AEAT/ENV/R/1861

Assessment of benzo[a]pyrene concentrations in the United Kingdom in the period 2003-2020

Report to the Department for Environment, Food and Rural Affairs, Welsh Assembly Government, the Scottish Executive, and the Department of the Environment for Northern Ireland

Keith Vincent

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Executive Summary

This is the second national scale assessment of benzo[a]pyrene (BaP) in the United Kingdom. The first assessment aimed to inform the development of a possible National Air Quality Strategy objective for benzo[a]pyrene (Coleman *et al.*, 2001). At that time the Expert Panel on Air Quality Standards had already recommended a guideline concentration (0.25 ng m^{-3} as an annual average) for BaP as a marker for the health effects of polyaromatic hydrocarbons. Since then the United Kingdom Government and the Devolved Administrations have adopted a 0.25 ng m^{-3} concentration value as the air quality standard for BaP to be achieved by 2010. The Forth Air Quality Daughter Directive sets a target value to be attained by the end of 2012 of 1 ng m^{-3}.

In 2003, total UK emissions were about 9.2 tonnes with about 5 % of the total arising from point sources. The remaining emissions were from area sources - domestic space heating (29 %), waste treatment and disposal (22 %) and natural fires (33 %) being the principle sources. As reported in the first national assessment, the emission inventory for BaP is subject to considerable uncertainty. This is since few emission measurements have been made both nationally and internationally and the relevant activity statistics in some cases are not collected regularly.

There has been a significant increase in the number of monitoring stations measuring BaP concentrations – there are now twenty-four sampling sites. This increase is required as the United Kingdom prepares for the monitoring requirements of the Fourth Daughter Directive. BaP concentrations in 2003 ranged from 0.04 ng m^{-3} at the semi-rural site at Hazelrigg in Lancashire to 1.26 ng m^{-3} at an industrial monitoring site at Scunthorpe.

The modelling method can predict the measured concentrations, at all but one site, according to the data quality modelling objectives of ± 60 %.

Nationally the number of people exposed to the air quality objective concentration of 0.25 ng m^{-3} decreased from 2.4 million in 2003 to 1.6 million by 2010. Between 2010 and 2020 the population exposed to more than 0.25 ng m^{-3} is predicted to decrease marginally. For the target value of 1.0 ng m^{-3} the proportional decrease is even larger- from 17000 exposed in 2003 to 5000 in 2010. However after then as BAT will be fully implemented at the site of concern no further decrease in the population exposed is predicted.

Contents

1 Introduction

This is the second national scale assessment of benzo[a]pyrene (BaP) in the United Kingdom. The first assessment aimed to inform the development of a possible National Air Quality Strategy objective for benzo[a]pyrene (Coleman *et al.*¸ 2001). At that time the Expert Panel on Air Quality Standards had already recommended an air quality standard of 0.25 ng m^{-3} as an annual average for BaP as a marker for the health effects of polyaromatic hydrocarbons.

Since then the fourth Air Quality Daughter Directive (2004/107/EC) has set a target value of 1.0 ng m^{-3} to be met, where possible, by 31 December 2012 with lower and upper assessment thresholds of 0.4 ng m^{-3} and 0.6 ng m^{-3}, respectively. The United Kingdom Government and the Devolved Administrations have adopted the 0.25 ng m^{-3} concentration value as an objective for BaP to be achieved by 2010.

The previous assessment highlighted a number of shortcomings in the national emission inventory for BaP – particularly for emissions from the domestic sector in Northern Ireland. A new "bottom up" approach was consequently adopted for the domestic inventory in Northern Ireland (Pye and Vincent, 2003 and Vincent *et al.,* 2003).

There has been a significant increase in the number of monitoring stations measuring BaP concentrations – there are now twenty-four. This increase is required to support the assessment of BaP concentrations in air as required as part of the Fourth Daughter Directive. Further increases are planned.

This report will describe the modelling work undertaken to produce concentration maps in the United Kingdom for 2003, 2010, 2015 and 2020. It is comprised of the following sections.

- Description of BaP emission sources (Section 2)
- Review of monitored BaP concentrations (Section 3)
- The modelling method (Section 4)
- Model results – model validation and maps (Sections 5 and 6)
- Population exposures (Section 7).
- Uncertainty (Section 8)

2 Emissions

2.1 PAST EMISSION TRENDS

BaP emissions obtained from the National Atmospheric Emissions Inventory (NAEI) are provided according to Standard Nomenclature for Air Pollutants format (SNAP sectors). Figure 2.1 shows the BaP emissions from each SNAP sector for the years 1990 to 2002. The rate of decrease of total BaP emissions remained high until about 1996 reflecting the changes in industrial pollution control resulting from the implementation of the Integrated Pollution Control (IPC) regime, changes in industrial activity and alterations in fuel choice for domestic space heating. After then the rate of emission decrease slowed but driven by similar factors.

The largest decrease in emissions occurred between 1992 and 1993 when BaP emissions from the Agriculture category (SNAP Sector 10) decreased from 18 tonnes in 1992 to 0.4 tonnes in 1993. This resulted from the ban on stubble burning that came into force in England Wales in April 1993. Since 1994 emissions from this sector have been reported as zero. Substantial decreases were also observed for the process sector.

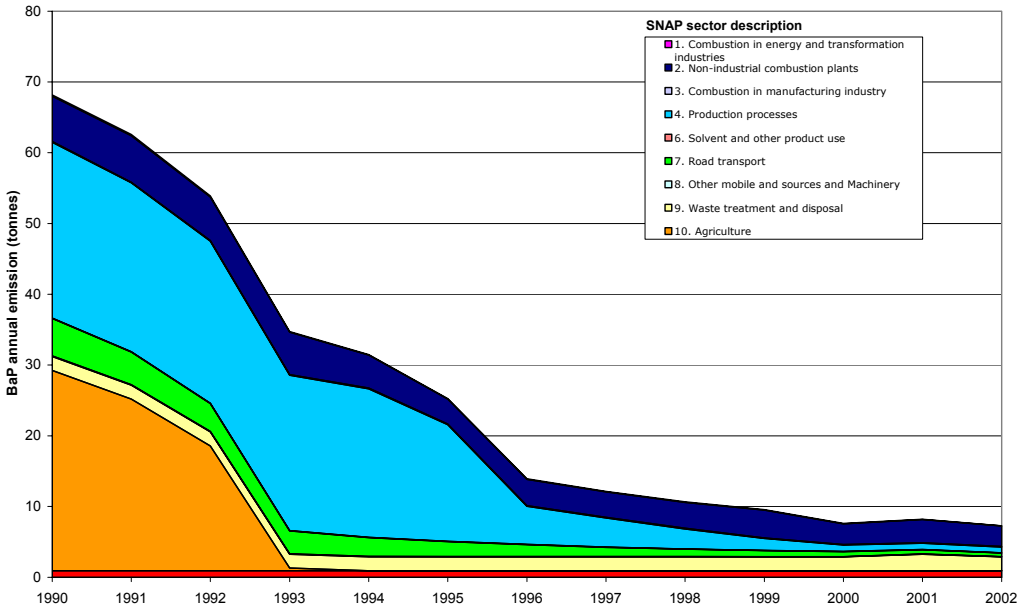


Figure 2.1 Emissions of BAP from each of the SNAP emission sectors – 1990 to 2002

The modelling for this work used the 2002 NAEI. Each year as part of the review cycle changes are made both through the addition of a further year and through revisions of emissions of past years. The NAEI estimates made for 2002 in the 2002 inventory will be different from those made for 2002 in the 2003 inventory.

2.2 EMISSION PROJECTIONS

In order to model future concentrations estimates of future emissions were made based on existing emission factors, the likely trends in activity in industrial sectors often derived from Department of Trade and Industry energy demand forecasts and possible trends in emission control which may influence emission factors estimates were made of future emissions for 2005, 2010, 2015 and 2020.

The emissions projections for BaP are consistent with the economic assumptions that were used in deriving emission projections for other pollutants such as sulphur dioxide and oxides of nitrogen.

2.3 EMISSION SOURCE SECTORS AND REGIONAL VARIATIONS

In 2002, emissions from the other sources and sinks sector (SNAP sector 11) was the largest emission sector contributing about 29 % to the UK total. The sources included in this total include natural fires in forests and on moorland. The next largest source was the non-industrial combustion plants (SNAP sector 02) with about 29% of the national

total. This consists principally of the estimates of emissions from domestic wood and coal combustion together with emissions from office and commercial heating systems. The next largest source group is "Waste treatment and disposal"(SNAP Sector 9) with about 22 % of the national total; this grouping includes principally the emissions from small scale burning of waste domestically, commercially and in agriculture which when carried out poorly can lead to very significant emissions.

Emissions from road transport and industrial processes both contributed about 7 % to the national total. The remaining source sectors are relatively insignificant – each contributing less than 1% of the total.

Table 2.1 presents UK total emissions of BaP for 2002 along with projections to 2020. Table 2.2 presents the reported BaP emissions by SNAP code for 2002 (Column 3). Also presented are total emissions provided for each of the Arcinfo 1 km x 1 km emission grids used in the area source modelling (see Section 4.1.1). Emissions were modelled for 2003, 2010, 2015 and 2020. Emissions for 2003 were obtained by linearly interpolating the 2002 and 2005 projected totals.

Table 2.1 Projected emission totals for 2002 to 2020 (kg per year).

Year	2002	2005	2010	2015	2020
Emission	9255	8026	7615	7668	8138

However the national total emissions were not used directly for the modelling as some industrial point sources do not significantly influence annual average ground level concentrations as a result of the height at which they are discharge then the PAH concentrations which were actually modelled were reduced to exclude certain point sources. Details of the emissions which were used for modelling are given in the final columns of Table 2.2. There was also an error in the reported NAEI BaP emissions for 2002, which lead to double counting of the emissions from open fires. This was corrected by removing the double counting. This reduced emissions from other sources and sinks by 1962kg.

Due to the large domestic consumption of solid fuel in Northern Ireland - the domestic sector (SNAP 02) is the dominant emission sector. Table 2.3 compares the area emission grids by SNAP sector in Northern Ireland and Great Britain.

Table 2.2 Projected emissions used for modelling from 2003 to 2020 (kg per year).

SNAP Code	Source description	Reported 2002 inventory (kg)	Modelled emissions (kg)				
			2002	2003[1]	2010	2015	2020
01	Combustion in industrial	48	7	7	9	9	9
02	Non-industrial combustion plants	2897	2896	2582	1624	1714	1714
03	Combustion in manufacturing	64	19	20	23	23	23
04	Production processes	826	54	50	45	45	45
06	Solvent and other product use	40	40	42	44	41	38
07	Road transport	509	509	426	245	204	196
08	Other mobile sources	29	29	29	29	29	29
09	Waste treatment and disposal	1962	1962	1962	1962	1962	1962
11	Other sources and sinks	2880[2]	918	918	918	918	918
	Emission from area sources		6434	6038	4899	6038	4899
	Modelled point sources		-	470[3]	417[3]	417[3]	417[3]
	Point sources not modelled		-	6[4]	6[4]	6[4]	6[4]
	Emission total	9255	-	6514	5316	5362	5351

[1] The 2003 projections were obtained by linear interpolating the 2002 to 2005 emission totals
[2] The emission reported for 2002 has been revised for the purposes of modelling to 918 kg for the naturally occurring fire sector.
[3] The emission amounts from each individual source are presented in Annex 1.
These are the 2003 emission amounts as provided in the Environment Agency's Pollution Inventory.
[4] These 6 kg of BaP emissions include emissions from the following sources Hope Works (Sheffield), Cottam and Didcot power stations and the Austerfield works (Doncaster). The BaP emissions from the power stations are expected to make a very insignificant contribution to ambient BaP concentrations. Data regarding the emission source at Austerfield works (Doncaster) will be used for the next review of BaP concentrations in 2006.

Table 2.3 A comparison of emissions for each of the area source sectors in Great Britain and Northern Ireland (2002).

SNAP code	Source description	Great Britain		Northern Ireland	
		BAP emission (kg)	Percentage of GB area emission	BAP emission (kg)	Percentage of NI area emission
01	Combustion in industrial	7	0.1%	0	0.0%
02	Non-industrial combustion plants (**Domestic Home heating**)	2282	40.0%	611	88.1%
03	Combustion in manufacturing	18	0.3%	1	0.1%
04	Production processes	52	0.9%	0	0.1%
06	Solvent and other product use	38	0.7%	2	0.3%
07	Road transport	492	8.6%	15	2.1%
08	Other mobile sources	26	0.5%	1	0.2%
09	Waste treatment and disposal (**Waste fires**)	1921	33.7%	39	5.6%
11	Other sources and sinks (**Natural fires**)	863	15.1%	25	3.6%
	Total	5699	100.0%	694	100.0%

3 Monitoring BaP concentrations

Monitoring of BaP concentrations has taken place at Hazelrigg, London, Middlesbrough and Manchester since the early 1990's. Since then there has been a significant reduction in concentrations at all sites. Figure 3.1 shows how the concentrations trends at Hazelrigg and London have generally decreased in line with the total national BaP emissions. Concentrations at the other two sites have not shown the same steady decline in concentration. For example, the peaks in concentration observed at Manchester in 1994 and 1997 and at Middlesbrough in 1996 and 1997 probably resulted from unknown local sources.

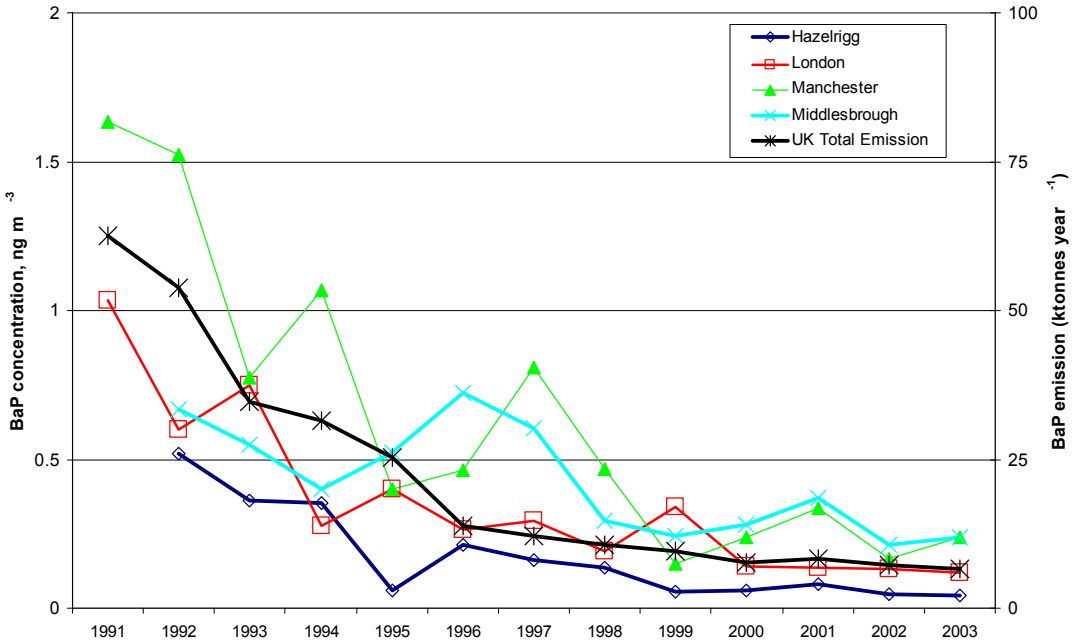


Figure 3.1 A figure showing the decline in national BAP emissions and the associated decline in BAP concentrations at the four longest running monitoring stations.

A detailed review of the pollutants measured in the polycyclic aromatic hydrocarbon network from 2000 to 2003 is provided by Coleman *et al.*, (2004). To aid the discussion in this work, current and historic mean concentrations are presented in Table 3.1. The table shows that concentrations tend to be highest closest to integrated steel works and at the Lisburn site where very local domestic emissions contribute to the high concentrations measured. In 2003, concentrations in large urban conurbations, such as Belfast and Glasgow exhibit concentrations as low as those measured in rural areas such as Stoke Ferry.

Table 3.1 Annual mean benzo[a]pyrene concentrations (ng m^{-3}) measured at all sites (former and current) within the UK polycyclic aromatic hydrocarbon monitoring network.

	Site	Site Type	Year														
			1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005*
1	Ashington	Urb-Industrial									0.20	0.17	0.20	0.15†[3]	0.19	0.15	0.16
2	Belfast	Urban											0.37	0.13	0.08	0.15	0.15
3	Birmingham 1	Urban											0.16	0.13	0.16	-	
4	Birmingham 2	Urban														0.14†[5]	0.11
5	Bolsover	Ex-Industrial									0.24	0.25	0.28	0.24	0.46	0.22	0.20
6	Brent	Urban												0.18†[2]	0.14	0.095	0.084
7	Bromley	Urban-Traffic											0.21†[3]	0.25	0.21	0.19	0.16
8	Cardiff 1	Urban	2.23†[3]	1.23†[3]	0.35†[2]											-	
9	Cardiff 2	Urban													0.12†[3]	0.069	0.074
10	Edinburgh	Urban													0.05[2]	0.035	0.035
11	Glasgow	Urban									0.20†[3]	0.12	0.12	0.12	0.06	0.071	0.068
12	Hazelrigg	Rural		0.52†[1]	0.36	0.35	0.06	0.21	0.16	0.14	0.06	0.06	0.08	0.05	0.04	<0.02	0.01
13	High Muffles	Rural							0.14	0.09	0.06	0.04	0.05	0.04	0.05	<0.026	0.011
14	Holyhead	Urb-Industrial									0.11	0.11	0.15	0.18†[3]	0.14	-	
15	Hove	Urban												0.18†[1]	0.10	0.094	0.086
16	Kinlochleven	Ex-Industrial									6.78	2.28	0.34	0.38	0.21	0.32	0.23
17	Leeds 1	Urban											0.16	0.18	0.21	-	
18	Leeds 2	Urban														0.13†[5]	0.13
19	Lisburn	Urban									0.74†[3]	0.93	0.96	0.66	0.95	0.62	0.33
20	London 1	Urban	1.03†[3]	0.60	0.75†[3]	0.28	0.40	0.27	0.29	0.19†[1]						-	
21	London 2a	Urban								0.27†[2]	0.34	0.14	0.14	0.13	0.12	<0.076	0.014
22	Manchester	Rban	1.63†[3]	1.53	0.78	1.07†[3]	0.40	0.47	0.81	0.47	0.15	0.24	0.34	0.17	0.24	0.11	0.036
23	Middlesbrough	Urban		0.67†[3]	0.55	0.40	0.53	0.73	0.60	0.30	0.24	0.28	0.37	0.21	0.24	0.14	0.14
24	Newcastle	Urban											0.11	0.12	0.16	0.064	0.059
25	Newport	Ex-Industrial									0.23	0.35	0.36	0.19	0.11	0.10	0.089
26	Port Talbot	Industrial									0.24	0.59	0.40	0.34	0.47	0.29	0.25
27	Scunthorpe	Industrial									0.37	1.18	0.34	1.35	1.26	-	
28	Scunthorpe 2	Industrial														0.69†[4]	0.75
29	Speke	Urban											0.08†[3]	0.14	0.14	0.10	0.098
30	Stevenage	Urban	0.60†[3]	0.70†[1]												-	
31	Stoke Ferry	Rural							0.14	0.18	0.11	0.09	0.09	0.08	0.08	<0.043	0.034

Notes: The result rounded to two significant figures

†[1] based on two quarters. †[2] based on two quarters. †[3] based on three quarters , †[4] based on Q1 Scunthorpe 1 and Q2, Q3 and Q4 for Scunthorpe 2 due to limited data capture at Scunthorpe 2 due to timing of site move, †[5] based on Q1 and Q2 from site 1and Q3 and Q4 from Site 2

*** based on Q1 and Q2**

4 Concentration modelling

4.1.1 Area source modelling

The NETCEN area source model has been used previously to predict annual sulphur dioxide and BaP concentrations (Abbott and Vincent, 1999 and Coleman *et al.,* 2001). The current NETCEN area source model incorporates results from the dispersion model, ADMS-3 and calculates the annual average contribution from area sources on a 1 km receptor grid covering the country. To take account of contributions at each receptor from sources at distances greater than 15 km in the north-south or east-west directions a rural background concentration of 0.05 ng m^{-3} was added (see Section 5). Wet and dry deposition were ignored on the basis of that they were shown to be insignificant in sensitivity studies (Abbott and Vincent, 2001). The emissions from each square for both industrial and domestic were assumed to be uniformly distributed throughout the square at an initial height of 10 m: i.e., each 1 km square was represented by an emitting volume 1 km $\times$ 1 km $\times$ 10 m high. The estimate of 10 m is based on the height of a typical house and assumes that emissions will be entrained in the building wake.

4.1.2 Point source modelling

BaP emissions from "point" sources are either fugitive, in the case of coking plants, or from clearly defined stacks for the other sources. The emission amount is derived from either a direct measurement or by emission factors. For this current BaP modelling assessment, emissions and their characteristics were obtained directly from the 2003 Pollution Inventory. The release parameters required for the dispersion modelling process are shown in Annex 1. The dispersion of the BaP emission was modelled using the dispersion model ADMS 3.2.

4.1.3 Meteorological data

In the previous national assessment of BaP concentrations (Coleman *et al.,* 2001) the United Kingdom was divided into 14 geographical regions with a characteristic meteorological data set applied to each region. For this current assessment concentrations are predicted using a much small number of meteorological data sets (Table 4.1). This is because the largest uncertainty in the modelling process is associated with the emissions in the area source- particularly for fires in the urban environment (SNAP code 9) and a more sophisticated treatment of the meteorological input is unlikely to significantly improve the model prediction. Also where each of the 14 different geographical areas met significant discontinuities in the concentration field were obtained- such discontinuities are not obtained when single meteorological data sets are used to model emissions in Great Britain and Northern Ireland.

Table 4.1 Meteorological data used to model BaP concentrations

Source category and SNAP sectors	Geographical Area	
	Great Britain	Northern Ireland
Area Sources	Heathrow Sequential 2003. Constant emission rate	Aldegrove 10 year Statistical 1987 to 1996 Constant emission rate
Point sources	Waddington 2003 sequential. Constant emission rate	There are no BaP point sources in Northern Ireland

5 Prediction of BAP concentrations in 2003 and 2010, 2015 and 2020

Concentrations from the area and point source were combined within a geographical information system and a background concentration value added. The background component (0.05 ng m^{-3}) will take account of distant sources of BaP outside of the modelled 15 km x 15 km. This concentration was the same as that used in the previous assessment (Coleman *et al.* 2001). This value seems reasonable when compared to the annual mean concentrations measured at the two most rural sites (Hazelrigg and High Muffles) in the network (Table 5.1).

Table 5.1 Annual mean concentrations measured at Hazelrigg and High Muffles

Site	1999	2000	2001	2002	2003
Hazelrigg	0.06	0.06	0.08	0.05	0.04
High Muffles	0.06	0.04	0.05	0.04	0.05

5.1.1 BaP concentration model validation

Figure 5.1 shows how the measured and modelled annual mean concentrations for BaP compare. Also presented on Figure 5.1, as dashed lines, are the data quality objectives of ± 60 %[1]. All sites apart from Bolsover (measured 0.46 ng m^{-3}; modelled 0.09 ng m^{-3}) show that the modelled concentration are acceptably predicted when compared with the data quality objectives. In previous years, emissions from the Coalite plant at Bolsover were expected to contribute to the concentrations measured at the sampling site - it is our understanding that this plant was not in operation in 2003 – so other unknown sources have contributed to the emission source.

[1] Directive 2004/107/EC of the European Parliament and of the Council of relating to arsenic, cadmium, mercury, nickel, and polyaromatic hydrocarbons in ambient air. Annex IV Official Journal 26/1/2005 p3.

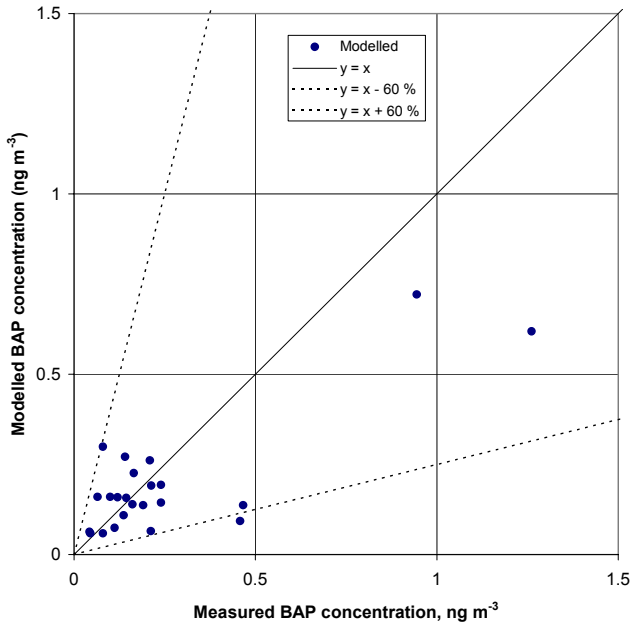


Figure 5.1 Scatter plot showing predicted and modelled BaP concentrations

5.1.2 Source apportionment for measured concentrations

Figure 5.2 shows the same data but with the modelled concentrations split by source sector. The source sectors are combined as follows- domestic emission (SNAP code 2), transport (SNAP code 7) and Other Area (SNAP codes 1, 3, 4, 6, 9 and 11).

The plot shows that at the Lisburn sampling site the domestic emission was the dominant emission source. Whereas at Scunthorpe, emissions from the coking plants dominate. At the majority of the other sites the emissions from the Other Area source was the dominant source. At these locations the emissions from the waste fires (SNAP Code 9) was the dominant component.

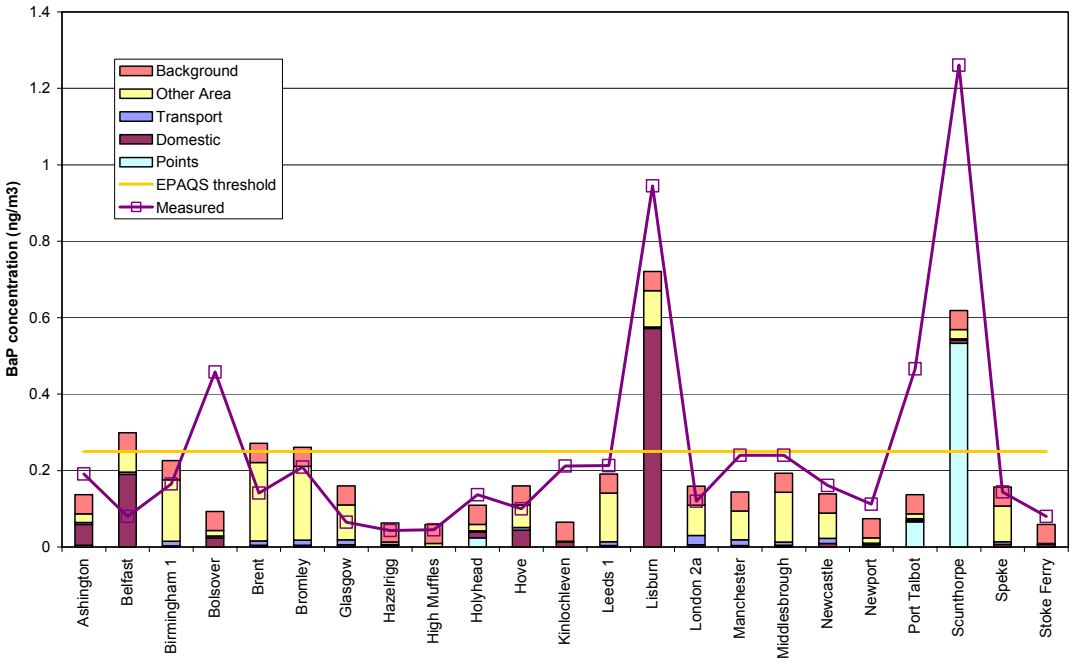


Figure 5.2 BaP source apportionment at monitoring site locations.

6 Concentration maps

The emissions modelled from the area, point and background sources (0.05 ng m^{-3}) were combined to produce BaP concentration maps for 2003, 2010, 2015 and 2020. Figure 6.1 show areas of the UK, in 2003 and 2010 estimated to exceed a BaP concentration of 0.25 ng/m^3. Figure 6.2 shows maps for 2015 and 2020. Where the 0.25 ng/m^3 concentration is exceeded, the overwhelming majority of 1 km squares do not exceed the lower assessment threshold of 0.4 ng/m^3.

A comparison of measured and modelled BaP concentration at the sampling site locations showed that the measured concentrations at most sites were predicted according to the data quality objectives. (see validation plot; Figure 5.1). The modelled concentration will reflect the inherent uncertainty in emission estimates or assumptions used in modelling emissions from both the point and area sources. For the point sources, few emission measurements have been made both nationally and internationally and the relevant activity statistics in some cases are not collected regularly. Further work is required to understand better the magnitude and spatial pattern of emissions from accidental, malicious, demolition and natural fires, waste fires and domestic solid fuel use particularly in urban and rural communities without access to natural gas.

It might be expected that a spatially varying background BaP concentration would improve prediction in rural areas. One approach to doing this would be to increase the number of sampling sites in rural locations and increase the sensitivity of the BaP sampling method.

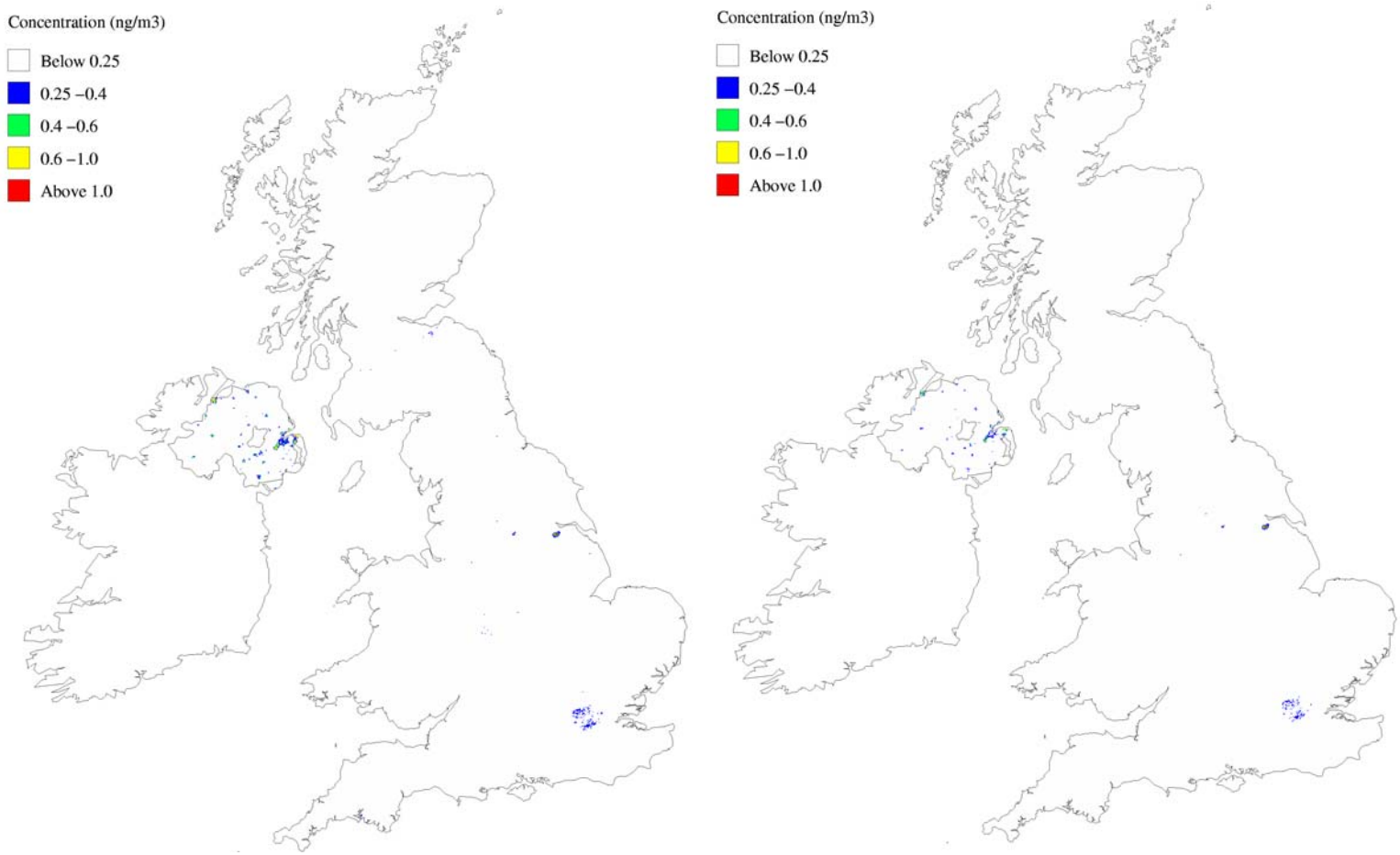
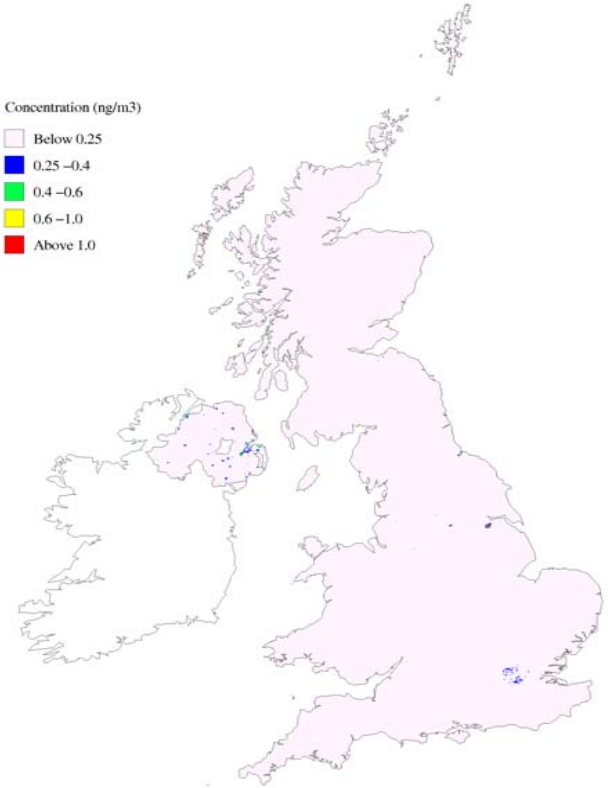
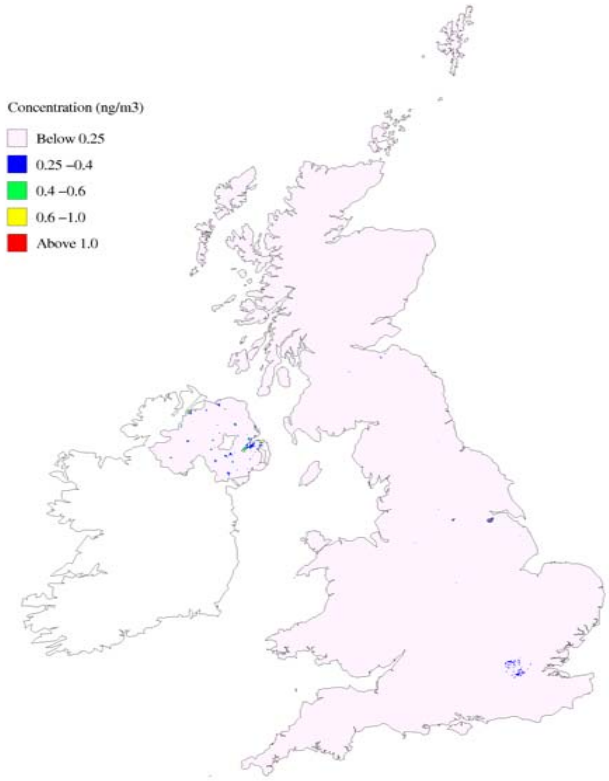


Figure 6.1 BaP concentrations in 2003 and 2010.



BAP concentrations, 2015.



BAP concentrations, 2020.

Figure 6.2 BaP concentrations in 2015 and 2020.

7 Population exposures

A summary of the number of people exposed to BaP concentrations at national and regional levels together with exposures within a number of urban areas, or urban agglomerations, is presented in this section. The urban and regional zones were defined previously for the preliminary Article 5 Assessment carried out in 2000 (Bush, 2000).

The urban agglomerations were defined as contiguous urban areas for which the population exceeded 250,000. The boundaries of the twenty eight agglomeration zones are presented in Figure 7.1. Figure 7.2 presents the boundaries for the 15 regional zones. For England these are based on official Government Office boundaries. For Scotland, Wales or Northern Ireland the boundaries were provided or authorised by the respective relevant office. For the purposes of the population exposure calculations the agglomerations zones are excluded from the larger regional zones.

The number of people within the urban agglomerations and regional zones exposed to a number of BaP concentration thresholds for 2003, 2010, 2015 and 2020 are provided in Tables 71 to 7.4. The thresholds chosen were the air quality objective value, 0.25 ng m^{-3}, the upper and lower assessment thresholds 0.6 ng m^{-3} and 0.4 ng m^{-3} and the target value of 1.0 ng m^{-3}.

Nationally the number of people exposed to the air quality objective concentration of 0.25 ng m^{-3} decreased from 2.4 million in 2003 to 1.6 million by 2010. An insignificant decrease is then predicted between 2010 and 2020. For the target value of 1.0 ng m^{-3} the proportional decrease is even larger- from 17000 exposed in 2003 to 5000 in 2010. As a result of the implementation of BAT being in place by 2010 for industrial plant this population is not predicted to decrease between 2010 and 2020.

For the urban agglomeration zones, the air quality objective concentration of 0.25 ng m^{-3} showed significant exposures within the Greater London, the West Midlands and Belfast agglomeration zones in 2003. By 2010 the number of people exposed to 0.25 ng m^{-3} decreased by at least 30,000 within each of these agglomeration zones.

For the regional zones, in 2003, there was significant numbers of people exposed to 0.25 ng m^{-3} in the South West, in Yorkshire and Humberside, in Central Scotland and Northern Ireland. By 2010, there were only significant exposures in Yorkshire and Humberside and Northern Ireland.

There are no agglomeration zones for which the target value of 1 ng m^{-3} was predicted to be exceeded. For the regional zones in 2003 there are small number of exceedences in Yorkshire and Humberside and Northern Ireland. By 2010, only a small number of people in Yorkshire and Humberside (in Scunthorpe) were predicted to be exposed to concentrations greater than the target concentration.

Code	Area
1	Greater London Urban Area
2	West Midlands Urban Area
3	Greater Manchester Urban Area
4	West Yorkshire Urban Area
5	Tyneside
6	Liverpool Urban Area
7	Sheffield Urban Area
8	Nottingham Urban Area
9	Bristol Urban Area
10	Brighton/Worthing/Littlehampton
11	Leicester Urban Area
12	Portsmouth Urban Area
13	Teesside Urban Area
14	The Potteries
15	Bournemouth Urban Area
16	Reading/Wokingham Urban Area
17	Coventry/Bedworth
18	Kingston upon Hull
19	Southampton Urban Area
20	Birkenhead Urban Area
21	Southend Urban Area
22	Blackpool Urban Area
23	Preston Urban Area
24	Glasgow Urban Area
25	Edinburgh Urban Area
26	Cardiff Urban Area
27	Swansea Urban Area
28	Belfast Urban Area

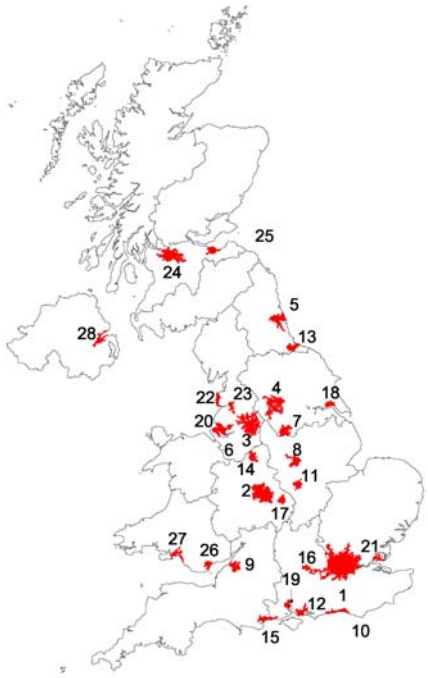


Figure 7.1 Location of agglomeration zones used to predict number of people exposed to various concentration thresholds.

Code	Area
29	Eastern
30	South West
31	South East
32	East Midlands
33	North West & Merseyside
34	Yorkshire & Humberside
35	West Midlands
36	North East
37	Central Scotland
38	North East Scotland
39	Highland
40	Scottish Borders
41	South Wales
42	North Wales
43	Northern Ireland

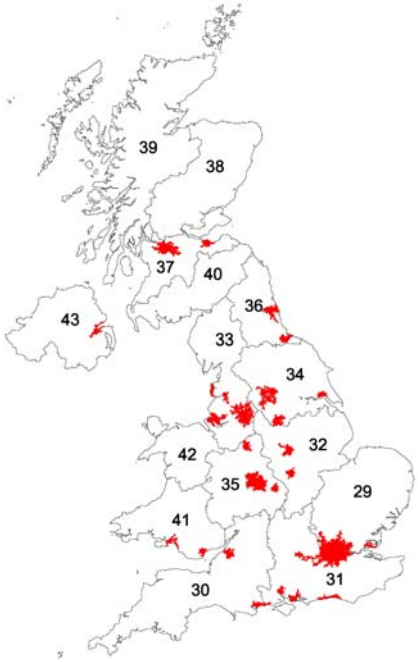


Figure 7.2 Regional zones used to predict number of people exposed to various concentration thresholds.

Table 7.1 BaP exposures in 2003

Agglomeration Zones/ Regional Zones	Code	Area (km^2)	Concentration threshold 0.25 ng m^{-3}		0.40 ng m^{-3}		0.60 ng m^{-3}		1.00 ng m^{-3}	
			Squares above threshold	Population exposed	Squares above threshold	Population exposed	Squares above threshold	Population exposed	Squares above threshold	Population exposed
Greater London Urban Area	1	1629	174	1316983	0	0	0	0	0	0
West Midlands Urban Area	2	599	5	30159	0	0	0	0	0	0
Greater Manchester Urban Area	3	538	0	0	0	0	0	0	0	0
West Yorkshire Urban Area	4	352	1	1666	0	0	0	0	0	0
Tyneside	5	211	0	0	0	0	0	0	0	0
Liverpool Urban Area	6	180	0	0	0	0	0	0	0	0
Sheffield Urban Area	7	168	0	0	0	0	0	0	0	0
Nottingham Urban Area	8	151	0	0	0	0	0	0	0	0
Bristol Urban Area	9	131	0	0	0	0	0	0	0	0
Brighton/Worthing/Littlehampton	10	90	0	0	0	0	0	0	0	0
Leicester Urban Area	11	92	0	0	0	0	0	0	0	0
Portsmouth Urban Area	12	84	0	0	0	0	0	0	0	0
Teesside Urban Area	13	103	1	6883	0	0	0	0	0	0
The Potteries	14	91	0	0	0	0	0	0	0	0
Bournemouth Urban Area	15	109	0	0	0	0	0	0	0	0
Reading/Wokingham Urban Area	16	94	0	0	0	0	0	0	0	0
Coventry/Bedworth	17	74	0	0	0	0	0	0	0	0
Kingston upon Hull	18	78	0	0	0	0	0	0	0	0
Southampton Urban Area	19	75	0	0	0	0	0	0	0	0
Birkenhead Urban Area	20	62	0	0	0	0	0	0	0	0
Southend Urban Area	21	66	0	0	0	0	0	0	0	0
Blackpool Urban Area	22	64	0	0	0	0	0	0	0	0
Preston Urban Area	23	67	0	0	0	0	0	0	0	0
Glasgow Urban Area	24	442	0	0	0	0	0	0	0	0
Edinburgh Urban Area	25	129	0	0	0	0	0	0	0	0
Cardiff Urban Area	26	72	0	0	0	0	0	0	0	0
Swansea Urban Area	27	89	2	43	2	43	0	0	0	0
Belfast Urban Area	28	122	74	240658	23	67130	8	24139	0	0
Eastern	29	19047	1	4046	0	0	0	0	0	0
South West	30	23457	5	28245	0	0	0	0	0	0
South East	31	18633	0	0	0	0	0	0	0	0
East Midlands	32	15512	2	7806	0	0	0	0	0	0
North West & Merseyside	33	13159	2	510	0	0	0	0	0	0
Yorkshire & Humberside	34	14786	61	74171	23	20267	12	12562	8	5055
West Midlands	35	12189	1	4632	0	0	0	0	0	0
North East	36	8285	2	3727	0	0	0	0	0	0
Central Scotland	37	9238	15	42762	0	0	0	0	0	0
North East Scotland	38	18577	1	3277	0	0	0	0	0	0
Highland	39	37964	8	15544	2	3874	0	0	0	0
Scottish Borders	40	11123	2	5969	1	3924	0	0	0	0
South Wales	41	12167	0	0	0	0	0	0	0	0
North Wales	42	8337	0	0	0	0	0	0	0	0
Northern Ireland	43	13602	365	620230	142	340061	58	181385	3	12083
Total			**722**	**2407310**	**193**	**435299**	**78**	**218086**	**11**	**17139**

Table 7.2 BaP exposures in 2010

Agglomeration Zones/Regional Zones	Code	Area (km^2)	Concentration threshold: 0.25 ng m^{-3}		0.40 ng m^{-3}		0.60 ng m^{-3}		1.00 ng m^{-3}	
			Squares above threshold	Population exposed	Squares above threshold	Population exposed	Squares above threshold	Population exposed	Squares above threshold	Population exposed
Greater London Urban Area	1	1629	124	987916	0	0	0	0	0	0
West Midlands Urban Area	2	599	0	0	0	0	0	0	0	0
Greater Manchester Urban Area	3	538	0	0	0	0	0	0	0	0
West Yorkshire Urban Area	4	352	1	1666	0	0	0	0	0	0
Tyneside	5	211	0	0	0	0	0	0	0	0
Liverpool Urban Area	6	180	0	0	0	0	0	0	0	0
Sheffield Urban Area	7	168	0	0	0	0	0	0	0	0
Nottingham Urban Area	8	151	0	0	0	0	0	0	0	0
Bristol Urban Area	9	131	0	0	0	0	0	0	0	0
Brighton/Worthing/Littlehampton	10	90	0	0	0	0	0	0	0	0
Leicester Urban Area	11	92	0	0	0	0	0	0	0	0
Portsmouth Urban Area	12	84	0	0	0	0	0	0	0	0
Teesside Urban Area	13	103	1	6883	0	0	0	0	0	0
The Potteries	14	91	0	0	0	0	0	0	0	0
Bournemouth Urban Area	15	109	0	0	0	0	0	0	0	0
Reading/Wokingham Urban Area	16	94	0	0	0	0	0	0	0	0
Coventry/Bedworth	17	74	0	0	0	0	0	0	0	0
Kingston upon Hull	18	78	0	0	0	0	0	0	0	0
Southampton Urban Area	19	75	0	0	0	0	0	0	0	0
Birkenhead Urban Area	20	62	0	0	0	0	0	0	0	0
Southend Urban Area	21	66	0	0	0	0	0	0	0	0
Blackpool Urban Area	22	64	0	0	0	0	0	0	0	0
Preston Urban Area	23	67	0	0	0	0	0	0	0	0
Glasgow Urban Area	24	442	0	0	0	0	0	0	0	0
Edinburgh Urban Area	25	129	0	0	0	0	0	0	0	0
Cardiff Urban Area	26	72	0	0	0	0	0	0	0	0
Swansea Urban Area	27	89	2	43	2	43	0	0	0	0
Belfast Urban Area	28	122	44	144984	11	33959	1	1955	0	0
Eastern	29	19047	0	0	0	0	0	0	0	0
South West	30	23457	1	6201	0	0	0	0	0	0
South East	31	18633	0	0	0	0	0	0	0	0
East Midlands	32	15512	0	0	0	0	0	0	0	0
North West & Merseyside	33	13159	1	65	0	0	0	0	0	0
Yorkshire & Humberside	34	14786	54	55191	23	20267	12	12562	8	5055
West Midlands	35	12189	0	0	0	0	0	0	0	0
North East	36	8285	0	0	0	0	0	0	0	0
Central Scotland	37	9238	2	6424	0	0	0	0	0	0
North East Scotland	38	18577	0	0	0	0	0	0	0	0
Highland	39	37964	3	5677	0	0	0	0	0	0
Scottish Borders	40	11123	1	3924	0	0	0	0	0	0
South Wales	41	12167	0	0	0	0	0	0	0	0
North Wales	42	8337	0	0	0	0	0	0	0	0
Northern Ireland	43	13602	194	442246	63	194275	12	42463	0	0
Total			**428**	**1661221**	**99**	**248543**	**25**	**56980**	**8**	**5055**

Table 7.3 BaP exposures in 2015

Agglomeration Zones/ Regional Zones	Code	Area (km^2)	Concentration threshold: 0.25 ng m^{-3}		0.40 ng m^{-3}		0.60 ng m^{-3}		1.00 ng m^{-3}	
			Squares above threshold	Population exposed	Squares above threshold	Population exposed	Squares above threshold	Population exposed	Squares above threshold	Population exposed
Greater London Urban Area	1	1629	118	946928	0	0	0	0	0	0
West Midlands Urban Area	2	599	0	0	0	0	0	0	0	0
Greater Manchester Urban Area	3	538	0	0	0	0	0	0	0	0
West Yorkshire Urban Area	4	352	1	1666	0	0	0	0	0	0
Tyneside	5	211	0	0	0	0	0	0	0	0
Liverpool Urban Area	6	180	0	0	0	0	0	0	0	0
Sheffield Urban Area	7	168	0	0	0	0	0	0	0	0
Nottingham Urban Area	8	151	0	0	0	0	0	0	0	0
Bristol Urban Area	9	131	0	0	0	0	0	0	0	0
Brighton/Worthing/Littlehampton	10	90	0	0	0	0	0	0	0	0
Leicester Urban Area	11	92	0	0	0	0	0	0	0	0
Portsmouth Urban Area	12	84	0	0	0	0	0	0	0	0
Teesside Urban Area	13	103	1	6883	0	0	0	0	0	0
The Potteries	14	91	0	0	0	0	0	0	0	0
Bournemouth Urban Area	15	109	0	0	0	0	0	0	0	0
Reading/Wokingham Urban Area	16	94	0	0	0	0	0	0	0	0
Coventry/Bedworth	17	74	0	0	0	0	0	0	0	0
Kingston upon Hull	18	78	0	0	0	0	0	0	0	0
Southampton Urban Area	19	75	0	0	0	0	0	0	0	0
Birkenhead Urban Area	20	62	0	0	0	0	0	0	0	0
Southend Urban Area	21	66	0	0	0	0	0	0	0	0
Blackpool Urban Area	22	64	0	0	0	0	0	0	0	0
Preston Urban Area	23	67	0	0	0	0	0	0	0	0
Glasgow Urban Area	24	442	0	0	0	0	0	0	0	0
Edinburgh Urban Area	25	129	0	0	0	0	0	0	0	0
Cardiff Urban Area	26	72	0	0	0	0	0	0	0	0
Swansea Urban Area	27	89	2	43	2	43	0	0	0	0
Belfast Urban Area	28	122	47	154252	12	36842	2	4792	0	0
Eastern	29	19047	0	0	0	0	0	0	0	0
South West	30	23457	1	6201	0	0	0	0	0	0
South East	31	18633	0	0	0	0	0	0	0	0
East Midlands	32	15512	0	0	0	0	0	0	0	0
North West & Merseyside	33	13159	1	65	0	0	0	0	0	0
Yorkshire & Humberside	34	14786	54	55191	23	20267	12	12562	8	5055
West Midlands	35	12189	0	0	0	0	0	0	0	0
North East	36	8285	0	0	0	0	0	0	0	0
Central Scotland	37	9238	2	6424	0	0	0	0	0	0
North East Scotland	38	18577	0	0	0	0	0	0	0	0
Highland	39	37964	3	5677	0	0	0	0	0	0
Scottish Borders	40	11123	1	3924	0	0	0	0	0	0
South Wales	41	12167	0	0	0	0	0	0	0	0
North Wales	42	8337	0	0	0	0	0	0	0	0
Northern Ireland	43	13602	210	466007	71	216097	13	43953	0	0
Total			**441**	**1653262**	**108**	**273249**	**27**	**61307**	**8**	**5055**

Table 7.4 BaP exposures in 2020

Agglomeration Zones/ Regional Zones	Code	Area (km^2)	Concentration threshold: 0.25 ng m^{-3}		0.40 ng m^{-3}		0.60 ng m^{-3}		1.00 ng m^{-3}	
			Squares above threshold	Population exposed	Squares above threshold	Population exposed	Squares above threshold	Population exposed	Squares above threshold	Population exposed
Greater London Urban Area	1	1629	117	940466	0	0	0	0	0	0
West Midlands Urban Area	2	599	0	0	0	0	0	0	0	0
Greater Manchester Urban Area	3	538	0	0	0	0	0	0	0	0
West Yorkshire Urban Area	4	352	1	1666	0	0	0	0	0	0
Tyneside	5	211	0	0	0	0	0	0	0	0
Liverpool Urban Area	6	180	0	0	0	0	0	0	0	0
Sheffield Urban Area	7	168	0	0	0	0	0	0	0	0
Nottingham Urban Area	8	151	0	0	0	0	0	0	0	0
Bristol Urban Area	9	131	0	0	0	0	0	0	0	0
Brighton/Worthing/Littlehampton	10	90	0	0	0	0	0	0	0	0
Leicester Urban Area	11	92	0	0	0	0	0	0	0	0
Portsmouth Urban Area	12	84	0	0	0	0	0	0	0	0
Teesside Urban Area	13	103	1	6883	0	0	0	0	0	0
The Potteries	14	91	0	0	0	0	0	0	0	0
Bournemouth Urban Area	15	109	0	0	0	0	0	0	0	0
Reading/Wokingham Urban Area	16	94	0	0	0	0	0	0	0	0
Coventry/Bedworth	17	74	0	0	0	0	0	0	0	0
Kingston upon Hull	18	78	0	0	0	0	0	0	0	0
Southampton Urban Area	19	75	0	0	0	0	0	0	0	0
Birkenhead Urban Area	20	62	0	0	0	0	0	0	0	0
Southend Urban Area	21	66	0	0	0	0	0	0	0	0
Blackpool Urban Area	22	64	0	0	0	0	0	0	0	0
Preston Urban Area	23	67	0	0	0	0	0	0	0	0
Glasgow Urban Area	24	442	0	0	0	0	0	0	0	0
Edinburgh Urban Area	25	129	0	0	0	0	0	0	0	0
Cardiff Urban Area	26	72	0	0	0	0	0	0	0	0
Swansea Urban Area	27	89	2	43	2	43	0	0	0	0
Belfast Urban Area	28	122	47	154252	12	36842	2	4792	0	0
Eastern	29	19047	0	0	0	0	0	0	0	0
South West	30	23457	1	6201	0	0	0	0	0	0
South East	31	18633	0	0	0	0	0	0	0	0
East Midlands	32	15512	0	0	0	0	0	0	0	0
North West & Merseyside	33	13159	1	65	0	0	0	0	0	0
Yorkshire & Humberside	34	14786	54	55191	23	20267	12	12562	8	5055
West Midlands	35	12189	0	0	0	0	0	0	0	0
North East	36	8285	0	0	0	0	0	0	0	0
Central Scotland	37	9238	2	6424	0	0	0	0	0	0
North East Scotland	38	18577	0	0	0	0	0	0	0	0
Highland	39	37964	3	5677	0	0	0	0	0	0
Scottish Borders	40	11123	1	3924	0	0	0	0	0	0
South Wales	41	12167	0	0	0	0	0	0	0	0
North Wales	42	8337	0	0	0	0	0	0	0	0
Northern Ireland	43	13602	209	464530	71	216097	13	43953	0	0
Total			439	1645323	108	273249	27	61307	8	5055

8 Uncertainty

The uncertainty in the modelling is discussed above in the context of how well the model predicts current benzo[a]pyrene concentrations. The principal factor which influences the uncertainty of the concentration modelling is the uncertainty in the emissions inventory.

A source of uncertainty in the projections is the estimate of future trends in emissions. Industrial and economic growth may not follow present forecasts. Individual significant plant may close or carry out major pollution control works. Emission factors for area sources may be revised. For pollutants for which a significant proportion of emissions are derived from combustion sources an important driver of emissions is the prediction of future energy consumption.

A number of approaches were used to investigate the sensitivity of the model to the input assumptions. Two extreme emission control sensitivity tests were used. Firstly a ceasing of PAH emissions from UK industry. Secondly a ceasing of PAH emissions from the UK domestic sector. These two sensitivity assessments were then combined to produce an estimate of concentrations in the absence of both of these sources. Estimates of population exposure were made for 2010 for these cases and the results are shown in Tables 8.1, 8.2 and 8.3 respectively.

The estimate of 2010 BaP concentrations in the absence of the domestic and industrial sources removes exceedences of the Lower Assessment Threshold (0.4 ng m^{-3}) and all but 5 squares in terms of the EPAQS standard (0.25 ng m^{-3}) except for the exceedence in Greater London. The source of exceedence in Greater London is the 'other area' sources. The extent and magnitude of this exceedence is not well defined within this study. Concentrations for the three monitoring sites in London are all over-predicted by the model. The spatial distribution and magnitude of the waste fires source is not well defined in the emission inventory. Exceedences of the LAT (0.4 ng m^{-3}) for the baseline assessment in 2010 are limited to a small number of squares resulting from industrial or domestic emissions. The EPAQS standard is nearly met with the domestic source switched off except for Scunthorpe and Port Talbot where BAT is nominally applied in the inventory.

Table 8.1 BaP exposures in 2010 with no domestic emissions

Agglomeration Zones/ Regional Zones	Code	Area (km^2)	Concentration threshold: 0.25 ng m^{-3}		0.40 ng m^{-3}		0.60 ng m^{-3}		1.00 ng m^{-3}	
			Squares above threshold	Population exposed	Squares above threshold	Population exposed	Squares above threshold	Population exposed	Squares above threshold	Population exposed
Greater London Urban Area	1	1629	105	861864	0	0	0	0	0	0
West Midlands Urban Area	2	599	0	0	0	0	0	0	0	0
Greater Manchester Urban Area	3	538	0	0	0	0	0	0	0	0
West Yorkshire Urban Area	4	352	1	1666	0	0	0	0	0	0
Tyneside	5	211	0	0	0	0	0	0	0	0
Liverpool Urban Area	6	180	0	0	0	0	0	0	0	0
Sheffield Urban Area	7	168	0	0	0	0	0	0	0	0
Nottingham Urban Area	8	151	0	0	0	0	0	0	0	0
Bristol Urban Area	9	131	0	0	0	0	0	0	0	0
Brighton/Worthing/Littlehampton	10	90	0	0	0	0	0	0	0	0
Leicester Urban Area	11	92	0	0	0	0	0	0	0	0
Portsmouth Urban Area	12	84	0	0	0	0	0	0	0	0
Teesside Urban Area	13	103	1	6883	0	0	0	0	0	0
The Potteries	14	91	0	0	0	0	0	0	0	0
Bournemouth Urban Area	15	109	0	0	0	0	0	0	0	0
Reading/Wokingham Urban Area	16	94	0	0	0	0	0	0	0	0
Coventry/Bedworth	17	74	0	0	0	0	0	0	0	0
Kingston upon Hull	18	78	0	0	0	0	0	0	0	0
Southampton Urban Area	19	75	0	0	0	0	0	0	0	0
Birkenhead Urban Area	20	62	0	0	0	0	0	0	0	0
Southend Urban Area	21	66	0	0	0	0	0	0	0	0
Blackpool Urban Area	22	64	0	0	0	0	0	0	0	0
Preston Urban Area	23	67	0	0	0	0	0	0	0	0
Glasgow Urban Area	24	442	0	0	0	0	0	0	0	0
Edinburgh Urban Area	25	129	0	0	0	0	0	0	0	0
Cardiff Urban Area	26	72	0	0	0	0	0	0	0	0
Swansea Urban Area	27	89	2	43	2	43	0	0	0	0
Belfast Urban Area	28	122	3	15426	0	0	0	0	0	0
Eastern	29	19047	0	0	0	0	0	0	0	0
South West	30	23457	0	0	0	0	0	0	0	0
South East	31	18633	0	0	0	0	0	0	0	0
East Midlands	32	15512	0	0	0	0	0	0	0	0
North West & Merseyside	33	13159	1	65	0	0	0	0	0	0
Yorkshire & Humberside	34	14786	52	54644	23	20267	12	12562	8	5055
West Midlands	35	12189	0	0	0	0	0	0	0	0
North East	36	8285	0	0	0	0	0	0	0	0
Central Scotland	37	9238	0	0	0	0	0	0	0	0
North East Scotland	38	18577	0	0	0	0	0	0	0	0
Highland	39	37964	0	0	0	0	0	0	0	0
Scottish Borders	40	11123	0	0	0	0	0	0	0	0
South Wales	41	12167	0	0	0	0	0	0	0	0
North Wales	42	8337	0	0	0	0	0	0	0	0
Northern Ireland	43	13602	2	5741	0	0	0	0	0	0
Total			**167**	**946333**	**25**	**20309**	**12**	**12562**	**8**	**5055**

Table 8.2 BaP exposures in 2010 with no industrial emissions

Agglomeration Zones/ Regional Zones	Code	Area (km^2)	Concentration threshold: 0.25 ng m^{-3}		0.40 ng m^{-3}		0.60 ng m^{-3}		1.00 ng m^{-3}	
			Squares above threshold	Population exposed	Squares above threshold	Population exposed	Squares above threshold	Population exposed	Squares above threshold	Population exposed
Greater London Urban Area	1	1629	117	940466	0	0	0	0	0	0
West Midlands Urban Area	2	599	0	0	0	0	0	0	0	0
Greater Manchester Urban Area	3	538	0	0	0	0	0	0	0	0
West Yorkshire Urban Area	4	352	0	0	0	0	0	0	0	0
Tyneside	5	211	0	0	0	0	0	0	0	0
Liverpool Urban Area	6	180	0	0	0	0	0	0	0	0
Sheffield Urban Area	7	168	0	0	0	0	0	0	0	0
Nottingham Urban Area	8	151	0	0	0	0	0	0	0	0
Bristol Urban Area	9	131	0	0	0	0	0	0	0	0
Brighton/Worthing/Littlehampton	10	90	0	0	0	0	0	0	0	0
Leicester Urban Area	11	92	0	0	0	0	0	0	0	0
Portsmouth Urban Area	12	84	0	0	0	0	0	0	0	0
Teesside Urban Area	13	103	0	0	0	0	0	0	0	0
The Potteries	14	91	0	0	0	0	0	0	0	0
Bournemouth Urban Area	15	109	0	0	0	0	0	0	0	0
Reading/Wokingham Urban Area	16	94	0	0	0	0	0	0	0	0
Coventry/Bedworth	17	74	0	0	0	0	0	0	0	0
Kingston upon Hull	18	78	0	0	0	0	0	0	0	0
Southampton Urban Area	19	75	0	0	0	0	0	0	0	0
Birkenhead Urban Area	20	62	0	0	0	0	0	0	0	0
Southend Urban Area	21	66	0	0	0	0	0	0	0	0
Blackpool Urban Area	22	64	0	0	0	0	0	0	0	0
Preston Urban Area	23	67	0	0	0	0	0	0	0	0
Glasgow Urban Area	24	442	0	0	0	0	0	0	0	0
Edinburgh Urban Area	25	129	0	0	0	0	0	0	0	0
Cardiff Urban Area	26	72	0	0	0	0	0	0	0	0
Swansea Urban Area	27	89	0	0	0	0	0	0	0	0
Belfast Urban Area	28	122	44	144984	10	28647	1	1955	0	0
Eastern	29	19047	0	0	0	0	0	0	0	0
South West	30	23457	0	0	0	0	0	0	0	0
South East	31	18633	0	0	0	0	0	0	0	0
East Midlands	32	15512	0	0	0	0	0	0	0	0
North West & Merseyside	33	13159	0	0	0	0	0	0	0	0
Yorkshire & Humberside	34	14786	0	0	0	0	0	0	0	0
West Midlands	35	12189	0	0	0	0	0	0	0	0
North East	36	8285	0	0	0	0	0	0	0	0
Central Scotland	37	9238	2	6424	0	0	0	0	0	0
North East Scotland	38	18577	0	0	0	0	0	0	0	0
Highland	39	37964	3	5677	0	0	0	0	0	0
Scottish Borders	40	11123	1	3924	0	0	0	0	0	0
South Wales	41	12167	0	0	0	0	0	0	0	0
North Wales	42	8337	0	0	0	0	0	0	0	0
Northern Ireland	43	13602	194	442246	63	194275	12	42463	0	0
Total			**361**	**1543721**	**73**	**222922**	**13**	**44418**	**0**	**0**

Table 8.3 BaP exposures in 2010 with no industrial or domestic emissions

Agglomeration Zones/ Regional Zones	Code	Area (km^2)	Concentration threshold: 0.25 ng m^{-3}		0.40 ng m^{-3}		0.60 ng m^{-3}		1.00 ng m^{-3}	
			Squares above threshold	Population exposed	Squares above threshold	Population exposed	Squares above threshold	Population exposed	Squares above threshold	Population exposed
Greater London Urban Area	1	1629	94	788316	0	0	0	0	0	0
West Midlands Urban Area	2	599	0	0	0	0	0	0	0	0
Greater Manchester Urban Area	3	538	0	0	0	0	0	0	0	0
West Yorkshire Urban Area	4	352	0	0	0	0	0	0	0	0
Tyneside	5	211	0	0	0	0	0	0	0	0
Liverpool Urban Area	6	180	0	0	0	0	0	0	0	0
Sheffield Urban Area	7	168	0	0	0	0	0	0	0	0
Nottingham Urban Area	8	151	0	0	0	0	0	0	0	0
Bristol Urban Area	9	131	0	0	0	0	0	0	0	0
Brighton/Worthing/Littlehampton	10	90	0	0	0	0	0	0	0	0
Leicester Urban Area	11	92	0	0	0	0	0	0	0	0
Portsmouth Urban Area	12	84	0	0	0	0	0	0	0	0
Teesside Urban Area	13	103	0	0	0	0	0	0	0	0
The Potteries	14	91	0	0	0	0	0	0	0	0
Bournemouth Urban Area	15	109	0	0	0	0	0	0	0	0
Reading/Wokingham Urban Area	16	94	0	0	0	0	0	0	0	0
Coventry/Bedworth	17	74	0	0	0	0	0	0	0	0
Kingston upon Hull	18	78	0	0	0	0	0	0	0	0
Southampton Urban Area	19	75	0	0	0	0	0	0	0	0
Birkenhead Urban Area	20	62	0	0	0	0	0	0	0	0
Southend Urban Area	21	66	0	0	0	0	0	0	0	0
Blackpool Urban Area	22	64	0	0	0	0	0	0	0	0
Preston Urban Area	23	67	0	0	0	0	0	0	0	0
Glasgow Urban Area	24	442	0	0	0	0	0	0	0	0
Edinburgh Urban Area	25	129	0	0	0	0	0	0	0	0
Cardiff Urban Area	26	72	0	0	0	0	0	0	0	0
Swansea Urban Area	27	89	0	0	0	0	0	0	0	0
Belfast Urban Area	28	122	3	15426	0	0	0	0	0	0
Eastern	29	19047	0	0	0	0	0	0	0	0
South West	30	23457	0	0	0	0	0	0	0	0
South East	31	18633	0	0	0	0	0	0	0	0
East Midlands	32	15512	0	0	0	0	0	0	0	0
North West & Merseyside	33	13159	0	0	0	0	0	0	0	0
Yorkshire & Humberside	34	14786	0	0	0	0	0	0	0	0
West Midlands	35	12189	0	0	0	0	0	0	0	0
North East	36	8285	0	0	0	0	0	0	0	0
Central Scotland	37	9238	0	0	0	0	0	0	0	0
North East Scotland	38	18577	0	0	0	0	0	0	0	0
Highland	39	37964	0	0	0	0	0	0	0	0
Scottish Borders	40	11123	0	0	0	0	0	0	0	0
South Wales	41	12167	0	0	0	0	0	0	0	0
North Wales	42	8337	0	0	0	0	0	0	0	0
Northern Ireland	43	13602	2	5741	0	0	0	0	0	0
Total			**99**	**809483**	**0**	**0**	**0**	**0**	**0**	**0**

9 Conclusions

There has been a significant increase in the number of sampling sites monitoring BaP concentrations. In 2003, there were twenty-three sites for which a valid annual mean concentration could be determined. Of these, only four (Port Talbot, Scunthorpe, Bolsover and Lisburn) measured an annual mean concentration greater than 0.25 ng m^{-3}. The first two sites are in industrial areas with emissions from industrial processes making significant contributions to the collected concentrations. In previous years, the emissions from the Coalite plant would be expected to make a contribution to the collected concentration at Bolsover- it is our understanding that this plant was not in operation in 2003 – so other unknown sources would contribute to the emission source. The modelling method predicts concentrations at most sampling are predicted according to the data quality objectives.

Nationally the number of people exposed to the air quality objective concentration of 0.25 ng m^{-3} decreased from 2.4 million in 2003 to 1.6 million by 2010. For the target value of 1.0 ng m^{-3} the proportional decrease is even larger- from 17000 exposed in 2003 to 5000 in 2010.

There are no agglomeration zones for which the target value of 1 ng m^{-3} was predicted to be exceeded. For the regional zones in 2003 there are small number of exceedences in Yorkshire and Humberside and Northern Ireland. By 2010, only a small number of people in Yorkshire and Humberside were predicted to be exposed to concentrations greater than the target concentration.

10 Acknowledgements

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Appendix 1
Assumed Industrial Plant Emission Characteristics

Table A.1 Emission characteristics for each of the individual industrial plant

Point source	Authorisation Number	Line or point source	Emissions (kg year^{-1})	Emission Height (m)	Stack diameter (m)	Velocity (m s^{-1})	Volume (m^3 s^{-1})	Temperature
Appleby coke works	AF7193	Line+	16.15	5	-	-	149	115
Dawes Lane coke works	AF7193	Line+	16.15	5	-	-	149	115
Monckton coke works	BK3441	Line+	32	5	-	-	49	115
Morfa coke works	AF8645	Line+	13	5	-	-	101	115
Redcar coke plant	AF8548	Line+	25	5	-	-	156	115
South Bank coke plant	AF8530	Line+	11	5	-	-	78	115
Anglesey	BL1100	Point[1]	203	121	9.807	-	594.4	82
Ashington (1)	BL6861	Point[2]	3.40	32	1.96	16.1	-	109
Ashington (2)	BL6861	Point	1.75	46	2.125	13	-	131
Ashington (3)	BL6861	Point	4.05	36	2.15	5.9	-	32
Castle Cement, Padeswood (1)	AI0349	Point[3]	26.5	76	2.47	14	-	250
Castle Cement, Padeswood (2)	AI0349	Point	26.5	61	2.97	9.2	-	220
Koppers, Scunthorpe	AU8296	Point	6.4	10.05	0.0508	0.05	-	150
Port Talbot sinter plant	AR0357	Point[4]	43	133	6.5	-	450	120
Sankley Bridge landfill (Arpley)	3CW005/53557	Point[5]	2	4.841	0.406	28.13	-	482
Scunthorpe sinter plant	AR0080	Point[6]	30.4	107	6.4	-	388	168
Teeside sinter plant	AR0241	Point[7]	9.8	105	6.2	-	257	134
		Total	**470**					

Notes

+ Each of the steel plant at Middlesbrough and Scunthorpe have two sets of coking ovens with the emission split as follows: 50:50 between Southbank and Redcar works; 50:50 between Dawes Lane and Appleby works. As the coking plant at Grange has been closed since the last modelling exercise 100 % of the emission is attributed to Morfa. Each of the coke works was treated as a line source with dimensions taken from the relevant Ordnance Survey 1:25000 map (typically 80-225 m long and 15 m wide). Coke ovens require gas heating in order to overcome heat losses and maintain the pyrolysis reaction.

The heat loss and volume flow rates were estimated by scaling the estimates for obtained previously for the Cwm coke works in South Wales. At this plant the total fuel consumption was estimated to be approximately 10500 m3 h-1. Assuming a heating value of the gas used of 4.7 MJ m-3 (Perry,1973), it is estimated that 13.6 MW is required to maintain the reaction. For this assessment, it has been assumed that all this heat is lost through the walls and roof of the coke ovens. This assumption ignores the heat lost through battery stacks and heat lost or gained from endothermic or exothermic reactions: however, it is considered that the assumption is sufficient to provide order of magnitude estimates of the heat loss. The heat loss from the ovens is then assumed to be contained within the discharging plume from the ovens, providing buoyancy so that there is some limited plume rise. A nominal initial plume temperature of 115°C, specific heat 1012 J K^{-}1 kg^{-}1 and density 1.25 kg m^{-3} was used to estimate the initial volume flow rate of the plume.

1. Dispersion characteristics for Ashington were provided by Alcan Smelting and Power UK. Personal Communication from John Clarkson to Peter Coleman, 9 th May and 15 th May 1999.
2. Information provided by Colin Hardman (EA), personal communication to Keith Vincent, 6 th July 1999. The stack at Holyhead exhausts gases from two separate processes; the carbon bake and the pot rooms. The stack consists of two concentric stacks, one inside the other with the exhaust from the pot room being the outer stack and carbon bake the inner one. BaP emissions are only expected to occur from the inner stack. As both processes are running at the same time it is necessary to take account of the influence of the buoyancy of the larger stack will have on the buoyancy of the emission from the inner stack. To do this the buoyancy and momentum of the both plumes were combined and an effective stack diameter and combined stack temperature was determined.
3. The emission characteristics were provided by Ian Walpole called from Castle Cement. The annual emission from this source is significant in that it is second only to the emissions from the aluminium smelter on Anglesey. The high emission results from the fuel used in the cement kiln. It has a high carbon content. The emissions from this site are due to reduce significantly when a new process comes on line in 2005.
4. The emission characteristic from the Port Talbot works was supplied by Mark Broom of the Environment Agency (21/10/04). All the BaP emission from the steel manufacture is assumed to come from the sinter plant.
5. Emissions from the Sankley Bridge landfill site in 2003 were the first emissions from a landfill site to be reported (2 kg). This landfill site is one of the largest in the country and contains 18 gas engines – emissions are estimated using the GasSim model. Emissions were modelled using stack characteristics typical of a single landfill gas engine.
6 The emission characteristics for the sinter plant were provided by Rob McClellen of the Environment Agency (20/10/04).
7. The emission characteristics for the sinter plant were provided by Paul Siddle of the Environment Agency (27/10/04).