UK PAH MONITORING AND ANALYSIS NETWORK

Annual Report for 2021

Report for: Environment Agency, Department for Environment, Food and Rural Affairs, Department of Environment Northern Ireland, Welsh Government and Scottish Government

Ref. EMC 58151
Ricardo ref. ED12330 Issue: 1 09/08/2022

Ricardo Energy & Environment, Gemini Building, Fermi Avenue, Harwell, Oxfordshire, OX11 0QR, UK | +44(0)1235 75 3000 | ee.ricardo.com
Registered company no. 08229264 | VAT no. GB 212 8365 24

Customer:
Environment Agency, Department for Environment, Food and Rural Affairs, Department of Environment Northern Ireland, Welsh Government and Scottish Government

Customer reference:
EMC 58151

Confidentiality, copyright and reproduction:

Ricardo reference:
ED12330

Contact:
Christopher Conolly, Gemini Building, Fermi Avenue, Harwell, Didcot, OX11 0QR, UK

T: +44 (0) 1235 753 375
E: christopher.conolly@ricardo.com

Authors:
Christopher Conolly and Sion Carpenter

Approved by:
Brian Donovan

Signed

Date:
09/08/2022

EXECUTIVE SUMMARY

This annual report for 2021 for the UK Polycyclic Aromatic Hydrocarbons (PAH) Monitoring and Analysis Network was prepared by Ricardo Energy & Environment (Ricardo) for the Environment Agency, the Department for Environment, Food and Rural Affairs, the Northern Ireland Department of Agriculture, Environment and Rural Affairs, the Welsh Government and the Scottish Government.

In the UK, ambient (outdoor) air quality is regulated by the Air Quality Standards Regulations (AQSR).

These Air Quality Standards Regulations set a 'Target Value' that relates to PAH as the annual mean concentration of Benzo[*a*]pyrene (B[*a*]P) which is set at 1 ng/m^3. Target values are not legally binding, but the UK must take all necessary measures not entailing disproportionate costs to meet them.

There is a more stringent UK National Air Quality Objective for B[*a*]P in ambient air as an annual mean concentration of 0.25 ng/m^3 as detailed in the Air Quality Strategy (Defra, 2007).

The UK PAH Monitoring and Analysis Network provides data that can be compared to the Target Value and Air Quality Objective with concentrations measured at sites around the UK.

During 2021 the number of ambient air sampling sites changed due to site installations and closures but at the end of the year there were 32 sites in the network. The network of two deposition samplers remained unchanged.

Most of the sampling locations in the network are urban background, but also includes urban industrial, rural background and a single site that is urban traffic. The rural background sites are located at Chilbolton Observatory, Hampshire and Auchencorth Moss, Midlothian. Results from these two rural background sites are used to support the European Monitoring and Evaluation Programme (EMEP) to Level 2. EMEP is a scientifically based and policy driven programme under the Convention on Long-range Transboundary Air Pollution (CLRTAP) (UNECE, 1979) for international co-operation to solve transboundary air pollution problems.

The UK PAH Monitoring Network comprises non automatic systems to measure PAH in ambient air and deposition. B[*a*]P has been identified as a human carcinogen by IARC and has been determined to be a suitable 'marker' for the PAH mixture in ambient air.

Key findings for 2021:

In 2021 the AQSR target value for B[*a*]P (annual mean concentration of 1 ng/m^3) was not exceeded any of the network sites.

In 2021 nine sites exceeding the UK Air Quality Objective for B[*a*]P (annual mean concentration of 0.25 ng/m^3), these were:

- Scunthorpe Town
- Derry Brandywell
- Scunthorpe Low Santon
- Port Talbot Margam
- Ruardean
- Ballymena Ballykeel
- Royston
- Kilmakee Leisure Centre
- Swansea Cwm Level Park

The average data capture of all the operational sites throughout the whole of 2021 was higher than in previous year at 94%.

CONTENTS

1. INTRODUCTION

This report was prepared by Ricardo as part of the UK PAH Monitoring and Analysis Network ('the Network' or 'the PAH Network') contract numbers 58151 and 28525 with the Environment Agency for the Department for Environment, Food and Rural Affairs, the Northern Ireland Department of Agriculture, Environment and Rural Affairs, the Welsh Government and the Scottish Government.

Ricardo originally established the UK's PAH monitoring network in 1991 and have managed the network continuously except for the period October 2010 - September 2016. The original network used high volume Andresen samplers which began to be upgraded to Digitel DHA-80 high volume PM_{10} aerosol samplers in late 2006 with the first full year of operation of many of the sites being 2007. This annual report presents and discusses data from the network since the upgrade to the Digitel DHA-80 samplers including data collected by a previous contractor.

This annual report contains:

- An introduction to polycyclic aromatic hydrocarbons (PAHs)
- Summary of air quality policy relating to PAHs
- Information relating to sources of PAHs in the UK
- A network overview including equipment and details of the sampling locations and changes
- Summary of analytical techniques employed
- A comparison of annual mean B[*a*]P concentrations with the Air Quality Standard Target Value and the more stringent UK Air Quality Objective
- Monthly PAH concentrations in 2021
- Review of concentration trends of B[*a*]P at each of the monitoring sites

The appendices of this report present data for the monthly deposition concentrations of B[*a*]P at all Network stations that were operational in 2021. However, all deposition and air concentration data for all other PAHs measured within the network can be accessed via the UK-AIR website.

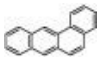
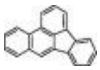
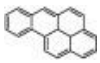
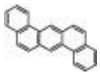
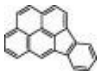
An interactive version of this report can also be accessed on the UK-AIR website.

1.1 POLYCYCLIC AROMATIC HYDROCARBONS

Polycyclic aromatic hydrocarbons (PAHs) are a group of persistent organic pollutant compounds they contain two or more benzene rings, they are generally produced through incomplete combustion or pyrolysis.

The International Agency for research on Cancer (IARC) has determined that B[*a*]P is carcinogenic to humans and is currently considered by IARC as the most carcinogenic PAH. Details of the assessment of the carcinogenicity of PAHs carried out by IARC can be found online.

Table 1-1: PAH structures of PAH that should be monitored according to Air Quality Standard Regulations. The IARC Carcinogenic Classification of PAH can be found on the IARC website.

Compound	Structure
Benz[*a*]anthracene	
Benzo[*b*]fluoranthene	
Benzo[*j*]fluoranthene	
Benzo[*k*]fluoranthene	
Benzo[*a*]pyrene	
Dibenz[*a,h*]anthracene	
Indeno[*1,2,3-c,d*]pyrene	
Benzo[*g,h,i*]perylene	

1.2 AIR QUALITY POLICY

In the UK there is a national air quality objective for B[*a*]P in ambient air, based on an annual mean concentration of 0.25 ng/m^3. Details can be found in the UK Air Quality Strategy (Defra, 2007).

In the UK, ambient (outdoor) air quality is regulated by the Air Quality Standards Regulations. These are as follows:

- The Air Quality Standards Regulations 2010 in England (UK Government, 2010), and their December 2016 amendment (UK Government, 2016)
- The Air Quality Standards (Scotland) Regulations 2010 in Scotland (Scottish Government, 2010), and their December 2016 amendment (Scottish Government, 2016)
- The Air Quality Standards (Wales) Regulations 2010 in Wales (Welsh Government, 2010)
- The Air Quality Standards Regulations (Northern Ireland) 2010 (DAERA, 2010), and their December 2016 amendment (DAERA, 2017)

The Air Quality Standard Regulations and their amendments sets a target value for B[*a*]P of 1 ng/m^3 (total content in the PM_{10} fraction averaged over a calendar year) along with mandatory measurement requirements.

B[*a*]P's suitability as a marker for the PAH mixture in ambient air as stated in the EC Position Paper on PAH (EC, 2001) led to it being selected as the measure for monitoring. The more stringent UK National Air Quality Objective for PAH also used B[*a*]P as a marker (annual mean of 0.25 ng/m^3 B[*a*]P in ambient air). The reference method for measurement of B[*a*]P in ambient air are detailed in a British Standard (BS 15549) (BSI, 2008).

Measurements of PAH in deposition are covered by another British Standard (BSI, 2011) which details the measurement method sampling, sample preparation and analysis for benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*j*]fluoranthene, benzo[*k*]fluoranthene, benzo[*a*]pyrene, dibenz[*a,h*]anthracene and indeno[*1,2,3-c,d*]pyrene. There is no limit or target value related deposition of PAH in the UK.

The two rural background sites located at Chilbolton Observatory, Hampshire and Auchencorth Moss, Midlothian are used to support the European Monitoring and Evaluation Programme (EMEP) to Level 2. EMEP is a scientifically based and policy driven programme under the Convention on Long-range Transboundary Air Pollution (CLRTAP) which was signed by the UK in 1979. The convention aids international co-operation to solve transboundary air pollution problems, provides access to emission, measurement and modelling data and provides information on the effects of air pollution on ecosystems, health, crops and materials.

1.3 SOURCES OF PAHS IN THE UK

Polycyclic aromatic hydrocarbons (PAHs) are a group of persistent organic pollutant compounds. They contain two or more benzene rings, they are generally produced through incomplete combustion or pyrolysis. The National Atmospheric Emissions Inventory (NAEI) has estimated the emission of PAH for the UK for many years. The inventory estimates the emissions of PAHs including B[*a*]P. As with all emissions inventories there is some uncertainty in the estimates as the emissions are not based solely on measurements and require some estimation of emission factors and activities being required.

In recent years the Inventory indicates that residential and commercial combustion are the dominate emission sources of B[*a*]P in the UK. (Defra's Clean Air Strategy) reports that the used of wood as a domestic fuel has been calculated to produce 78% of total national emission of B[*a*]P. Most recent information relating to UK Emissions of PAH and other pollutant can be accessed via the (NAEI website). This data is updated on an annual basis.

2. THE PAH NETWORK

2.1 NETWORK OBJECTIVES

The objective of the PAH Network is to determine the ambient concentrations of PAHs in ambient air in the UK through monitoring and chemical analysis, and deliver or aid the delivery the following:

- A UK assessment of current concentrations of PAHs for assessment against the Air Quality Standards Regulations and the UK Air Quality Strategy objectives, and provide measurement input for any future reviews.
- A Review of the measurements and trends of airborne concentrations of PAHs in representative UK industrial, urban and rural locations.
- Provide data and metadata to UK-AIR to enable demonstration of the UK's compliance with the Air Quality Standards Regulations, the OSPAR convention (OSPAR, 2017) and the UNECE Convention on Long Range Transboundary Air Pollutants (UNECE, 1979), to enable a better understanding of sources or potential sources of PAH.

2.2 NETWORK OVERVIEW

The monitoring stations operating in the UK PAH Network during 2021 are shown in Figure 2-1. Two monitoring sites where both Digitel particulate samplers and deposition samples are taken are marked with blue circles (Auchencorth Moss and Chilbolton Observatory). Other sites where only Digitel particulate samples are taken are marked with red circles.

Figure 2-1: Map of UK PAH monitoring stations in 2021.

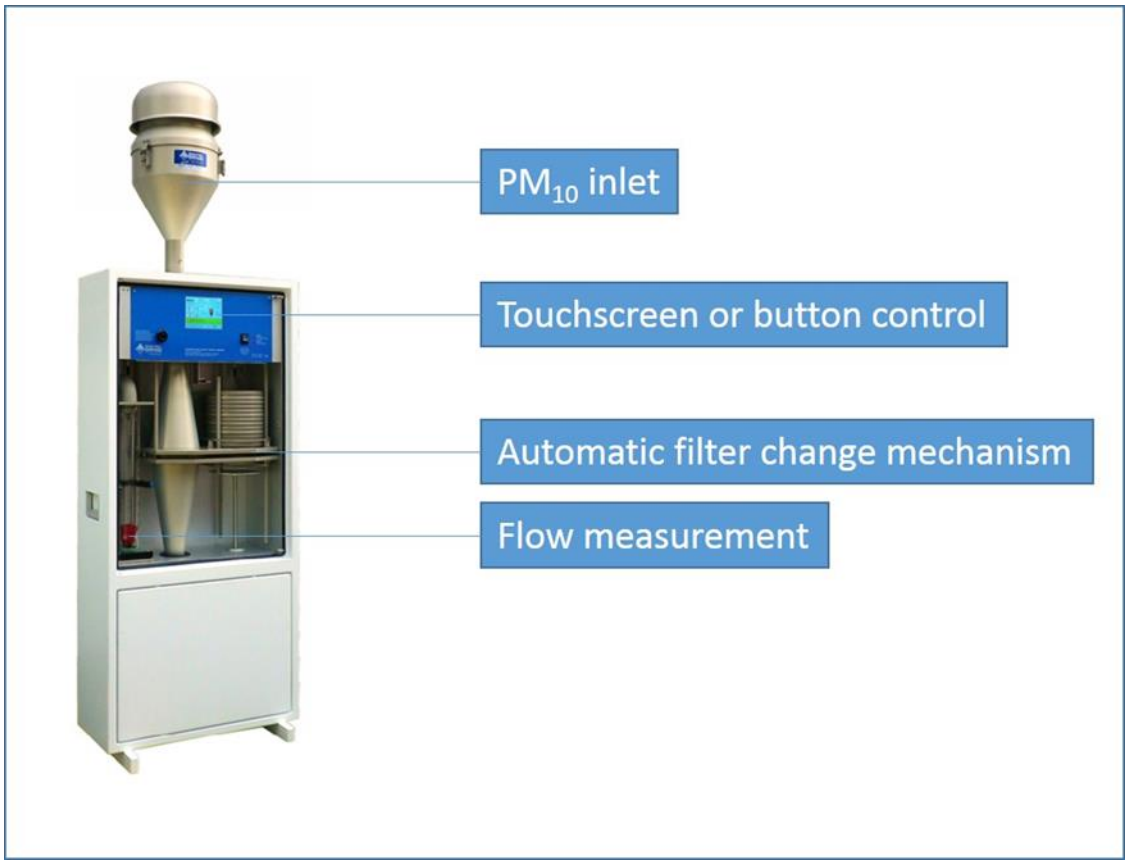
In 2021 there were 33 ambient air sampling sites operational in the network in the UK in addition to two deposition samplers. The majority of the sampling locations are urban background, but the network also includes urban industrial, two rural background sites located at Chilbolton Observatory, Hampshire and Auchencorth Moss, Midlothian and a single urban traffic site at London Marylebone Road. The rural background sites are used to support the European Monitoring and Evaluation Programme (EMEP).

2.3 SAMPLERS IN THE PAH NETWORK

The Network requires the sampling and analysis of two types of samples these are particulate and deposition samples.

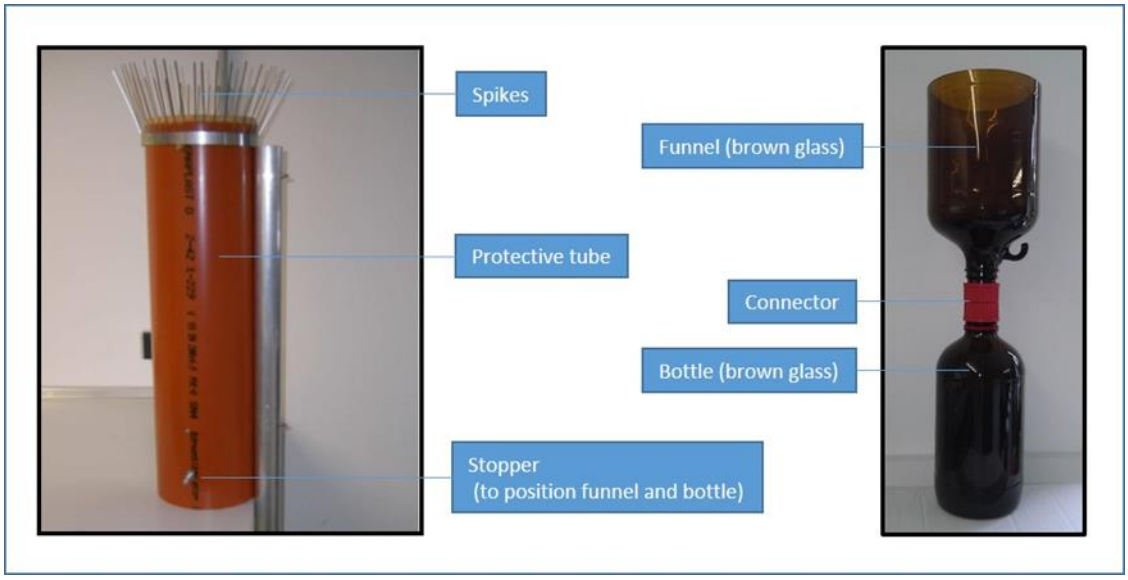
'PAH Digitel (solid phase)' particulate samplers. These samples are in the PM_{10} fraction of ambient air on a filter and are taken daily at all network stations using Digitel DHA-80 samplers with automatic filter changers. Each sample is taken for 24 hours with the sample changeover occurring at midnight (GMT). The samples are bulked into groups representing calendar months per location for analysis. The Digitel DHA-80 samplers (see Figure 2-2) used throughout the Network are considered to be equivalent to the requirements of the Standard for sampling PM_{10} matter (EN 12341) (BSI, 2014b). The samplers are therefore valid for use with the Standard method for the measurement of B[*a*]P in ambient air (EN 15549). The solid phase filter samples have a measurement period of 24 hours at a flowrate of approximately 30 m^3/h.

Figure 2-2: Digitel DHA-80 sampler deployed to measure solid phase PAH in the UK Network.



'PAH deposition' samplers. These deposition samples are taken fortnightly at two rural stations within the network at Auchencorth Moss and Chilbolton Observatory (prior to 2016 the equipment at Chilbolton was located at Harwell). Each sample is taken for 14 days using a deposition sampler (Figure 2-3) that meets the requirement of the Standard for the measurement of the deposition of PAHs (BS EN 15980). The deposition sampler itself consist of a glass funnel and a four litre brown glass collection bottle, which are located inside a protective tube in order to minimise photochemical reactions and the degradation of PAHs. The spikes seen on the image have been fitted to the top of the protective tubes to prevent damage and contamination by bird strikes.

Figure 2-3: Samplers to measure deposition of PAH in the UK Network.



2.3.1 Sampling Quality Control

To ensure the quality of the sampling procedure there are a number of checks and quality assurance and quality control measures that are undertaken on the data and the filters used in the samplers prior to use. These include the inspection of sampling media prior to use at sampling sites, analysis of field and sample blanks, checking of equipment operation via online systems, review of the measurement data associated with the filters being returned from the sites to ensure they meet the requirement of the BS EN 15549 standard. In addition to these checks the network is supported by an infrastructure of local site operators who are fully trained and provided with detailed working instructions for site operation.

2.4 NETWORK ACTIVITIES DURING 2021

2.4.1 Station Infrastructure and Network Re-organisation

The following network infrastructure changes took place which are not detailed in previous reports covering the time period at the end of 2015 and 2021:

- Hove PAH sampling ceased 31st December 2015
- London Crystal Palace Parade PAH sampling ceased 31st December 2015
- Nottingham Centre PAH sampling began 16th November 2016
- Ruardean PAH sampling began 15th March 2017
- Sheffield Tinsley PAH sampling began 16th March 2017
- Birmingham Tyburn PAH sampling ceased 24th May 2017
- Newport PAH sampling suspended from 16th August 2017 to 6th April 2018 due to safety work at the monitoring site
- Birmingham Ladywood PAH sampling began 1st June 2018
- Scunthorpe Santon PAH sampling suspended from 9th September 2020 to 22nd October 2019 due to roof replacement
- Bristol St Paul's PAH sampling began 1st November 2019
- Liverpool Speke sampling suspended from the 7th of September 2020 due to site safety work at the monitoring site and restarted in August 2021
- Cardiff Lakeside sampling suspended from 22nd September to the 28th October due to electrical work and renovations at the school where the sampler is located.
- South Hiendley site closed 17th August 2021
- Southampton Centre site opened 16th June 2021
- Ruardean site closed 20th December 2021
- Plymouth Centre site opened 1st January 2022

2.4.2 Data capture, Station Calibrations, Services and Breakdowns

All Stations were calibrated and serviced in 2021 and checks on flow were undertaken. Table 2-2 below shows the data captures for 2021.

Table 2-1: PAH data capture in 2021

Site	Data capture
Auchencorth Moss	96%
Ballymena Ballykeel	95%
Birmingham Ladywood	98%
Bolsover	85%[d]
Bristol St Paul's	99%
Cardiff Lakeside	100%
Chilbolton Observatory	100%
Derry Brandywell	100%
Edinburgh St Leonards	99%
Glasgow Townhead	95%
Hazelrigg	100%
High Muffles	99%
Kilmakee Leisure Centre	100%
Kinlochleven	98%
Leeds Millshaw	100%
Liverpool Speke	35%[d]
London Brent	98%
London Marylebone Road	99%
Lynemouth 2	99%
Middlesbrough	99%
Newcastle Centre	100%
Newport	98%
Nottingham Centre	98%
Port Talbot Margam	100%
Royston	99%
Ruardean[a]	96%
Salford Eccles	100%
Scunthorpe Low Santon*	100%
Scunthorpe Town	100%
Sheffield Tinsley	97%
South Hiendley[b]	62% (99%[e])
Southampton Centre[c]	52% (96%[e])
Stoke Ferry	99%
Swansea Cwm Level Park	100%
Network Average	**94% (96%[d] [e])**

[a] Ruardean site closed 20th December 2021 [b] South Hiendley site closed 17th August 2021 [c] Southampton Centre site opened 16th June 2021 [d] Bolsover and Liverpool Speke data capture impacted by safety issues. Data capture for these sites not adjusted [e] Data capture taking into account site start and end dates in 2021.

The average data capture of all of the operational sites throughout the whole of 2021 was 94%. However, this value is impacted by the following site safety issues or changes to the network itself:

- Bolsover site having electrical safety issues that had to be resolved after they were identified during a routine electrical safety test.
- Liverpool Speke site being not operational for the majority of the year as a result of safety and electrical issues being rectified by the Automatic Urban and Rural Network which manages the site.
- South Hiendley site closure on the 17th August 2021 which has a data capture of 99% prior to the site closure.
- Southampton Centre only being operational from 16th June 2021 which had a data capture of 96% since it's installation.

If the site closures and start dates are taken into account the average data capture for the network is 96%. Thirty-one of the thirty-four monitoring sites achieved data capture of 95% with only Ballymena Ballykeel (94.7%) and the sites with safety issues not meeting this (Bolsover 85% and Liverpool Speke 35%).

2.5 ANALYTICAL TECHNIQUES AND PAH REPORTED

In 2021 all analysis was undertaken by Environment Agency, National Laboratory Service. The analytical method used to analyse for PAH in both sampling media is Gas chromatography–mass spectrometry (GC-MS). The PAH analysed and reported from deposition and particulate samples, typical detection limits and accreditation information are shown in Appendix 2 (Table A2).

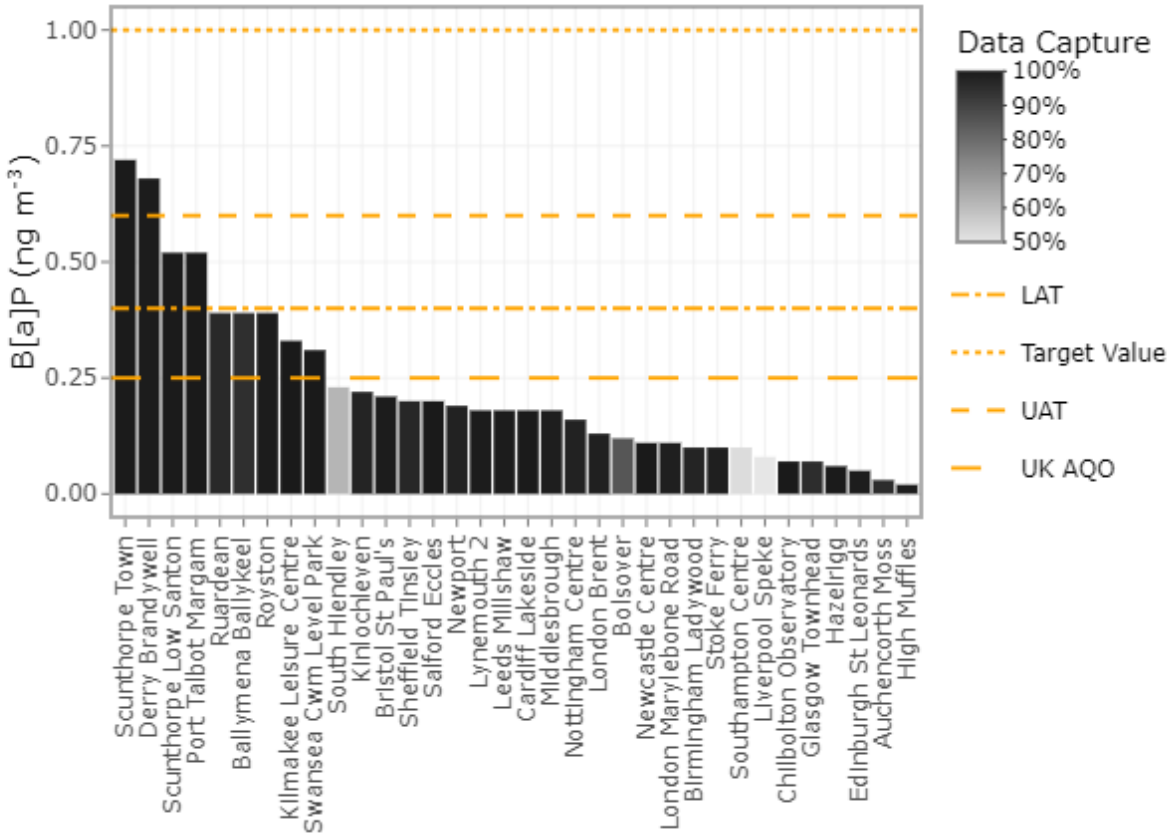
3. RESULTS & DISCUSSIONS

This section presents and discusses the results from the PAH Digitel (solid phase) particulate samplers' stations. The discussion focuses on B[*a*]P as the Air Quality Standard Regulations Target Value and UK Air Quality Objective both use B[*a*]P as the marker for the PAH mixture in ambient air. Some data for other PAHs are also presented below and data for all PAHs for all stations are made available on the UK-AIR website.

3.1 COMPARISON OF B[*A*]P ANNUAL CONCENTRATIONS AGAINST AQSR TARGET VALUES AND UK AIR QUALITY OBJECTIVE

The annual mean B[*a*]P concentration measured at all the PAH Digitel (solid phase) particulate samplers are shown in Figure 3-1. The darkness of the shading provides an indication of data capture.

Figure 3-1: Comparison of Annual B[*a*]P concentrations at all the monitoring stations against Target Value assessment thresholds and the UK Air Quality Objective.



No sites in the UK PAH Network measurement sites exceeded the Target Value of 1 ng/m^3. Two sites exceeded upper assessment threshold (UAT) of 0.6 ng/m^3. These were Scunthorpe Town (0.72 ng/m^3) and Derry Brandywell (0.68 ng/m^3). A further two sites exceeded the lower assessment threshold (LAT) of 0.4 ng/m^3. These were Scunthorpe Low Santon (0.52 ng/m^3) and Port Talbot (0.51 ng/m^3).

The more stringent UK Air Quality Objective for PAH (0.25 ng/m^3 B[*a*]P) was exceeded at nine sites:

- Scunthorpe Town (0.72 ng/m^3)
- Derry/Londonderry Brandywell (0.68 ng/m^3)
- Scunthorpe Low Santon (0.52 ng/m^3)
- Port Talbot Margam (0.51 ng/m^3)
- Ruardean (0.39 ng/m^3)
- Royston (0.39 ng/m^3)
- Ballymena Ballykeel (0.39 ng/m^3)
- Kilmakee Leisure Centre (0.33 ng/m^3)
- Swansea Cwm Level Park (0.31 ng/m^3)

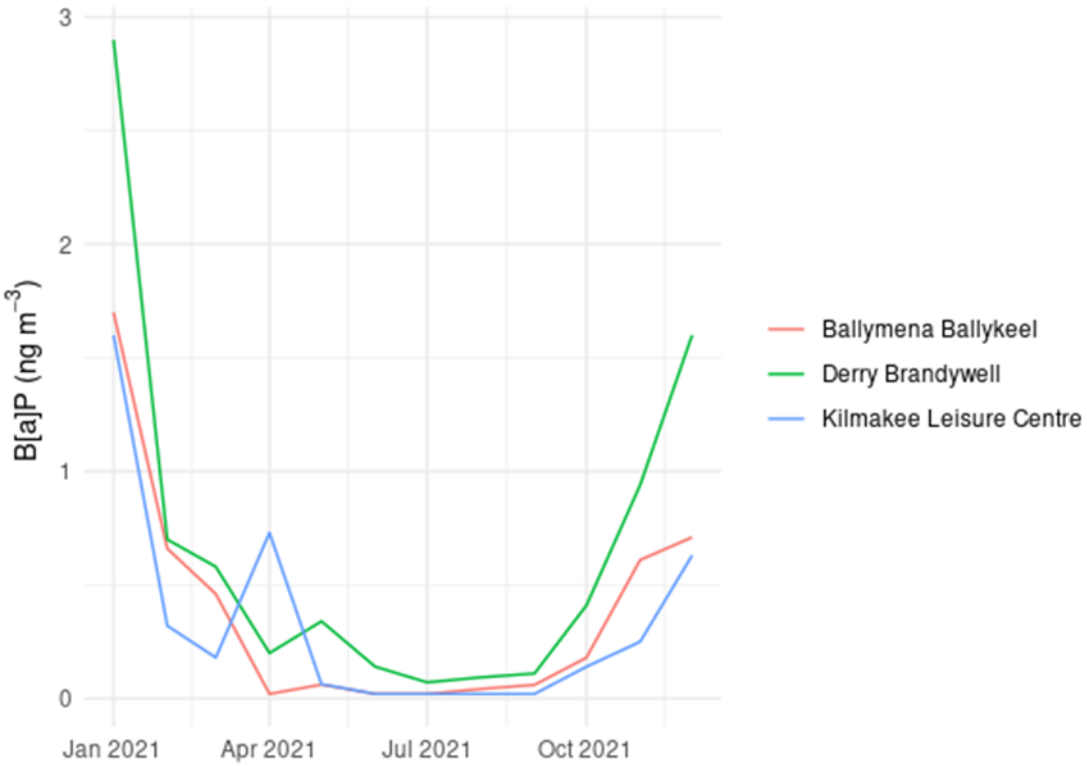
Whilst some of the above sites have specific emission sources such as steel works (Scunthorpe sites and Port Talbot Margam), other urban sites may have solid fuel/wood use contributing to their exceedance of the UK Air Quality Objective for PAH.

3.2 B[A]P MONTHLY CONCENTRATIONS

PAH are expected to show seasonality with the higher concentrations observed during the winter months as a result of domestic and industrial combustion processes usually related with heating during the colder months. Industrial sites would generally be expected to show less seasonality as any seasonality related to such domestic and industrial combustion process for heating would be masked by the emissions that are likely to be less seasonal from industrial processes unless there were unusual releases of process shut-downs during the year. The monthly concentrations of B[*a*]P for 2021 grouped by the site characteristic types are shown in Figure 3-2 to 3-6.

3.2.1 Northern Ireland Sites

Figure 3-2: Monthly average B[*a*]P concentrations at the Northern Ireland sites in 2021.



The Northern Ireland measurement sites generally have much higher concentrations of B[*a*]P than the UK mainland sites. This is particularly noticeable in the winter months. As in previous years the Monthly variation of B[*a*]P concentrations in Northern Ireland for 2021 continued to show pronounced seasonal variation with low concentrations in the summer months and higher in winter.

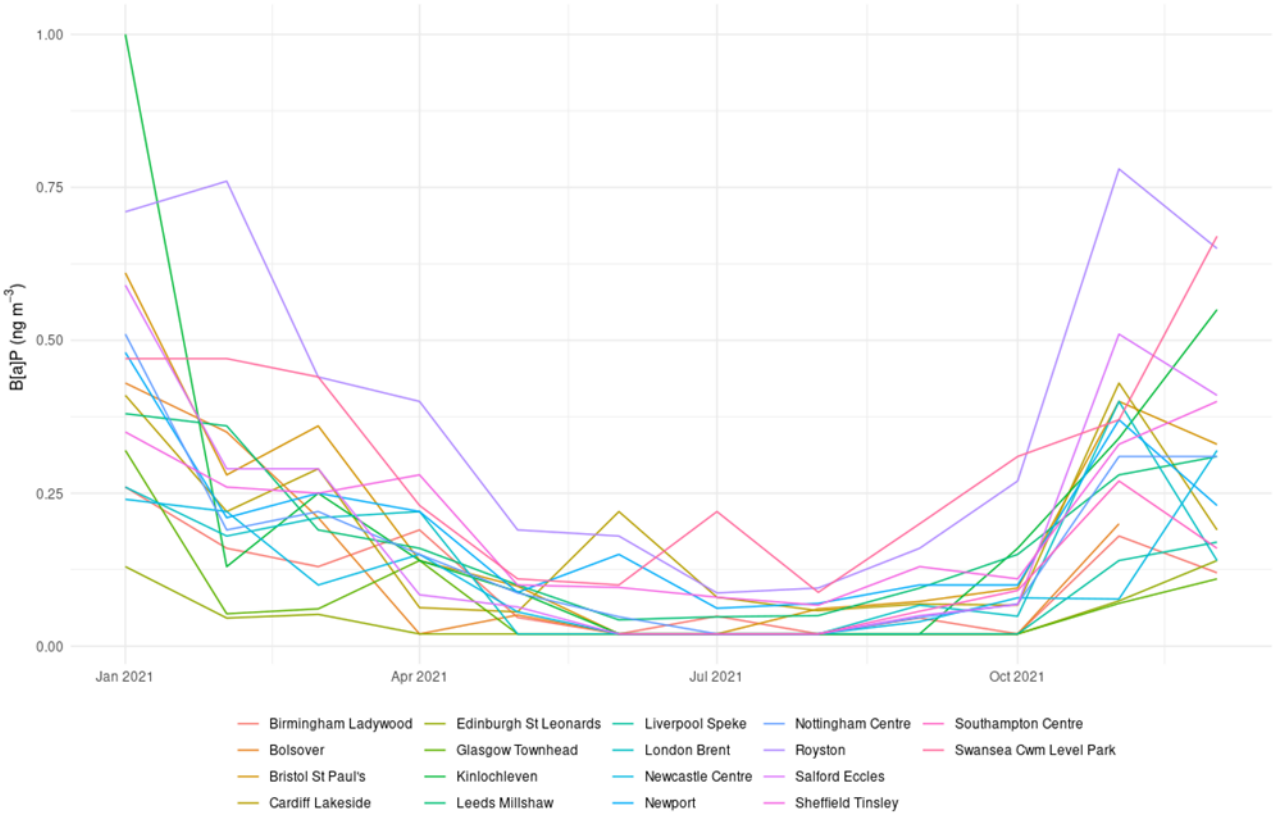
This supports the understanding that the PAH sites in Northern Ireland are highly influenced by emission from wood and other solid fuel usage for domestic heating.

Unlike in Great Britain an elevation in November as a result of Guy Fawkes/bonfire night (the 5th of November) is not apparent as it is not generally celebrated in Northern Ireland.

The lower boundary layer depth in the winter months also contributes to the increased concentrations in the winter months. The boundary layer (often called the Atmospheric Boundary Layer) is the layer of atmosphere next to the surface of the earth. Within this layer air is very well mixed. If the boundary layer decreases in height, as is common in winter months this can increase concentrations of pollutants within the layer.

3.2.2 GB Urban Background

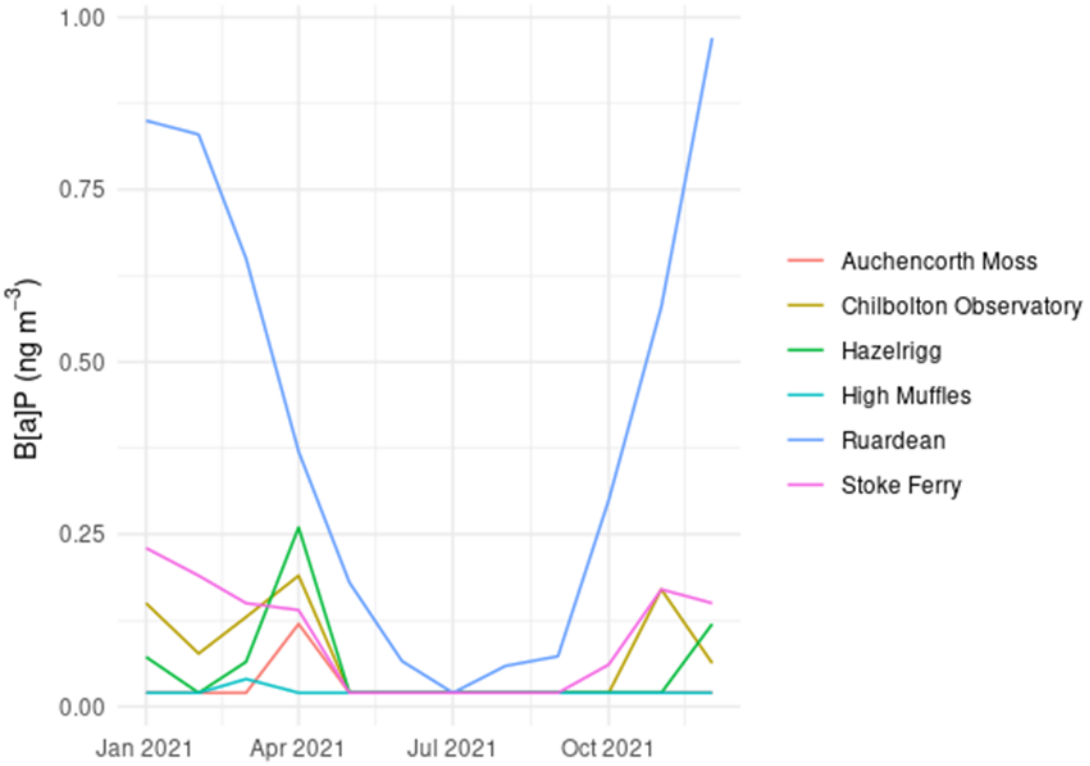
Figure 3-3: Monthly average B[*a*]P concentrations at urban background sites in GB in 2021.



Urban background sites in Great Britain generally exhibited seasonal variability resulting from the anticipated wood and other solid fuel usage. Whilst this is not as pronounced as the Northern Ireland sites, there is still an observed decrease in concentrations during the summer months. At most of the urban sites there is an elevation in concentrations observed from October to November, which, like in previous years, is likely to be a combination of solid and wood fuel use and the effect of Guy Fawkes Night.

3.2.3 GB Rural Background

Figure 3-4: Monthly average B[*a*]P concentrations at rural background sites in GB in 2021.



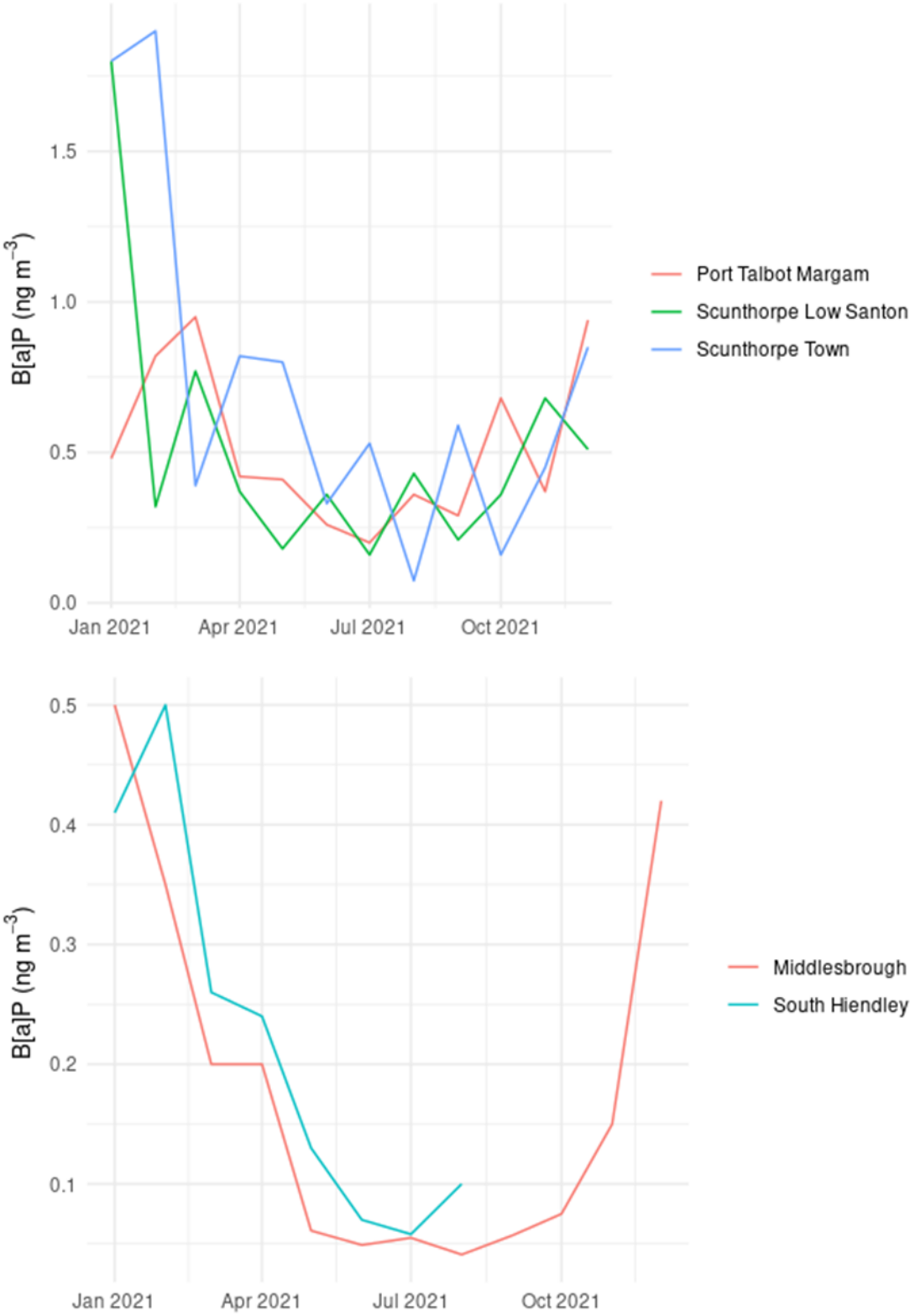
As in 2020 the Ruardean site has the highest concentration of sites classified as rural. It shows a seasonal profile that is more pronounced than the other rural sites. This is likely to be due to the Ruardean site being located within the village whereas the other sites of Chilbolton and Stoke Ferry only have some local influences being close to small villages.

The most rural site in the PAH network is generally considered to be Auchencorth Moss (orange line), it is not thought that this site is influenced significantly by any local sources or by industry and would be the best site to represent the PAH concentration of regional background.

The rural PAH network sites excluding Ruardean show much lower concentrations throughout the year than most of the urban and industrial sites. However, there is still seasonality observed at the sites. The ‘Guy Fawkes Night effect’ does not appear to be as prominent at the rural locations where PAH are measured but it does appear to be present at the Chilbolton site in 2021.

3.2.4 GB Industrial

Figure 3-5: Monthly average B[*a*]P concentrations at operating industrial sites and those where industrial processes are no longer operational.



The monitoring sites at active industrial sites are likely to be influenced by the nearby industrial activities, which are relatively invariant throughout the year. Therefore, seasonality is less pronounced as ongoing releases may mask any seasonality.

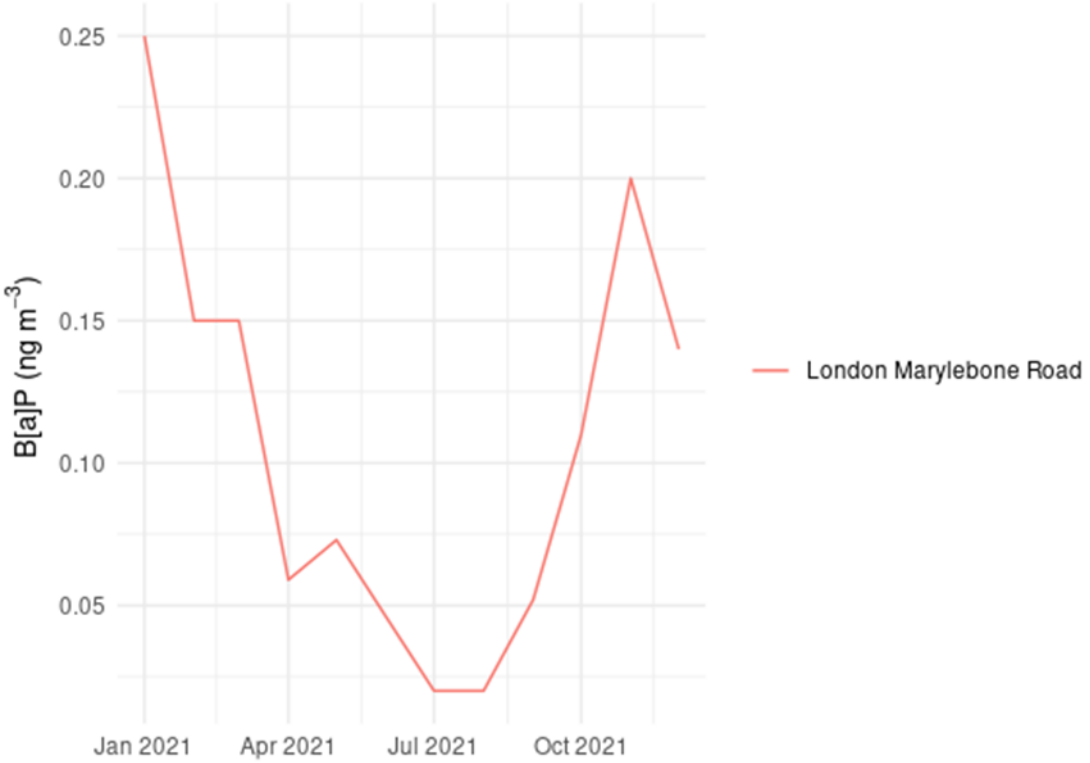
Sites that are still influenced by industry are Port Talbot Margam, Scunthorpe Town and Scunthorpe Low Santon. These sites show some limited seasonality due to the seasonal sources that may be present such as for domestic heating are masked by the more consistent and dominating industrial emissions at these locations. Industrial sources are more likely to deviate from the usual seasonal patterns seen with PAH concentrations as relatively high concentrations are observed during non-winter months as well as the winter months.

The sites that did have industrial sources now do show seasonality. These are Lynemouth, Middlesbrough, South Hiendley and Royston. These sites may be influenced by emission from domestic heating emission from solid fuel in addition the lower boundary layer depth in the winter months also contributes to the increased concentrations.

In 2021, the highest B[*a*]P concentrations were observed at the Scunthorpe sites in January and February. Concentrations at both Scunthorpe sites was around 1.8 ng/m^3 in January and the Scunthorpe Town sites was 1.9 ng/m^3 in February.

3.2.5 GB Urban Traffic

Figure 3-6: Monthly average B[*a*]P concentrations at the urban traffic site in GB in 2021.



Marylebone Road is the only urban traffic site that measures PAH and is a site that has significant traffic flow. There is a clear seasonality observed at the site and the magnitude of the seasonality of B[*a*]P measured at Marylebone road is comparable to that measured at other urban background sites in Great Britain. This could indicate that the concentrations of B[*a*]P at the site may not dominated by traffic even though the site is a traffic site and could indicate that it is as a result of seasonal emissions relating to domestic and other heating emissions. There is also a slight elevation in concentrations in November in 2021 which is smaller than at other urban background sites it is possible that that could be attributed to Guy Fawkes Night.

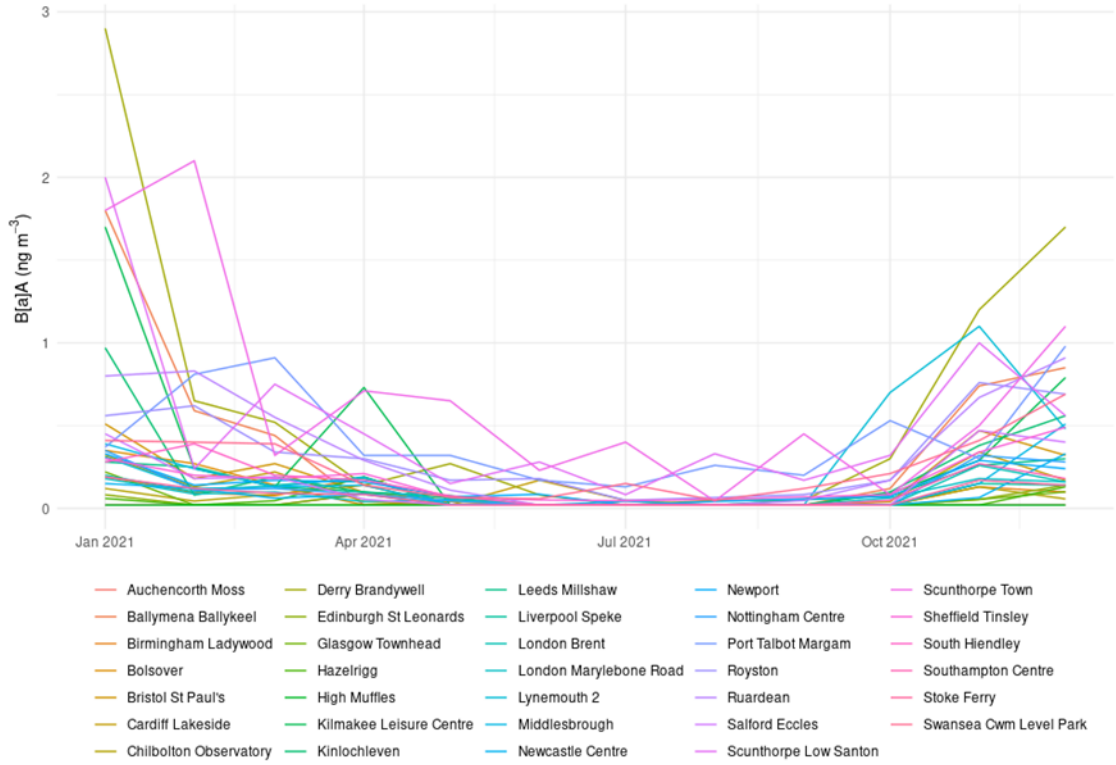
3.3 OTHER PAHS MONTHLY CONCENTRATIONS

Air Quality Standards Regulations also specifies that six other PAHs should be monitored at a limited number of measurement stations. The PAH referred to are benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*j*]fluoranthene, benzo[*k*]fluoranthene, indeno[*1,2,3-c,d*]pyrene, and dibenz[*a,h*]anthracene. The European Committee for standardization (CEN TC264 WG21) developed a Technical Specification for the measurement of these PAHs and benzo[*g,h,i*]perylene in the particulate phase. The UK PAH Network measures all of the PAH referred to in the Technical Specification at all stations and since Ricardo took over the network from the previous contractor, these have been analysed and reported separately. The monthly mean concentration of each of these PAHs measured at the sites are shown in the figures below. On a review of the figures on a visual basis only, these PAH appear to follow similar seasonal trends to those of the 'marker' B[*a*]P, which indicates that the assumptions made in using B[*a*]P as a marker are well founded.

Review of the concentrations at the industrial sites of Scunthorpe Town and Scunthorpe Low Santon in January and February give confidence in the recorded measurement of B[*a*]P as the concentration profile through the year is similar to that for B[*a*]P which would be expected if the source has a similar PAH composition.

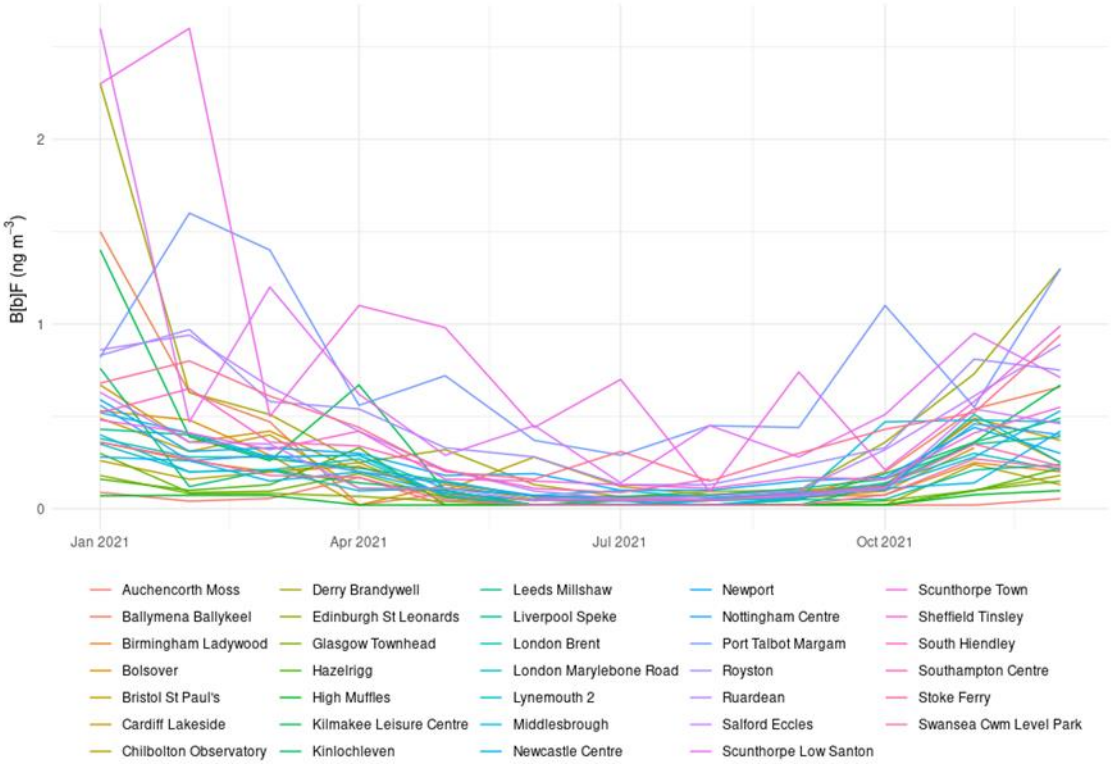
3.3.1 Benz[*a*]anthracene

Figure 3-7: Monthly mean benz[*a*]anthracene concentrations at the UK PAH sites.



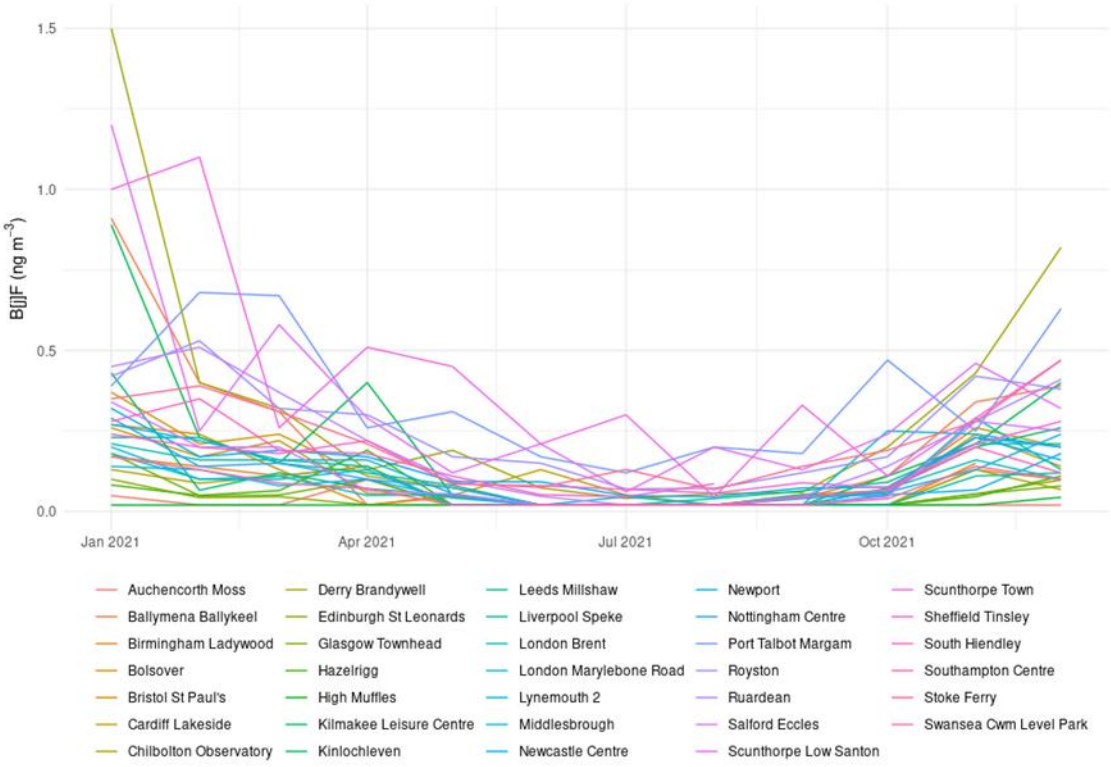
3.3.2 Benzo[*b*]fluoranthene

Figure 3-8: Monthly Benzo[*b*]fluoranthene concentrations at the UK PAH sites.



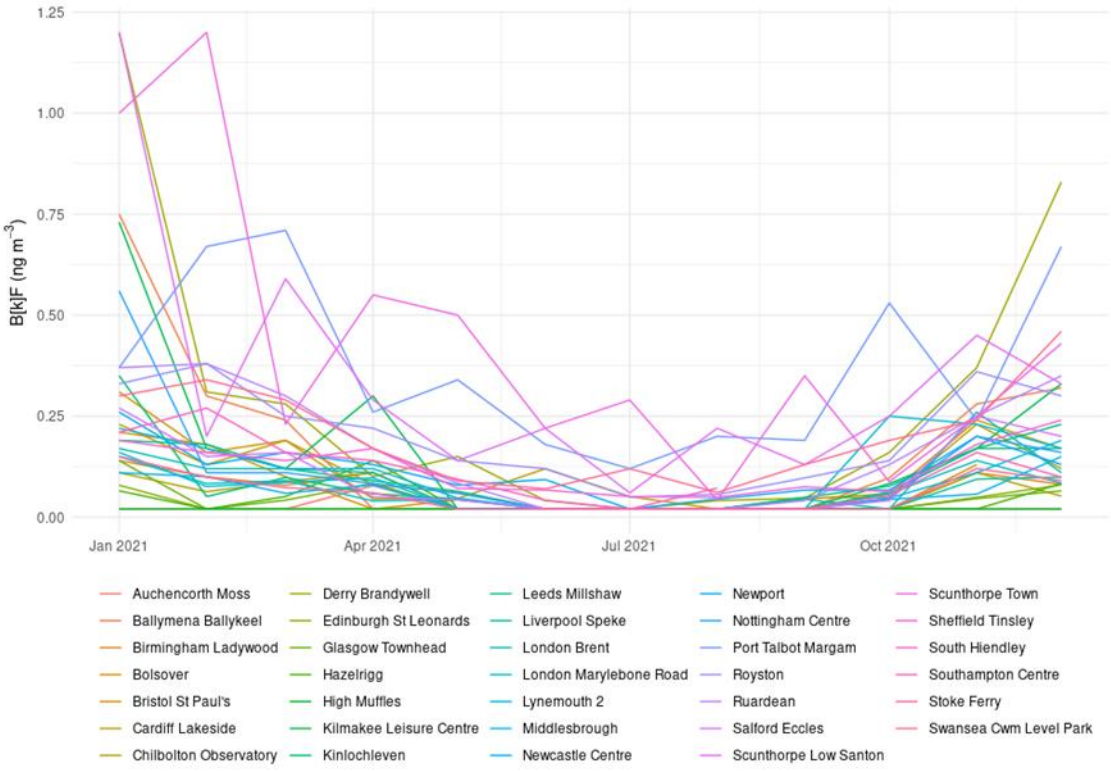
3.3.3 Benzo[*j*]fluoranthene

Figure 3-9: Monthly Benzo[*j*]flouranthene concentrations at the UK PAH sites.



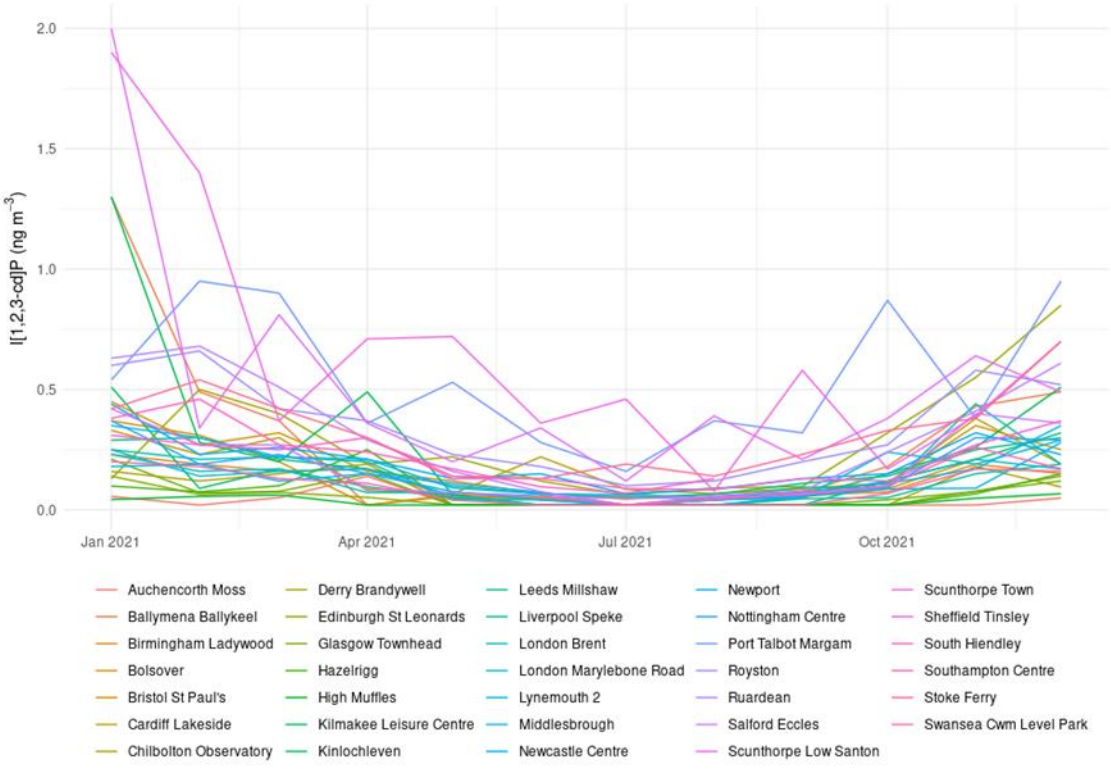
3.3.4 Benzo[*k*]fluoranthene

Figure 3-10: Monthly mean Benzo[*k*]fluoranthene concentrations at UK PAH sites.



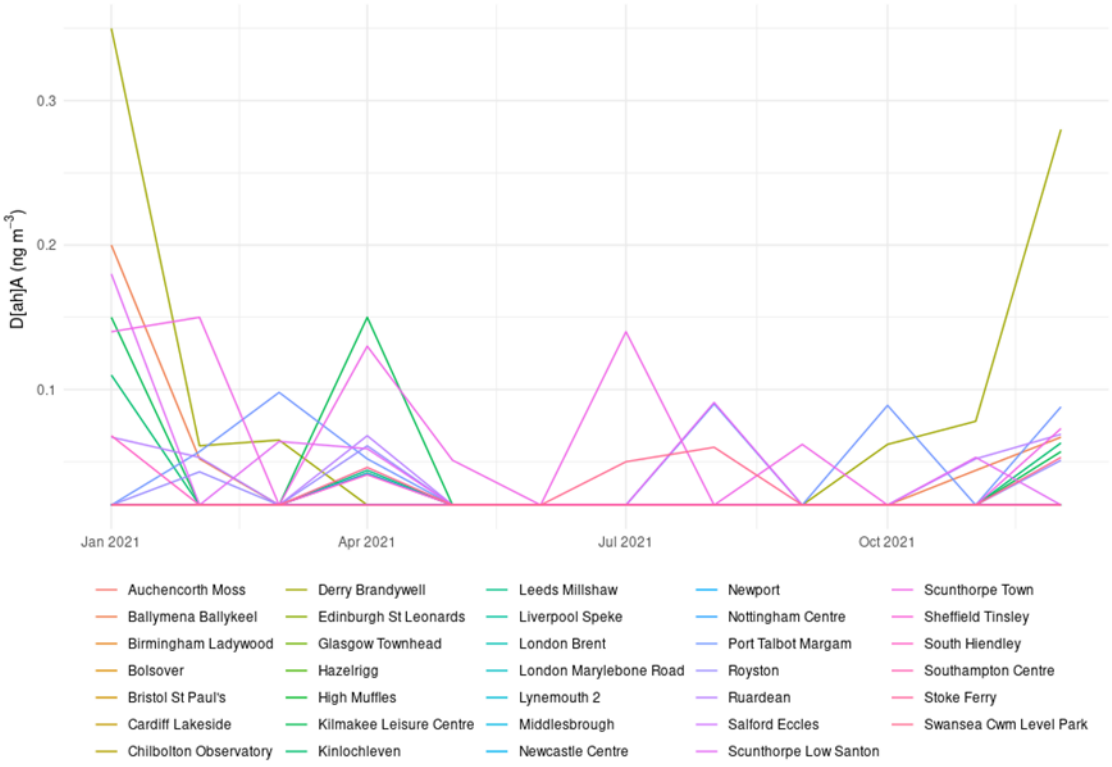
3.3.5 Indeno[*1,2,3-c,d*]pyrene

Figure 3-11: Monthly Indeno[*1,2,3-c,d*]pyrene concentrations at the UK PAH sites.



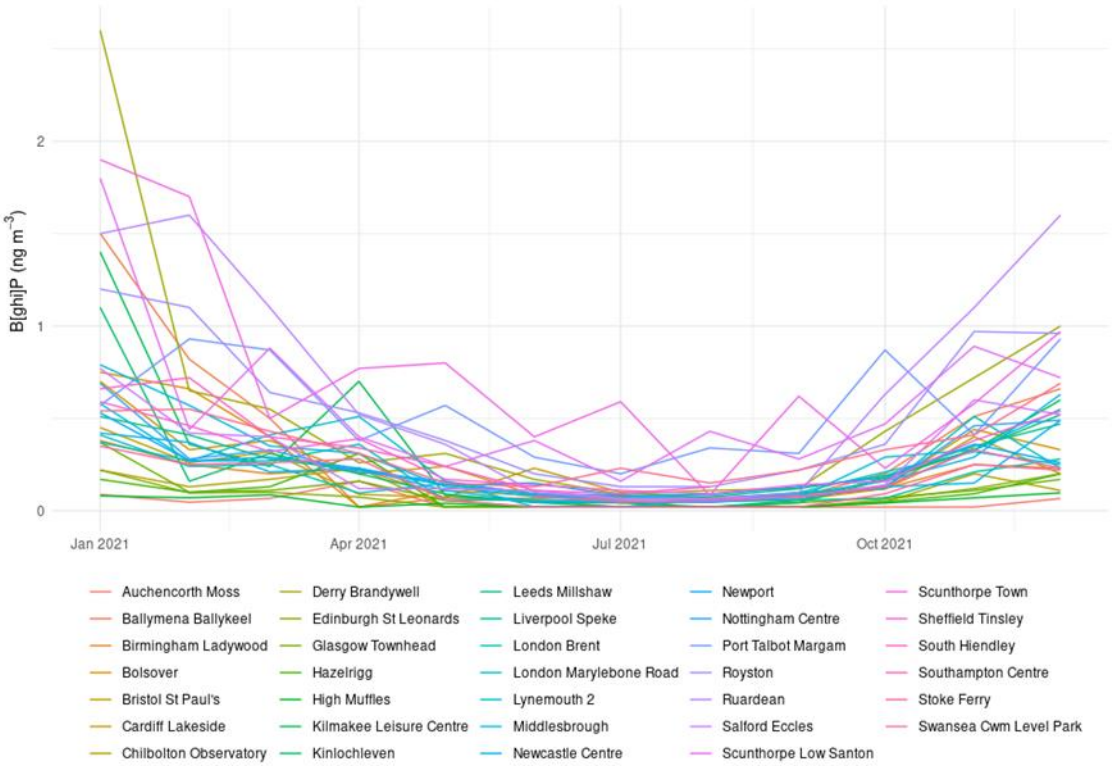
3.3.6 Dibenz[*a,h*]anthracene

Figure 3-12: Monthly Dibenz[*a,h*]anthracene concentrations at the UK PAH sites.



3.3.7 Benzo[*g,h,i*]perylene

Figure 3-13: Monthly Benzo[*g,h,i*]perylene concentrations at the UK PAH sites.



3.4 DEPOSITION ('C') SAMPLES

The 4 weekly bulked samples of B[*a*]P concentrations measured in deposition at the Auchencorth Moss and Chilbolton sites are displayed in Appendix 1. The levels of PAH at these rural sites in the UK are very low as reported in the previous annual reports.

There are not objectives or Target Value associated with the deposition measurements. However, the monitoring conducted at the two sites does enable the UK to report measured concentrations at these. All deposition data is available on the UK-AIR website.

In 2021 there were a number of samples damaged between sampling and extraction which is the reason for the data gaps and the resulting annual data capture being lowered.

3.5 LONG-TERM TRENDS IN B[A]P

Figure 3-14 to 3-18 show the annual mean B[*a*]P concentrations measured at Digitel (solid phase) PAH Network stations since 2007 split by site type or location. The annual mean concentrations can also be downloaded on the UK-AIR website.

3.5.1 Northern Ireland Sites

Figure 3-14: Annual average B[*a*]P concentrations at the Northern Ireland Network sites from 2007 to 2021.

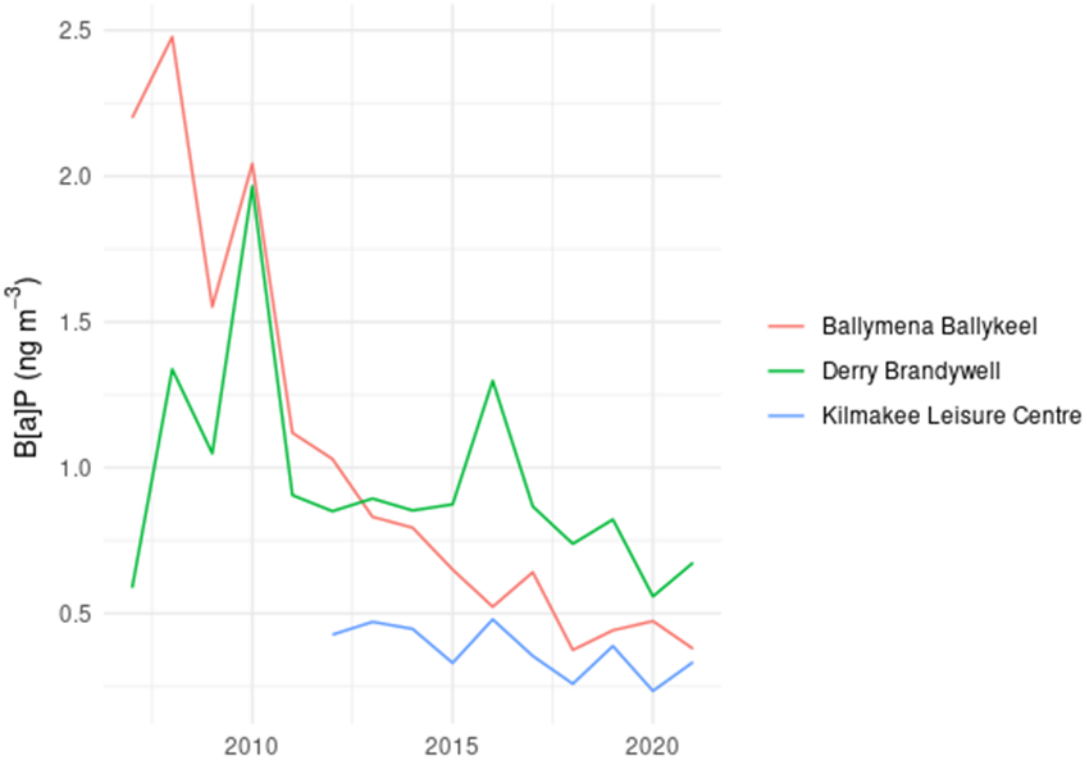
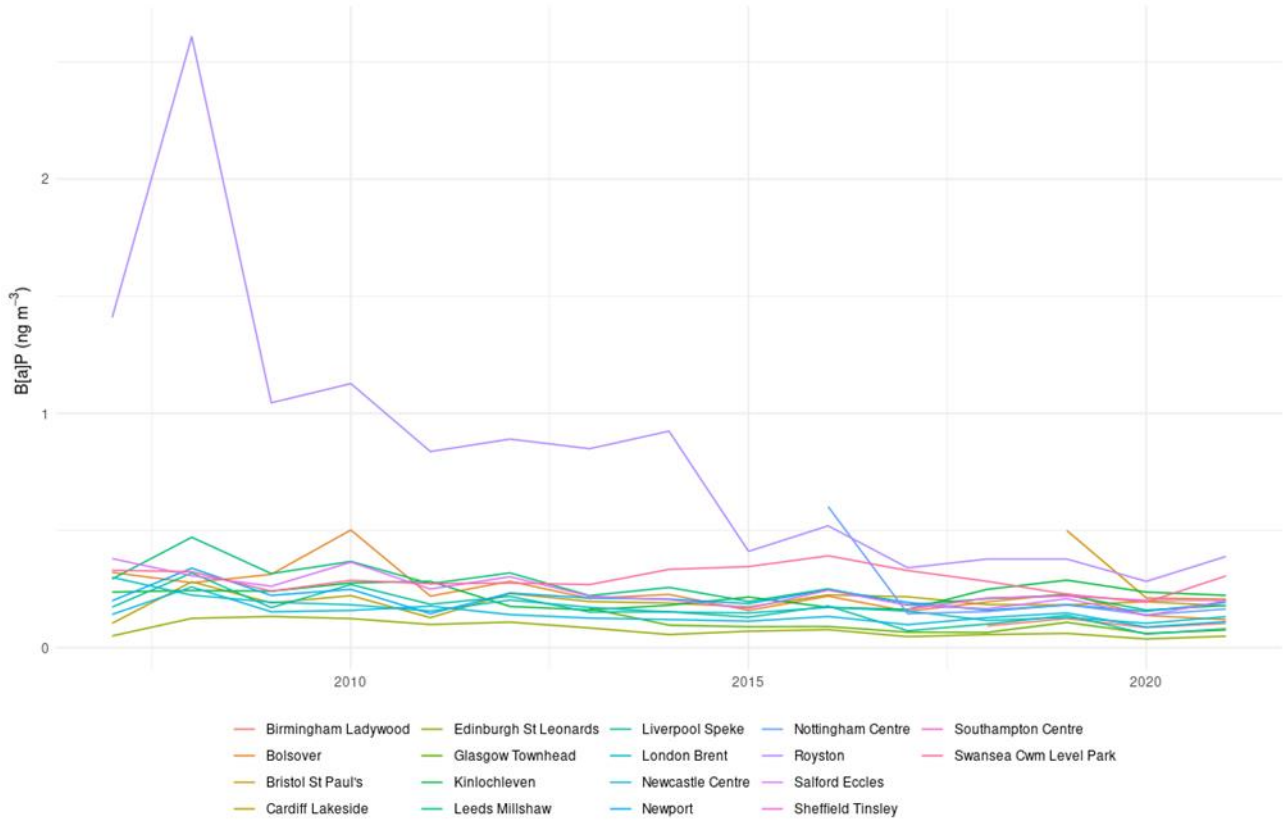


Figure 3-14 shows that whilst there is a clear downward trend in B[*a*]P concentrations at the Ballymena Ballykeel site over the last 13 years, the same trend is not as apparent at the Derry Brandywell where there appears to be a limited downward trend. The Kilmakee Leisure Centre site does not appear to show a significant trend.

3.5.2 GB Urban Background

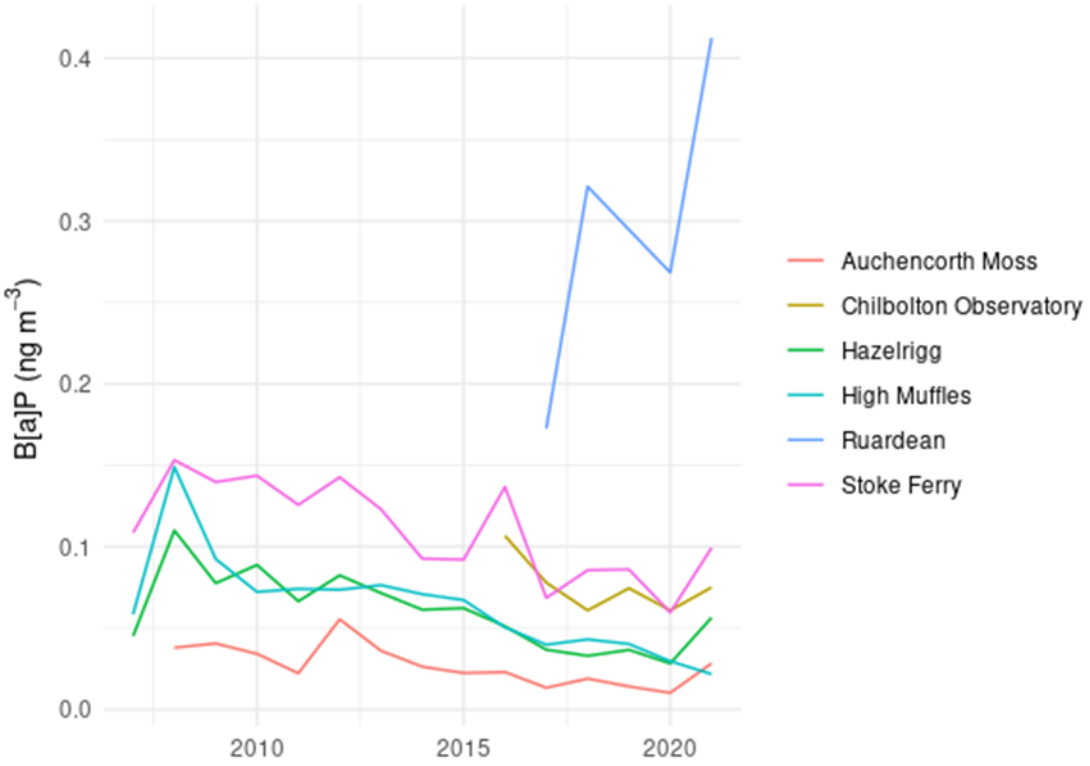
Figure 3-15: Annual average B[*a*]P concentrations at the Urban sites in Great Britain from 2007 to 2021.



There appears to be a general decreasing trends in concentrations at many urban background sites in Great Britain however some sites such as Glasgow Townhead, Kinlochleven, Swansea and Cardiff Lakeside sites. The trends do not appear to be as significant as the ex-industrial sites where concentrations have been influenced by source being removed from the local area.

3.5.3 GB Rural Background

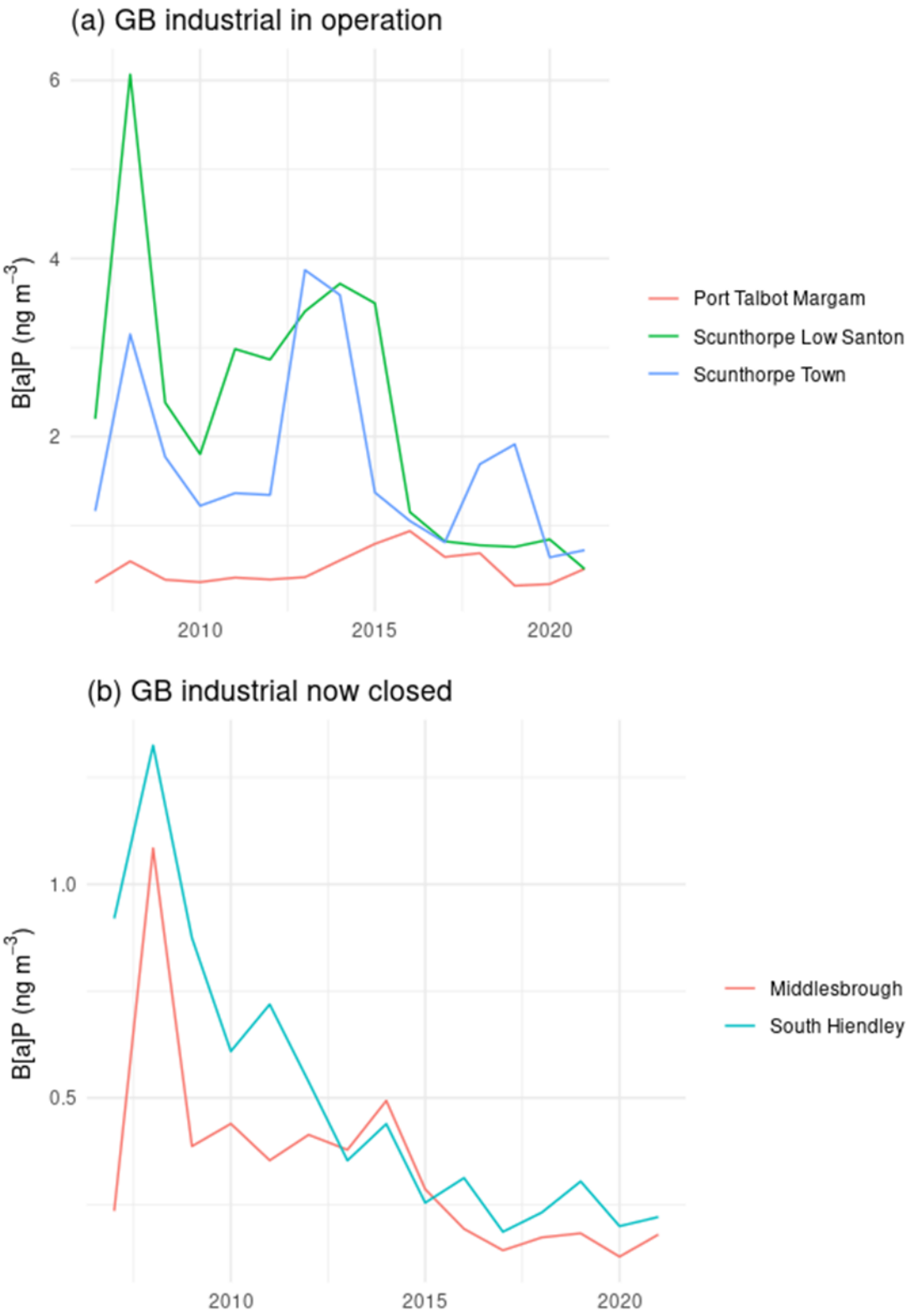
Figure 3-16: Annual average B[*a*]P concentrations at the Rural sites in Great Britain from 2007 to 2021.



The rural background sites appear to show a slight downward trend in B[*a*]P concentration over the full period of measurement. However, these sites show the least decrease in concentration with the exception of some industrial sites. As these sites are likely to have no major local sources for the majority of the year, this is to be expected.

3.5.4 GB industrial

Figure 3-17: Annual mean B[*a*]P concentrations at operating industrial sites and those that are now closed from 2007 to 2021



The Scunthorpe sites (Low Santon and Town) and Port Talbot Margam site currently have operational industrial sources (steel works) located near them. The Scunthorpe sites appear to show decreasing concentrations. However, they continue to show significant variation from year to year. The large reduction seen in 2016 at the Scunthorpe sites are likely to be due to the closure of one of the coke ovens at the steelworks and a reduced operation through 2016. In the years following the closure of one of the coke ovens

the Scunthorpe Town site has continued to exceeded the Target Value (1 ng/m^3) in two of the four years, 2018 and 2019 whereas the Scunthorpe Low Santon site has been just below the Target Value since closure. However, both the Scunthorpe Town and Low Santon sites have been well above the annual mean UK Air Quality Objective (0.25 ng/m^3) with concentrations measures in 2021 being 0.72 ng/m^3 and 0.52 ng/m^3 respectively.

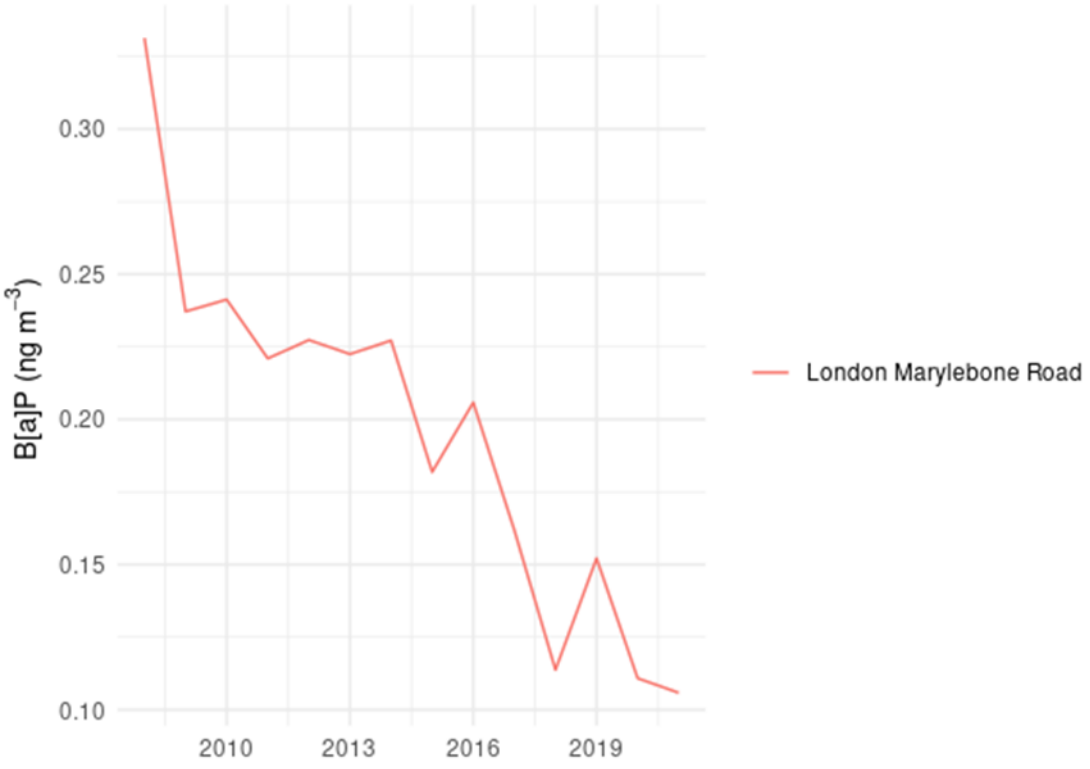
The only Port Talbot site, Port Talbot Margam does not show any obvious trend in B[*a*]P concentration. The site has not exceeded the Target Value for B[*a*]P (1 ng/m^3) since measurements began using the Digitel DHA-80 in 2007. The concentrations observed at the site are slightly lower than those seen at the Scunthorpe sites in 2021. The annual average concentration was 0.51 ng/m^3 at Port Talbot in 2021. The concentration measured at the site is above the UK Air Quality Objective (0.25 ng/m^3).

As might be expected the sites that have experienced reduction in emissions due to the closure of the industrial sources they were measuring show reducing trends in B[*a*]P concentrations. The sites that appear to show reducing trend are listed below with the likely industrial process that contributed to the decrease in concentrations. Details of the relevant industrial site closures are shown below:

- Middlesbrough: Redcar Steel Works Closure in 2015.
- Royston and South Hiendley: Royston Coking plant closure at the end of 2014.
- Lynemouth 2: Lynemouth Aluminium Smelter closure 2012.

3.5.5 GB Urban Traffic

Figure 3-18: Annual average B[*a*]P concentrations at the London Marylebone Road site from 2007 to 2021.



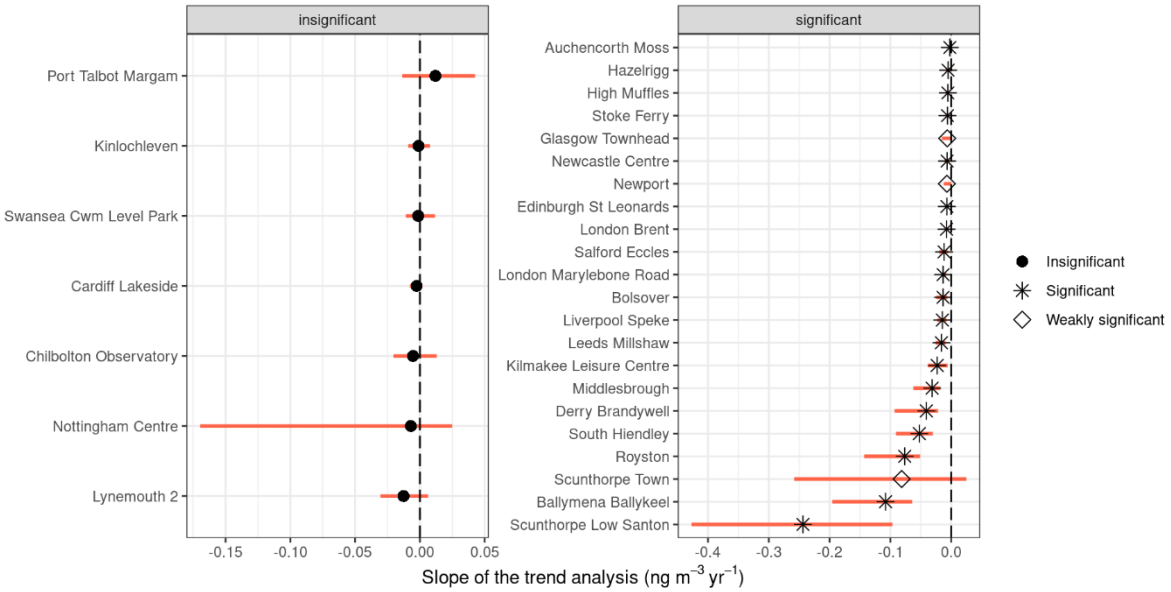
The London Marylebone Road PAH Monitoring site shows a steady decreasing trend since installation and levels have been below the UK Air Quality Objective for PAH (0.25 ng/m^3 B[*a*]P) since 2009.

3.6 TREND ASSESSMENT AT THE UK PAH NETWORK SITES

To summarise the long-term trend at each monitoring site, the slope of the trend for each site was calculated using `TheilSen` function in the `openair` R package (Figure 3-19). A positive slope means that there is an

increasing trend of B[*a*]P annual mean and a negative slope means a decreasing trend. The slope of each site's B[*a*]P concentration over time was also calculated with its 95% confidence interval, which indicates the uncertainty of the slope coefficient. Figure 3-19 shows separately the sites that had a significant trend and the sites that did not. Some sites are denoted as weakly significant, meaning that although the trend is statistically significant (p-value < 0.1), they do not show as strong trend as the other significant sites (p-value < 0.05). It should be noted that sites which have not been installed for very long have not been included due to the limited number of data points, the sites affected are: Bristol St Paul's, Nottingham and Ruardean.

Figure 3-19: B[*a*]P concentration trend (ng m^{-3} yr^{-1}) from 2008 to 2021.



The trend calculated from many of the monitoring sites did not show a large decreasing or increasing trend. This was either because there was very little change in the annual concentrations (i.e. a slope was not significantly different from zero) or there were large variations between years but not in a consistent direction (as indicated by the large confidence intervals (red bars) at the two Scunthorpe sites). Sites showing large decreasing trend were Scunthorpe Low Santon, Ballymena Ballykeel, Royston, South Hiendley, Derry/Londonderry Brandywell and Middlesbrough. These site all appear to have decreasing trends in B[*a*]P concentrations but do also have large uncertainties in the trends due to the inter-year variability in measured concentrations.

4. CONCLUSIONS

The average data capture of all the operational sites throughout the whole of 2021 was higher than 2020 at 94% however, if dates of new site commissioning and site closures are taken into account the average data capture is 96%. This would have been higher still however there were two sites which had large periods of non-operation due to safety issues.

The annual mean B[*a*]P concentrations observed at the UK networks during 2021 continued to vary greatly between sites with the highest concentrations at industrial sites and urban sites in Northern Ireland.

In 2021 the highest annual mean was observed at the Scunthorpe Town site with an annual mean B[*a*]P concentration of 0.72 ng/m^3 and the lowest concentration continued to be measured at the High Muffles site (0.022 ng/m^3).

In 2021 all measurement sites were below the Target Value for B[*a*]P (annual mean concentration of 1 ng/m^3). However nine sites exceeding the UK Air Quality Objective for B[*a*]P (annual mean concentration of 0.25 ng/m^3). These were Scunthorpe Town, Derry/Londonderry Brandywell, Scunthorpe Low Santon, Port Talbot Margam, Ruardean, Royston, Ballymena Ballykeel, Kilmakee Leisure Centre and Swansea Cwm Level Park.

REFERENCES

BSI, 2014a. PD CEN/TS 16645:2014 ambient air method for the measurement of benz[a]anthracene, benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, dibenz[a,h]anthracene, indeno[1,2,3-cd]pyrene and benzo[ghi]perylene.

BSI, 2014b. BS EN 12341:2014 Ambient air. Standard gravimetric measurement method for the determination of the PM10 or PM2.5 mass concentration of suspended particulate matter.

BSI, 2011. BS EN 15980:2011 Air quality. Determination of the deposition of benz[a]Anthracene, benzo[b]Fluoranthene, benzo[j]Fluoranthene, benzo[k]Fluoranthene, benzo[a]Pyrene, dibenz[a,h]Anthracene and indeno[1,2,3-cd]Pyrene.

BSI, 2008. Air quality. Standard method for the measurement of the concentration of benzo(a)Pyrene in ambient air. BS EN 15549:2008.

DAERA, 2017. Air Quality Standards (Northern Ireland Amendment) Regulations.
URL https://www.legislation.gov.uk/nisr/2017/2/contents/made

DAERA, 2010. Air Quality Standards (Northern Ireland) Regulations.
URL http://www.legislation.gov.uk/nisr/2010/188/contents/made

Defra, 2007. The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (Volume 1).
URL https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69336/pb12654-air-quality-strategy-vol1-070712.pdf

EC, 2001. Ambient air pollution by Polycyclic Aromatic Hydrocarbons (PAH). Position Paper.
URL http://ec.europa.eu/environment/air/pdf/pp_pah.pdf

Scottish Government, 2016. Air Quality Standards (Scotland Amendment) Regulations.
URL http://www.legislation.gov.uk/ssi/2016/376/contents/made

Scottish Government, 2010. Air Quality Standards (Scotland) Regulations.
URL http://www.legislation.gov.uk/ssi/2010/204/contents/made

UK Government, 2016. UK Air Quality Standards (Amendment) Regulations.
URL http://www.legislation.gov.uk/uksi/2016/1184/contents/made

UK Government, 2010. UK Air Quality Standards Regulations.
URL http://www.legislation.gov.uk/uksi/2010/1001/contents/made

UNECE, 1979. 1979 Convention on long-range transboundary air pollution.
URL https://treaties.un.org/doc/Treaties/1979/11/19791113%2004-16%20PM/Ch_XXVII_01p.pdf

Welsh Government, 2010. Air Quality Standards (Wales) Regulations.
URL http://www.legislation.gov.uk/uksi/2010/1433/contents/made

Appendices

APENDICES

Appendix 1 PAH Deposition

Table A1: PAH deposition for B[*a*]P in 2021.

Station name	Start date	End date	Measurement (ng/m²/day)
Auchencorth Moss	30/12/2020	27/01/2021	24
Auchencorth Moss	27/01/2021	24/02/2021	N/A[a]
Auchencorth Moss	24/02/2021	24/03/2021	<9
Auchencorth Moss	24/03/2021	21/04/2021	<9
Auchencorth Moss	21/04/2021	19/05/2021	18
Auchencorth Moss	19/05/2021	16/06/2021	<9
Auchencorth Moss	16/06/2021	14/07/2021	<9
Auchencorth Moss	14/07/2021	11/08/2021	<9
Auchencorth Moss	11/08/2021	08/09/2021	22
Auchencorth Moss	08/09/2021	06/10/2021	<9
Auchencorth Moss	06/10/2021	03/11/2021	<9
Auchencorth Moss	03/11/2021	01/12/2021	<9
Auchencorth Moss	01/12/2021	29/12/2021	<9
Auchencorth Moss	29/12/2021	26/01/2022	<9
Chilbolton Observatory	30/12/2020	27/01/2021	N/A[a]
Chilbolton Observatory	27/01/2021	24/02/2021	N/A[a]
Chilbolton Observatory	24/02/2021	24/03/2021	N/A[a]
Chilbolton Observatory	24/03/2021	21/04/2021	N/A[a]
Chilbolton Observatory	21/04/2021	19/05/2021	30
Chilbolton Observatory	19/05/2021	16/06/2021	29
Chilbolton Observatory	16/06/2021	14/07/2021	22
Chilbolton Observatory	14/07/2021	11/08/2021	20
Chilbolton Observatory	11/08/2021	08/09/2021	31
Chilbolton Observatory	08/09/2021	06/10/2021	<9
Chilbolton Observatory	06/10/2021	03/11/2021	<9
Chilbolton Observatory	03/11/2021	01/12/2021	<9
Chilbolton Observatory	01/12/2021	29/12/2021	<9
Chilbolton Observatory	29/12/2021	26/01/2022	<9

[a] were measurement samples not available as samples were damaged between sampling and extraction.

Appendix 2 Environment Agency, National Laboratory Service PAH 2021 Analysis

For both particulate and deposition PAH measurements 27 PAH are currently measured, these are detailed in Table A2.

Analyses of particulate samples are carried out in accordance with BS EN 15549:2008. Samples are bulked into monthly batches and extracted by sonication in an ultrasonic bath using dichloromethane as the extraction solvent. The extracts are cleaned for particulates, reduced in volume and analysed using gas chromatography – mass spectrometry (GC-MS). The GC-MS is calibrated using a series of calibration standards containing all the PAH reported at a range of concentrations covering the concentrations expected in the samples.

Analysis of deposition samples is carried out in accordance with BS EN 15980:2011. In summary, the deposition samples collected over a fortnightly period are bulked into a four-week period and extracted using liquid-liquid extraction. The resulting extract is dried, reduced to a volume then analysed using GC-MS.

The limits of detection of the GC-MS method are determined by running a series of filter blanks and solvent blank. PAH and typical detection limits for the measurement in the PAH network are 0.04 ng/m^3 and 9 ng/m2/day for particulate and deposition respectively.

PAH number	Compound	PAH number	Compound
1	Phenanthrene	15	Benzo[e]pyrene
2	Anthracene	16	Benzo[a]pyrene
3	Fluoranthene	17	Perylene
4	Pyrene	18	Dibenzo[a,c]anthracene
5	Retene	19	Dibenzo[a,h]anthracene
6	Benzo[b]naphtho[2,1-d]thiophene	20	Indeno[1,2,3-cd]pyrene
7	Benzo[c]phenanthrene	21	Benzo[ghi]perylene
8	Benzo[a]anthracene	22	Anthanthrene
9	Cyclopenta[c,d]pyrene	23	Dibenzo[a,l]pyrene
10	Chrysene	24	Dibenzo[a,e]pyrene
11	5-Methylchrysene	25	Coronene
12	Benzo[b]Fluoranthene	26	Dibenzo[a,i]pyrene
13	Benzo[k]Fluoranthene	27	Dibenzo[a,h]pyrene
14	Benzo[j]Fluoranthene	NA	

T: +44 (0) 1235 75 3000
E: enquiry@ricardo.com
W: ee.ricardo.com