

PAH OBJECTIVE: MODELLING BAP CONCENTRATIONS

Issue

The 2003 Addendum to the 2000 Air Quality Strategy for England, Wales, Scotland and Northern Ireland adopted an air quality objective of 0.25ng/m^3 as an annual average to guard against the long-term effects of polycyclic aromatic hydrocarbons using benzo[a]pyrene as a marker (BaP – a genotoxic carcinogen). The objective is more stringent than Directive 2004/107/EC, which sets a Target Value of 1ng/m^3 .

In recent years, some UK industries have suggested the BaP objective is an example of 'gold plating'. This paper sets out work undertaken by Defra, the devolved administrations and the HPA to consider whether the objective should be retained and why it remains important even if it is not legally binding.

Background

Directive 2004/107/EC sets an annual average air quality target value for BaP of 1.0ng/m^3 for the protection of human health to be achieved where possible by 31 December 2012. The UK Air Quality Strategy has set an alternative objective for BaP of an annual average of 0.25ng/m^3 .

The BaP objective was set following recommendations by the Expert Panel on Air Quality Standards (EPAQS) in 1999. EPAQS concluded that BaP should be used as a marker for the total mixture of polycyclic aromatic hydrocarbons in UK ambient air. When producing their recommendation EPAQS used the lowest level at which effects have been observed, equivalent to $0.25\mu\text{g/m}^3$ BaP for 40 years as their starting point. They then applied 3 safety factors of 10 – to go from a 'lowest observed adverse effects level' to a 'no observed adverse effects level'; to go from a working life to a lifetime; and finally to take account of the range of sensitivity in the general population. This gave a composite safety factor of 1000 to derive a standard of 0.25ng/m^3 .

The World Health Organisation (WHO) have also produced an estimated unit risk for BaP of 8.7×10^{-5} per ng/m^3 . The corresponding concentrations of BaP producing excess lifetime cancer risks of 1/10,000, 1/100,000 and 1/1,000,000 are 1.2, 0.12 and 0.012ng/m^3 respectively. The Target Value in Directive 2004/107/EC was derived from the recommendations of the WHO. The UK does not use lifetime risk estimates when setting standards.

There are few remaining exceedences of the BaP objective within the UK. In 2005, 5 of the 23 monitoring sites recorded exceedences of the BaP objective. Of these, 2 were related to coking plant, 1 to an aluminium smelter (now closed) and 2 to domestic coal burning.

This note summarises the work undertaken to produce concentration maps of BaP emissions required as part of the process to review the Air Quality Strategy. Concentrations are predicted for 2005, 2010, 2015 and 2020.

Approach

The inputs to the modelling process are presented below:

- Emissions data for 2004 were obtained from the National Atmospheric Emissions Inventory and the Pollution Inventory (from Environment Agency). These were produced using UEP26 energy projections.
- Meteorological data from Waddington for 2005 was used in Great Britain. Area emissions in Northern Ireland were modelled using a ten-year statistical summary for Aldergrove (Belfast International Airport).
- Concentrations from area emissions were predicted for each $1\text{ km} \times 1\text{ km}$ throughout the United Kingdom. For the coking plant concentrations were predicted for receptor areas of $31\text{ km} \times 31\text{ km}$, all other point sources used a receptor area of $51\text{ km} \times 51\text{ km}$.

- Further information on the modelling methodology can be found in Vincent et al, 2006¹. This methodology was used for the 2006 AQS consultation document and the 2003 AQS Addendum.

Results

Table 1 shows the estimated emission in 2004 together with projected estimates for 2005, 2010, 2015 and 2020. Table 1 shows that the projected BaP emissions for future years from the energy, combustion in industry, production processes and solvent sectors are expected to be higher than emissions in 2004 while emissions from the residential and commercial sector will decrease.

The source sectors making large contributions to the total UK 2004 emissions are:

- Residential and commercial – domestic combustions contribute 97% of the sector total;
- Combustion in Industry – other industrial combustion (industrial combustion of coal and treated wood) contributes 97% of the sector total;
- Production processes – coke production contributes 68% of the sector total and anode baking for aluminium smelting contributes 18% of the sector total; and
- 'Other sources and sinks' - Bonfire night, natural fires (approx 90% of the sector total) and accidental building fires.

Table 1: Benzo [a] pyrene emissions in 2004 and projected estimates for 2005, 2010, 2015 and 2020 for the UK (kg y⁻¹).

Source sector	2004	2005	2010	2015	2020
Energy	57.1	67.0	66.9	66.3	64.2
Residential and commercial	2526.4	2350.9	1968.6	2006.7	2135.2
Combustion in industry	2266.4	2265.6	2600.6	2531.7	2566.1
Production processes	1027.2	1293.7	1341.7	1341.7	1341.7
Road transport	442.2	341.1	245.5	203.6	196.3
Other transport and machines	59.13	58.8	57.7	57.4	57.3
Waste treatment and disposal	680.6	680.7	680.7	680.7	680.8
Solvent and other product use	25.2	43.9	51.2	51.2	51.2
Other sources and sinks	3185.3	3185.3	3185.3	3185.3	3185.3
Total	10269.7	10287.0	10198.2	10124.8	10278.1

Area of exceedence for the AQS objective, assessment thresholds and EU Target Value.

Table 2 shows the number of 1 km x 1 km squares predicted to exceed the concentration thresholds of 0.25 ng/m³, 0.4 ng/m³, 0.6 ng/m³ and 1.0 ng/m³ for 2005, 2010, 2015 and 2020. Areas exceeded will decrease from 2005 to 2010 and 2015, then rise slightly again by 2020.

The main areas exceeding the 1.0 ng/m³ threshold are:

- Between the Sheffield and West Yorkshire urban areas, the exceedence is attributed to the emissions from a coking plant. Emission from domestic sources is the dominant source elsewhere within this area of exceedence.
- In North Lincolnshire, emissions from a coking plant are the dominant source.

¹ Vincent, K J, Coleman, P, Stedman, J R (2006) Assessment of benzo[a]pyrene concentrations in the UK in 2003. AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/. www.airquality.co.uk/archive/aqsreview2006.php

- For the Northwest and Merseyside zone the dominant source is the other industry sources (industrial combustion of coal and treated wood).
- For Northern Ireland, concentrations are dominated by emissions from the domestic sector.

Table 2: Number of 1 km x 1 km grid squares that exceed the concentration thresholds of 0.25 ng/m³, 0.4 ng/m³, 0.6 ng/m³ and 1.0 ng/m³ for BaP for 2005, 2010, 2015 and 2020.

2005				
	> 0.25 ng/m ³	> 0.4 ng/m ³	> 0.6 ng/m ³	> 1.0 ng/m ³
London	0	0	0	0
Rest of England	480	68	25	10
Scotland	26	6	0	0
Wales	9	2	2	1
Northern Ireland	258	77	17	0
Total	773	153	44	11
Percentage of UK	0.32%	0.06%	0.02%	0.005%

2010				
	> 0.25 ng/m ³	> 0.4 ng/m ³	> 0.6 ng/m ³	> 1.0 ng/m ³
London	0	0	0	0
Rest of England	409	64	24	9
Scotland	20	4	0	0
Wales	6	2	2	1
Northern Ireland	216	60	7	0
Total	651	130	33	10
Percentage of UK	0.27%	0.05%	0.01%	0.004%

2015				
	> 0.25 ng/m ³	> 0.4 ng/m ³	> 0.6 ng/m ³	> 1.0 ng/m ³
London	0	0	0	0
Rest of England	412	64	25	9
Scotland	20	4	0	0
Wales	6	2	2	1
Northern Ireland	217	62	7	0
Total	655	132	34	10
Percentage of UK	0.27%	0.05%	0.01%	0.004%

2020				
	> 0.25 ng/m ³	> 0.4 ng/m ³	> 0.6 ng/m ³	> 1.0 ng/m ³
London	0	0	0	0
Rest of England	448	65	25	10
Scotland	23	5	0	0
Wales	7	2	2	1
Northern Ireland	233	69	12	0
Total	711	141	39	11
Percentage of UK	0.29%	0.06%	0.02%	0.005%

Population exposure to exceedence the AQS objective, assessment thresholds and EU Target Value.

Table 3 shows the number of people exposed to the concentration thresholds of 0.25 ng/m³, 0.4 ng/m³, 0.6 ng/m³ and 1.0 ng/m³ for 2005, 2010, 2015 and 2020. The table shows that there are no exceedences of the EU Limit value of 1.0 ng/m³ in London, Scotland and Northern Ireland in 2005, 2010, 2015 and 2020.

Table 3: Population exposed to the concentration thresholds of 0.25 ng/m³, 0.4 ng/m³, 0.6 ng/m³ and 1.0 ng/m³ for 2005, 2010, 2015 and 2020.

2005				
	> 0.25 ng/m ³	> 0.4 ng/m ³	> 0.6 ng/m ³	> 1.0 ng/m ³
London	0	0	0	0
Rest of England	480153	35738	8809	2210
Scotland	90597	26100	0	0
Wales	8940	43	43	19
Northern Ireland	508489	207930	53973	0
Total	1088180	269810	62825	2229
Percentage of UK	1.87%	0.46%	0.11%	0.004%
2010				
	> 0.25 ng/m ³	> 0.4 ng/m ³	> 0.6 ng/m ³	> 1.0 ng/m ³
London	0	0	0	0
Rest of England	418794	34550	8793	2060
Scotland	62932	20628	0	0
Wales	4732	43	43	19
Northern Ireland	451045	167593	25483	0
Total	937504	222814	34319	2079
Percentage of UK	1.61%	0.38%	0.06%	0.004%
2015				
	> 0.25 ng/m ³	> 0.4 ng/m ³	> 0.6 ng/m ³	> 1.0 ng/m ³
London	0	0	0	0
Rest of England	413760	34550	8809	2060
Scotland	62932	20628	0	0
Wales	4732	43	43	19
Northern Ireland	453254	175833	25483	0
Total	934678	231055	34334	2079
Percentage of UK	1.60%	0.40%	0.06%	0.004%
2020				
	> 0.25 ng/m ³	> 0.4 ng/m ³	> 0.6 ng/m ³	> 1.0 ng/m ³
London	0	0	0	0
Rest of England	460121	34567	8809	2210
Scotland	75461	22891	0	0
Wales	5601	43	43	19
Northern Ireland	472123	190856	39785	0
Total	1013306	248357	48637	2229
Percentage of UK	1.74%	0.43%	0.08%	0.004%

Population-weighted mean concentrations

Table 4 shows the population-weighted mean concentrations throughout the United Kingdom in 2005, 2010, 2015 and 2020. The highest populated weighted means are predicted to occur in Northern Ireland.

Table 4: Population weighted mean concentrations determined throughout the United Kingdom (ng/m³)

	2005	2010	2015	2020
Scotland	0.105	0.103	0.102	0.104
Wales	0.110	0.105	0.105	0.107
Northern Ireland	0.228	0.209	0.210	0.218
Inner London	0.111	0.106	0.104	0.103
Outer London	0.109	0.108	0.106	0.106
Rest of England	0.112	0.112	0.111	0.112
UK	0.115	0.113	0.112	0.113

Tables 2, 3 & 4 indicate that there remains around 711 km² and around 1 million individuals above the BaP objective by 2020, although general population weighted mean concentrations will be around half the objective..

Maps

Figure 1 to 4 shows the extent of the exceedence of the 0.25 ng/m³, 0.4 ng/m³, 0.6 ng/m³ and 1.0 ng/m³ concentration thresholds.

Figure 1: Predicted BaP concentrations in 2005, ng/m³

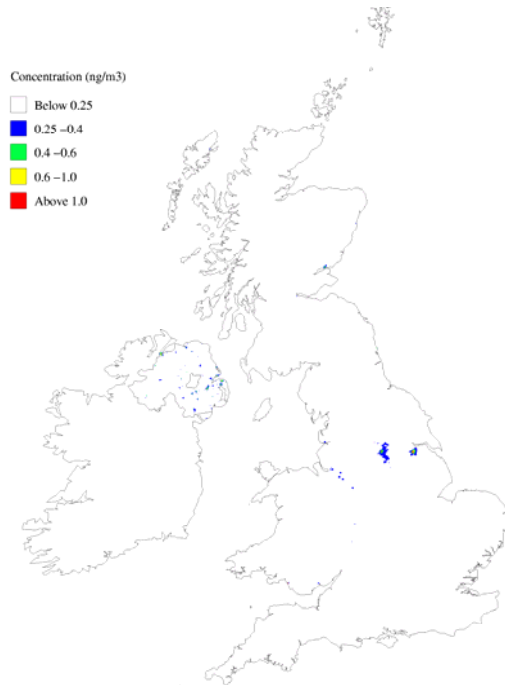


Figure 2: Predicted BaP concentrations in 2010, ng/m³

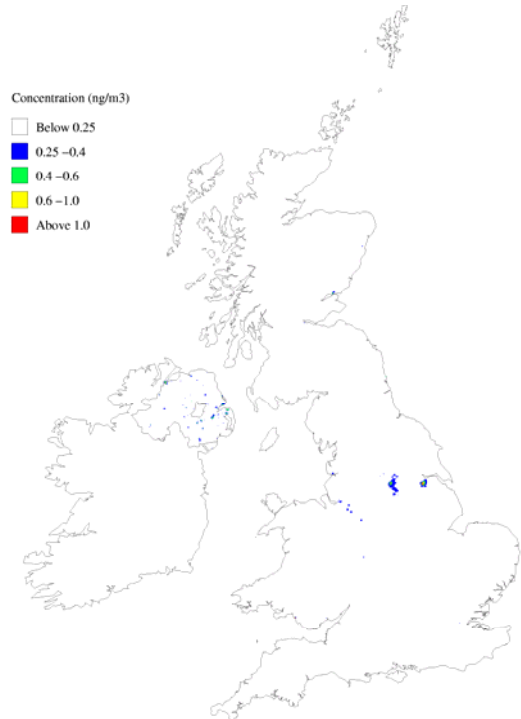


Figure 3: Predicted BaP concentrations in 2015, ng/m³

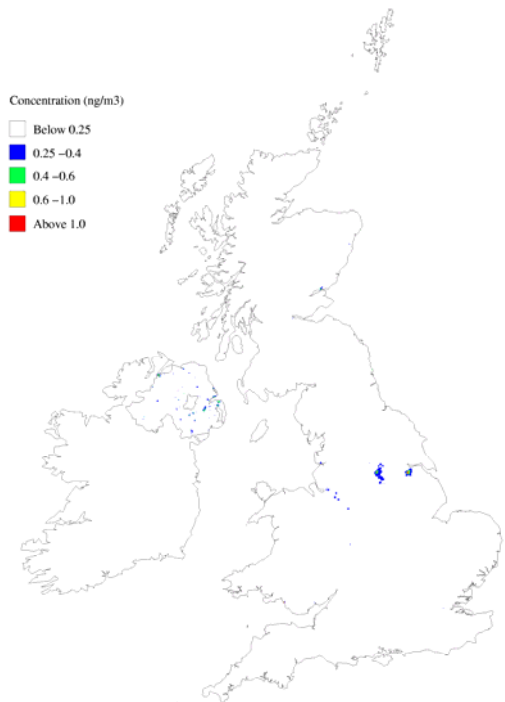
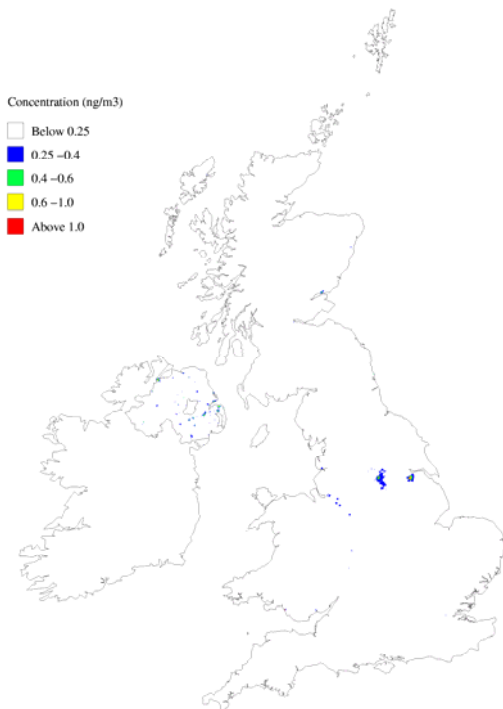


Figure 4: Predicted BaP concentrations in 2020, ng/m³



Source apportionment

Figure 5 shows the source apportionment at each of the BaP monitoring stations in 2005. The industrial component can be seen to be making a significant contribution at Port Talbot and Scunthorpe, though the concentration at Port Talbot is underestimated. The domestic emissions are estimated to be making a significant contribution to concentrations measured at the Lisburn and Belfast sampling sites.

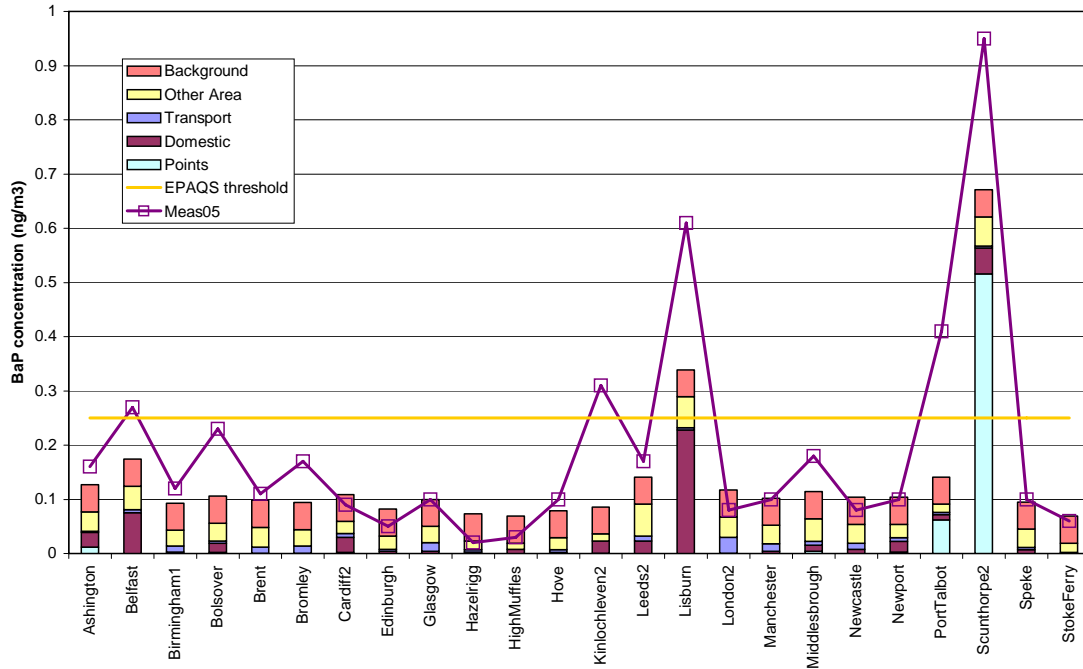


Figure 5: Source apportionment at BaP sampling sites

Model validation

Figure 6 compares the modelled and measured BaP concentration. Also plotted are the $\pm 60\%$ data quality objectives for BaP prediction. The concentrations predicted at Kinlochleven (measured 0.31 ng/m^3) and Port Talbot (measured 0.41 ng/m^3) fall below the lower DQO line.

The uncertainties are not as high as 2003 base year modelled in the consultation document, however they still remain higher than the other classical pollutants. The main problems are the emission factors for the 4 or so key source sectors. One of the main improvements since the 2003 base year modelling is the use of an improved spatial distribution of domestic fuel use.

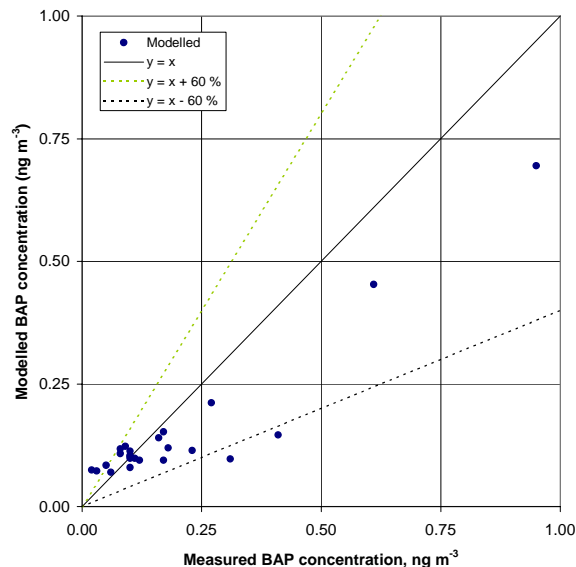


Figure 6: A comparison of modelled and measured concentrations.

Conclusions

- Updated modelling is considerably improved over that presented in the AQS consultation document.
- Uncertainties have been reduced with an improved spatial distribution of domestic fuel use removing some artefacts observed in the previous modelling.
- The key emissions sectors remain: domestic combustion; coke production; natural fires; and industrial combustion of coal and treated wood.