UK PAH Monitoring and Analysis Network 2020

Issue 1

Report for the Environment Agency Customer Ref: 58151 and 28525

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Executive Summary

This annual report for 2020 for the UK PAH Monitoring and Analysis Network was prepared by Ricardo Energy and Environment for the Environment Agency, the Department for Environment, Food and Rural Affairs, the Department of Environment Northern Ireland, the Welsh Government and the Scottish Government.

During 2020 the number of ambient air sampling sites in the UK PAH network was 33. 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 Polycyclic Aromatic Hydrocarbons (PAH) Monitoring Network comprises non automatic systems to measure PAH in ambient air and deposition. Benzo[*a*]pyrene (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.
There is an EU Target Value that relates to the annual mean concentration of Benzo[*a*]pyrene (1 ng/m^3). There is also a more stringent UK National Air Quality Objective for B[*a*]P in ambient air is an annual mean concentration of 0.25 ng/m^3 as detailed in the Air Quality Strategy (Defra, 2007).

Key findings for 2020:

- In 2020 the EC target value for B[*a*]P (annual mean concentration of 1 ng/m^3) was not exceeded any of the network sites.
- In 2020 seven sites exceeding the UK Air Quality Objective for B[*a*]P (annual mean concentration of 0.25 ng/m^3), these are:
  - Scunthorpe Low Santon measuring 0.84 ng/m^3
  - Scunthorpe Town measuring 0.64 ng/m^3
  - Derry/Londonderry Brandywell measuring 0.56 ng/m^3
  - Ballymena Ballykeel measuring 0.47 ng/m^3
  - Port Talbot Margam measuring 0.34 ng/m^3
  - Royston measuring 0.29 ng/m^3
  - Ruardean measuring 0.27 ng/m^3
- The average data capture of all of the operational sites throughout the whole of 2020 was lower than in previous year at 92.5%. This was due to two sites having electrical work carried out and the Environment Agency and Defra requesting that a proportion of the filters be retained for a university study.

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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 (DAERA), 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 PM10 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 interactive 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 EU Target Value and the more stringent UK Air Quality Objective
- Monthly PAH concentrations in 2020
- Review of concentration trends of B[*a*]P at each of the monitoring sites

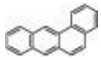
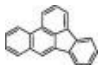
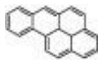
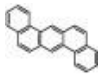
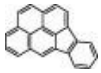
The appendices of this report present data for the monthly deposition concentrations of B[*a*]P at all Network stations that were operational in 2020. However, this information air concentration data and other monthly concentration data for all other PAHs measured within the network can be accessed via 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 below shows the details of PAH that are required to be measured under the Fourth Daughter Directive (2004/107/EC) (EC, 2005) in the UK, plus benzo[*ghi*]perylene which was more recently included in the 2014 technical standard CEN/TS 16645:2014 (BSI, 2014).

Table 1: PAH structures of PAH that should be monitored according to the 4th Daughter Directive (2004/107/EC). 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-cd*]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).

The EC Air Quality Framework Directive (Directive 96/62/EC) (EC, 1996) set a strategic framework to tackle air quality in a consistent way across Europe by setting limit and target values for air pollutants via a series of Daughter Directives. The Fourth Daughter Directive sets a target value for B[*a*]P of 1 ng/m^3 (total content in the PM10 fraction averaged over a calendar year). Mandatory measurement requirements relating to the measurement of B[*a*]P can be found in the Fourth Daughter Directive (Directive 2004/107/EC).

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 in the Fourth Daughter Directive (Directive 2004/107/EC) and the more stringent UK National Air Quality Objective for PAH (annual mean of 0.25 ng/m^3 B[*a*]P in ambient air). Measurements of B[*a*]P in ambient air are covered by the European standard EN 15549 (BSI, 2008), which has been adopted as the European reference method.

Measurements of PAH in deposition are covered by European standard EN 15980 (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-cd*]pyrene. There is no limit or target value related deposition of PAH in the UK or Europe.

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 benzo[*a*]pyrene. 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 Benzo[a]pyrene (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 Fourth Daughter Directive 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 Fourth Daughter Directive, 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 33 monitoring stations operating in the UK PAH Network during 2020 are shown in Figure 1. Two monitoring sites where both Digitel particulate samplers and deposition samples are taken are marked with the drop marker (Auchencorth Moss and Chilbolton Observatory). Other sites where only Digitel particulate samples are taken are marked with red circles.

Figure 1: Map of UK PAH monitoring stations in 2020.

In 2020 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) used throughout the Network are considered to be equivalent to the requirements of the European Standard for sampling PM_{10} matter (EN 12341) (BSI, 2014). The samplers are therefore valid for use with the European 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.

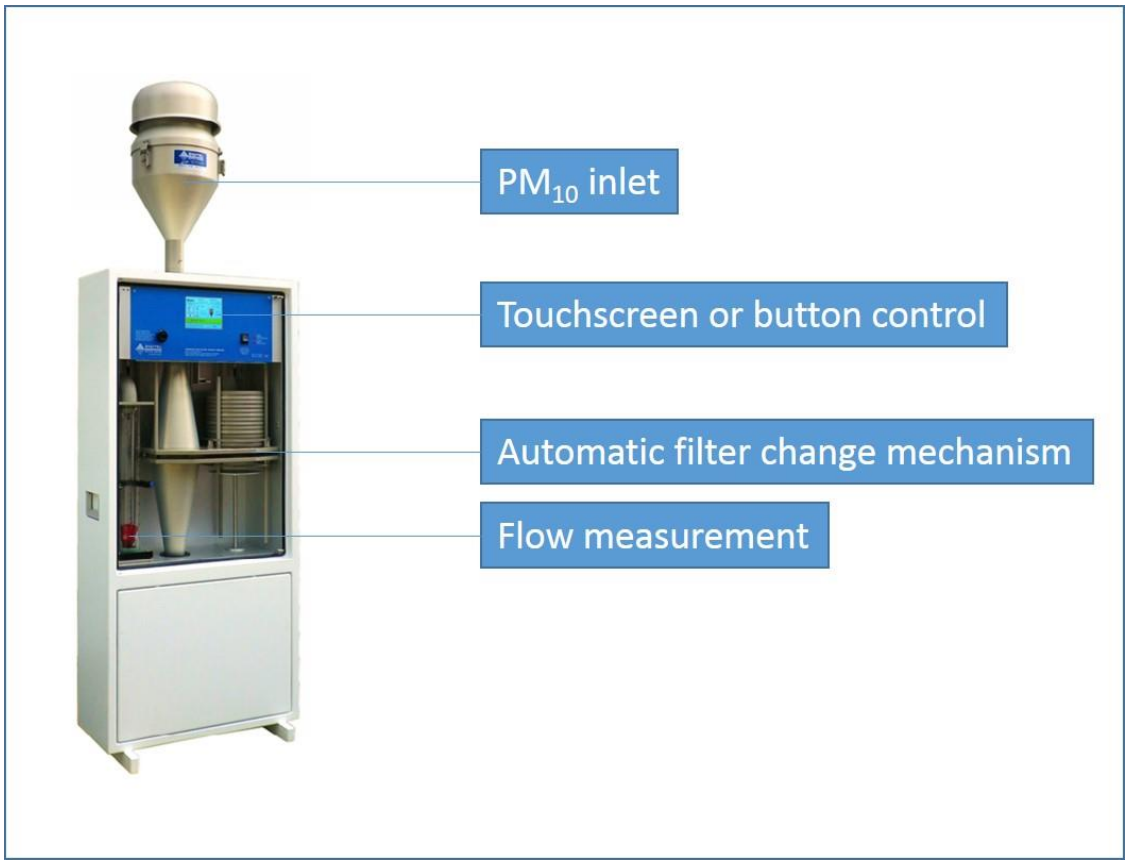


Figure 2: Digitel DHA-80 sampler deployed to measure solid phase PAH in the UK Network.

'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 3) that meets the requirement of the European Standard for the measurement of the deposition of PAHs (EN 15980). The deposition samplers 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.

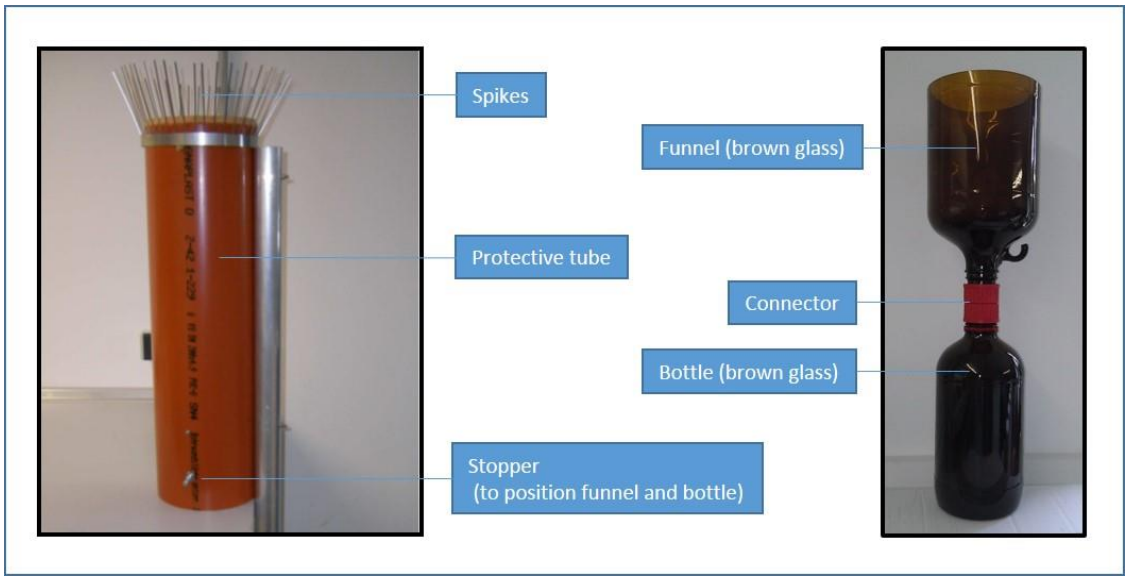


Figure 3: Samplers to measure deposition of PAH in the UK Network.

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 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 2020

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 2020:

- 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 due to site safety work at the monitoring site and is expected to restart in summer 2021
- Cardiff Lakeside sampling suspended from 22nd September to the 28th October due to electrical work and renovations at the school the sampler is located.

2.4.2 Data capture, Station Calibrations, Services and Breakdowns

All Stations were calibrated and serviced in 2020 and checks on flow were undertaken. Table 2 below shows the data captures for 2020.

Table 2: PAH data capture in 2020.

Site	Data capture
Auchencorth Moss	92.2%
Ballymena Ballykeel	95.6%
Birmingham Ladywood	90.9%
Bolsover	90.6%
Bristol St Paul's	91.2%
Cardiff Lakeside	80.9%
Chilbolton Observatory	95.0%
Derry Brandywell	94.5%
Edinburgh St Leonards	94.8%
Glasgow Townhead	91.5%
Hazelrigg	93.3%
High Muffles	95.0%
Kilmakee Leisure Centre	95.8%
Kinlochleven	96.4%
Leeds Millshaw	92.3%
Liverpool Speke	62.0%
London Brent	89.7%
London Marylebone Road	89.2%
Lynemouth 2	95.0%
Middlesbrough	95.3%
Newcastle Centre	90.1%
Newport	91.4%
Nottingham Centre	90.9%
Port Talbot Margam	99.6%
Royston	94.7%
Ruardean	94.5%
Salford Eccles	91.6%
Scunthorpe Low Santon*	99.2%
Scunthorpe Town	97.1%
Sheffield Tinsley	95.3%
South Hiendley	95.3%
Stoke Ferry	95.9%
Swansea Cwm Level Park	96.0%
Network Average	**92.5%**

The average data capture of all of the operational sites throughout the whole of 2020 was lower than in previous year at 93%. This was due to the Environment Agency and Defra requesting that a proportion of the filter be removed for a university study at many urban sites.
Fourteen of the thirty-three monitoring sites achieved data capture above 95% and despite the use of filters from most urban sites for the study. Twenty-nine of the thirty-three sites achieved data captures above 90%.
The sites of London Brent and London Marylebone Road were just below 90% due to filters being taken from these sites for the study.
Cardiff Lakeside and Liverpool Speke sites had data capture of 81% and 62% respectively as a result of loss of electrical supply at the sites due to improvement works being carried out in late 2020.

2.5 Analytical Techniques and PAH reported

In 2020 all analysis was undertaken by TNO (Netherlands Organisation for Applied Scientific Research). 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 TNO 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 Fourth Daughter Directive Target Values 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. 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 EC 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 4.

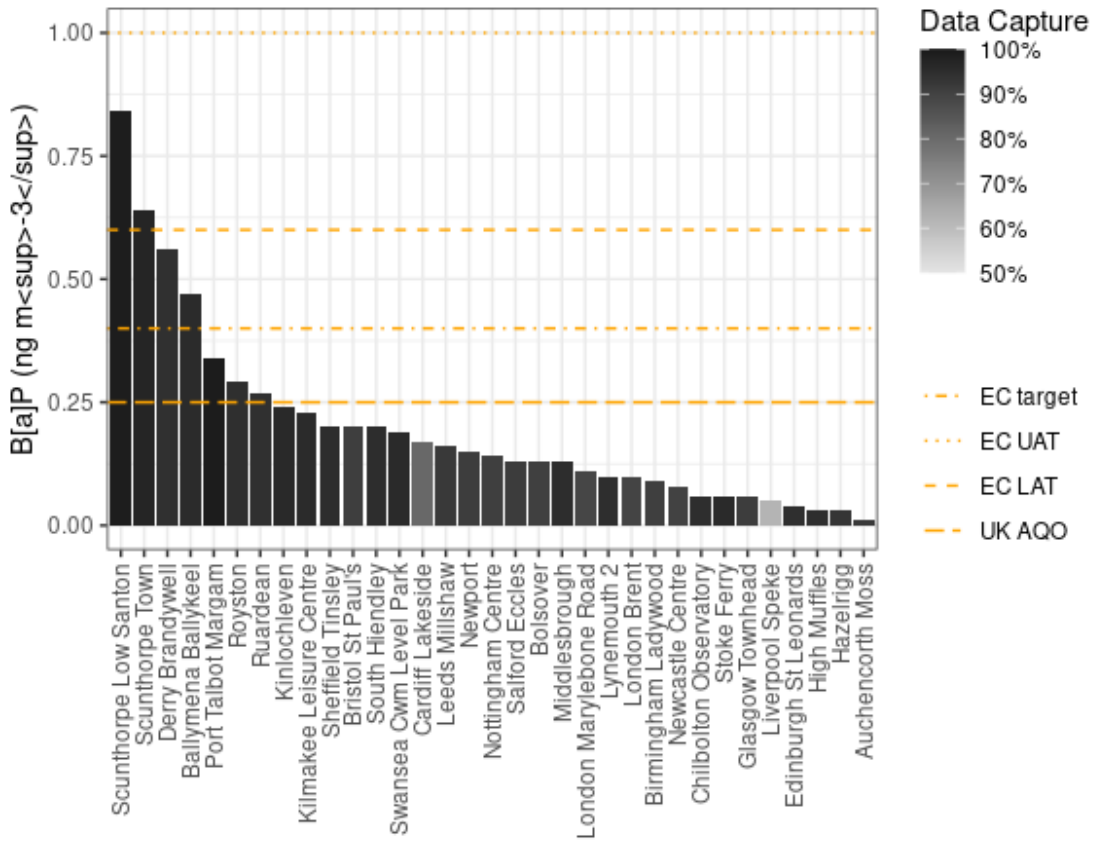


Figure 4: Comparison of annual B[a]P concentrations at all the monitoring stations against EC and UK target values and UK Air Quality Objective.

No sites in the UK PAH Network measurement sites exceeded the EC target value of 1 ng/m^3. Two sites exceeded upper assessment threshold (UAT) of 0.6 ng/m^3. These were Scunthorpe Town (0.84 ng/m^3) and Scunthorpe Low Santon (0.64 ng/m^3). A further two sites exceeded the lower assessment threshold (LAT) of 0.4 ng/m^3. These were Derry Brandywell (0.56 ng/m^3) and Ballymean Ballykeel (0.47 ng/m^3).

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

- Scunthorpe Town
- Scunthorpe Low Santon
- Derry/Londonderry Brandywell
- Port Talbot Margam
- Royston
- Ballymena Ballykeel
- Ruardean

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 more constant emissions from industrial processes unless there were unusual releases of process shut downs during the year. The monthly concentrations of B[*a*]P for 2020 grouped by the site characteristic types are shown in Figure 5 - 9.

3.2.1 Northern Ireland sites

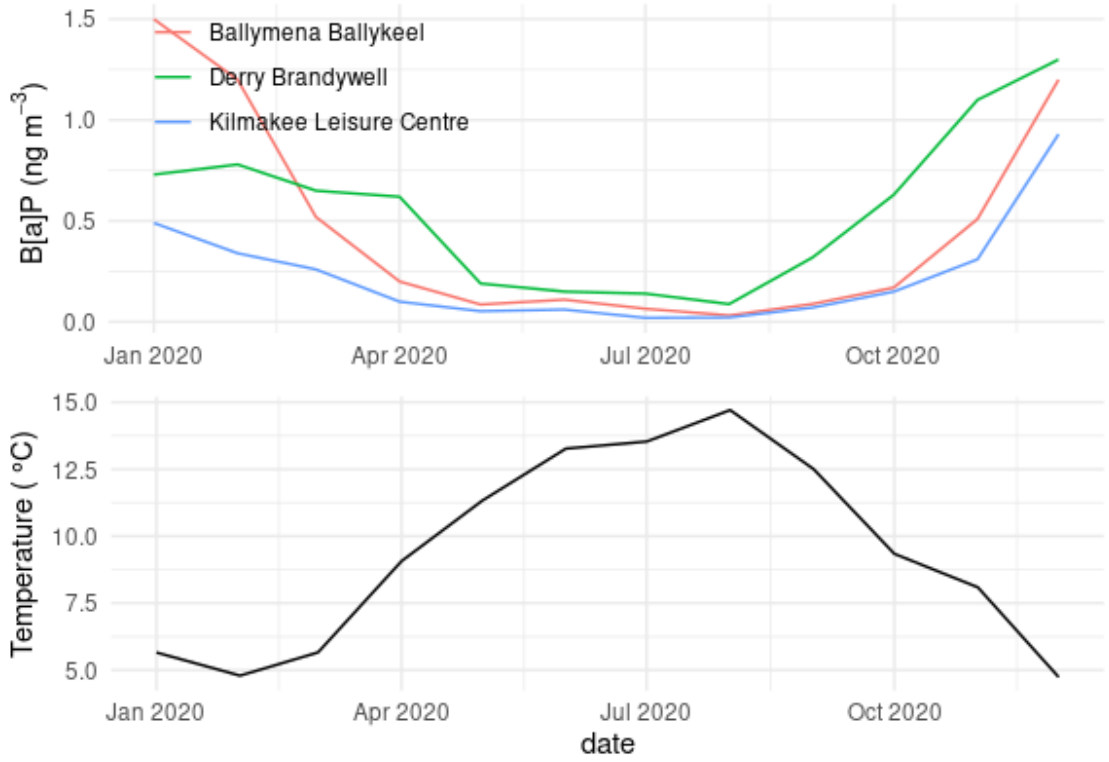


Figure 5: Monthly average B[a]P concentrations at the Northern Ireland sites and average regional temperatures in 2020.

The Northern Ireland measurement sites generally have much higher concentrations of benzo[*a*]pyrene than the UK mainland sites. This is particularly noticeable in the winter months. The Monthly variation of B[*a*]P concentrations in Northern Ireland for 2020 continued to show pronounced seasonal variation with low concentrations in the summer months and higher in winter. The above figure shows that when lower temperatures are observed, there is an increase in B[*a*]P. 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.

As Guy Fawkes/bonfire night (the 5th of November) is not generally celebrated in Northern Ireland. There was not an elevation in concentrations in November that is often seen in Great Britain sites, which is thought to be as a result of emission from domestic bonfires and arranged bonfire night events.

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

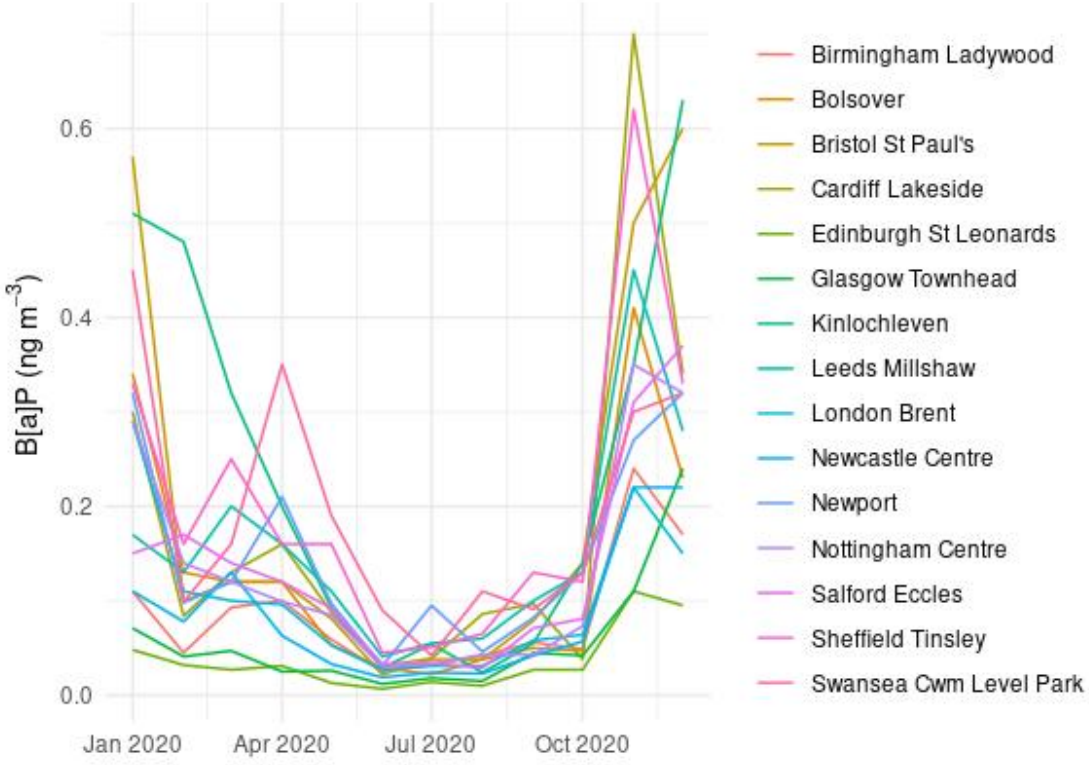


Figure 6: Monthly average B[a]P concentrations at urban background sites in GB in 2020.

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 in 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. In 2020, nine of the fifteen urban background sites in Great Britain have their highest concentrations observed in November, which demonstrates the influence this event may have on urban background concentrations.

3.2.3 GB rural background

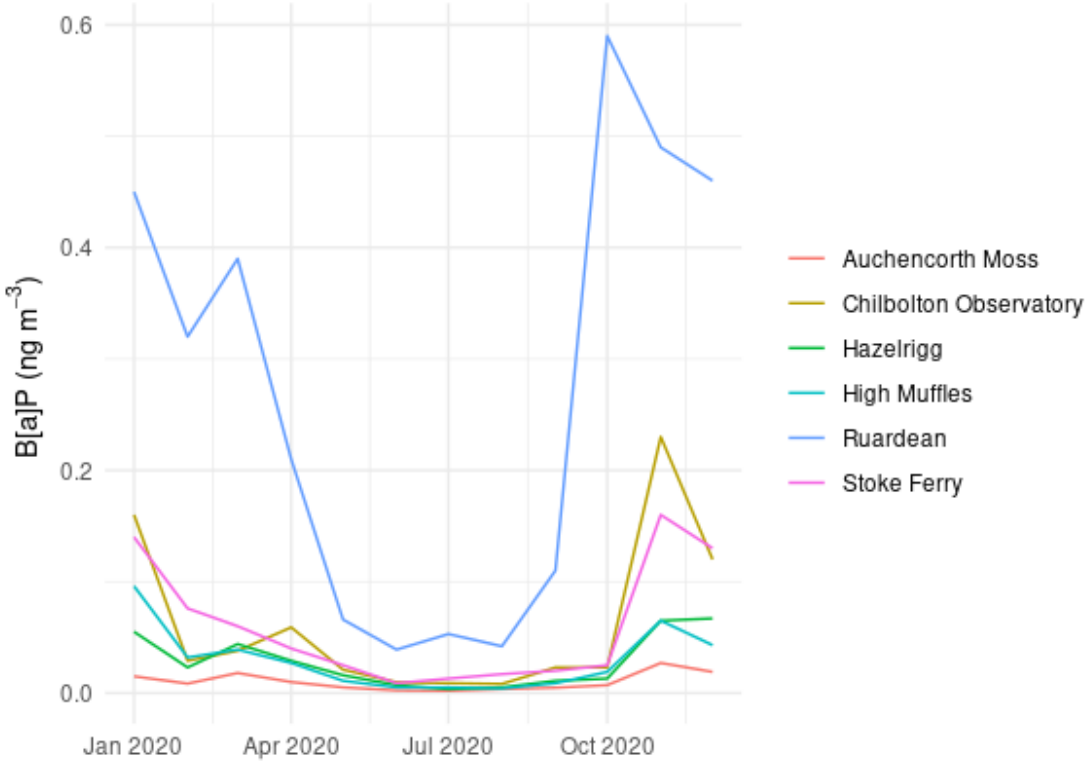


Figure 7: Monthly average B[a]P concentrations at rural background sites in GB in 2020.

The Ruardean site has the highest concentration of the rural sites and shows a seasonal profile that is more pronounced than the other rural sites. This is likely to be due to the site being located within the village. The other sites of Chilbolton and Stoke Ferry also have local influences being close to small villages that could potentially contribute to PAH concentrations particularly during the winter months. The most rural site in the PAH network is 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 show much lower concentrations throughout the year than most of the urban and industrial sites. However, there is 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 is present at some sites. Half of the six rural sites do have their highest monthly concentration of 2020 in November.

3.2.4 GB industrial

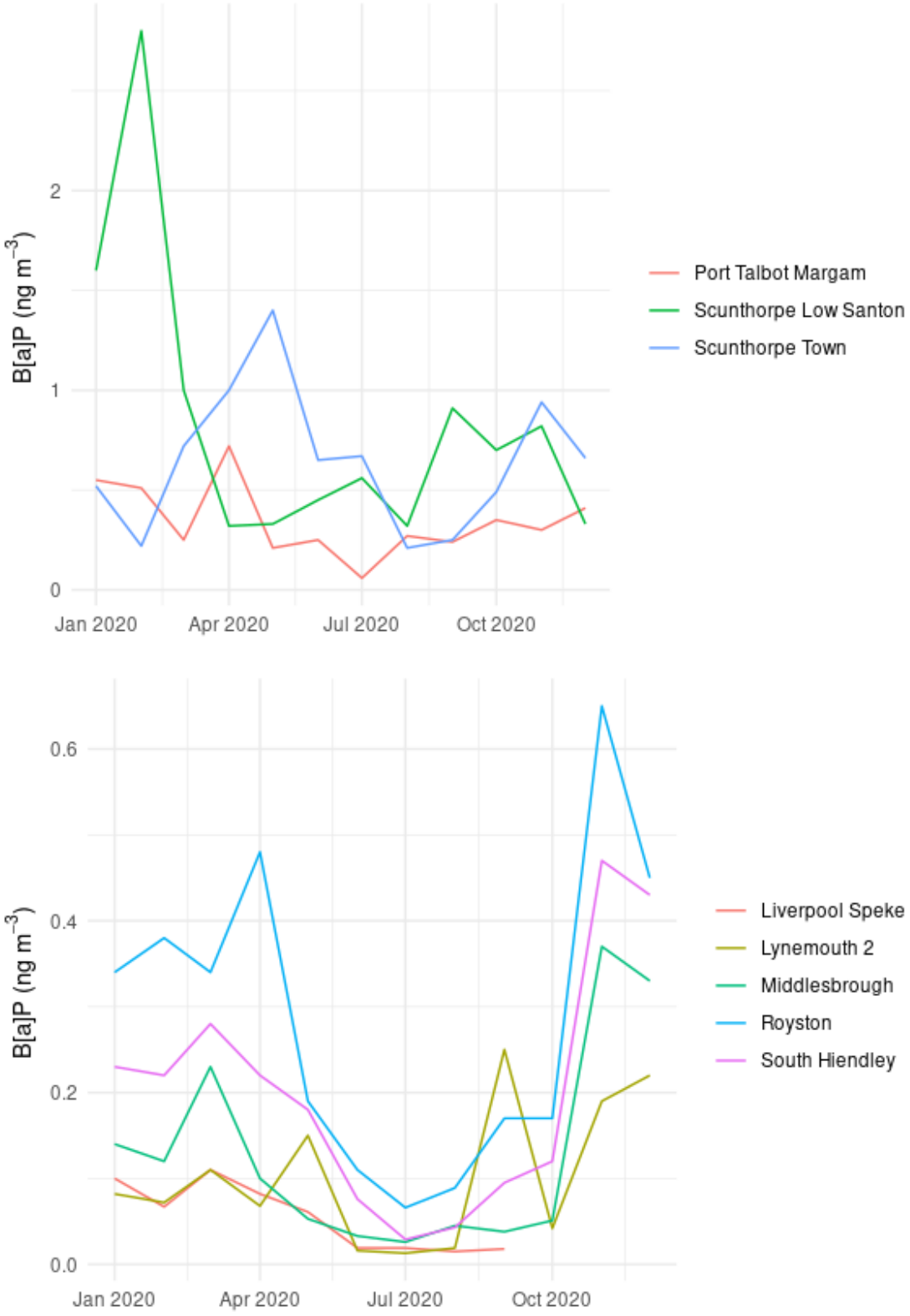


Figure 8: Monthly average B[a]P concentrations at operating industrial sites and those that are now closed in 2020.

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 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 industrial sites that do show seasonality are the sites where the local industrial PAH sources have closed. 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.

Three of the four sites with local industrial PAH sources, which were operating in November, have their highest monthly concentration of 2020 in November. Again this demonstrates the impact of the 'Guy Fawkes Night effect' on urban PAH concentrations.

In 2020, the Scunthorpe sites appear to have peaks in concentrations in February at Scunthorpe Low Santon (2.8 ng/m^3) and May at Scunthorpe Town (1.4 ng/m^3). On review of release data shared by the Scunthorpe steel works, it is apparent that the larger more significant releases occurred in February, March and May with the highest being February. The source of the releases are the coke ovens where to avoid serious over pressurisation, process safety pressure relief systems release unrefined coke oven (fuel) gas that is normally abated by designed flaring systems at multiple permitted stacks. Wind direction and speed at the time of release will have an influence on the impact of this on concentrations at the measurement sites being at fixed locations, nominally up-wind and down-wind, however this may also explain the elevations in February and May. It should be noted that the Scunthorpe Steel works came out of business liquidation and was purchased as a new legal entity on 9th March 2020.

3.2.5 GB urban traffic

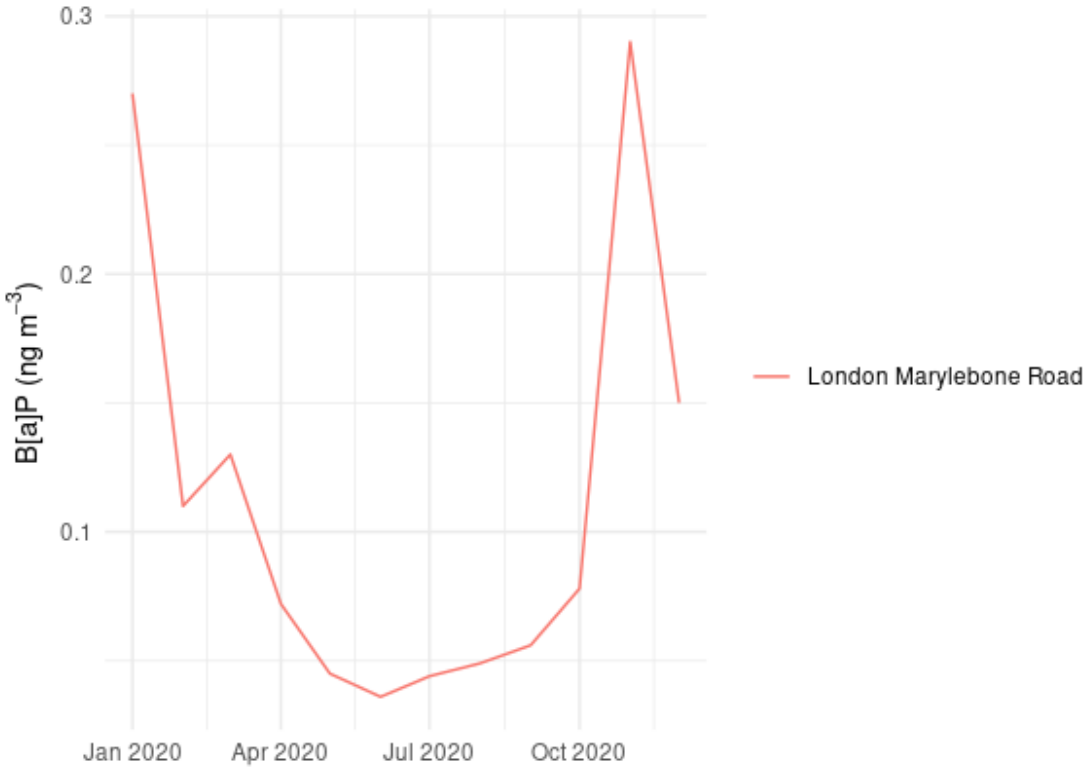


Figure 9: Monthly average B[a]P concentrations at the urban traffic site in GB in 2020.

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 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 2020 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

As detailed earlier in this report the Fourth Daughter Directive also specifies that six other PAHs should be monitored at a limited number of measurement stations. The PAH the directive refers to are benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*j*]fluoranthene, benzo[*k*]fluoranthene, indeno[*1,2,3-cd*]pyrene, and dibenz[*a,h*]anthracene. The CEN TC264 WG21 developed a Technical Specification for the measurement of these PAHs and benzo[*ghi*]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 Energy & Environment 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 elevations in concentrations at the industrial sites of Scunthorpe Town and Scunthorpe Low Santon give confidence in the recorded measurement of Benzo[*a*]pyrene as the concentration profile through the year is similar to that for Benzo[*a*]pyrene.

3.3.1 Benz[*a*]anthracene

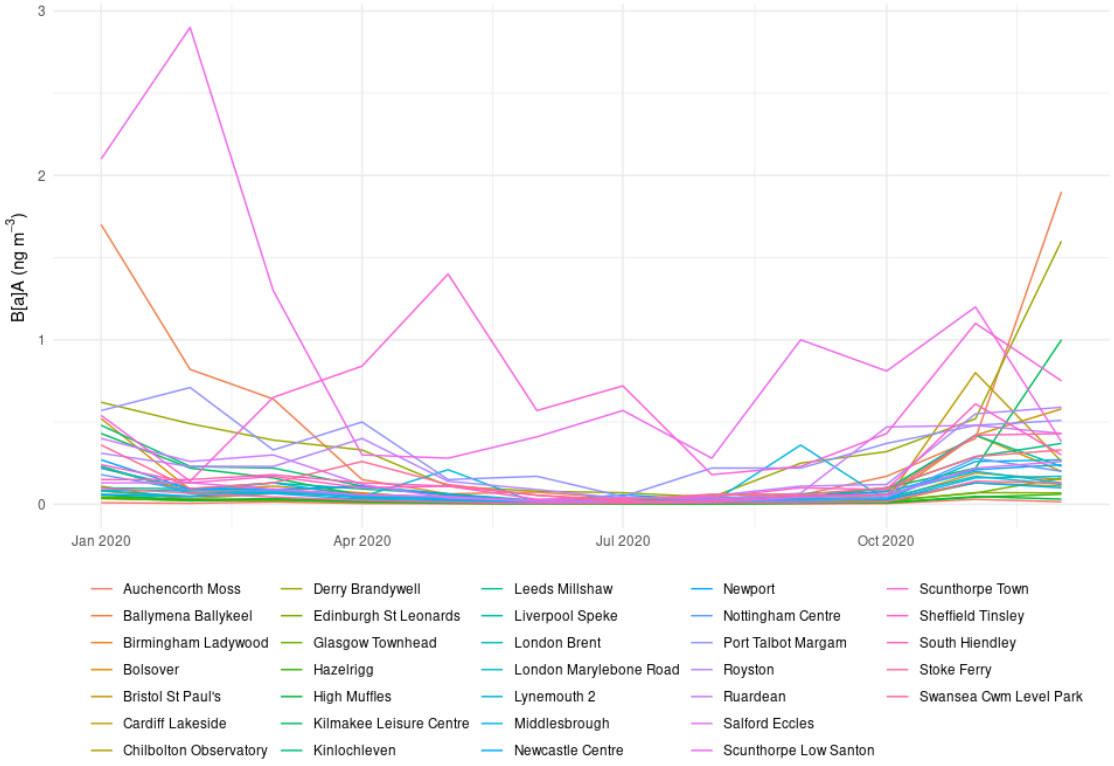


Figure 10: Monthly mean benz[a]anthracene concentrations at the UK PAH sites.

3.3.2 Benzo[*b*]fluoranthene

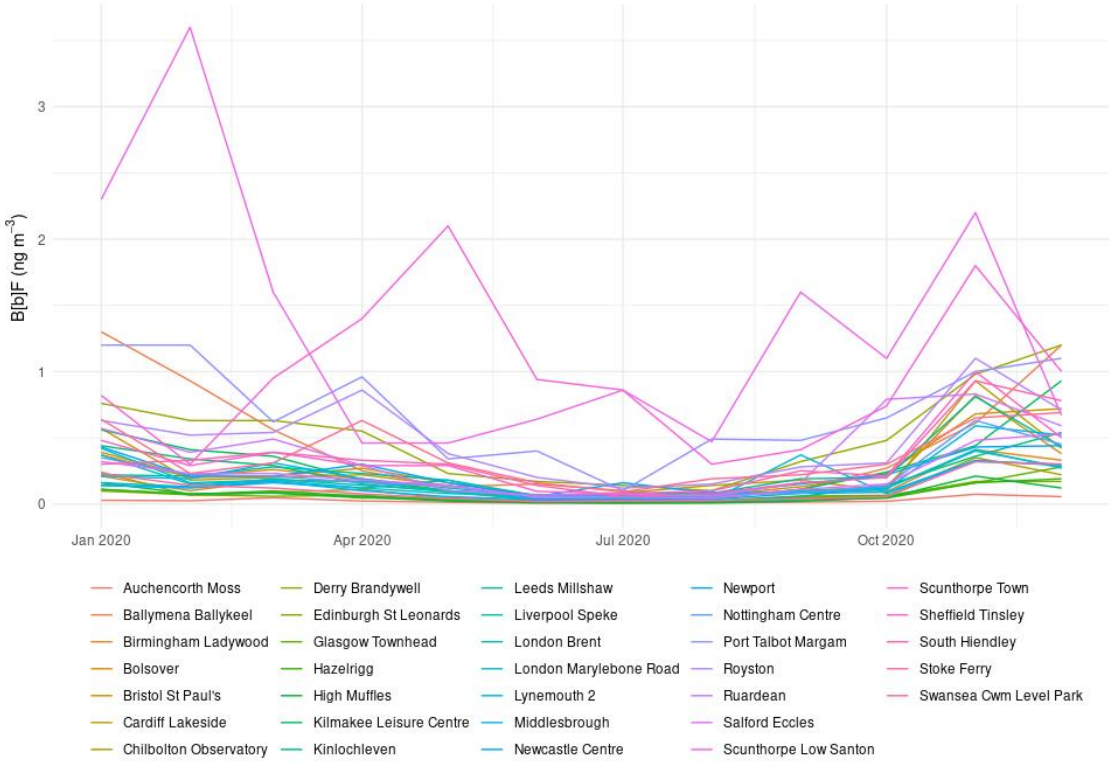


Figure 11: Monthly mean benz[b]fluoranthene concentrations at the UK PAH sites.

3.3.3 Benzo[*j*]fluoranthene

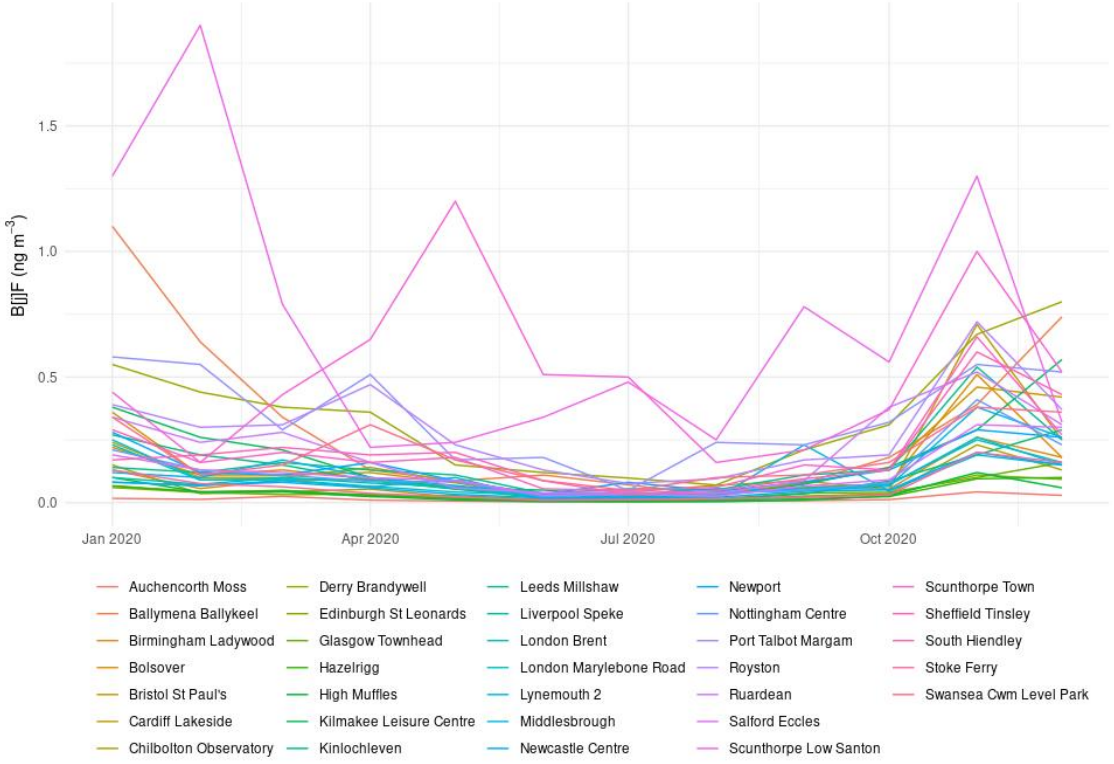


Figure 12: Monthly mean benzo[j]fluoranthene concentrations at the UK PAH sites.

3.3.4 Benzo[*k*]fluoranthene

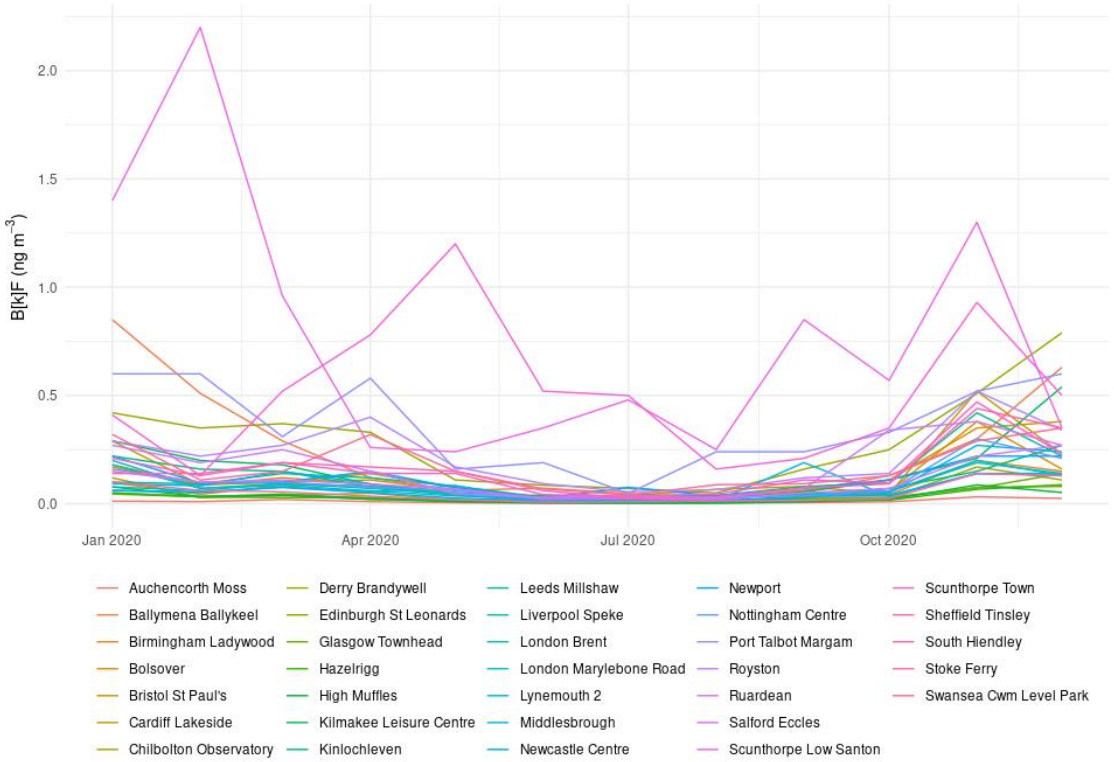


Figure 13: Monthly mean benzo[k]fluoranthene concentrations at the UK PAH sites.

3.3.5 Indeno[*1,2,3-cd*]pyrene

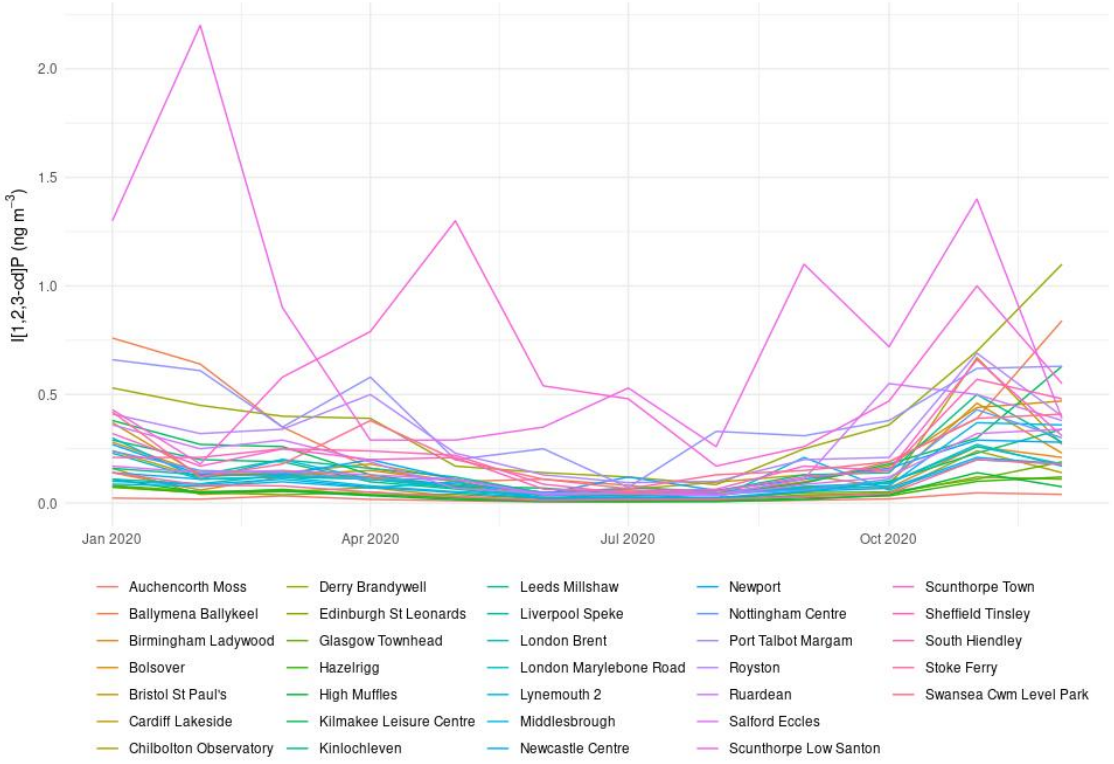


Figure 14: Monthly mean indeno[1,2,3-cd]pyrene concentrations at the UK PAH sites.

3.3.6 Dibenz[*ah*]anthracene

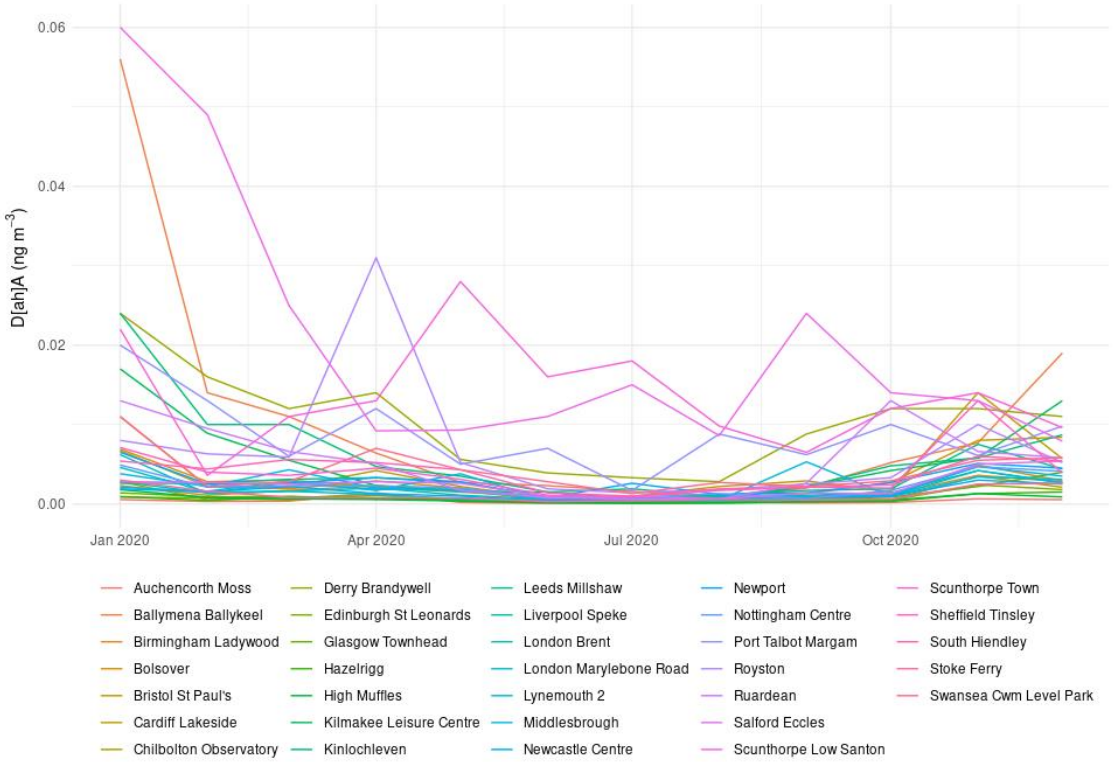


Figure 15: Monthly mean dibenz[a,h]anthracene concentrations at the UK PAH sites.

3.3.7 Benzo[*ghi*]perylene

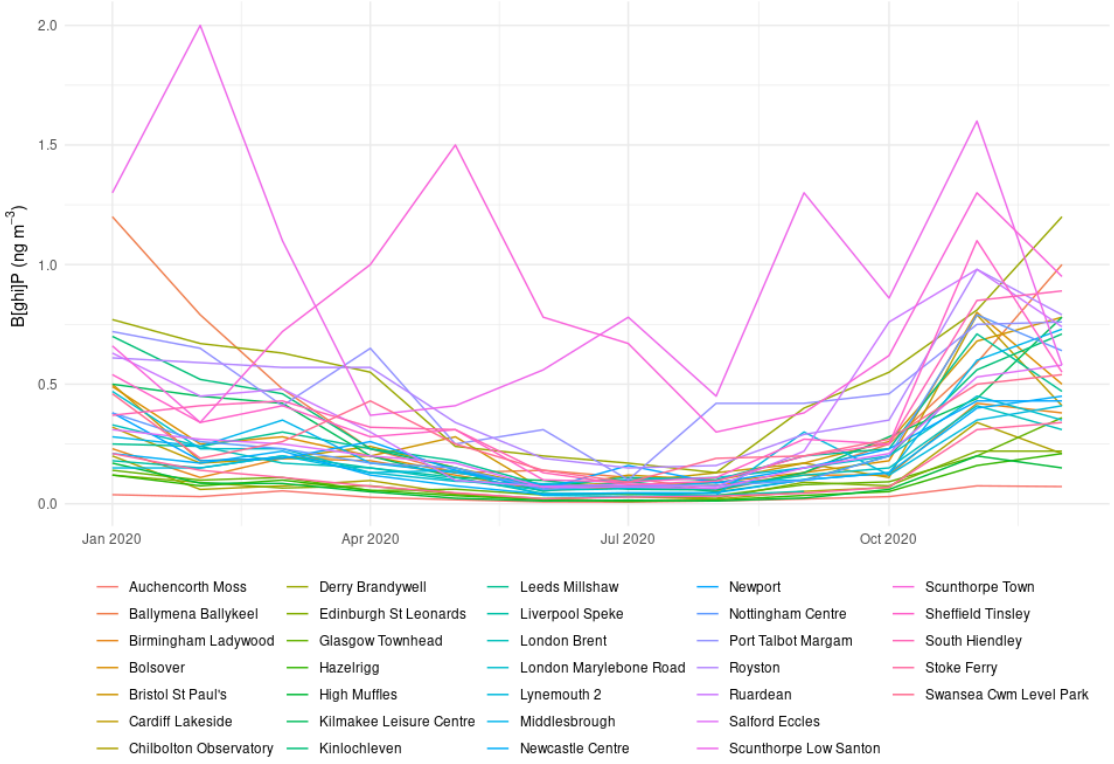


Figure 16: Monthly mean benzo[ghi]perylene concentrations at the UK PAH sites.

3.4 Depositon ('C') samples

The 4 weekly bulked samples of Benzo[*a*]pyrene 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. Whist the detection limits that TNO have are lower than the previous analytical laboratory the levels found are often within an order or magnitude of the Benzo[*a*]pyrene detection limit. There are not objectives or target values associated with the deposition measurements. However, the monitoring conducted at the two sites does enable the UK to meet its obligations under the Forth Daughter Directive. All deposition data is available on the UK-AIR website.

3.5 Long-term trends in B[*a*]P

Figure 17 - 21 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

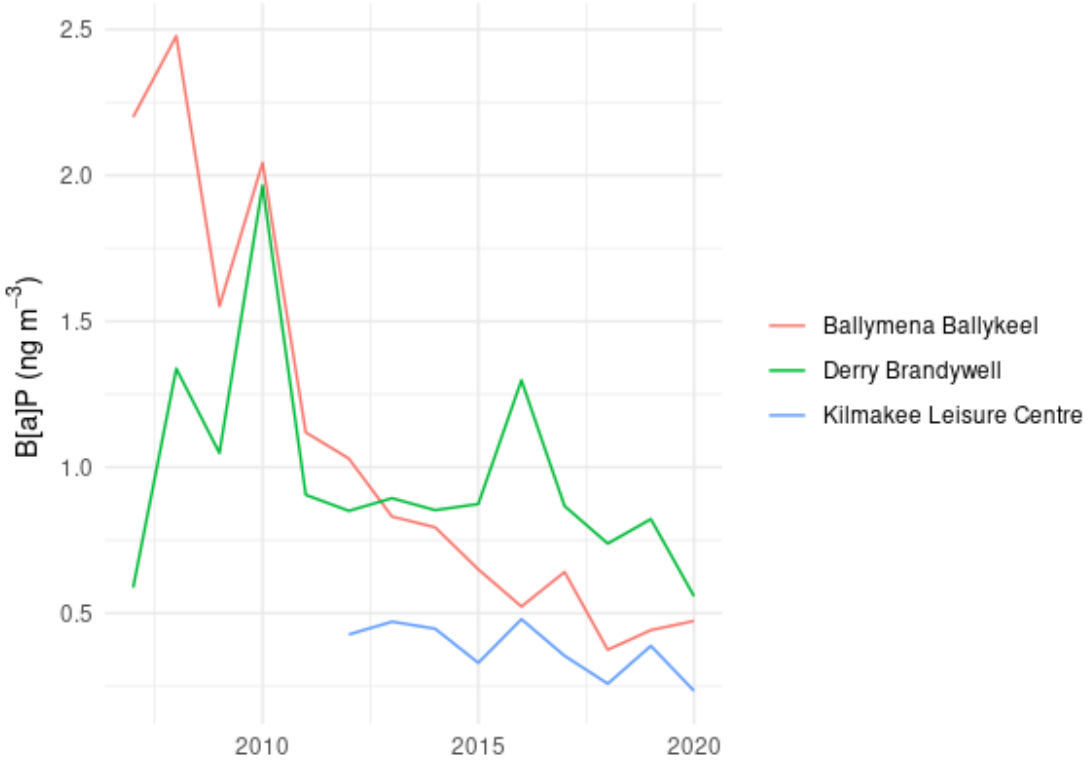


Figure 17: Annual average B[a]P concentrations at the Northern Ireland Network sites from 2007 to 2020.

Figure 17 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 Lisburn Kilmakee Leisure Centre sites does not appear to show a significant trend.

3.5.2 GB urban background

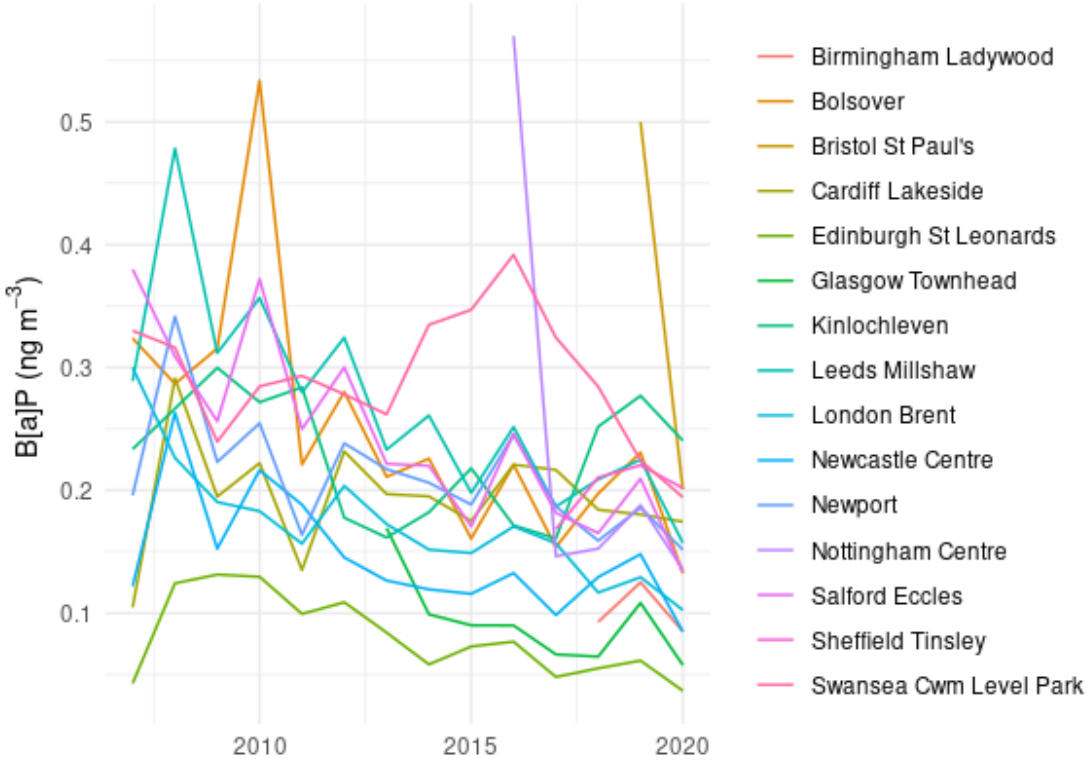


Figure 18: Annual average B[a]P concentrations at the Urban sites in Great Britain from 2007 to 2020.

There appears to be a general decreasing trends in concentrations at most urban background sites in Great Britain with the exception of Glasgow Townhead, Swansea and Cardiff Lakeside sites. The trends do not appear to be as significant as the ex-industrial sites where concentrations have dropped more significantly due to a major source being removed from the local area.

3.5.3 GB rural background

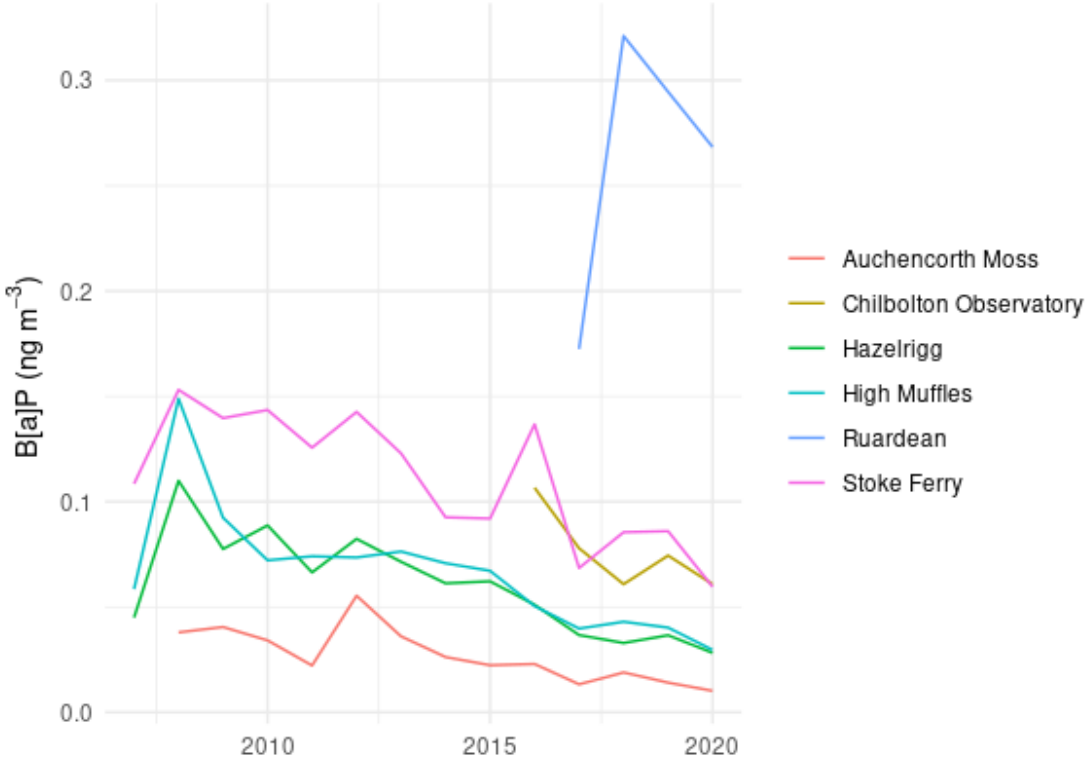


Figure 19: Annual average B[a]P concentrations at the Rural sites in Great Britain from 2007 to 2020.

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, this is to be expected.

3.5.4 GB industrial

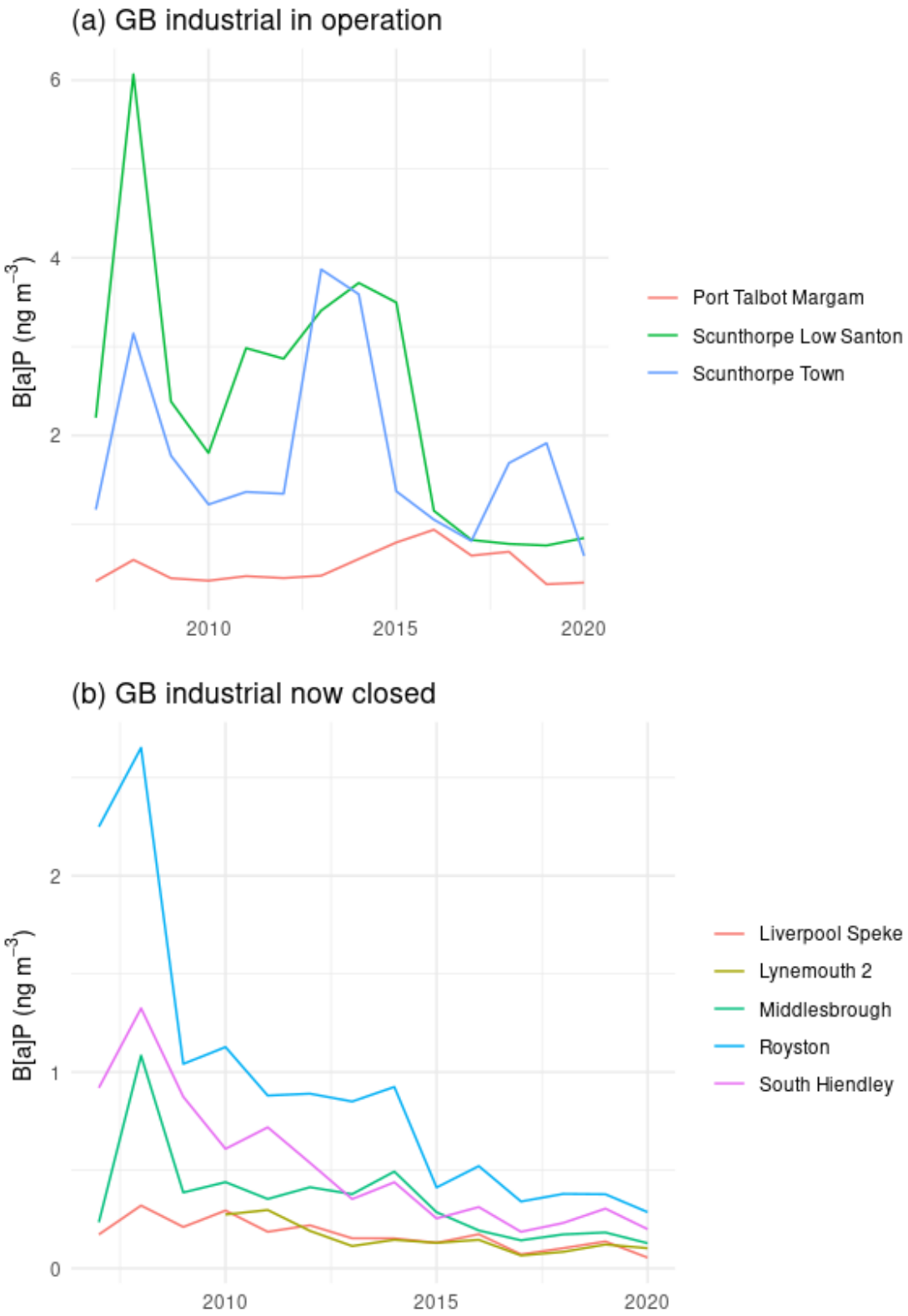


Figure 20: Annual mean B[a]P concentrations at operating industrial sites and those that are now closed from 2007 to 2020.

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 EU 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 2020 being 0.64 ng/m^3 and 0.84 ng/m^3 respectively.

The only Port Talbot site, Port Talbot Margam does not show any obvious trend in B[*a*]P concentration since. The site has not exceeded the EU 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 lower than those seen at the Scunthorpe sites in 2020. The annual average concentration of 0.34 ng/m^3 at Port Talbot in 2020 which is almost identical to the annual mean recorded in 2019. The concentration measured at the sites 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

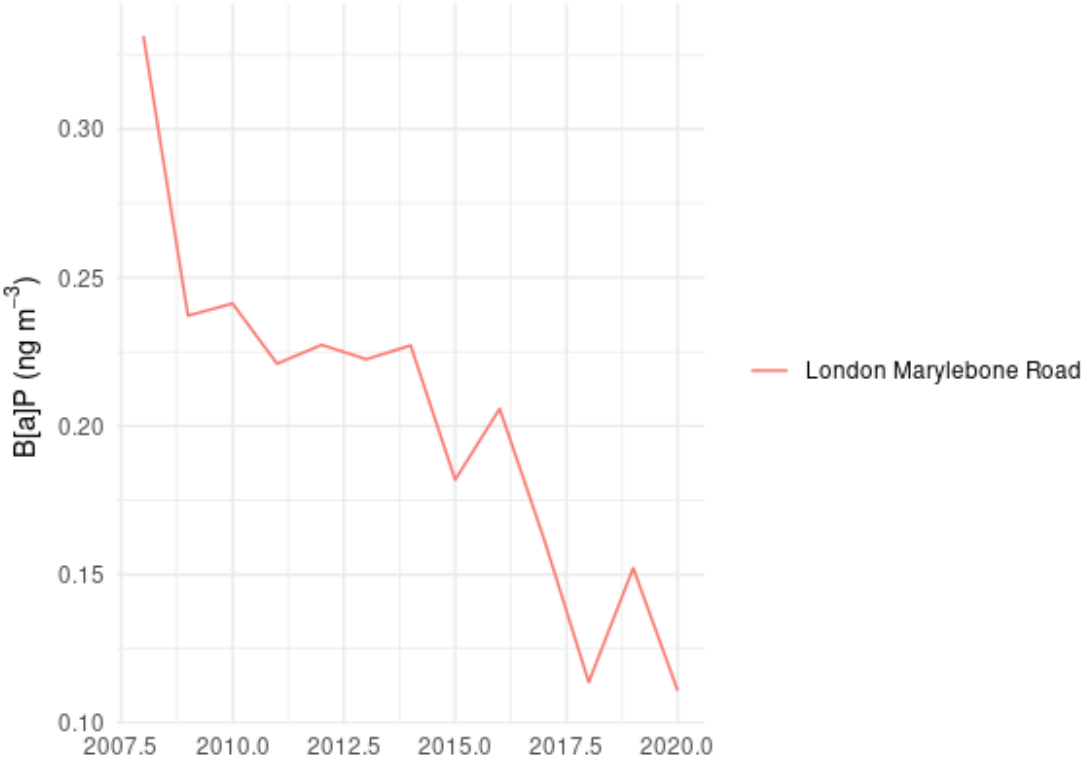


Figure 21: Annual average B[a]P concentrations at the London Marylebone Road site from 2007 to 2020.

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 each at each monitoring site, the slope of the trend for each site was calculated using TheilSen function in the openair R package (Figure 22). 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 22 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, Chilbolton, Nottingham and Ruardean.

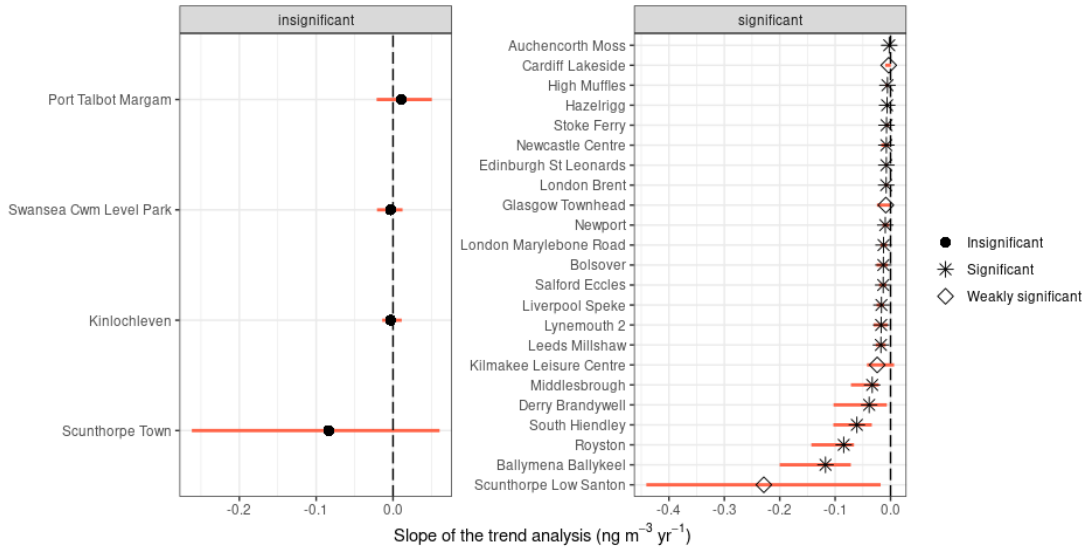


Figure 22: B[a]P concentration trend (ng m^{-3} yr^{-1}) from 2008 to 2020.

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/Londondery 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 of the operational sites throughout the whole of 2020 was lower than in previous year at 93%. This was due to two sites having electrical work carried out and the Environment Agency and Defra requesting that a proportion of the filters be retained for a university study.

The annual mean Benzo[*a*]pyrene concentrations observed at the UK networks during 2020 continued to vary greatly between sites with highest concentrations at the industrial sites and urban sites in Northern Ireland.
In 2020 the highest annual mean was observed at the Scunthorpe Low Santon site with an annual mean B[*a*]P concentration of 0.84 ng/m^3 and the lowest concentration continued to be measured at the Auchencorth Moss site 0.01 ng/m^3.
In 2020 all measurement sites were below EC target value for B[*a*]P (annual mean concentration of 1 ng/m^3). However seven sites exceeding the UK Air Quality Objective for B[*a*]P (annual mean concentration of 0.25 ng/m^3). These were Scunthorpe Low Santon, Scunthorpe Town, Derry/Londonderry Brandywell, Ballymena Ballykeel, Port Talbot Margam, Royston and Ruardean.

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Appendices

Appendix 1 PAH Deposition Data
Appendix 2 TNO PAH 2020 Analysis

Appendix 1 PAH Deposition Data

Table A1: PAH deposition for B[a]P in 2020.

Station name	Start date	End date	Measurement (ng/m^2/day)
Auchencorth Moss	02/01/2020	29/01/2020	4.1
Auchencorth Moss	29/01/2020	26/02/2020	4.0
Auchencorth Moss	26/02/2020	25/03/2020	3.6
Auchencorth Moss	25/03/2020	22/04/2020	7.1
Auchencorth Moss	22/04/2020	20/05/2020	10.0
Auchencorth Moss	20/05/2020	17/06/2020	3.8
Auchencorth Moss	17/06/2020	15/07/2020	4.4
Auchencorth Moss	15/07/2020	12/08/2020	8.0
Auchencorth Moss	12/08/2020	09/09/2020	4.2
Auchencorth Moss	09/09/2020	07/10/2020	7.7
Auchencorth Moss	07/10/2020	04/11/2020	4.3
Auchencorth Moss	04/11/2020	02/12/2020	3.7
Auchencorth Moss	02/12/2020	30/12/2020	5.1
Chilbolton Observatory	31/12/2019	29/01/2020	4.0
Chilbolton Observatory	29/01/2020	26/02/2020	11.0
Chilbolton Observatory	26/02/2020	25/03/2020	10.0
Chilbolton Observatory	25/03/2020	22/04/2020	27.0
Chilbolton Observatory	22/04/2020	20/05/2020	12.0
Chilbolton Observatory	20/05/2020	17/06/2020	16.0
Chilbolton Observatory	17/06/2020	15/07/2020	12.0
Chilbolton Observatory	15/07/2020	12/08/2020	35.0
Chilbolton Observatory	12/08/2020	09/09/2020	5.8
Chilbolton Observatory	09/09/2020	07/10/2020	27.0
Chilbolton Observatory	07/10/2020	31/10/2020	10.0
Chilbolton Observatory	31/10/2020	02/12/2020	7.0
Chilbolton Observatory	02/12/2020	30/12/2020	6.2

Appendix 2 TNO PAH 2020 Analysis

TNO were the chosen analytical laboratory for the UK PAH network from May 2019 analysis forward. TNO are an ISO 17025 accredited laboratory for the analysis of PAH in the samples from the PAH network. The procedure used to measure PAH in ambient air sampled on filters and deposition samples is Gas chromatography mass spectrometry (GC/MS). The performance of this method is validated in accordance with internationally recognised procedures and meet the requirement for PAH analysis detailed in the standards for the measurement of PAH in ambient air and deposition (EN15549:2008 and EN15980:2011 respectively).

TNO undertake national PAH analysis in the Netherlands and take part in international inter-comparisons including those run annually by INERIS (the French National Institute for Industrial Environment and Risks).
PAH and typical detection limits for the analysis in the PAH network are presented in Table A2 below.

Table A2: PAH analysed by TNO in Deposition and particulate samples and their typical detection limits.

		Deposition samples	Particulate samples
PAH	ISO 17025 accredited	Typical LOD ng/m^2/day	Typical LOD ng/m^3
Benzo(a)antracene	Yes	0.19 to 0.26	0.00004 to 0.00056
Cyclopenta(c,d)pyrene	No	0.28 to 0.38	0.00004 to 0.00056
Chrysene	Yes	0.20 to 0.26	0.00004 to 0.00056
5-methylchrysene	No	0.34 to 0.47	0.00004 to 0.00056
Benzo(b)fluorantene	Yes	0.22 to 0.28	0.00004 to 0.00056
Benzo(k)fluorantene	Yes	0.23 to 0.30	0.00004 to 0.00056
Benzo(j)fluorantene	No	0.24 to 0.31	0.00004 to 0.00056
Benzo(e)pyrene	No	0.23 to 0.30	0.00004 to 0.00056
Benzo(a)pyrene	Yes	0.23 to 0.32	0.00004 to 0.00056
Indeno(123-cd)pyrene	Yes	0.18 to 0.27	0.00004 to 0.00056
Dibenzo(ah)antracene	Yes	0.27 to 0.37	0.00004 to 0.00056
Denzo(ghi)perylene	Yes	0.27 to 0.37	0.00004 to 0.00056
Dibenzo(al)pyrene	No	0.46 to 0.59	0.00004 to 0.00056
Dibenzo(ae)pyrene	No	0.41 to 0.52	0.00004 to 0.00056
Denzo(ai)pyrene	No	0.81 to 1.23	0.00004 to 0.00056
Dibenzo(ah)pyrene	No	0.57 to 0.87	0.00004 to 0.00056

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