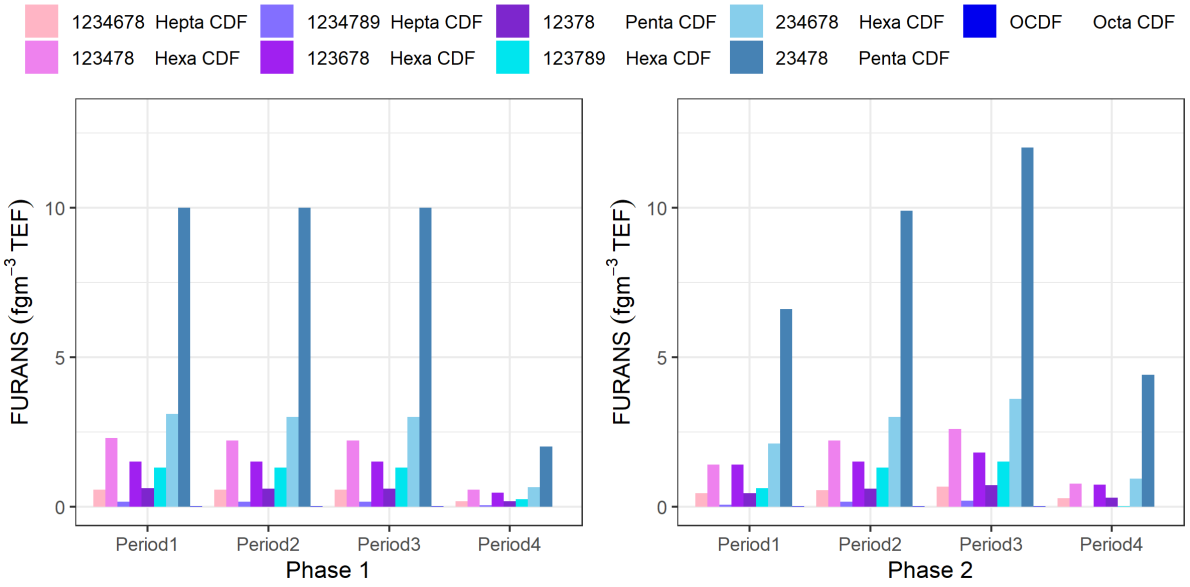

Figure 8: Furan concentrations measured at Helsby during Phase 1 and Phase 2

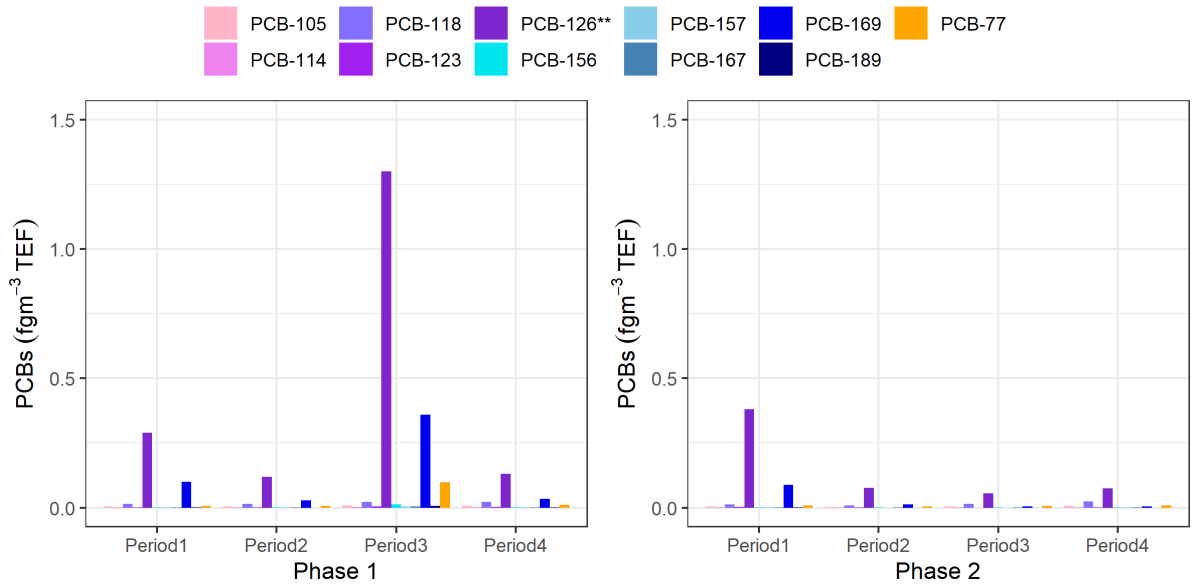

Figure 9: PCB concentrations measured at Helsby during Phase 1 and Phase 2. Note for PCB-126 actual concentrations are x10.

3.2.2 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 10 shows the daily, weekly, and monthly variability in concentrations for the two phases.

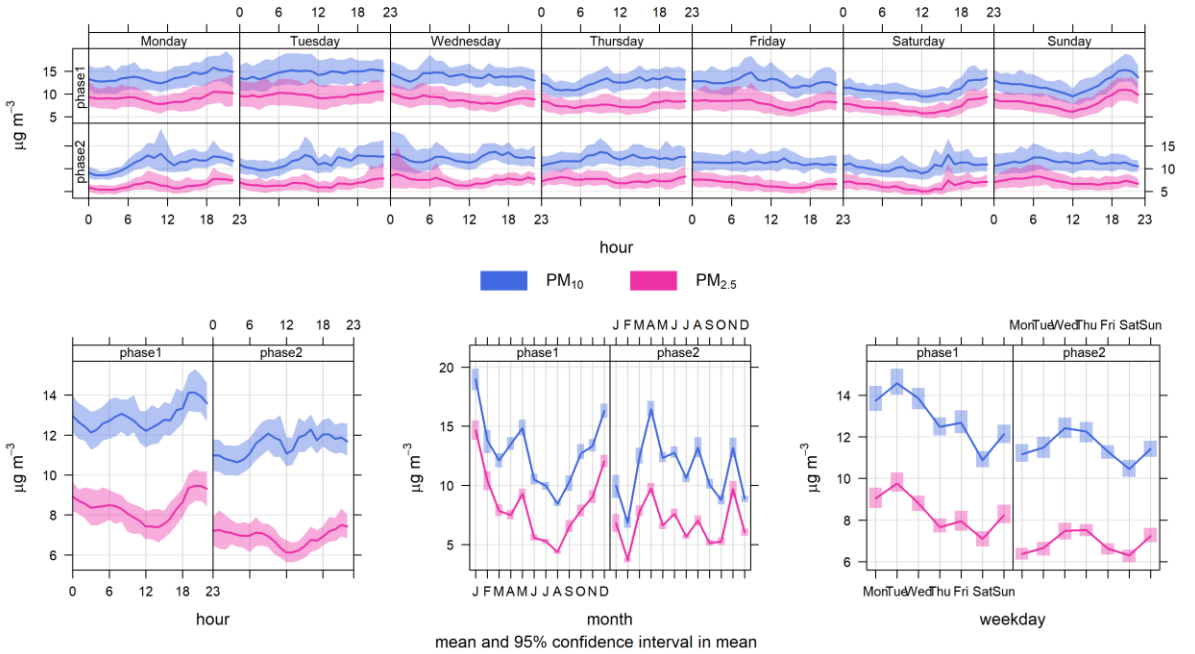

Figure 10: Temporal variations in PM_{10} and $PM_{2.5}$ concentrations measured at Helsby during Phase 1 and Phase 2.

Seasonal: Variations in the PM concentrations across seasons can be seen in the "month" plot in Figure 10. The elevation in PM concentrations over winter/spring are similar to observations at other sites in the UK and is likely to be the result of an increase in emissions from residential heating, coupled with low dispersion under cold/stable conditions. During Phase 2 the elevated PM levels are less obvious over winter, this may be related to meteorological conditions and changes due to the impact of lockdown in early 2020.
Weekly: The weekly cycles are similar for Phase 1 and Phase 2 with higher levels typically observed during the weekdays and lower levels on a Saturday, which may be related to local traffic.
Diurnal: The diurnal cycle, as seen in the "hour" plot in Figure 10, shows a minimum in PM_{10} and $PM_{2.5}$ during the day, and some evidence of a morning and evening rush hour peak. Overall PM levels are lower during Phase 2 when compared to Phase 1.

3.2.3 Polar Plots

To investigate possible sources of PM and changes between the two phases, 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 11 shows the frequency of counts by wind direction for Phase 1 and Phase 2. The plots show that the wind direction and average wind speed are very similar between the two phases.

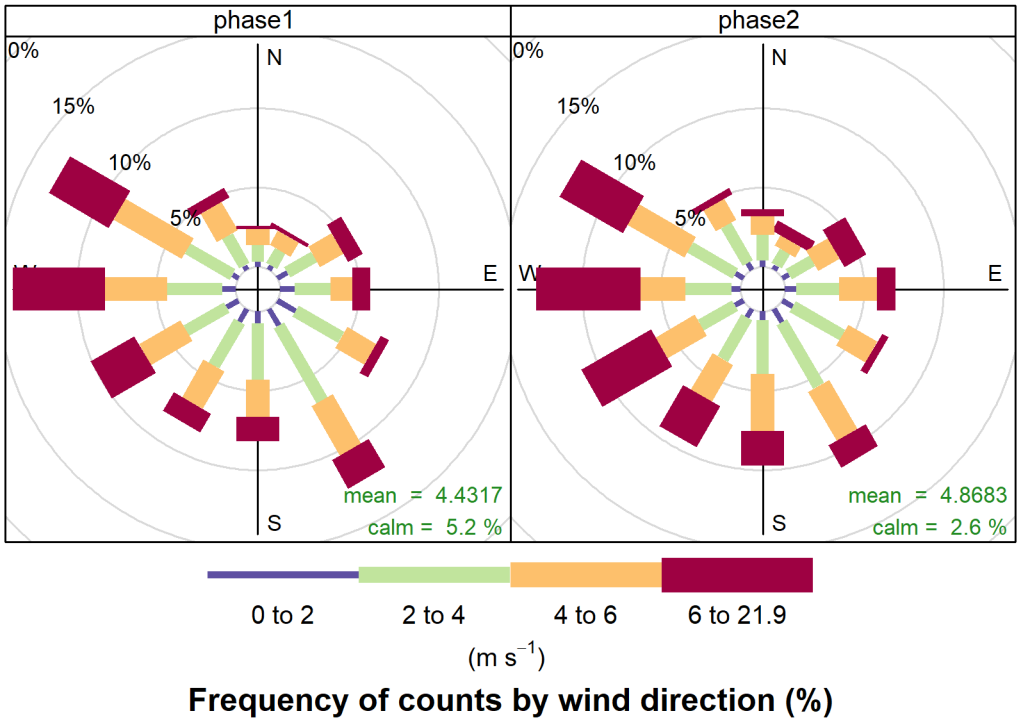

Figure 11: Wind roses showing the frequency of counts by wind direction for Phase 1 and Phase 2.

Figure 12 and Figure 13 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 darker colours representing low PM levels, and lighter colours high PM levels.
During Phase 1 there are high concentrations of PM_{10} and $PM_{2.5}$ towards the East under moderate (0-10 ms^{-1}) wind speeds and towards the North West when wind speeds are higher (> 10 ms^{-1}). This is less clear in Phase 2 with the highest PM_{10} concentrations in this case observed when the wind is from the South East and the wind speeds are above 10 ms^{-1}.

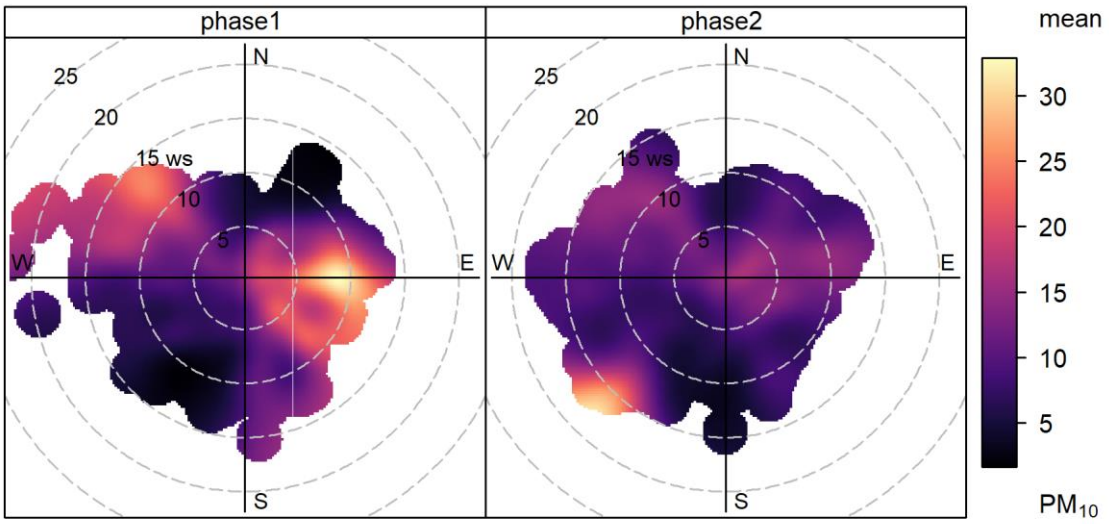

Figure 12: Bivariate polar plots of PM_{10} for Phase 1 and Phase 2.

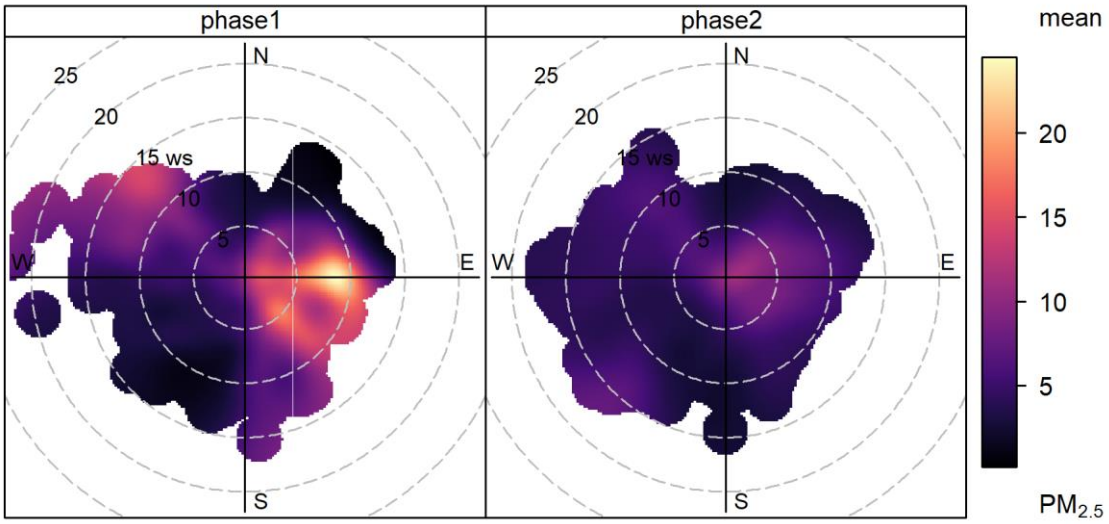

Figure 13: Bivariate polar plots of $PM_{2.5}$ for Phase 1 and Phase 2.

3.3 Comparison between Phase 1 and Phase 2

This section draws on the data presented in Section 3.2, to assess whether there has been any noticeable change in the concentrations of PM, metals, and TOMPS between Phase 1 and Phase 2. Particulate levels measured at Helsby decreased slightly from Phase 1 to Phase 2, with mean PM_{10} concentrations decreasing by 1.4 μgm^{-3}, and $PM_{2.5}$ by 1.5 μgm^{-3}. The observed change may in part be the result of variations in local meteorology, or regional/transboundary sources, between the two phases. The bivariate polar plots given in Figure 12 and Figure 13 do not suggest there was any notable increase in PM from the direction of the Ince Bio Power Plant.

Figure 6 to Figure 9 indicate that concentrations of metals and TOMPs, vary across the year and between phases.

Table 8 provides a summary of the percentage change in the mean concentration of each compound measured at Helsby.

All PCBs measured showed a decrease in concentration from Phase 1 to Phase 2, whereas the metals show an increase, with the exception of Zinc and Chromium VI.
For dioxins, only one compound indicated an increase (123678 Hexa CDD), with all other measured dioxins decreasing. Furans remained almost constant between the two phases, with only small increases or decreases in concentrations. A large variability in measured PAHs is observed between phases, with some compounds increasing, and others decreasing.

Table 8: Percentage change in average concentration of measured compounds between Phase 1 and Phase 2. Numbers in red indicate those compounds that have increased in concentration from Phase 1 to Phase 2.

Compound	% Change between Phase 1 and 2	Compound	% Change between Phase 1 and 2
DIOXINS		**PAHs**	
2378 Tetra CDD	-58%	Napthalene	-56%
12378 Penta CDD	-38%	Acenapthylene	117%
123478 Hexa CDD	-45%	Acenapthene	99%
123678 Hexa CDD	19%	Fluorene	-18%
123789 Hexa CDD	-15%	Phenanthrene	-75%
1234678 Hepta CDD	-49%	Anthracene	-40%
OCDD Octa CDD	-30%	Fluoranthene	-38%
FURANS		Pyrene	-16%
2378 Tetra CDF	6%	Benzo(a)anthracene	-3%
12378 Penta CDF	2%	Chrysene	-46%
23478 Penta CDF	3%	Benzo(b+j)fluoranthene	-66%
123478 Hexa CDF	-4%	Benzo(k)fluoranthene	-27%
123678 Hexa CDF	10%	Benzo(a)pyrene	8%
234678 Hexa CDF	-1%	Indeno(1,2,3-cd)pyrene	-38%
123789 Hexa CDF	-17%	Dibenzo(ah/ac)anthracene	-73%
1234678 Hepta CDF	3%	Benzo(ghi)perylene	-64%
1234789 Hepta CDF	-21%	**Metals**	
OCDF Octa CDF	-9%	As	14%
PCBs		Cd	11%
PCB-81	-72%	Co	11%
PCB-77	-75%	Cr	18%
PCB-123	-67%	Cu	15%
PCB-118	-16%	Hg	11%
PCB-114	-54%	Mn	11%

Compound	% Change between Phase 1 and 2	Compound	% Change between Phase 1 and 2
PCB-105	-25%	Ni	19%
PCB-126	-68%	Pb	7%
PCB-167	-69%	Sb	52%
PCB-156	-76%	Tl	30%
PCB-157	-78%	V	22%
PCB-169	-79%	Zn	-14%
PCB-189	-86%	Cr VI	-4%

4 Conclusions

An analysis of the pollutant data measured at the site in Helsby was performed to investigate changes in concentrations prior to (Phase 1) and post (Phase 2) commissioning of the Ince Bio Power site. The results indicate that, on average, PM_{10} and $PM_{2.5}$ decreased slightly between Phase 1 and Phase 2. For Phase 1, mean PM_{10} and $PM_{2.5}$ concentrations were 12.9 μgm^{-3} and 8.4 μgm^{-3} respectively, decreasing to 11.5 μgm^{-3} and 6.9 μgm^{-3} in Phase 2. For both phases mean PM_{10} and $PM_{2.5}$ were below the annual mean air quality objectives.

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} and $PM_{2.5}$ were associated with winds from the East and North West during Phase 1 and from the South East during Phase 2. Filter samples of PM_{10} were collected every month and heavy metal concentrations extracted. For all heavy metals analysed, there was an observed increase in mean concentrations between Phase 1 and Phase 2, however, all mean concentrations were below target values.

Samples were collected and collated every 3 months for analysis of dioxins, furans, PCBs, and PAHs. Most of the dioxins, furans, and PCBs either decreased or remained constant between the two phases. For PAHs, all compounds observed a decrease in concentrations from Phase 1 to Phase 2, except B[a]P, acenapthylene, and acenapthene.

5 References

Carslaw, David. 2020. “worldmet: Import Surface Meteorological Data from NOAA Integrated Surface Database (ISD).” https://CRAN.R-project.org/package=worldmet.

NOAA. 2020. *Integrated Surface Database (ISD).* https://www.ncdc.noaa.gov/isd.

Appendices

A1 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 A1. 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 A1 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		

A2 Datasets

Table A2: Analysis of heavy metals for each period in Phase 1 and Phase 2

Phase 1																
start	end	Report ID	As	Cd	Co	Cr	Cu	Hg	Mn	Ni	Pb	Sb	Tl	V	Zn	Cr VI
19/10/2016	16/11/2016	ASC26041.002	2.95	<3.28	<1.31	9.83	26.22	<3.28	6.56	<2.62	22.94	6.56	<6.56	3.28	39.33	<3.28
16/11/2016	14/12/2016	ASC/27286.001	<3.29	<4.11	<1.64	8.22	16.43	<4.11	4.11	3.29	12.33	3.70	<8.22	3.70	24.65	<1.23
14/12/2016	04/01/2017	ASC27064.001	<3.43	<4.28	<1.71	12.85	17.13	<4.28	4.28	4.28	12.85	3.85	<4.28	4.28	25.69	<1.28
05/01/2017	25/01/2017	ASC27094.002	3.23	<3.58	<1.43	10.75	14.33	<3.58	7.17	3.58	14.33	3.58	<3.58	7.17	21.50	<1.08
25/01/2017	15/02/2017	ASC27094.003	<5.23	<6.54	<2.61	13.07	6.54	<6.54	6.54	<5.23	45.75	<5.23	<6.54	5.88	39.22	<1.96
15/02/2017	08/03/2017	ASC27826.002	<2.56	<3.21	<1.28	9.62	12.82	<3.21	6.41	3.21	19.23	3.21	<6.41	3.21	22.44	<0.96
08/03/2017	05/04/2017	ASC/28805.001	<2.47	<3.09	<1.23	9.26	12.35	<3.09	6.17	<2.47	12.35	3.09	<6.17	3.09	18.52	<0.93
05/04/2017	03/05/2017	ASC/28805.002	<2.40	<3.00	<1.20	3.00	5.99	<3.00	3.00	<2.40	3.00	<2.40	<5.99	2.40	17.97	<0.90
03/05/2017	01/06/2017	ASC/29926.001	3.00	<3.00	<1.20	8.99	14.99	<3.00	8.99	3.00	8.99	3.00	<6.00	<6.00	17.99	<0.90
01/06/2017	29/06/2017	ASC/29926.002	<2.40	<3.00	<1.20	8.99	14.98	<3.00	5.99	5.99	5.99	3.00	<5.99	<5.99	8.99	<0.90
29/06/2017	27/07/2017	ASC/29926.003	<2.40	<3.00	<1.20	8.99	14.98	<3.00	5.99	3.00	5.99	3.00	<5.99	<5.99	14.98	<0.90
27/07/2017	24/08/2017	ASC/29926.004	<2.40	<3.00	<1.20	8.99	11.98	<3.00	5.99	3.00	5.99	2.40	<5.99	<5.99	8.99	<0.90
24/08/2017	20/09/2017	ASC/32447.001	<2.53	<3.17	<1.27	9.50	15.84	<3.17	6.33	3.17	9.50	3.17	<6.33	6.33	12.67	<0.95
20/09/2017	18/10/2017	ASC/32447.002	<2.40	<3.00	<1.20	8.99	20.97	<3.00	5.99	3.00	8.99	3.00	<5.99	5.99	14.98	<0.90

Phase 2																
start	end	Report ID	As	Cd	Co	Cr	Cu	Hg	Mn	Ni	Pb	Sb	Tl	V	Zn	Cr VI
27/06/2019	15/07/2019	ASC/43113.001	<4.28	<5.35	<2.14	16.04	16.04	<5.35	5.35	5.35	10.70	<4.28	<10.70	5.35	<5.35	<1.60
28/08/2019	05/09/2019	ASC/43113.002	<4.76	<5.95	<2.38	11.90	5.95	<5.95	5.36	<4.76	<5.95	<4.76	<11.90	5.95	<5.95	<1.79
30/10/2019	03/12/2019	ASC/43113.003	4.27	<4.27	<1.71	12.80	38.40	<4.27	12.80	4.27	42.67	17.07	<8.53	4.27	55.47	<1.28
03/01/2020	07/02/2020	ASC/32447.001	<3.50	<4.38	<1.75	13.13	21.88	<4.38	8.75	4.38	13.13	4.38	<8.75	8.75	17.51	<1.31
07/02/2020	06/03/2020	ASC/32447.002	<2.40	<3.00	<1.20	9.00	12.00	<3.00	6.00	3.00	9.00	3.00	<6.00	6.00	14.99	<0.90
06/03/2020	03/04/2020	ASC/32447.003	2.99	<2.99	<1.20	8.98	20.96	<2.99	5.99	2.99	20.96	5.99	<5.99	5.99	23.96	<0.90
03/04/2020	01/05/2020	ASC/32447.004	<2.48	<3.10	<1.24	9.29	12.39	<3.10	6.20	3.10	9.29	3.10	<6.20	6.20	12.39	<0.93
01/05/2020	29/05/2020	ASC/32447.005	2.70	<2.99	<1.20	8.98	11.98	<2.99	2.99	2.99	8.98	2.70	<5.99	5.99	8.98	<0.90
29/05/2020	26/06/2020	ASC/32447.006	<2.42	<3.03	<1.21	9.09	12.12	<3.03	6.06	6.06	9.09	2.73	<6.06	6.06	15.15	<0.91

Table A3: Analysis of PAHs for each period in Phase 1 and Phase 2

	Phase 1				Phase 2			
Compound	Period 1	Period 2	Period 3	Period 4	Period 1	Period 2	Period 3	Period 4
Napthalene	0.029	0.341	0.120	0.123	0.019	0.099	0.089	0.060
Acenapthylene	0.010	0.055	0.030	0.039	0.006	0.044	0.141	0.100
Acenapthene	0.024	0.170	0.130	0.131	0.009	0.086	0.384	0.425
Fluorene	0.061	0.752	0.249	0.231	0.061	0.346	0.296	0.354
Phenanthrene	0.615	6.717	0.110	4.237	0.484	2.078	0.120	0.229
Anthracene	0.013	0.130	0.120	0.100	0.019	0.060	0.025	0.115
Fluoranthene	0.164	1.504	0.748	0.578	0.083	0.148	0.536	1.084
Pyrene	0.064	0.692	0.459	0.847	0.082	0.277	0.430	0.936
Benzo(a)anthracene	0.024	0.211	0.040	0.100	0.009	0.050	0.072	0.232
Chrysene	0.066	0.511	0.140	0.108	0.038	0.129	0.134	0.147
Benzo(b+j)fluoranthene	0.058	0.571	0.110	0.054	0.028	0.148	0.067	0.024
Benzo(k)fluoranthene	0.016	0.130	0.030	0.015	0.009	0.030	0.074	0.027
Benzo(a)pyrene	0.025	0.160	0.040	0.031	0.009	0.059	0.119	0.088
Indeno(1,2,3-cd)pyrene	0.028	0.221	0.060	0.023	0.019	0.055	0.067	0.065
Dibenzo(ah/ac)anthracene	0.006	0.063	0.020	0.008	0.005	0.003	0.008	0.011
Benzo(ghi)perylene	0.046	0.311	0.060	0.031	0.019	0.003	0.082	0.057

Table A4: Analysis of Dioxins, Furans and PCBs, for each period in Phase 1 and Phase 2

	Phase 1				Phase 2			
Compound	Period 1	Period 2	Period 3	Period 4	Period 1	Period 2	Period 3	Period 4
DIOXINS								
2378 Tetra CDD	2	1.7	1.3	3.9	<1.9	0.99	0.59	0.27
12378 Penta CDD	11	13	4.2	3.9	8.1	6.9	2.2	2.7
123478 Hexa CDD	1	0.91	0.27	0.15	0.47	0.4	0.17	0.23
123678 Hexa CDD	1.5	0.25	0.66	0.34	1.1	1.1	0.47	0.6
123789 Hexa CDD	1.2	0.82	0.5	0.28	0.86	0.76	0.33	0.44
1234678 Hepta CDD	1.6	3.1	0.36	0.27	0.84	0.8	0.41	0.65
OCDD Octa CDD	0.03	0.05	0.0089	0.0069	0.02	0.02	0.0091	0.018
FURANS								
2378 Tetra CDF	1.2	1.2	1.2	0.32	0.95	1.2	1.4	0.61
12378 Penta CDF	0.61	0.6	0.6	0.18	0.44	0.59	0.71	0.29
23478 Penta CDF	10	10	10	2	6.6	9.9	12	4.4
123478 Hexa CDF	2.3	2.2	2.2	0.57	1.4	2.2	2.6	0.77
123678 Hexa CDF	1.5	1.5	1.5	0.46	1.4	1.5	1.8	0.74
234678 Hexa CDF	3.1	3	3	0.65	2.1	3	3.6	0.94
123789 Hexa CDF	1.3	1.3	1.3	0.24	0.61	1.3	1.5	*
1234678 Hepta CDF	0.57	0.56	0.56	0.18	0.44	0.55	0.66	0.28
1234789 Hepta CDF	0.16	0.16	0.16	0.049	0.066	0.16	0.19	*
OCDF Octa CDF	0.0055	0.0054	0.0054	0.0012	0.0023	0.0053	0.0064	0.0019
PCBs								
PCB-81	0.0092	0.016	0.036	0.012	0.013	0.0036	0.0017	0.0025
PCB-77	0.0077	0.0063	0.098	0.01	0.0088	0.0044	0.0069	0.0099
PCB-123	0.0021	0.0019	0.0054	0.0028	0.0024	0.001	0.00017	0.00047
PCB-118	0.015	0.014	0.022	0.022	0.013	0.0086	0.015	0.025

	Phase 1				Phase 2			
Compound	Period 1	Period 2	Period 3	Period 4	Period 1	Period 2	Period 3	Period 4
PCB-114	0.00092	0.00045	0.0028	0.0006	0.00094	0.00027	0.00039	0.00058
PCB-105	0.0052	0.0054	0.009	0.0072	0.0054	0.0028	0.0045	0.0074
PCB-126	2.9	1.2	13	1.3	3.8	0.77	0.55	0.75
PCB-167	0.0011	0.00096	0.0054	0.00095	0.0012	0.00042	0.00034	0.00064
PCB-156	0.0017	0.0012	0.013	0.0012	0.0015	0.00068	0.0007	0.0013
PCB-157	0.00092	0.0003	0.0051	0.00051	0.00088	0.0002	0.00017	0.00028
PCB-169	0.1	0.028	0.36	0.035	0.088	0.013	0.0048	0.0058
PCB-189	0.0019	0.00018	0.0063	0.00035	0.00083	0.00015	0.000087	0.00014

*Not detected

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