UK PAH MONITORING AND ANALYSIS NETWORK

Annual Report for 2022

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/PAH2022AR/Issue 1 Issue: 1 29/08/2023

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

Customer:
The Environment Agency

Customer reference:
EMC 58151

Ricardo reference:
ED12330/PAH2022AR/Issue 1

Contact:
Christopher Conolly Ricardo, Gemini Building, Harwell, Didcot, OX11 0QR, United Kingdom

T: +44 (0) 1235 753 375
E: Christopher.Conolly@ricardo.com

Author:
Christopher Conolly/ Sion Carpenter

Approved by:
Brian Donovan

Signed

Date:
29/08/2023

EXECUTIVE SUMMARY

This annual report for 2022 for the UK Polycyclic Aromatic Hydrocarbons (PAH) Monitoring and Analysis Network was prepared by 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).

In 1999, the UK Expert Panel on Air Quality Standards issued a report (EPAQS, 1999) recommending an air quality standard for B[*a*]P in air of 0.25 ng/m^3 as an annual average concentration and judged that the attainment of this would make the risk to human health from inhalation of PAH insignificant and was included in the 2007 Air Quality Strategy (Defra, 2007) document which was however superseded in England only by the 2023 Air Quality Strategy: framework for local authority delivery (Defra, 2023).

The UK PAH Monitoring and Analysis Network provides data that can be compared to the Target Value and level recommended by the Expert Panel on Air Quality Standards (EPAQS) 0.25ng/m^3 with concentrations measured at sites around the UK.

During 2022 the number of ambient air sampling sites changed due to site installations and closures but at the end of the year there were 34 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, 2010) and has been determined to be a suitable 'marker' for the PAH mixture in ambient air.

Key findings for 2022:

- In 2022 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 2022 nine sites exceeded the level for B[*a*]P (annual mean concentration of 0.25 ng/m^3), recommended by EPAQS (EPAQS, 1999), these were:
    - Port Talbot Margam
    - Scunthorpe Town
    - Derry Brandywell
    - Scunthorpe Low Santon
    - Ballymena Ballykeel
    - Royston
    - Swansea Cwm Level Park
    - Kilmakee Leisure Centre
    - Bristol St Paul's
- The average data capture of the operational sites in 2022, taking into account any closure or start dates continued to be very high at 98% which is slightly higher than in 2021.
- The concentrations of B[*a*]P at urban and rural sites don't appear to show much downward trends in the last two years.

CONTENTS

Appendices

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 level recommended by EPAQS
- Monthly PAH concentrations in 2022
- 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 2022. 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. IARC monographs evaluate cancer hazards, these are provided online in reports relating to PAH (IARC, 2010) and chemical agents (IARC, 2012) including B[*a*]P.

Table 1-1 below shows the details of PAH that are required to be measured under the Air Quality Standard Regulations in the UK, plus benzo[*ghi*]perylene which was more recently included in the 2014 technical standard CEN/TS 16645:2014 (BSI, 2014a).

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 RELATING TO PAH

In 1999, the UK Expert Panel on Air Quality Standards issued a report (EPAQS, 1999) recommending an air quality standard for B[*a*]P in air of 0.25 ng/m^3 as an annual average concentration and judged that the attainment of this would make the risk to human health from inhalation of PAH insignificant and was included in the 2007 Air Quality Strategy (Defra (2007)) document which was superseded in England by the 2023 Air Quality Strategy: framework for local authority delivery (Defra (2023)).

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 (UK Government, 2016) and January 2019 (UK Government, 2019) amendments
- 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) and their February 2019 amendment (Welsh Government, 2019)
- The Air Quality Standards Regulations (Northern Ireland) 2010 (DAERA, 2010), and their December 2016 (DAERA, 2017), December 2018 (DAERA, 2018) and November 2020 (DAERA, 2020) amendments

Following the UK's exit from the EU, under retained EU law, the UK is required to continue to meet limit and target values for a range of air pollutants and other legal obligations covered by EU directives.

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 reference method for measurement of B[*a*]P in ambient air is 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 PAH IN THE UK

Polycyclic aromatic hydrocarbons (PAHs) are a group of persistent organic pollutant compounds. They contain two or more benzene rings and 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 dominant emission sources of B[*a*]P in the UK. Defra's Clean Air Strategy (Defra, 2019) 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 level recommended by EPAQS (0.25ng/m^3), 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 2022 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. More details can be found via the interactive map on (UK-AIR).

Figure 2-1: Map of UK PAH monitoring stations in 2022.

During 2022 the number of ambient air sampling sites changed due to site installations and closures but at the end of 2022 there were 34 sites in the network. 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. In 2021 and 2022 the samplers were upgraded by Ricardo to include improved communication to the samplers to allow improved remote monitoring of individual samplers.

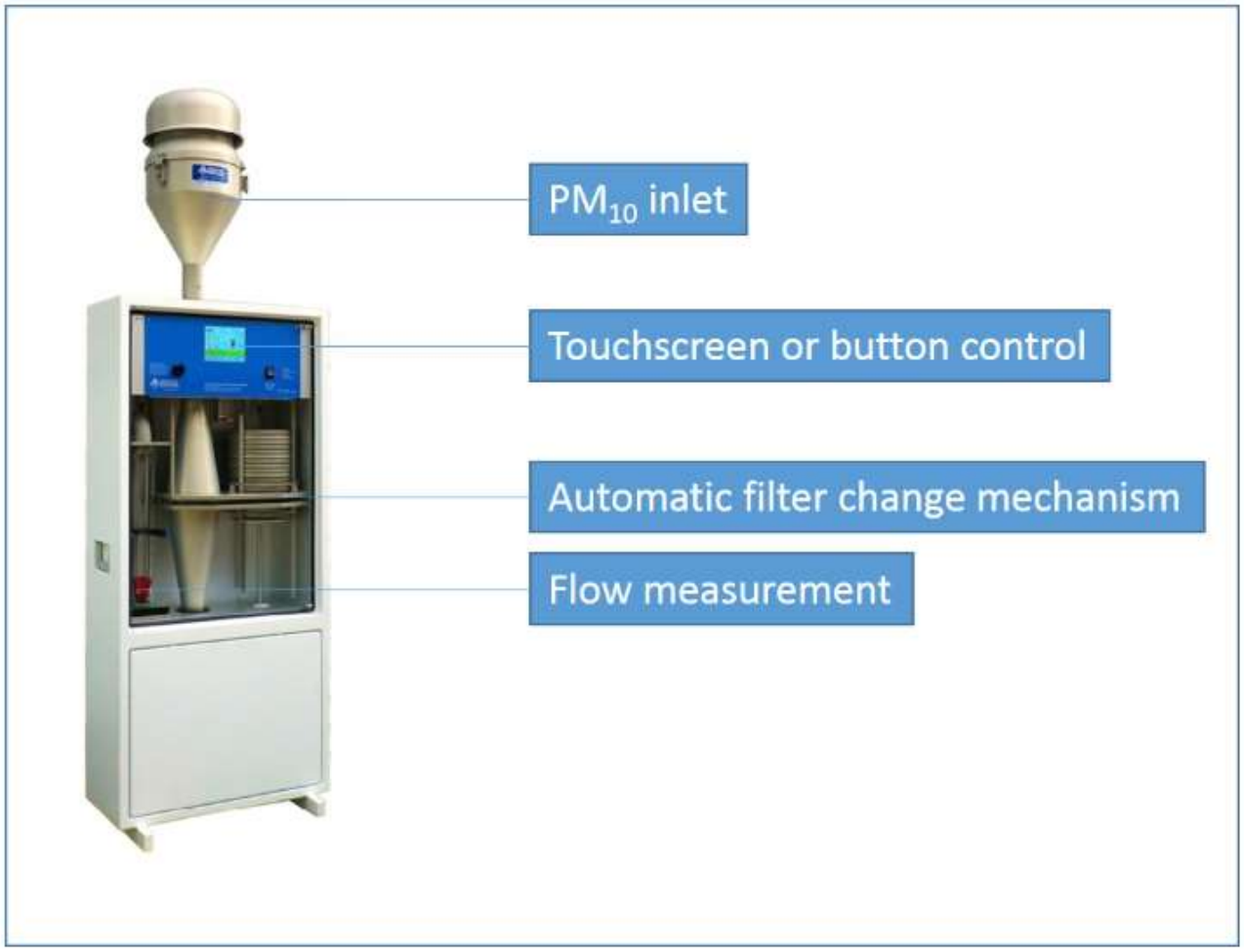

Figure 2-2: Digitel DHA-80 sampler deployed to measure solid phase PAH in the UK Network.

'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.

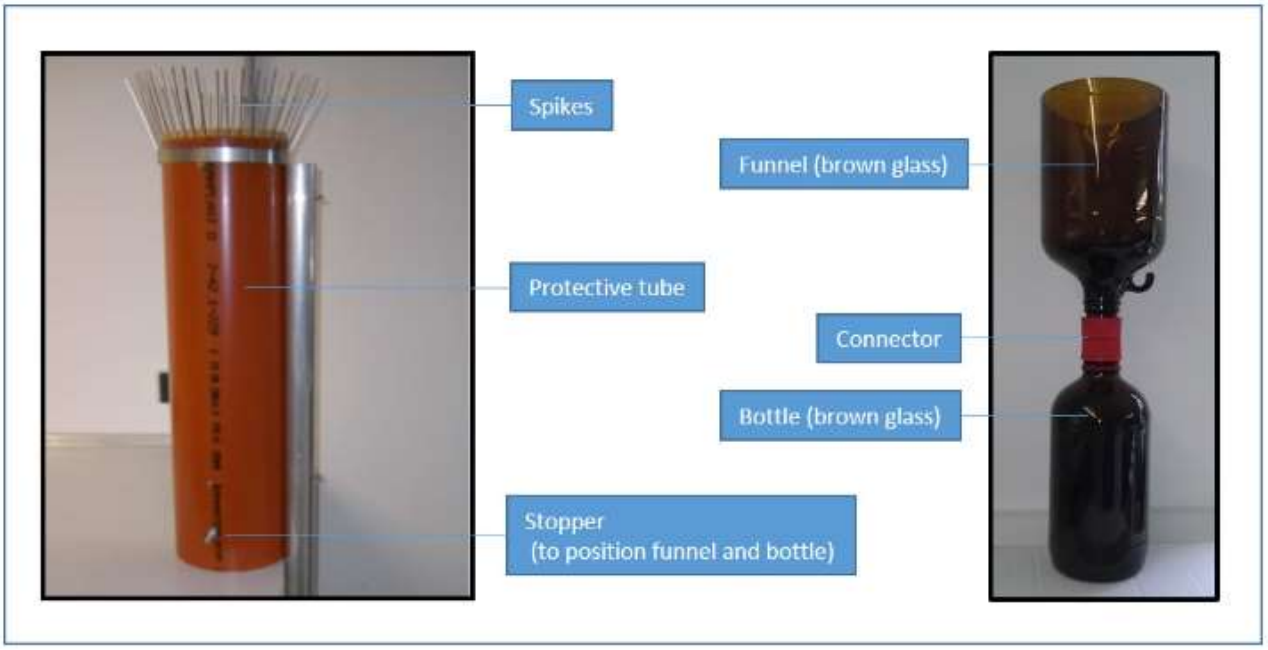

Figure 2-3: Samplers to measure deposition of PAH in the UK Network.

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 ACTIVITES DURING 2022

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 early 2023:

- 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
- Preston site opened 2nd March 2022
- Lynemouth 2 site closes 14th June 2022
- Armagh Roadside site opened 20th October 2022
- Portsmouth site opened 25th January 2023
- Margam Youth Centre site opened 1st January 2023

2.4.2 Data Capture, Station Calibrations, Services and Breakdowns

All Stations were calibrated and serviced in 2022 and checks on flow were undertaken. Table 2-1 below shows the data captures for 2022.

Table 2-1: PAH data capture 2022.

UK-AIR ID	Site	Data capture
UKA00541	Armagh Roadside [a]	20%(99% [d])
UKA00451	Auchencorth Moss	96%
UKA00503	Ballymena Ballykeel	100%
UKA00655	Birmingham Ladywood	99%
UKA00376	Bolsover	91%
UKA00494	Bristol St Paul's	98%
UKA00452	Cardiff Lakeside	100%
UKA00614	Chilbolton Observatory	99%
UKA00499	Derry Brandywell	99%
UKA00454	Edinburgh St Leonards	100%
UKA00576	Glasgow Townhead	94%
UKA00507	Hazelrigg	100%
UKA00169	High Muffles	95%
UKA00570	Kilmakee Leisure Centre	99%
UKA00378	Kinlochleven	96%
UKA00480	Leeds Millshaw	100%
UKA00247	Liverpool Speke	96%
UKA00059	London Brent	100%
UKA00315	London Marylebone Road	99%
UKA00556	Lynemouth 2 [b]	45%(99% [d])
UKA00220	Middlesbrough	99%
UKA00213	Newcastle Centre	99%
UKA00380	Newport	98%
UKA00274	Nottingham Centre	99%
UKA00360	Plymouth Centre	100%
UKA00501	Port Talbot Margam	99%
UKA00408	Preston [c]	83% (99% [d])
UKA00508	Royston	99%

UK-AIR ID	Site	Data capture
UKA00339	Salford Eccles	100%
UKA00506	Scunthorpe Low Santon	100%
UKA00381	Scunthorpe Town	100%
UKA00181	Sheffield Tinsley	100%
UKA00235	Southampton Centre	97%
UKA00317	Stoke Ferry	89%
UKA00510	Swansea Cwm Level Park	99%
	Network Average	94% (98% [d])

a Armagh Roadside site opened 20th October 2022 b Lynmouth 2 site closed 14th June 2022 c Preston site opened 2nd March 2022 d Data capture taking into account site start and end dates in 2022.

The average data capture of all of the operational sites throughout the whole of 2022 was 94%. However, this value is impacted by the following site safety issues or changes to the network itself:

Armagh Roadside site only operating from 20th October 2022 onwards, which had a data capture of 99% for the period of operation in 2022.

Lynmouth 2 site closed 14th June 2022, which had a data capture of 99% prior to closure.

Preston site only operating from 2nd March 2022 onwards, which has a data capture of 99% for the period of operation in 2022.

If the site closures and start dates are taken into account the average data capture for the network is 98%. With thirty-two of the thirty-five monitoring sites achieving data capture of 95% with only Bolsover (91%), Glasgow Townhead (94%) and Stoke Ferry (89%) not achieving this data capture. The Stoke Ferry site experienced issues with inconsistent temperature sensors that required investigations and equipment replacements.

2.5 ANALYTICAL TECHNIQUES AND PAH REPORTED

In 2022 all analysis was undertaken by the Environment Agency, Monitoring 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 AND 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 level recommended by EPAQS 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 B[*a*]P LEVEL RECOMMENDED BY EPAQS

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.

With Armagh Roadside site only operating for less than three months it is not sensible to assess the concentration at that site using a mean based on only three months therefore it has been excluded from this assessment. However, it is apparent that the levels measured during the period of operation at Armagh Roadside that levels are similar to other Northern Ireland sites (Derry Brandywell, Ballymena Ballykeel and Kilmakee Leisure Centre) therefore, it is likely that annual concentration may be similar.

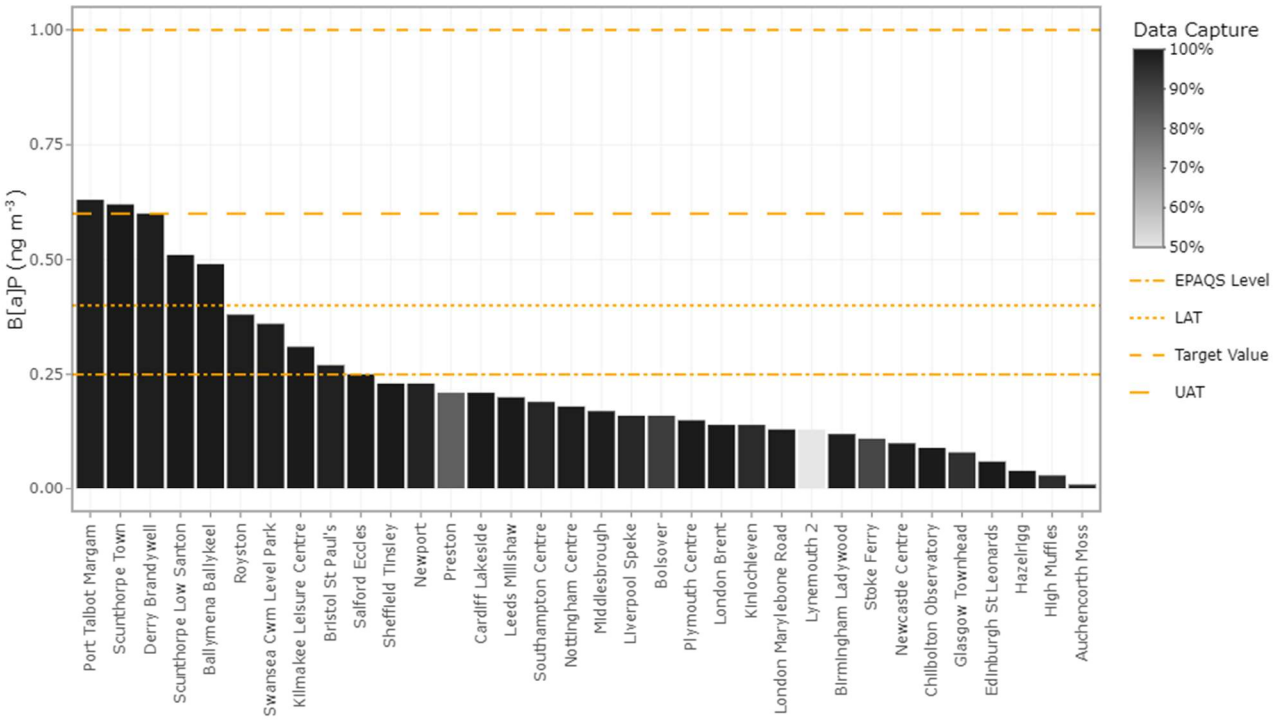

Figure 3-1: Comparison of annual B[*a*]P concentrations at all the monitoring stations against Target Value assessment thresholds and level recommended by EPAQS 0.25ng/m^3.

No sites in the UK PAH Network measurement sites exceeded the Target Value of 1 ng/m^3. Only two sites exceeded upper assessment threshold (UAT) of 0.6 ng/m^3. These were Port Talbot Margam (0.62 ng/m^3) and Scunthorpe Town (0.61 ng/m^3). A further three sites exceeded the lower assessment threshold (LAT) of 0.4 ng/m^3. These were Derry Brandywell (0.60 ng/m^3), Scunthorpe Low Santon (0.51 ng/m^3) and Ballymena Ballykeel (0.49 ng/m^3).

The level recommended by EPAQS 0.25ng/m^3 for B[*a*]P was exceeded at nine sites:

- Port Talbot Margam (0.62 ng/m^3)
- Scunthorpe Town (0.61 ng/m^3)
- Derry/Londonderry Brandywell (0.60 ng/m^3)
- Scunthorpe Low Santon (0.51 ng/m^3)

- Ballymena Ballykeel (0.49 ng/m^3)
- Royston (0.38 ng/m^3)
- Swansea Cwm Level Park (0.36 ng/m^3)
- Kilmakee Leisure Centre (0.31 ng/m^3)
- Bristol St Paul's (0.27 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 the levels at the sites.

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 due to process shut-downs during the year. The monthly concentrations of B[*a*]P for 2022 grouped by the site characteristic types are shown in Figures 3-2 to 3-7.

3.2.1 Northern Ireland Sites

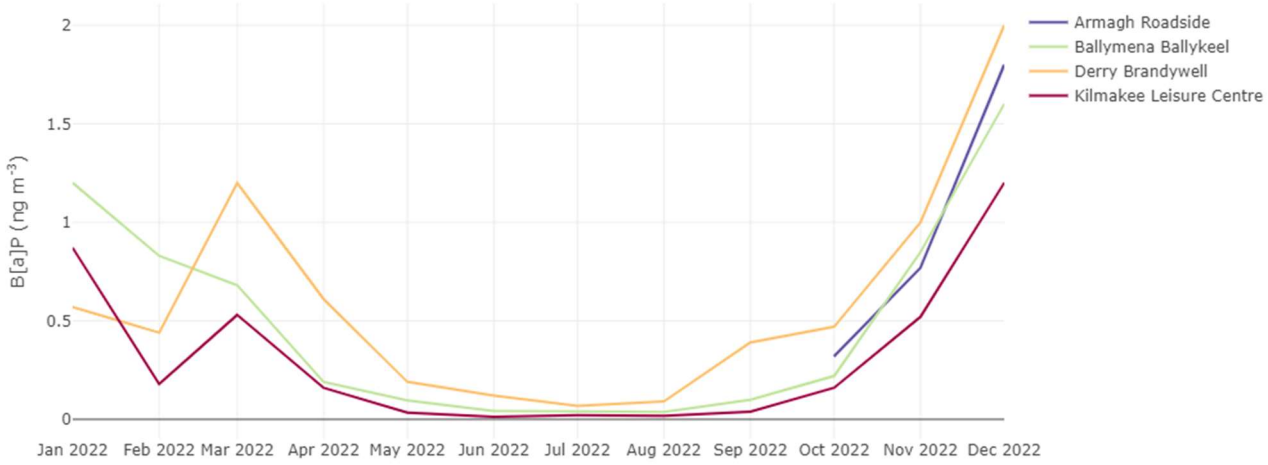

Figure 3-2 Monthly average B[*a*]P concentrations at the Northern Ireland sites in 2022.

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 2022 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.

The newly established site of Armagh Roadside which was installed in October 2022 shows that the concentrations measured during that period appear to be around that of Derry Brandywell and Ballymena Ballykeel.

Unlike in Great Britain (GB) 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

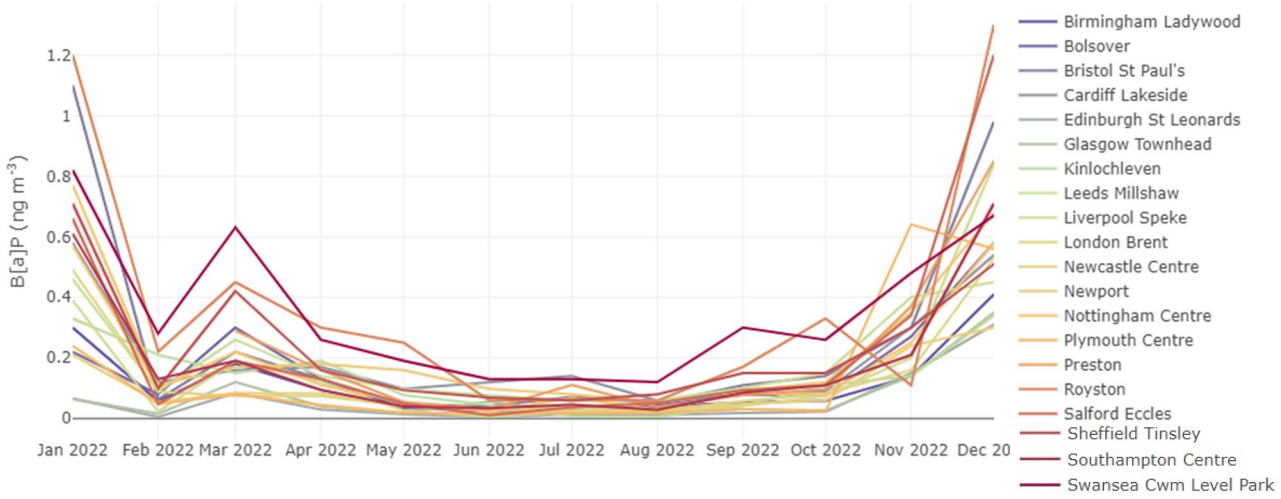

Figure 3-3: Monthly average B[*a*]P concentrations at urban background sites in Great Britain (GB) in 2022.

Urban background sites in GB 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 elevation in concentrations during the winter months. Unlike in previous years there didn't appear to be the same elevation in concentrations observed from October to November which might have been expected as a result of solid and wood fuel use and the effect of Guy Fawkes Night.

3.2.3 GB Rural Background

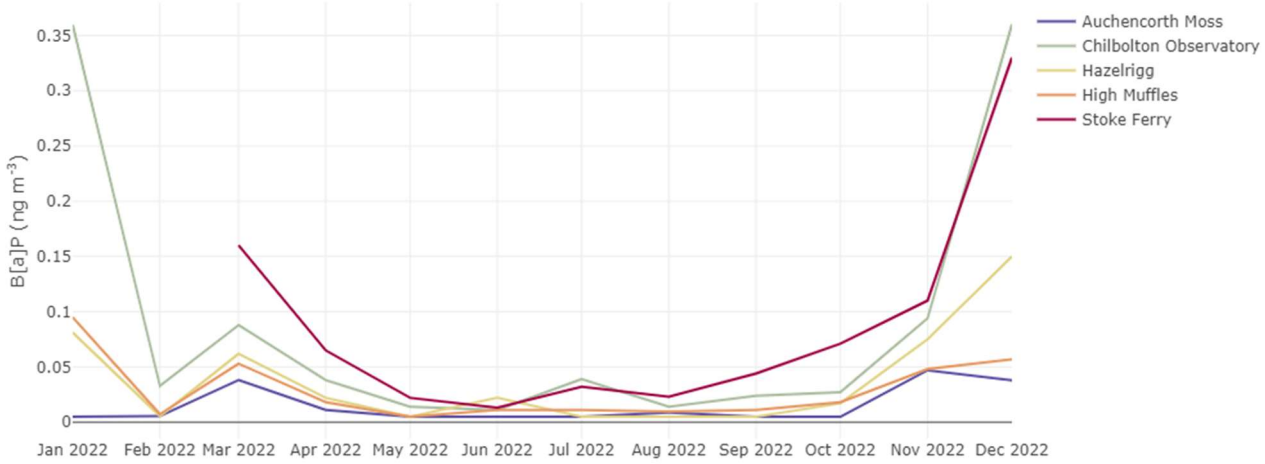

Figure 3-4: Monthly average B[*a*]P concentrations at rural background sites in GB in 2022.

It should be noted that February data is missing for Stoke Ferry in 2022 due to equipment issues.

The most rural site in the PAH network is generally considered to be Auchencorth Moss (red 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 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 prominent at the rural locations in 2022.

3.2.4 GB Industrial

Figure 3-5: Monthly average B[*a*]P concentrations at operating industrial sites.

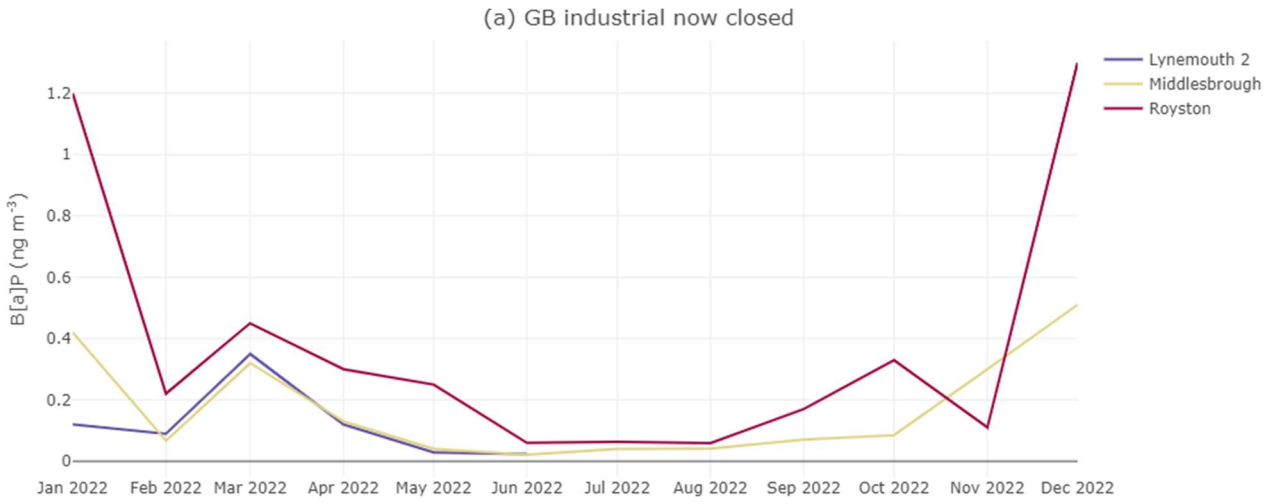

Figure 3-6: Monthly average B[*a*]P concentrations at sites where industrial processes are no longer operational.

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 can show some limited seasonality due to the seasonal sources that may be present such as for domestic heating, however these are generally masked to a varying extent 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 all months.

The sites that did have industrial sources that have since ceased operation now do show seasonality. These are Middlesbrough and Royston in 2022. 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.

The Lynemouth 2 site was only operating until June 2022 therefore no review of seasonality is possible.

In 2022, the highest B[*a*]P concentrations were observed at the Port Talbot Margam which was 1.7ng/m^3 and 1.2 ng/m^3 in November and June respectively and 1.5ng/m^3 in March at the Scunthorpe Town site.

3.2.5 GB Urban Traffic

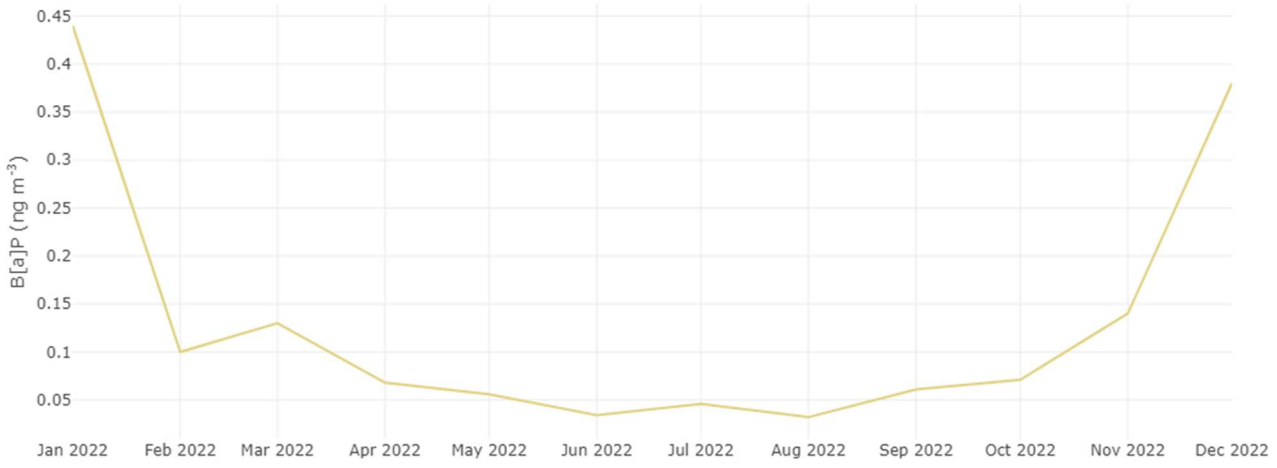

Figure 3-7: Monthly average B[*a*]P concentrations at the urban traffic site in GB in 2022.

London 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 London 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. As with the other urban sites there doesn't appear to be the same elevation in concentrations in November in 2022 which have been seen in previous years that are generally 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 3-8 to 3-14, the legend can be used in reference to each figure. 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.

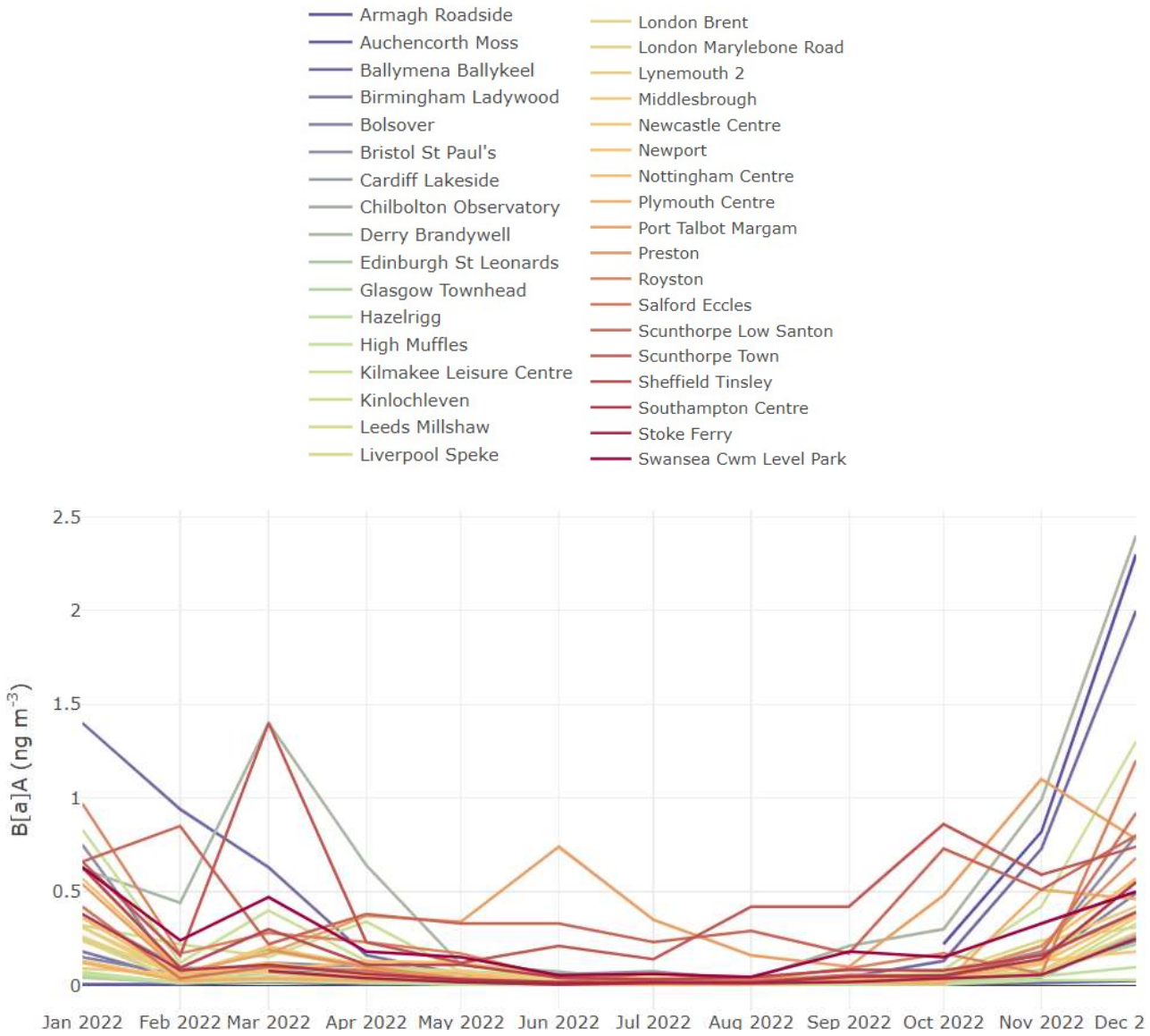

Figure 3-8: Monthly mean benz[*a*]anthracene concentrations at the UK PAH sites.

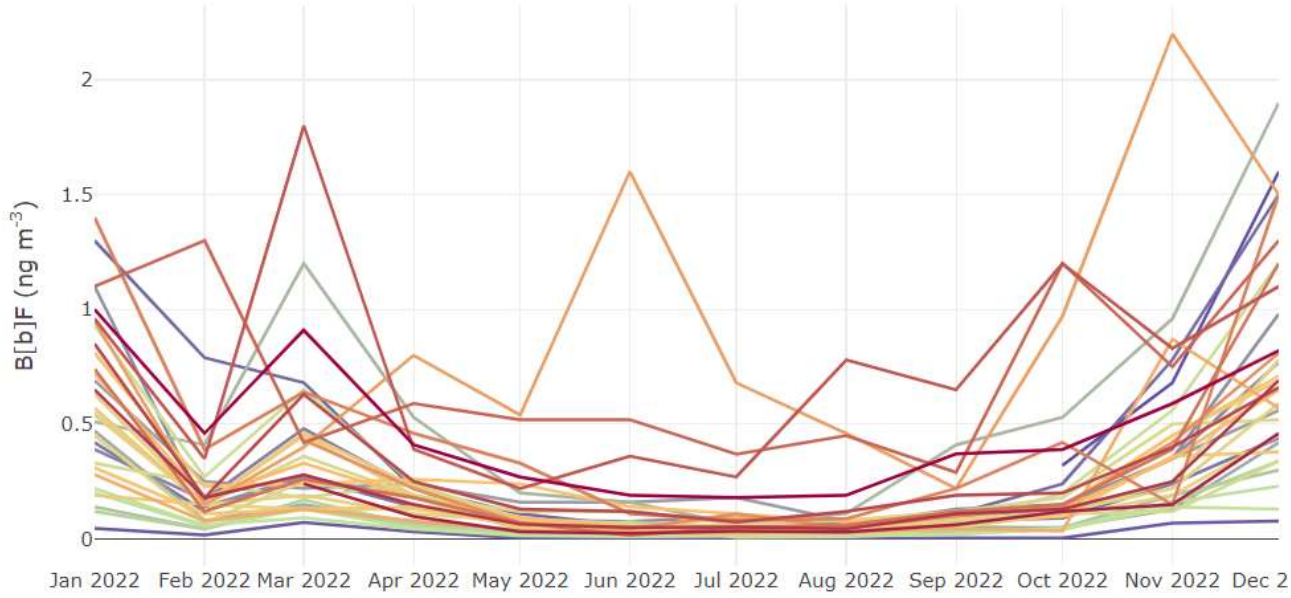

Figure 3-9: Monthly mean benz[*b*]fluoranthene concentrations at the UK PAH sites.

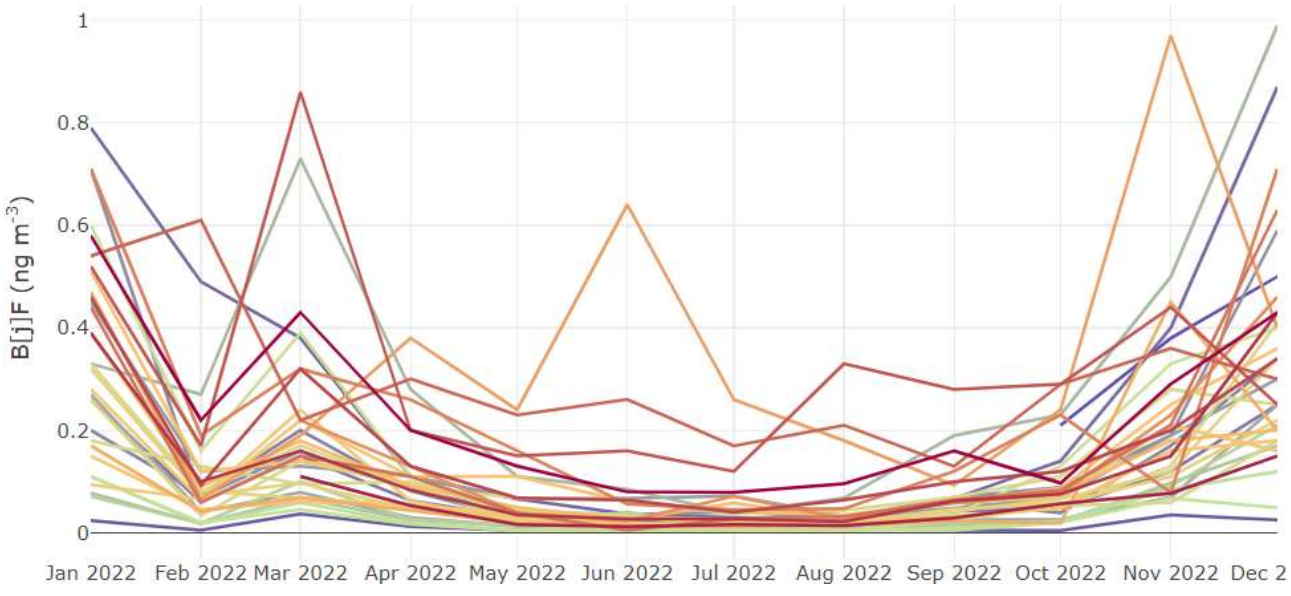

Figure 3-10: Monthly mean benzo[*j*]fluoranthene concentrations at the UK PAH sites.

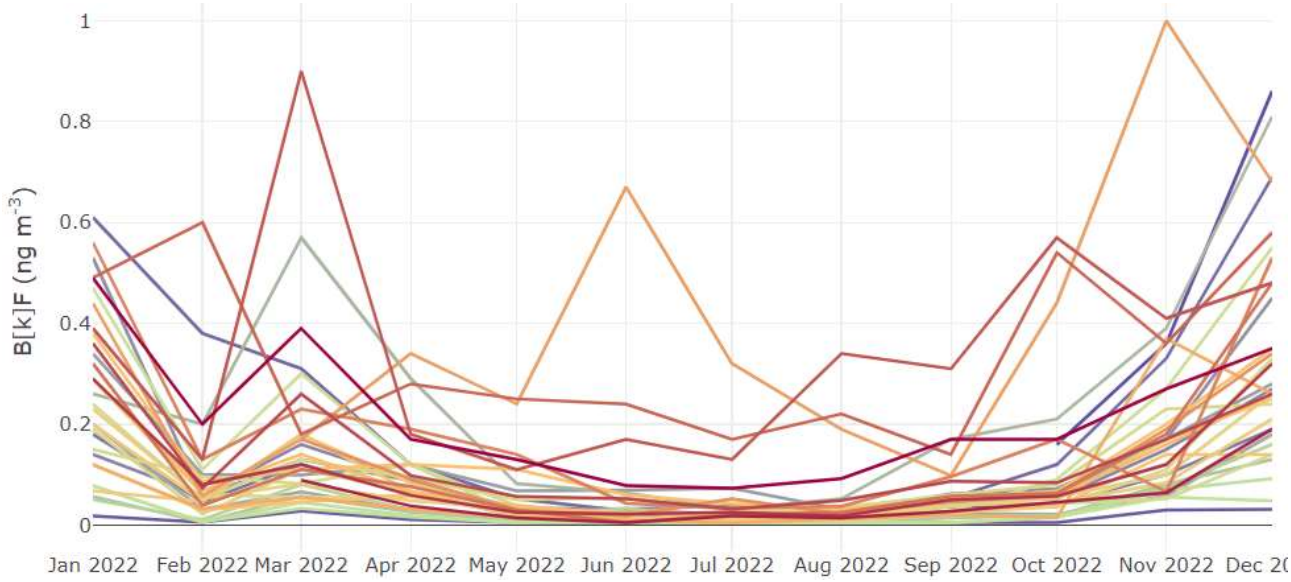

Figure 3-11: Monthly mean benzo[*k*]fluoranthene concentrations at the UK PAH sites.

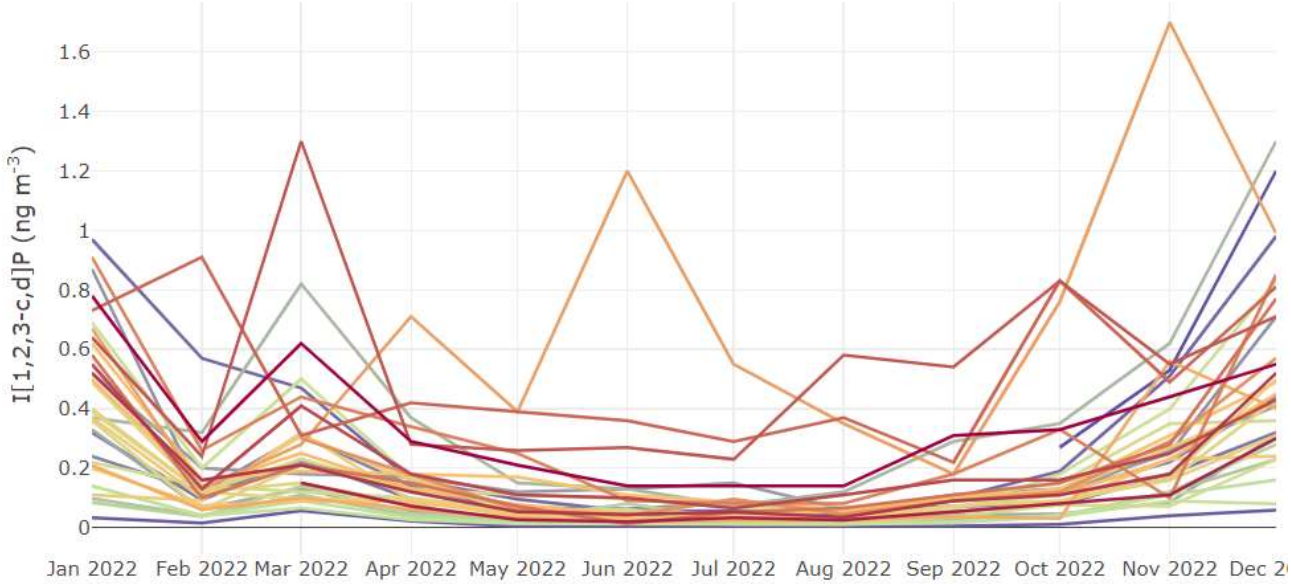

Figure 3-12: Monthly mean indeno[*1,2,3-cd*]pyrene concentrations at the UK PAH sites.

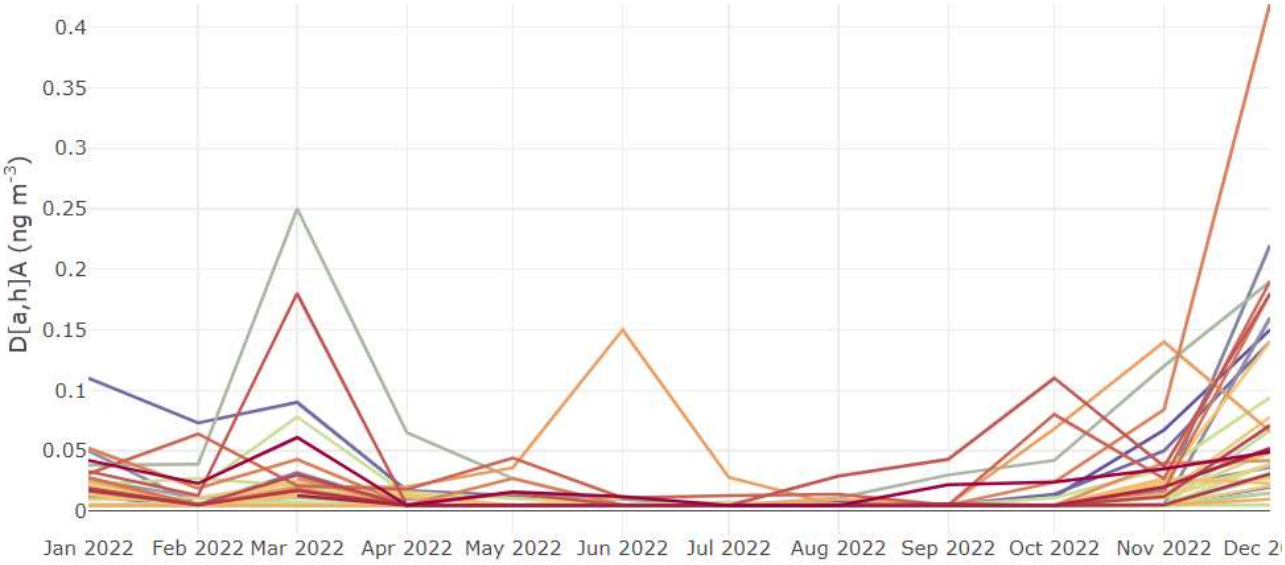

Figure 3-13: Monthly mean dibenz[*a,h*]anthracene concentrations at the UK PAH sites.

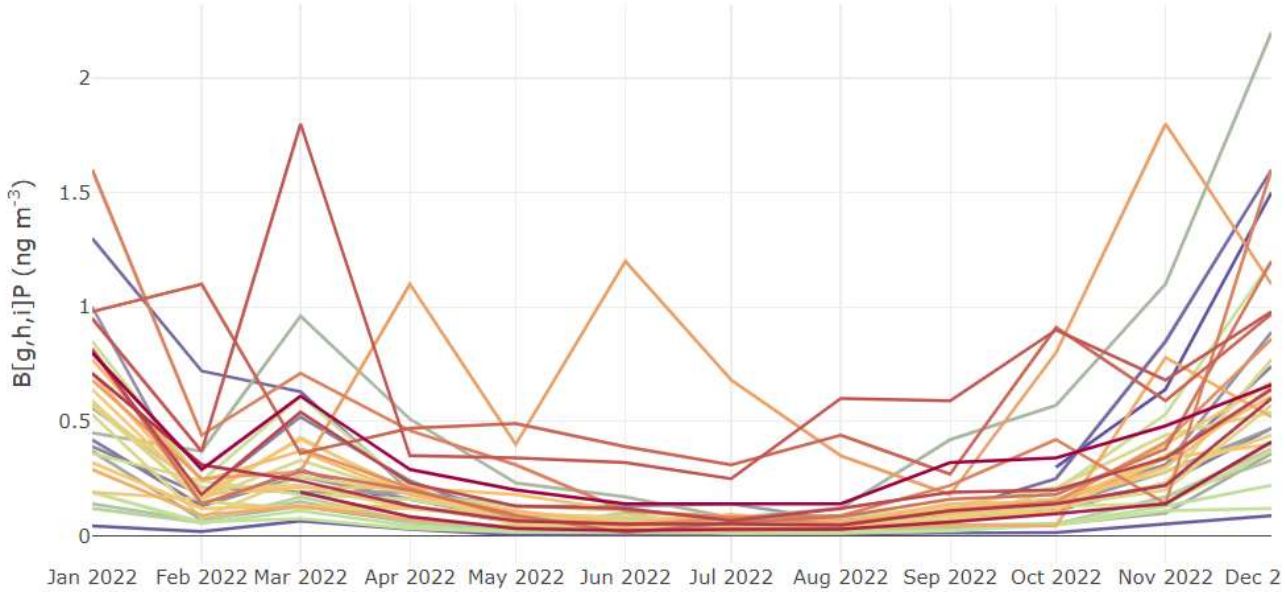

Figure 3-14: Monthly mean benzo[*g,h,i*]perylene concentrations at the UK PAH sites.

3.4 DEPOSITION ('C') SAMPLES

The 4 weekly bulked samples of B[*a*]P concentrations measured in deposition at the Auchencorth Moss and Chilbolton Observatory 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 isn't a Target Value associated with the deposition measurements. However, the monitoring conducted at the two sites does enable the UK to report and review trends in measured concentrations at these sites. All deposition data is available on the UK-AIR website.

3.5 LONG-TERM TRENDS IN B[*a*]P

Figure 3-15 to 3-20 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.

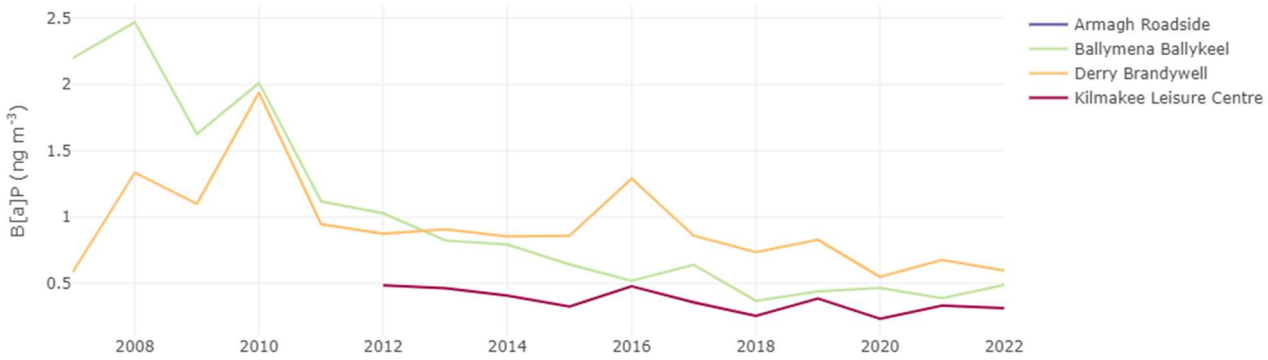

Figure 3-15: Annual average B[*a*]P concentrations at the Northern Ireland Network sites from 2007 to 2022.

Figure 3:15 shows that whilst there is a clear downward trend in B[*a*]P concentrations at the Ballymena Ballykeel site over the measurement period, the same trend is not as apparent at the Derry Brandywell or the Kilmakee Leisure Centre site where there appears to be only a slight downward trend.

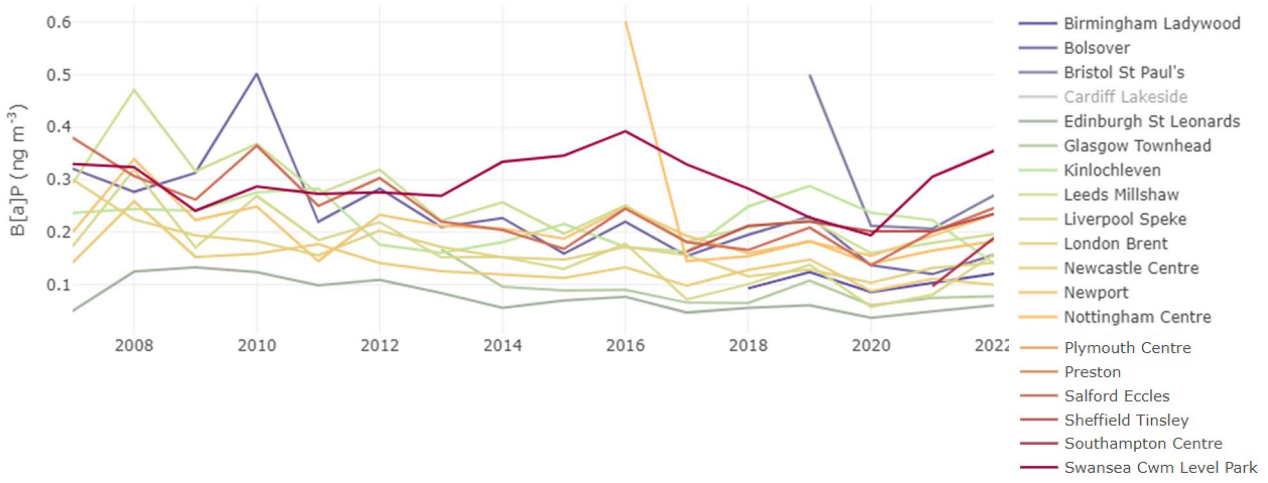

Figure 3-16: Annual average B[*a*]P concentrations at the Urban sites in Great Britain from 2007 to 2022.

Over the whole period 2007-2022 there appears to be a general decreasing trends in concentrations at most of the urban background sites in Great Britain. However, in the last two years since 2020 there appears to be

a slight increase at many of the sites. With sources at these sites being likely to be domestic and commercial combustion the slight increase could be related to increased solid fuel used which may be related to energy prices.

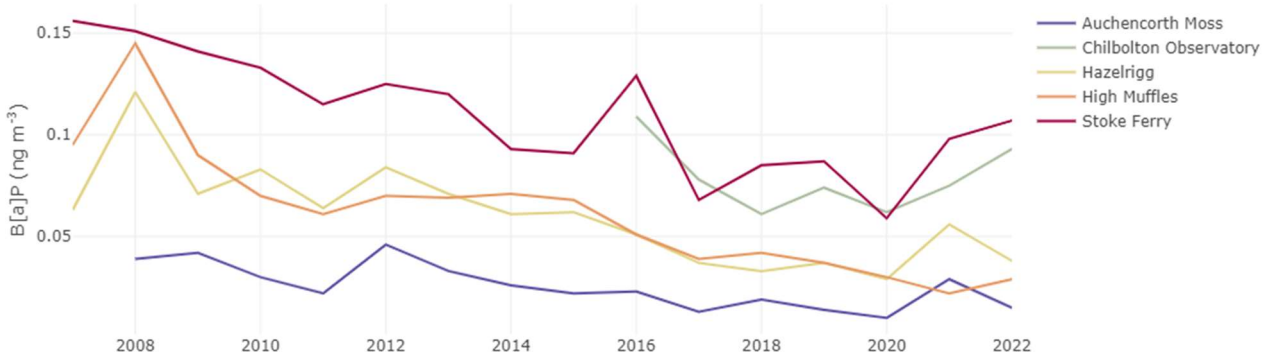

Figure 3-17: Annual average B[*a*]P concentrations at the Rural sites in Great Britain from 2007 to 2022.

Over the whole period 2007-2022 the rural background sites appear to show a slight downward trend in B[*a*]P concentration. However, in recent years there doesn't appear to be much observable decrease in concentrations.

The rural 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 so this is to be expected.

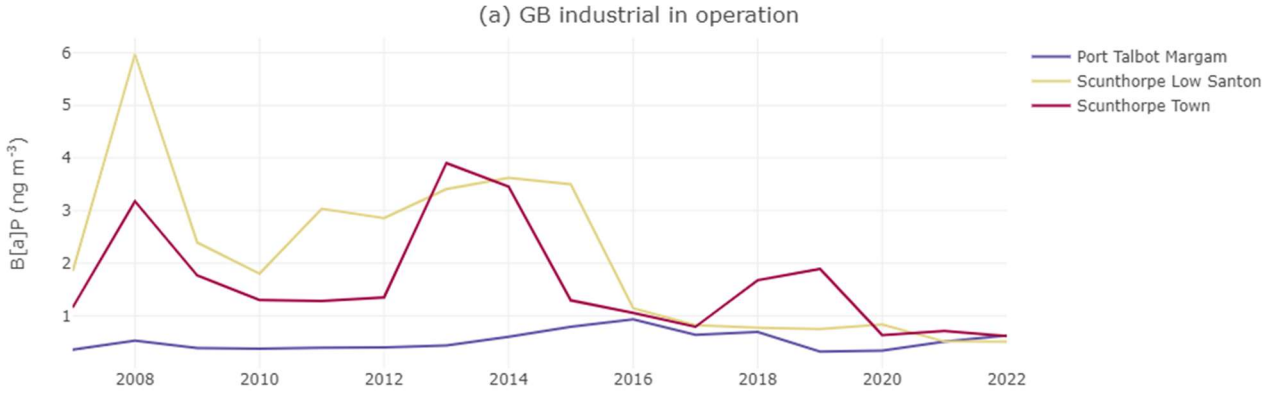

Figure 3-18: Annual mean B[*a*]P concentrations at operating industrial sites from 2007 to 2022.

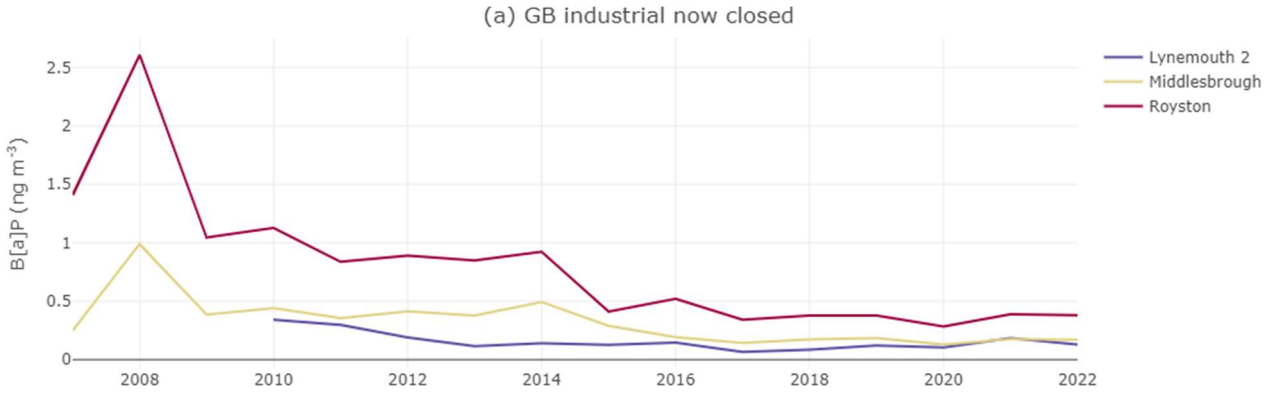

Figure 3-19: Annual mean B[*a*]P concentrations at operating industrial sites that are now closed from 2007 to 2022.

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. They appear to have less variation from year to year in recent years.

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 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 one of the coke ovens closed. However, both the Scunthorpe Town and Low Santon sites have been well above the annual mean level recommended by EPAQS (0.25 ng/m^3) with concentrations measures in 2022 being 0.61 ng/m^3 and 0.51 ng/m^3 respectively.

The only Port Talbot site operating in 2022, 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 higher than those seen at the Scunthorpe sites in 2022. The annual average concentration was 0.62 ng/m^3 at Port Talbot Margam in 2022. The concentration measured at the site is also well above the level recommended by EPAQS (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.

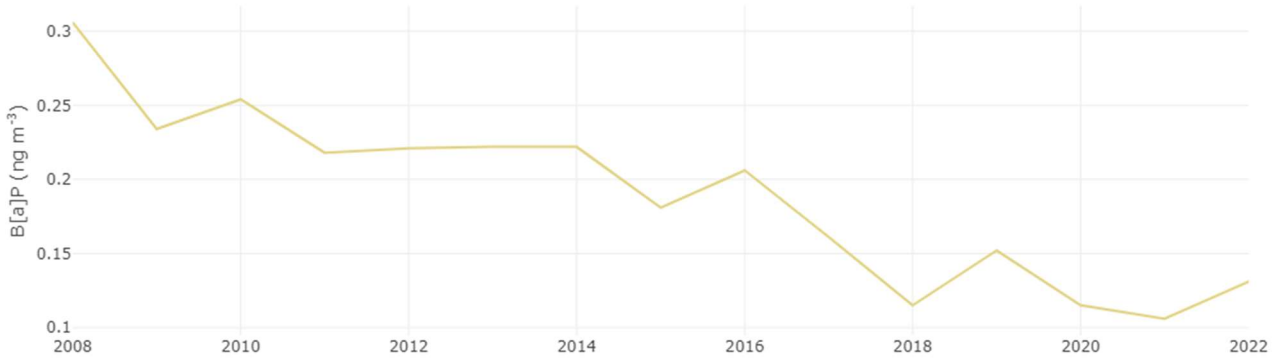

Figure 3-20: Annual average B[*a*]P concentrations at the London Marylebone Road site from 2007 to 2022.

The London Marylebone Road PAH Monitoring site shows a steady decreasing trend since installation and levels have been below the level recommended by EPAQS (0.25 ng/m^3) since 2009. In the last two years since 2020 there appears to be a slight increase in concentration which was also noted for other urban locations.

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), which is a free and open-source programming language. The outputs are summarised in (Figure 3-21) which displays the significant trends on the right and insignificant trends on the left of the figure. Sites with 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 (shown as red bars), which indicates the uncertainty of the slope coefficient. 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.

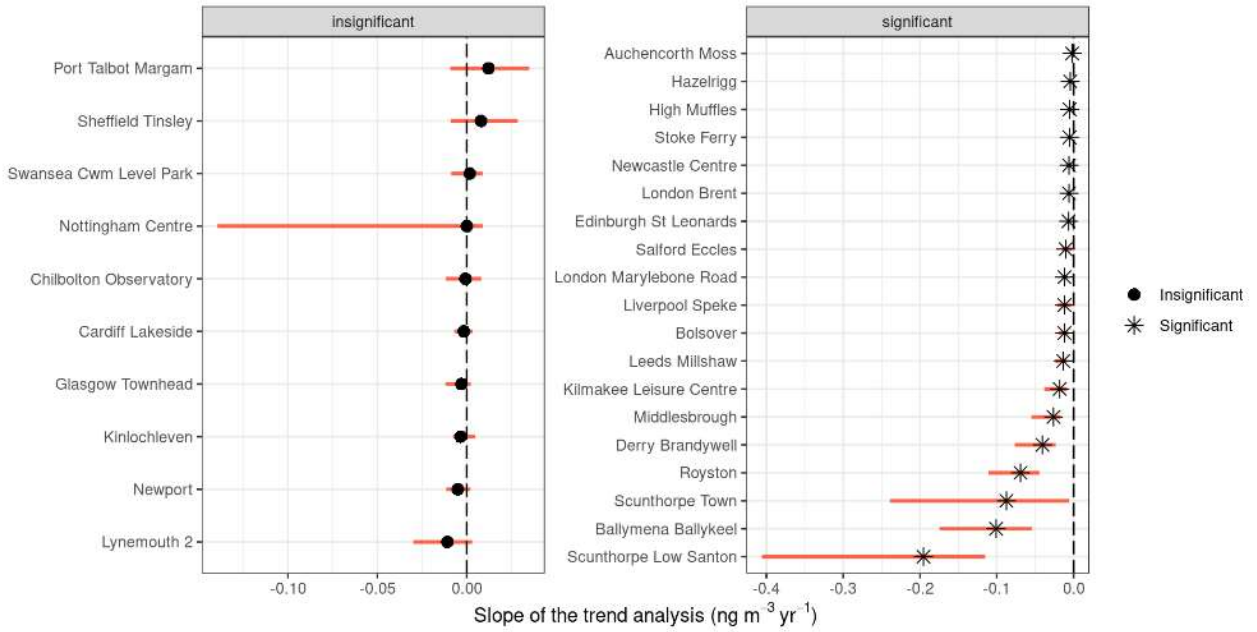

Figure 3-21: B[*a*]P concentration trend (ng m^{-3} yr^{-1}) from 2008 to 2022.

The slope of the trend calculated for 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 shown as red bars).

Sites showing more significant decreasing trend are at the bottom of the right-hand side of (Figure 3-21) (Scunthorpe Low Santon, Ballymena Ballykeel, Scunthorpe Town, Royston, Derry Brandywell and Middlesbrough). These site all appear to have decreasing trends in B[*a*]P concentrations but some site have large uncertainties in the trends due to the inter-year variability (Scunthorpe Town and Scunthorpe Santon) shown by the length of the red bars.

4. CONCLUSIONS

The average data capture of the operational sites in 2022, taking into account any closure or start dates continued to be very high at 98% which is slightly higher than in 2021. The annual mean B[*a*]P concentrations observed at the UK networks during 2022 continued to vary greatly between sites with the highest concentrations at industrial sites and urban sites in Northern Ireland.

The annual mean B[*a*]P concentrations observed at the UK networks during 2022 continued to vary greatly between sites with the highest concentrations at industrial sites and urban sites in Northern Ireland.

In 2022 the highest annual mean was observed at the Port Talbot Margam site with an annual mean B[*a*]P concentration of 0.62 ng/m^3 and the lowest concentration continued to be measured at the Auchencorth Moss site (0.001 ng/m^3).

In 2022 all measurement sites were below the Target Value for B[*a*]P (annual mean concentration of 1 ng/m^3). However, excluding Armagh (which was operating for less than 3 months) nine sites are exceeding 0.25 ng/m^3, the level recommended by EPAQS. These were Port Talbot Margam, Scunthorpe Town, Derry Brandywell, Scunthorpe Low Santon, Ballymena Ballykeel, Royston, Swansea Cwm Level Park, Kilmakee Leisure Centre and Bristol St Paul's.

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, 2020. The Air Quality (Amendment) (Northern Ireland Protocol) (EU Exit) (No. 2) Regulations 2020. URL https://www.legislation.gov.uk/uksi/2020/1352/regulation/2/made

DAERA, 2018. The Air Quality (Amendment, etc.) Regulations (Northern Ireland) 2018. URL https://www.legislation.gov.uk/nisr/2018/215/contents/made

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, 2023. Policy paper. Air quality strategy: Framework for local authority delivery. URL https://www.gov.uk/government/publications/the-air-quality-strategy-for-england/air-quality-strategy-framework-for-local-authority-delivery

Defra, 2019. Clean air strategy 2019. URL https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/770715/clean-air-strategy-2019.pdf

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

EPAQS, 1999. Expert panel on air quality standards, polycyclic hydrocarbons, report for the department of the environment, transport and the regions. URL not available

IARC, 2012. IARC monographs on the evaluation of carcinogenic risks to humans. Volume 92: Some non-heterocyclic polycyclic aromatic hydrocarbons and some related exposures. International Agency for Research on Cancer. URL https://publications.iarc.fr/123

IARC, 2010. Chemical agents and related occupations. IARC monographs on the evaluation of carcinogenic risks to humans volume 100F. International Agency for Research on Cancer. URL https://monographs.iarc.fr/wp-content/uploads/2018/06/mono92.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, 2019. The Air Quality (Amendment of Domestic Regulations) (EU Exit) Regulations 2019. URL https://www.legislation.gov.uk/uksi/2019/74/contents

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, 2019. The Air Quality Standards (Wales) (Amendment) (EU Exit) Regulations 2019.
URL https://www.legislation.gov.uk/wsi/2019/390/contents

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

APPENDIX 1 PAH DEPOSITION

Table A1: PAH deposition for B[*a*]P in 2022.

Station name	Start date	End date	Measurement (ng/m2/day)
Auchencorth Moss	29/12/2021	26/01/2022	<9
Auchencorth Moss	26/01/2022	23/02/2022	20
Auchencorth Moss	23/02/2022	23/03/2022	<9
Auchencorth Moss	23/03/2022	20/04/2022	28
Auchencorth Moss	20/04/2022	18/05/2022	<9
Auchencorth Moss	18/05/2022	15/06/2022	<9
Auchencorth Moss	15/06/2022	13/07/2022	<18
Auchencorth Moss	13/07/2022	10/08/2022	<9
Auchencorth Moss	10/08/2022	07/09/2022	35
Auchencorth Moss	07/09/2022	05/10/2022	<9
Auchencorth Moss	05/10/2022	02/11/2022	<9
Auchencorth Moss	02/11/2022	01/12/2022	<9
Auchencorth Moss	01/12/2022	28/12/2022	<10
Auchencorth Moss	28/12/2022	25/01/2023	<9
Chilbolton Observatory	29/12/2021	26/01/2022	<9
Chilbolton Observatory	26/01/2022	23/02/2022	<9
Chilbolton Observatory	23/02/2022	23/03/2022	30
Chilbolton Observatory	23/03/2022	20/04/2022	20
Chilbolton Observatory	20/04/2022	18/05/2022	<9
Chilbolton Observatory	18/05/2022	15/06/2022	<18
Chilbolton Observatory	15/06/2022	13/07/2022	<18
Chilbolton Observatory	13/07/2022	10/08/2022	31
Chilbolton Observatory	10/08/2022	07/09/2022	22
Chilbolton Observatory	07/09/2022	05/10/2022	<9
Chilbolton Observatory	05/10/2022	02/11/2022	<9
Chilbolton Observatory	02/11/2022	30/11/2022	<9
Chilbolton Observatory	30/11/2022	28/12/2022	41
Chilbolton Observatory	28/12/2022	11/01/2023	<18

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

APPENDIX 2 ENVIRONMENT AGENCY, MONITORING LABORATORY SERVICE PAH 2022 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/m^2/day for particulate and deposition respectively.

Table A2: PAH analysed by Environment Agency, Monitoring Laboratory Service in Deposition and particulate samples.

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-ee@ricardo.com

W: www.ricardo.com