UK modelling under the Air Quality Framework Directive (96/62/EC) and Fourth Daughter Directive (2004/107/EC) for 2009 covering As, Cd, Ni and B(a)P

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Executive summary

European Union directives on ambient air quality require member states including the UK to undertake air quality assessments, and to report the findings of these assessments to the European Commission on an annual basis. Historically this has been performed according to:

- The Air Quality Framework Directive (1996/62/EC)
- The four Daughter Directives 1999/30/EC, 2000/69/EC, 2002/3/EC and 2004/107/EC.

In June 2008, a new directive came into force: the Council Directive on ambient air quality and cleaner air for Europe (2008/50/EC), which is known as the ‘Air Quality Directive’ (AQD). This directive consolidates the first three Daughter Directives, and was transposed into Regulations in England, Scotland, Wales and Northern Ireland in June 2010. The 4th Daughter Directive (AQDD4), 2004/107/EC, remains in force.

In 2009 the UK undertook the annual air quality assessment in accordance with the requirements of the AQD and the AQDD4. The assessment presented in this report takes the form of comparisons of measured and modelled air pollutant concentrations with the target values set out in the AQDD4. Air quality modelling has been carried out to supplement the information available from the UK national air quality monitoring networks. The results were submitted to the European Commission in the form of a standard questionnaire (the ‘questionnaire’) which each member state must complete and upload onto the Common Data Repository of the European Environment Agency: http://cdr.eionet.europa.eu/gb/eu/annualair.

AQDD4 sets target values for the ambient concentrations to be achieved for:

- Arsenic (As)
- Cadmium (Cd)
- Nickel (Ni)
- Benzo(a)Pyrene (B(a)P)

This report provides a summary of key results from the questionnaire for the AQDD4 pollutants and additional technical information on the modelling methods that have been used. Full details of the assessment carried out under the AQD are included in the accompanying report (Grice et al., 2010).

The UK has been divided into 43 zones for air quality assessment. There are 28 agglomeration zones (large urban areas) and 15 non-agglomeration zones. The status of the zones in relation to the limit values, target values and long term objectives have been assessed. The results of the assessment against the target values are presented in Table E1.

Table E1. Summary results of AQDD4 air quality assessment for 2009: comparison with target values

Pollutant	Averaging time	Number of zones exceeding target value
As	Annual	None
Cd	Annual	None
Ni	Annual	2 zones modelled (Swansea, S Wales)
B(a)P	Annual	6 zones, (2 zones measured: N Ireland, Yorkshire & Humberside + 4 zones modelled: Teesside UA, Swansea UA, NE England Zone, S Wales Zone)

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Appendices

1 Introduction

1.1 The EU ambient air quality directives

European Union directives on ambient air quality require the UK to undertake air quality assessments, and to report the findings of these assessments to the European Commission on an annual basis. Historically this has been under:

- The Air Quality Framework Directive (1996/62/EC)
- The four Daughter Directives 1999/30/EC, 2000/69/EC, 2002/3/EC and 2004/107/EC

In June 2008, a new directive came into force: the Council Directive on ambient air quality and cleaner air for Europe (2008/50/EC), which is known as the ‘Air Quality Directive’ (AQD). This directive consolidates the first three Daughter Directives, and was transposed into Regulations in England, Scotland, Wales and Northern Ireland in June 2010. The fourth Daughter Directive (AQDD4), 2004/107/EC, which covers the pollutants presented in this report, remains in force.

In 2009 the UK undertook the annual air quality assessment in accordance with the requirements of the AQD and the AQDD4. This assessment takes the form of comparisons of measured and modelled air pollutant concentrations with the limit values, target values and long term objectives set out in the air quality directives. The results were submitted to the European Commission in the form of a standard reporting questionnaire (the ‘questionnaire’) which each member state must complete and upload onto the Common Data Repository of the European Environment Agency: http://cdr.eionet.europa.eu/gb/eu/annualair (CDR, 2010).

The AQD sets limit values for the ambient concentrations to be achieved for:

- sulphur dioxide (SO_2)
- nitrogen dioxide (NO_2) and oxides of nitrogen (NO_X)
- particles (PM_{10})
- lead (Pb)
- benzene (C_6H_6)
- carbon monoxide (CO)

The AQD also includes:

- a target value, limit values, an exposure concentration obligation and exposure reduction targets for fine particles ($PM_{2.5}$)
- target values and long-term objectives for ozone (O_3)

AQDD4 sets target values to be achieved for:

- arsenic (As)
- cadmium (Cd)
- nickel (Ni)
- polycyclic aromatic hydrocarbons with benzo(a)pyrene (B(a)P) as an indicator species

The number of monitoring sites required for compliance is defined within the air quality directives and is significantly reduced if other means of assessment, in addition to fixed monitoring sites, are also available for inclusion in the annual air quality assessment. Air quality modelling has therefore been carried out to supplement the information available from the UK national air quality monitoring networks.

1.2 The current report

This report provides detailed information on the modelling methods that have been used to assess concentrations of As, Cd, Ni and B(a)P in 2009 throughout the UK and a summary of the key results of the air quality assessment for AQDD4. Full details of the assessment carried out for SO_2, NO_2/NO_X, PM_{10}, $PM_{2.5}$, lead, benzene, CO and ozone (all covered by the new AQD) are included in the accompanying report (Grice et al., 2010). A report summarising the UK's 2009 submission on air quality to the European Commission and presenting air quality modelling data and measurements from the UK national air quality monitoring networks has also been uploaded onto the CDR (Air Pollution in the UK, 2009, Edition A. September 2010).

Sections 2 and 3 of this report describe the Pollution Climate Mapping (PCM) modelling methods used to calculate concentrations of heavy metals (arsenic, cadmium and nickel) and B(a)P. These include:

- Details of the modelling methods
- Information on the verification of the models used and comparisons with data quality objectives (DQO)
- Detailed modelling results

The status of zones in relation to the target values for the AQDD4 pollutants have been reported to the EU in the questionnaire (CDR, 2010) and a summary of the results of the assessments are included in Section 4. The status has been determined from a combination of monitoring data and model results.

2009 is the second year for which an annual air quality assessment for these pollutants has been carried out. The results of the air quality assessment for 2008 and a description of the modelling methods used have been presented by Yap et al. (2009).

1.3 Preliminary assessments and definition of zones

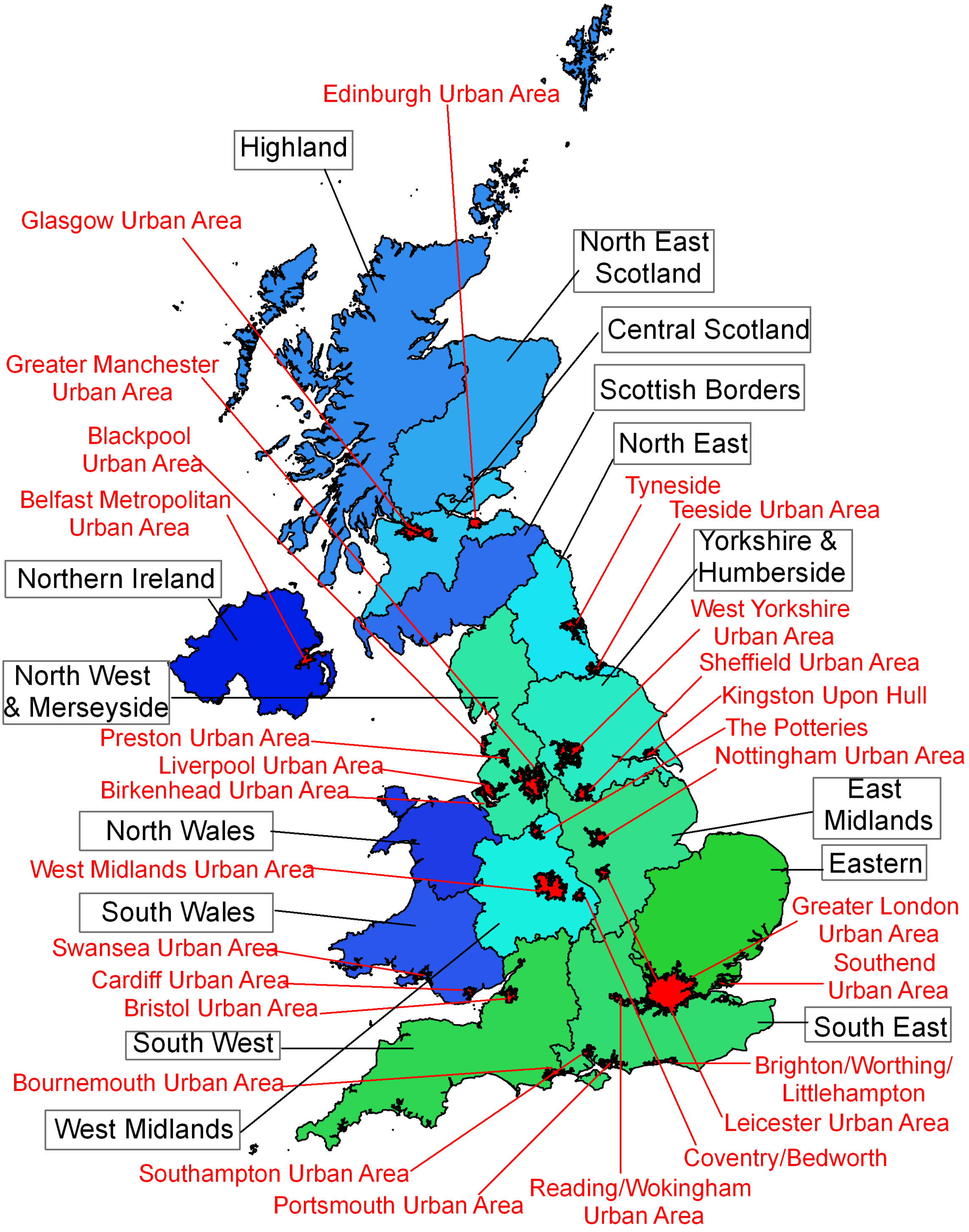
The Framework Directive included a requirement for member states to undertake preliminary assessments of ambient air quality, prior to the implementation of the Daughter Directives under Article 5 of this Directive. The objectives of these assessments were to establish estimates for the overall distribution and levels of pollutants, and to identify additional monitoring required to fulfil obligations within the Framework Directive. A report describing the preliminary assessment for the UK for AQDD4 has been prepared (Bush, 2007) which includes the definition of a set of zones to be used for air quality assessment in the UK. Table 1.1 contains details of area, population (from 2001 census) and urban road length contained in each zone and agglomeration. The zones and agglomerations map for the UK is presented in Figure 1.1.

Table 1.1: Zones for Ambient Air Quality Directive reporting

Zone	Zone code	Ag or non-ag*	Population	Area (km^2)	Number of urban road links	Length of urban road links (km)
Greater London Urban Area	UK0001	ag	8278251	1629.9	1909	1895.3
West Midlands Urban Area	UK0002	ag	2284093	599.7	385	544.7
Greater Manchester Urban Area	UK0003	ag	2244931	556.5	554	670.9
West Yorkshire Urban Area	UK0004	ag	1499465	370.0	282	422.6
Tyneside	UK0005	ag	879996	210.7	167	206.0
Liverpool Urban Area	UK0006	ag	816216	186.1	251	213.6
Sheffield Urban Area	UK0007	ag	640720	162.2	113	161.8
Nottingham Urban Area	UK0008	ag	666358	158.4	124	134.5
Bristol Urban Area	UK0009	ag	551066	139.8	112	116.2
Brighton/Worthing/Littlehampton	UK0010	ag	461181	94.1	60	90.7
Leicester Urban Area	UK0011	ag	441213	101.6	66	81.3
Portsmouth Urban Area	UK0012	ag	442252	94.4	56	78.5
Teesside Urban Area	UK0013	ag	365323	114.3	62	72.1
The Potteries	UK0014	ag	362403	96.6	112	129.0
Bournemouth Urban Area	UK0015	ag	383713	108.1	48	72.2
Reading/Wokingham Urban Area	UK0016	ag	369804	93.2	65	76.8
Coventry/Bedworth	UK0017	ag	336452	75.5	29	39.9
Kingston upon Hull	UK0018	ag	301416	80.4	38	60.1
Southampton Urban Area	UK0019	ag	304400	72.8	61	77.5
Birkenhead Urban Area	UK0020	ag	319675	89.1	64	71.9
Southend Urban Area	UK0021	ag	269415	66.8	31	50.6
Blackpool Urban Area	UK0022	ag	261088	65.8	48	64.8
Preston Urban Area	UK0023	ag	264601	60.4	35	47.4
Glasgow Urban Area	UK0024	ag	1168270	368.7	219	325.5
Edinburgh Urban Area	UK0025	ag	452194	120.1	60	102.3
Cardiff Urban Area	UK0026	ag	327706	75.6	38	58.8
Swansea Urban Area	UK0027	ag	270506	79.7	30	71.3
Belfast Metropolitan Urban Area	UK0028	ag	515484	198.1	34	200.2
Eastern	UK0029	non-ag	4909880	19133.7	571	806.6
South West	UK0030	non-ag	4039460	23562.6	428	647.8
South East	UK0031	non-ag	6160630	18672.6	797	1290.0
East Midlands	UK0032	non-ag	3261330	15495.9	400	658.1
North West & Merseyside	UK0033	non-ag	3470620	13722.9	511	833.9
Yorkshire & Humberside	UK0034	non-ag	3003870	14796.6	313	567.2
West Midlands	UK0035	non-ag	2624020	12186.3	329	505.8
North East	UK0036	non-ag	1443910	8291.4	180	272.1
Central Scotland	UK0037	non-ag	1883010	9347.6	213	345.2
North East Scotland	UK0038	non-ag	976022	18631.4	129	226.7
Highland	UK0039	non-ag	341329	39134.5	10	35.4
Scottish Borders	UK0040	non-ag	250529	11184.1	35	47.3
South Wales	UK0041	non-ag	1698080	12228.4	163	316.9
North Wales	UK0042	non-ag	702506	8382.6	84	157.1
Northern Ireland	UK0043	non-ag	1149150	13974.1	90	288.1

*** ag = agglomeration zone; non-ag = non-agglomeration zone**

Figure 1.1: UK zones and agglomerations for 2009



Agglomeration zones (red)

Non-agglomeration zones (blue/green)

1.4 Monitoring sites

The monitoring stations operating during 2009 for the purpose of AQDD4 reporting are listed in Form 3 of the questionnaire, which can be found on the CDR (2010). Not all sites had sufficient data capture during 2009 for data to be reported. The data quality objective (DQO) for AQDD4 measurements is 90% data capture, however, all measurements with at least 75% data capture for the entire year have been included in the analysis in order to ensure that maximum use is made of data from the monitoring sites operational for the whole of 2009 for reporting purposes. Data capture statistics for sites operational during 2009 are also presented in Form 3 of the reporting questionnaire.

The monitoring data for the sites used in this assessment are shown in Table 2.1 (heavy metals) and Table 3.1 (B(a)P).

1.5 Target values

The target values (TV) included in AQDD4 are listed in Table 1.2. The Directive states that Member States should take all necessary measures not entailing disproportionate costs to ensure that the target values are met by the compliance date.

Table 1.2: Target values for As, Cd, Ni and B(a)P

Pollutant	Averaging period	TV (ng/m^3)	Date by which TV is to be met
As	Calendar year	6	31 December 2012
Cd	Calendar year	5	31 December 2012
Ni	Calendar year	20	31 December 2012
Benzo(a)pyrene	Calendar year	1	31 December 2012

1.6 Data quality objectives for modelling results and model verification

AQDD4 sets data quality objectives (DQOs) in terms of accuracy, which acts as a guide for quality assurance programmes when identifying an acceptable level of accuracy for assessment methods appropriate for supplementary assessment. Accuracy is defined in the Directive as the maximum deviation of the measured and calculated concentration levels, over the period considered by the target value, without taking into account the timing of events. DQOs have been set at 60% for annual averages of As, Cd, Ni and B(a)P.

Model accuracy has been defined in more detail in the AQD as the maximum deviation of the measured and calculated concentration levels for 90% of individual monitoring points over the period considered by the limit value or target value, without taking into account the timing of events. The uncertainty of modelling should be interpreted as applicable in the region of the appropriate LV or TV. The fixed measurements that have been selected for comparison with the modelling results should be representative of the scale covered by the model. Final guidance clarifying the recommended methods for assessing model performance with respect to the DQOs has yet to be agreed. The comparisons with monitoring data presented in this report have therefore included data from all sites including those with measured values not in the vicinity of the TV and a highly detailed assessment of the spatial representativity of the sites has not been carried out.

The models used to calculate the air pollution maps presented in this report have been calibrated and verified using national network monitoring data for those sites that are listed in

Form 3 of the reporting questionnaire. Model verification results are listed in the following sections for each pollutant.

1.7 Air quality in Gibraltar in 2009

Air quality monitoring data collected in Gibraltar are submitted to the Commission each year via a separate questionnaire from that compiled for the UK (CDR, 2010). Further information on air quality monitoring in Gibraltar can be found at http://www.gibraltarairquality.gi/.

2 Heavy metals

2.1 Introduction

Heavy metals are dangerous to both human health and to the environment. Scientific evidence shows that heavy metals are human genotoxic carcinogens and that there is no identifiable threshold below which these substances do not pose a risk to human health. Impact on human health and the environment occurs via concentrations in ambient air and via deposition. TVs were set in the fourth Daughter Directive (AQDD4) for As, Cd, Ni with the aim of minimising the harmful effects on human health of airborne heavy metals, paying particular attention to sensitive populations and the environment as a whole.

An assessment to determine the concentration of each of the heavy metals listed above in ambient air has been undertaken. The annual mean background concentration of each of the pollutants is calculated by summing the contributions from:

- Area sources
- Point sources
- Heavy metal component of regional primary PM resulting from long range transport
- Resuspension of heavy metals from bare soils and associated vehicle activity

Modelling work was previously undertaken by Vincent and Passant (2008) to predict ambient concentrations of As, Cd and Ni in preparation for the implementation of AQDD4. Measured concentrations were under-predicted by the model which suggested that the source apportionment of ambient concentrations was poorly understood. Only area and point sources were considered as sources of ambient concentrations – the resuspension of heavy metals from bare soils and vehicles was not included in the previous modelling assessment, which used only reported emissions inventories.

Abbott (2008) recommended methods for estimating the contribution of soil and vehicle related re-suspension processes to ambient heavy metal concentrations. These methods were applied for the first time in the modelling carried out for the 2008 air quality assessment (Yap et al., 2009). The methods used to estimate PM mass and the heavy metal concentrations from re-suspension processes are described below.

The preliminary assessment carried out for AQDD4 (Bush, 2007), highlighted the need for additional monitoring at 11 locations across the UK. The National Physical Laboratory (NPL) expanded the Heavy Metals Network by 11 sites in 2008, on behalf of Defra. The details of the additional monitoring sites are shown in the NPL report (Butterfield et al., 2008).

2.2 Monitoring sites

Annual mean concentrations of As, Cd and Ni are presented in Table 2.1 for those sites where data capture was at least 75%. Applying a data capture threshold of 75% rather than 90% ensures that maximum use of available data is made for reporting purposes.

Table 2.1: Measured annual mean heavy metal concentrations and data capture (DC) recorded in 2009 where data capture >75%

EoI code	Site Name	Site Type	Annual Mean As		Annual Mean Cd		Annual Mean Ni	
			ng/m^3	DC %	ng/m^3	DC %	ng/m^3	DC %
GB0852A	Auchencorth	Rural	0.20	94	0.03	94	0.32	94
GB0878A	Bristol Avonmouth	Urban	0.66	98	0.22	98	1.27	98
GB0091R	Banchory	Rural	0.29	80	0.04	80	0.32	80
GB0855A	Beacon Hill	Rural	0.51	76	0.10	76	0.70	76
GB0975A	Belfast Centre Metals	Urban centre	0.35	92	0.10	92	1.77	92
GB0789A	Bristol Hallen	Urban	0.61	100	0.25	100	0.78	100
GB0369A	Cardiff Llandaff	Urban background	0.81	98	0.17	98	1.18	98
GB0984A	Cardiff Rumney	Industrial background	0.64	90	0.16	90	0.74	90
GB0537A	Central London Metals	Urban	0.76	98	0.17	98	1.14	98
GB0985A	Chadwell St Mary	Industrial background	0.81	98	0.24	98	2.42	98
GB0853A	Cockley Beck	Rural	0.25	77	0.04	77	0.52	77
GB0854A	Cwmystwyth	Rural	0.20	84	0.03	84	0.48	84
GB0986A	Dartford Bean	Urban background	0.78	96	0.20	96	1.68	96
GB0886A	Detling	Rural	0.73	93	0.29	93	1.55	93
GB0361A	Eskdalemuir Metals	Rural	0.13	98	0.03	98	0.14	98
GB0017R	Heigham Holmes	Rural	0.46	75	0.10	75	1.81	75
GB0332A	London Cromwell Road	Rural	0.77	90	0.16	90	1.64	90
GB0846A	London Marylebone Road Metals	Urban	1.00	87	0.10	87	2.50	87
GB0370A	Manchester Wythenshawe	Urban	0.86	94	0.16	94	1.52	94
GB0856A	Monks Wood	Rural	0.62	76	0.11	76	0.98	76
GB0241A	Motherwell Centre	Urban	0.35	92	0.07	92	0.45	92
-----	Pontardawe *	Suburban	0.67	100	0.19	100	24.00	100
GB0976A	Port Talbot Margam Metals	Industrial	0.52	92	0.24	92	1.42	92
GB0977A	Redcar Metals	Industrial background	0.53	94	0.21	94	1.00	94
GB0980A	Redcar Normanby	Urban background	0.34	94	0.10	94	0.55	94
GB0877A	Runcorn Weston Point	Urban	0.50	90	0.11	90	0.88	90
GB0982A	Scunthorpe Santon Metals	Industrial background	0.94	96	0.21	96	1.27	96
GB0987A	Scunthorpe Town Metals	Urban background	0.83	96	0.20	96	0.84	96

EoI code	Site Name	Site Type	Annual Mean As		Annual Mean Cd		Annual Mean Ni	
			ng/m^3	DC %	ng/m^3	DC %	ng/m^3	DC %
GB0792A	Sheffield Brinsworth	Urban	1.02	96	0.36	96	9.81	96
GB0978A	Sheffield Centre Metals	Urban centre	0.61	98	0.16	98	1.69	98
GB0981A	Swansea Coedgwilym	Urban	0.61	96	0.20	96	16.01	96
GB0979A	Swansea Morriston	Urban background	0.87	98	0.30	98	9.34	98
GB0382A	Walsall Centre	Industrial background	1.08	90	0.48	90	0.82	90
GB0983A	Walsall Willenhall Metals	Suburban	1.14	94	2.78	94	2.97	94
GB0858A	Wytham Wood	Rural	0.57	92	0.09	92	0.83	92
GB0013R	Yarner Wood Metals	Rural	0.38	86	0.04	86	0.92	86

* The Pontardawe monitoring site is operated by the Local Authority, and is not part of the national network (therefore there is no EoI code for this site)

2.3 Emissions

Emissions estimates for heavy metals are published annually in the National Atmospheric Emissions Inventory (NAEI). The latest available inventory year is 2008, details of which are given in Murrells et al., 2010. Projections of emissions estimates for 2010, 2015 and 2020 have been derived from the 2008 NAEI estimates using the Updated Energy Projections (UEP 38) provided by the Department of Energy and Climate Change (DECC). The emissions estimates for 2008, 2010, 2015 and 2020 by SNAP code are shown in Figure 2.1, Figure 2.2 and Figure 2.3 for As, Cd and Ni respectively. Values for intermediate years have been interpolated in these figures.

Point source emissions (the top two categories in Figure 2.1 to Figure 2.3) are emissions of a known amount from a known location, such as power stations. Area source emissions (the remaining categories in Figure 2.1 to Figure 2.3) are ‘diffuse emissions’ from many unspecified locations, such as the emissions from domestic heating.

Figure 2.1 shows that only a small, gradual reduction in As emissions is forecast over the period 2008-2020. In all years, SNAP code 3: Combustion in Industry, accounts for over 70% of total emissions. Emissions of arsenic are primarily from the combustion of solid fuel, and as such, the majority of emissions are estimated to be from the burning of wood treated with copper chromium arsenate. There are no reliable estimates of the extent of this activity, and since the emission factor for this source is also very uncertain, the total emission estimate for this source is highly uncertain. Point sources are also a significant source of As emissions in the UK.

Figure 2.2 shows a small decrease in emissions of Cd across the time period presented. A 5% decrease in total emissions is estimated in 2010 relative to 2008. Point sources are the dominant source of Cd across the time series, with emissions from road transport, SNAP Code 7, also shown as a significant source.

Figure 2.3 shows an 8% decrease in Ni emissions in 2010, relative to 2008. This decrease slows beyond 2010, with a 13% decrease in Ni emissions in 2020 relative to 2008 emission levels. The Figure indicates that point sources, shipping (SNAP code 8) and Combustion in Industry (SNAP code 3) are the dominant emissions sources of Ni in the UK. Ni emissions are primarily from the combustion of liquid fuels.

Ambient concentrations of the heavy metals are influenced by the relative location and release characteristics of emissions. They are also influenced by sources which are not explicitly included in the emissions inventory, such as re-suspension.

Maps of emissions from area sources in 2009 have been derived from the 2008 inventory maps using specific scaling factors for each combination of source and activity (typically fuel type) which have been derived from these projections. Emissions from point sources have not been scaled and the emissions for 2008 have been assumed to apply in 2009.

Figure 2.1: UK total As emissions for 2008 and emission projections up to 2020 by SNAP code (NAEI 2008)

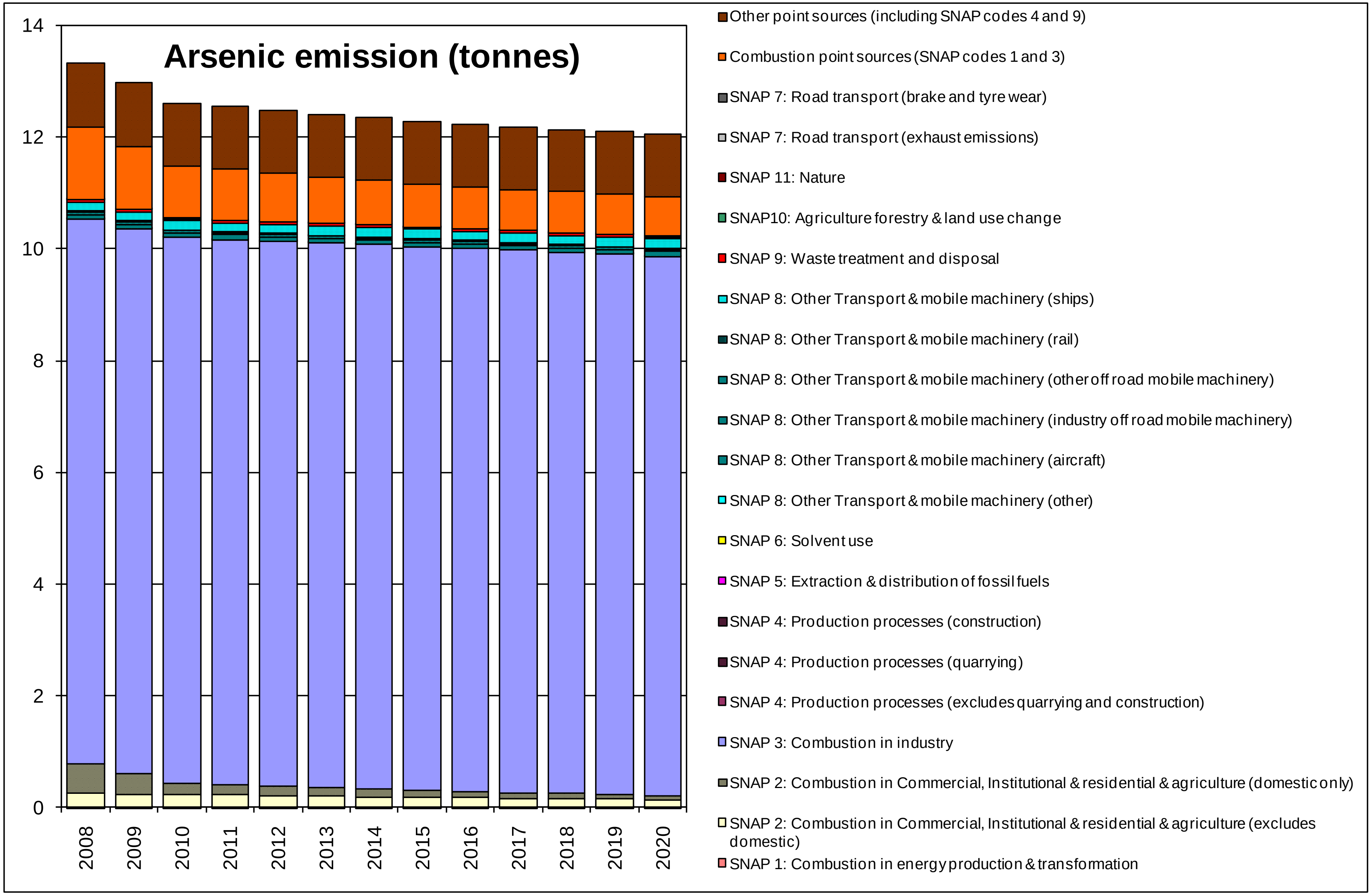


Figure 2.2: UK total Cd emissions for 2008 and emissions projections up to 2020 by SNAP code (NAEI 2008)

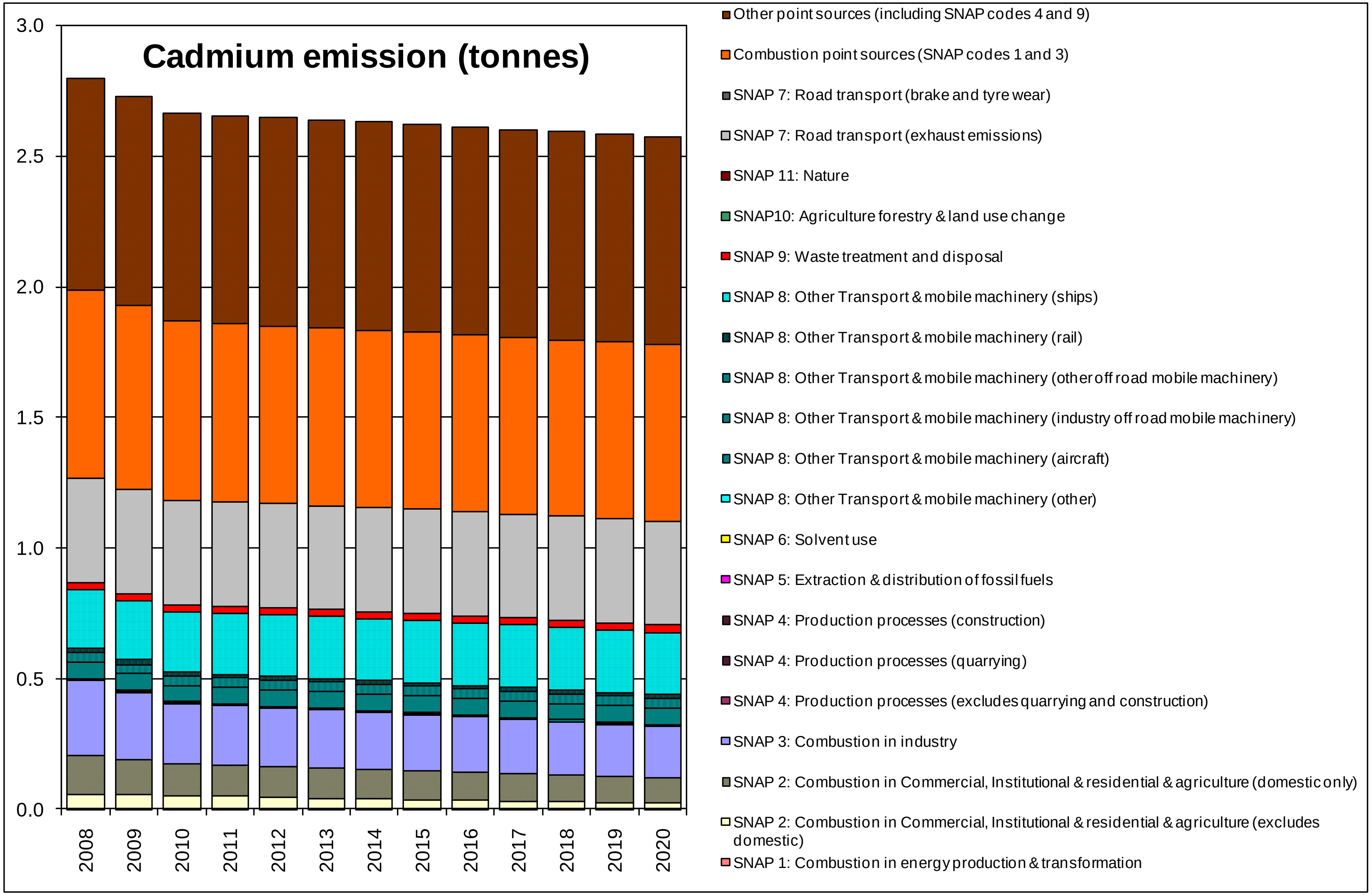
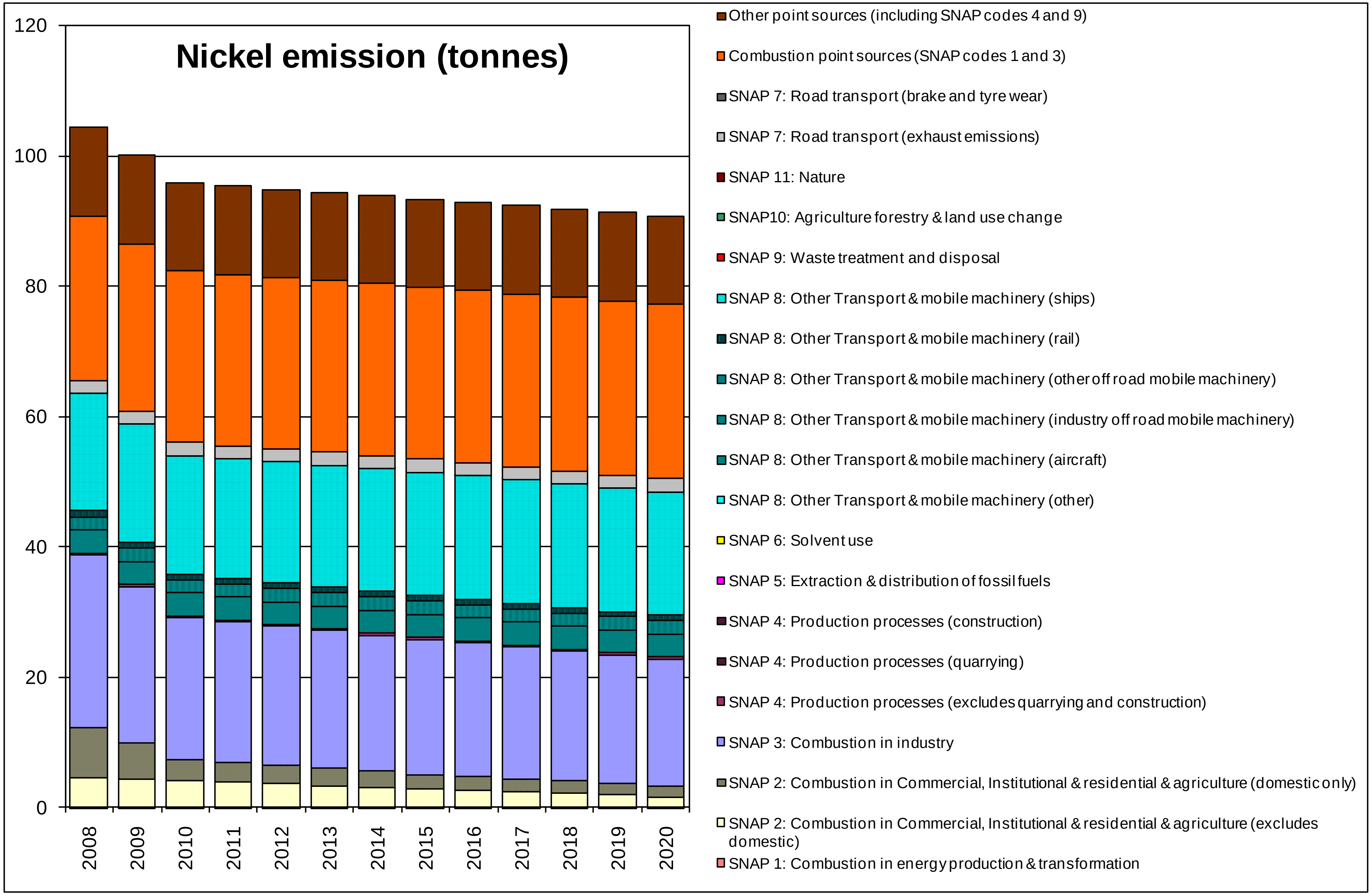


Figure 2.3: UK total Ni emissions for 2008 and emissions projections up to 2020 by SNAP code (NAEI 2008)



2.4 The model

2.4.1 Heavy metal contribution from large point sources

The contribution to ground level annual mean heavy metal concentrations from emissions from large point sources (those with annual emissions of greater than 1.2 tonnes per year or with stack parameters datasets in the database) in the 2008 NAEI was estimated by modelling each source explicitly using an atmospheric dispersion model (ADMS 4.2) and sequential meteorological data for 2009 from Waddington, UK. A total of 205, 207 and 212 large point sources were modelled for As, Cd and Ni, respectively. Surface roughness was assumed to be 0.1m at the dispersion site and 0.02m at the meteorological site. Concentrations were calculated for a 99km x 99km grid square composed of a regularly spaced 1km x 1km resolution receptor grid. Each 99km x 99km grid square was centred on the point source, for which information was retrieved from the stack parameters database, which has been developed over a period of time under the PCM contract and is updated annually as required. Data sources for this database include a survey of Part A authorisation notices held by the Environment Agency and previously collated datasets on emission release parameters from large SO_2 point sources (Abbott and Vincent, 1999). Parameters used in the modelling from the stack parameters database include:

- Stack height
- Stack diameter
- Discharge velocity
- Discharge temperature

2.4.2 Heavy metal contribution from small point and fugitive sources

The contribution of emissions from fugitive and small point sources (those without stack parameters datasets) in the 2008 NAEI to ambient concentrations of heavy metals was modelled using the small point model. The model consists of separate ‘in-square’ and ‘out-of-square’ components, in which concentrations are estimated using a point source dispersion kernel. The dispersion kernel was calculated by using the dispersion model ADMS 4.2 to model the dispersion of unit emissions from a central source to a 31km x 31km grid of receptors at a spatial resolution of 1km x 1km, using the stack characteristics presented in Table 2.2. Hourly sequential meteorological data from Waddington in 2009 was used to construct the dispersion kernels.

The greatest concentrations would be expected close to the point of emission. The receptor for the central grid square within the dispersion kernel is at exactly the same location as the point of release and the concentration at this location is therefore zero. The value for the central square within the dispersion kernel has therefore been assigned to be equal to the highest of the values for the adjacent grid squares.

Table 2.2: Stack release parameters used to characterise emissions from point sources with no available stack parameters

Variable	Parameters
Stack height	15m
Diameter	1m
Temperature	15˚C
Surface roughness at dispersion site	0.5m
Surface roughness at met site	0.02m

Characterising the fugitive heavy metal emissions from an industrial plant is notoriously difficult. The emission release parameters used in the model for fugitive emissions are provided in Table 2.3. Once again, the value for the central square within the dispersion kernel has been set to the maximum of the values in the surrounding grid squares. Assuming a fugitive emission of 0.05 times the reported emission has been found to provide the best agreement with available measurement data.

Table 2.3: Stack release parameters used to characterise fugitive emission release

Variable	Parameters
Stack height	10m
Diameter	1m
Temperature	15˚C
Surface roughness at dispersion site	0.5m
Surface roughness at met site	0.02m

2.4.3 Heavy metal contribution from local area sources

The uncalibrated modelled area source contribution was calculated by applying an ADMS 4.2 derived dispersion kernel to calculate the contribution to ambient concentrations at a central receptor location from area source emissions within a 33km x 33km square surrounding each receptor. Hourly sequential meteorological data from Waddington in 2009 was used to construct the dispersion kernels, as described in Appendix 1.

The area source calibration coefficient of 1.2486, derived within the 2009 PCM model for NO_X (Grice at al., 2010), was applied to calculate the calibrated area source contribution for each grid square in the country.

The coefficient was derived for NO_X, a pollutant for which the emissions, source apportionment and measurements are better characterised than for the heavy metals. The source apportionment for heavy metals is subject to a greater uncertainty than NO_X, however it was found that using the coefficient provided a reasonable estimate of heavy metal concentrations as demonstrated in the verification plots presented for each pollutant below. In contrast it was found that the NO_X coefficient did not yield such good estimates of B(a)P concentrations. A B(a)P-specific calibration coefficient was hence applied for this pollutant (see Section 3).

For certain sectors (noted within each pollutant section described below) caps have been applied to emissions based on expert judgement of the model results in order to address known artefacts in the area source emissions grids and to reconcile the model results with the measured data at each monitoring site. The application of these caps is annually reported back to the NAEI as part of the quality checking process to ensure that continual improvements are made in the emissions grids.

2.4.4 Heavy metal contribution from regional PM as a result of long-range transport

The contribution to ambient concentrations from long range transport of heavy metals was derived from estimates of regional primary particulate matter used in the 2009 PCM model for PM_{10} mass (Grice et al., 2010). Contributions from the long range transport of PM particles on a 20km x 20km grid were estimated using the TRACK receptor oriented, Lagrangian statistical model (Lee et al., 2000). Emissions of primary PM were taken from the NAEI for UK sources and from EMEP (Webdab data, http://www.ceip.at/) for sources in the rest of Europe. Primary PM was modelled as an inert tracer, with all sources within 10km of the receptor point excluded from the TRACK model. This allowed the area source and the point source models to be nested within the long-range transport model without duplicating any source contributions.

The contribution of long range transport sources to ambient heavy metal concentrations was derived by calculating a fraction of the PM mass for each heavy metal. This fraction was estimated as the ratio of the UK total emissions for each metal for each SNAP sector to the total PM_{10} emission for that sector. These ratios were also assumed to apply to the contribution from non-UK European sources.

2.4.5 Heavy metal contribution from re-suspension

The 2009 model for heavy metal concentrations includes a contribution to ambient concentrations from re-suspension. The contributions from two processes have been included:

- Rural PM dusts from re-suspension of soils
- PM dusts from re-suspension due to vehicle activity

The heavy metal contribution from re-suspension was calculated using the methodology suggested by Abbott (2008). The methods used to estimate the total PM mass from these processes were revised by Grice et al (2009) to provide estimates suitable for inclusion in the PCM model.

PM_{10} mass re-suspension of soils

The contribution to PM mass from re-suspension from soils is calculated using the proportions of bare soils, root crops and cereal crops in 1km x 1km grid squares across the UK, within the Land Cover Map 2000 (Land Cover Map 2000, 2009). The concentration of PM mass cannot be calculated using the standard approach, which is by use of an estimate of the annual emissions and an air dispersion model. This is because the rate of re-suspension and the atmospheric dispersion of these emissions are both dependent upon the meteorological conditions. The emission rate will be higher when the wind is stronger but the dispersion of these emissions will also be more efficient under these conditions.

The method presented by Abbott (2008) makes use of combined emission and dispersion kernels for cereal and root crop fields and for bare soils. Concentrations were calculated for each hour of the year based upon hourly sequential meteorological data from twelve sites throughout the UK for 1999. This year was selected because the data were readily available.

This methodology has been adapted for use within the PCM model by using an inverse distance weighted average of the results from the different kernels for each receptor location. This revised method avoids the discontinuities caused by the use of a simpler ‘nearest met site to the receptor’ method, used in the original work.

PM_{10} mass re-suspension due to vehicle activity

Abbott (2008) also developed a method for estimating the contribution to PM mass from re-suspension due to vehicle activity. This method takes vehicle km statistics for heavy-duty vehicles (heavy goods vehicles and buses) as its starting point. These estimates are likely to be subject to greater uncertainty than the estimates for re-suspension from rural soils because there is little information on the availability of material on road surfaces to be re-suspended.

Abbott (2008) calculated two sets of combined emission and dispersion kernels for each of the twelve meteorological stations for 1999; one to represent rural, and one to represent urban conditions. The estimated re-suspension rate was considerably higher for rural conditions due to the higher vehicle speeds assumed. These two sets of kernels were then used to calculate the contribution to PM_{10} concentrations according to the proportion of urban and rural land cover within each 1km x 1km grid square. A detailed examination of the results from this assessment showed that the concentrations in urban areas were largely driven by the small proportion of rural land cover in the urban areas. The urban kernel was hence applied to all roads within the PCM model.

Estimating heavy metal concentrations

The maps of PM mass from the re-suspension of soils and re-suspension associated with vehicle movements are used to estimate contributions to the ambient concentration of heavy metals (Abbott, 2008). This is undertaken using a combination of information on the heavy metal content of soils and enhancement factors.

The National Soil Inventory (http://www.landis.org.uk/data/natmap.cfm) provides a data set of arsenic, cadmium and nickel concentrations in topsoil at 5km resolution throughout England and Wales. Measurements of heavy metals in topsoil for other areas of the UK can be obtained from the Geochemical Atlas of Europe, developed under the auspices of the Forum of European Geological Surveys (FOREGS) (www.gtk.fi/publ/foregsatlas). These data were interpolated to a 1km x 1km grid. The predicted annual PM emission rates and the contribution to atmospheric concentrations were multiplied by the topsoil concentrations to estimate the annual metal re-suspension rates and the contributions to atmospheric concentrations of heavy metals.

There is some evidence that metal concentrations in the surface soils are higher than in the underlying topsoil. EMEP have suggested that there may be some enhancement of the metal content of the re-suspended dust because the metals may form complexes with humic matter (Abbott, 2008). Abbott (2008) carried out regression analyses of measured heavy metal concentrations against the combined model predictions for sites in the UK Rural Heavy Metal Network. This analysis suggested that there may be other mechanisms by which heavy metals are concentrated in the small particle fraction of soils. For example, much of the metal content may be present as the result of historical deposition of small particles or the application of sewage sludge and farmyard slurries. These materials may only be loosely bonded to the surface of the soil particles. The fine particles released by re-suspension mechanisms would therefore be likely to contain a much higher concentration of metals than the underlying topsoil. The enhancement factors listed in Table 2.4 have been chosen to provide the best agreement of the total model predictions with measured heavy metal concentrations. The factors are broadly consistent with the regression coefficients determined by Abbott (2008).

Table 2.4: Heavy metal enhancement factors used in the assessment

Pollutant	Enhancement factor
As	35
Cd	35
Ni	7

2.5 Arsenic

2.5.1 Introduction

The method used to estimate the As ambient concentration across the UK is described in Section 2.4 above.

A cap of 3.5 ng/m^3 was applied to the contribution generated from the re-suspension of bare soils. This value was chosen as an estimate of the maximum likely concentration generated from this source.

2.5.2 Maps of annual mean concentrations

Figure 2.4 shows the modelled annual mean As concentrations. There are no modelled exceedences of the target value of 6 ng/m^3 in 2009. The maximum estimated As annual mean concentration was 5.20 ng/m^3.

2.5.3 Source apportionment

Figure 2.5 shows the modelled As contribution from different sources at 36 monitoring locations. Measured concentrations at the sites are also presented, giving an indication of the level of agreement between modelled and measured concentrations. This analysis suggests that the main sources of arsenic are emissions from point sources, non-road area sources and re-suspension processes.

2.5.4 Verification of mapped concentrations

An alternative presentation of the comparison between modelled and measured annual mean As concentrations in 2009 at different monitoring site locations are shown in Figure 2.6 to Figure 2.9. These figures include lines to represent the AQDD4 data quality objective for modelled annual mean As concentrations: y=x-60% and y=x+60% (see Section 1.6).

Summary statistics for modelled and measured As concentrations are listed in Table 2.5, including the percentage of sites at which modelled concentrations are outside of the data quality objectives (DQOs), and the total number of sites included in the analysis.

The mean of measured and modelled concentrations agree well for the industrial, urban background and roadside monitoring sites. The agreement between measured and modelled concentrations on a site-by-site basis (quantified using R^2) is poor for all monitoring sites, with the exception of rural monitoring locations.

It should be noted that non-emission inventory sources (such as fugitive, re-suspension and long range transport of primary PM) result in additional uncertainty when compared with a pollutant such as NO_X, for which the source apportionment is better known. The agreement between the measured and modelled annual mean heavy metal concentrations in this current assessment is much better than the assessment presented by Vincent and Passant (2008). This is because the current assessment includes contributions from resuspension processes in addition to emission sources included within the emissions inventory. The agreement is much better at the rural sites in particular, where the previous assessment predicted much lower concentrations.

2.5.5 Comparison of modelling and measurement results with the target value

There were no modelled of measured exceedences of the target value for As in 2009.

Figure 2.4: Annual mean map of As concentrations for comparison with the As target value of 6ng/m^3, 2009 (ng/m^3)

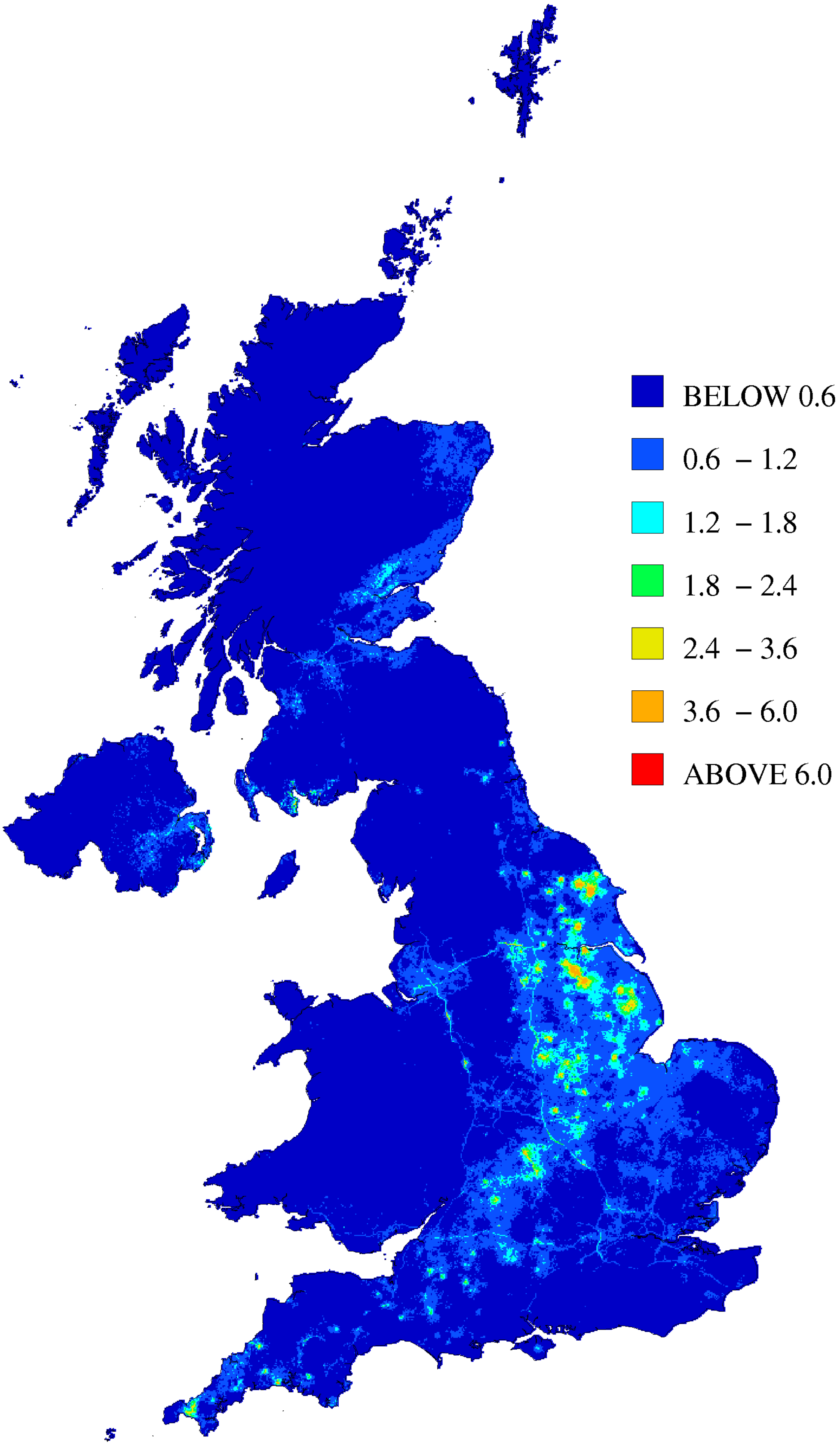


Figure 2.5: Source apportionment for As, 2009

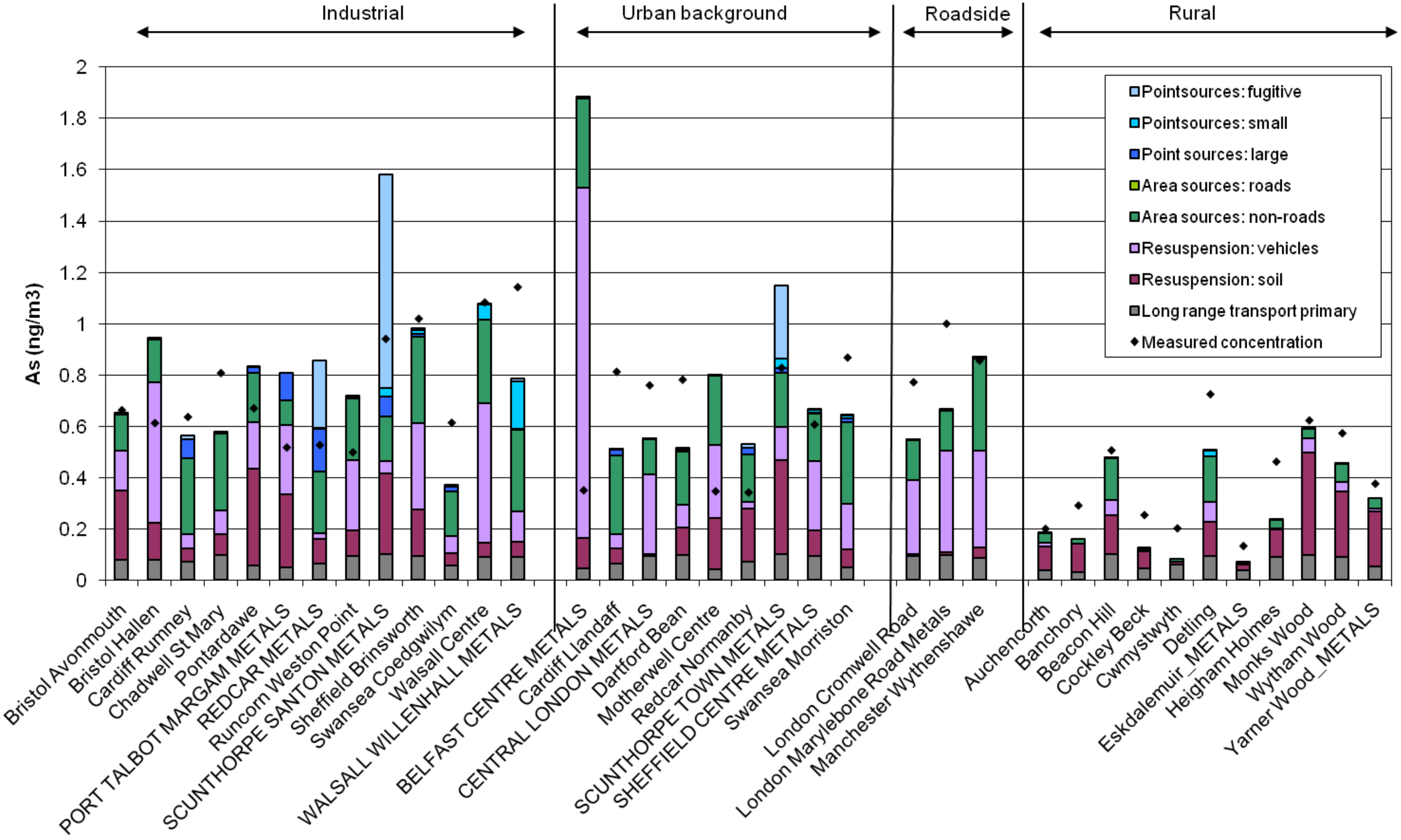


Figure 2.6: Verification of annual mean As at Industrial sites

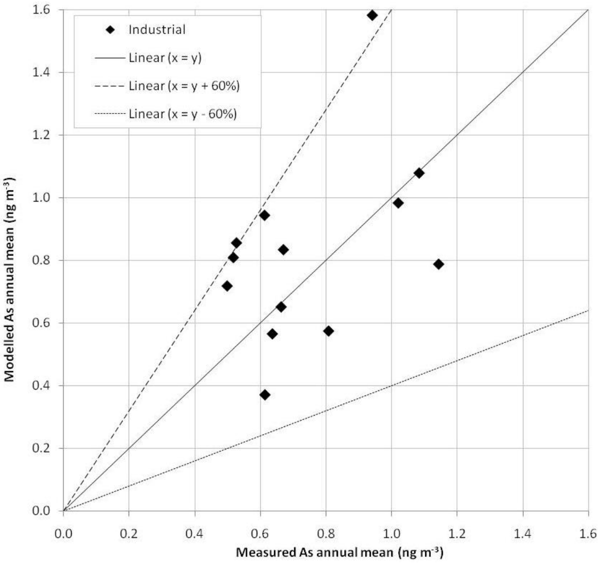


Figure 2.7: Verification of annual mean As at urban background sites

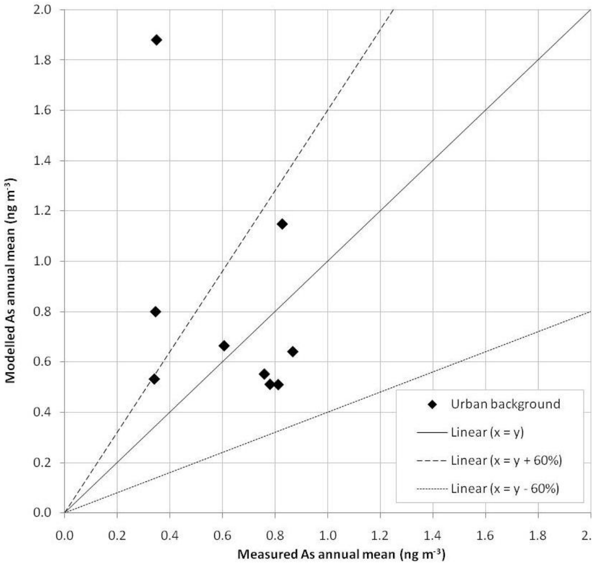


Figure 2.8: Verification of annual mean As at roadside sites

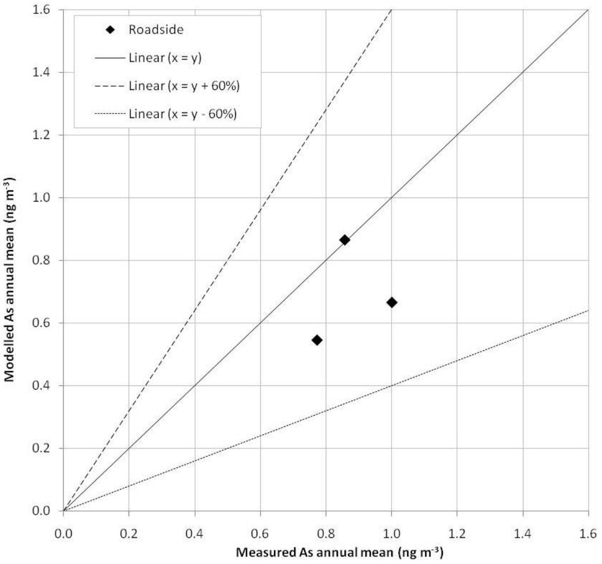


Figure 2.9: Verification of annual mean As at rural sites

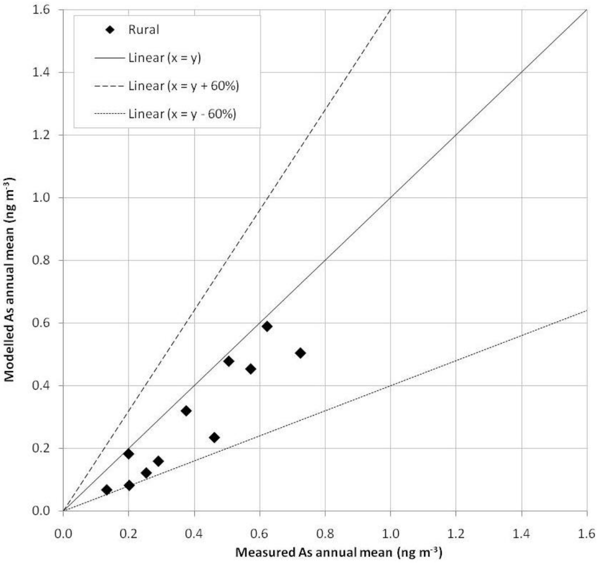


Table 2.5: Summary statistics for comparison between modelled and measured annual mean As concentrations at different monitoring sites, 2009

	Mean of measurements (ng/m^3)	Mean of model estimates (ng/m^3)	R^2	% of sites outside DQO of ±60%	Number of sites in assessment
Industrial sites	0.75	0.83	0.20	15.4	13
Urban background sites	0.63	0.80	0.14	22.2	9
Roadside sites	0.88	0.69	0.05	0.0	3
Rural sites	0.40	0.29	0.86	0.0	11

2.6 Cadmium

2.6.1 Introduction

The method used to estimate the Cd ambient concentration across the UK is described in Section 2.4.

2.6.2 Maps of annual mean concentrations

Figure 2.10 shows the modelled annual mean Cd concentrations. There are no modelled exceedences of the target value of 5 ng/m^3 in 2009. The maximum estimated Cd annual mean concentration was 2.74 ng/m^3.

2.6.3 Source apportionment

Figure 2.11 shows the modelled Cd contribution from different sources at 36 monitoring site locations. Measured concentrations at the sites are also presented, giving an indication of the level of agreement between modelled and measured concentrations. This analysis suggests that at those sites where the highest concentrations are measured, the main sources of cadmium are point source emissions (particularly fugitive industrial emissions) and re-suspension processes associated with vehicles.

2.6.4 Verification of mapped concentrations

An alternative presentation of the comparisons of modelled and measured annual mean Cd concentrations in 2009 at different monitoring site locations are shown in Figure 2.12 to Figure 2.15. These figures include lines to represent the AQDD4 data quality objective for modelled annual mean Cd concentrations: y=x-60% and y=x+60% (see Section 1.6).

Summary statistics for modelled and measured Cd concentrations are listed in Table 2.6, including the percentage of sites at which modelled concentrations are outside of the DQOs and the total number of sites included in the analysis.

The agreement between measured and modelled concentrations on a site-by-site basis (quantified using R^2) is poor for urban and industrial monitoring sites. The agreement is better at roadside and rural monitoring locations.

It should be noted that non-emission inventory sources (such as fugitive, re-suspension and long range transport of primary PM) result in additional uncertainty when compared with a pollutant such as NO_X, for which the source apportionment is better known. The agreement between the measured and modelled annual mean heavy metal concentrations in this current assessment is much better than the assessment presented by Vincent and Passant (2008). This is because the current assessment includes contributions from resuspension processes in addition to emission sources included within the emissions inventory. The agreement is much better at the rural sites in particular, where the previous assessment predicted much lower concentrations.

2.6.5 Comparison of modelling and measurement results with the target value

There were no modelled of measured exceedences of the target value for Cd in 2009.

Figure 2.10: Annual mean map of Cd concentrations for comparison with the Cd target value of 5ng/m^3, 2009 (ng/m^3)

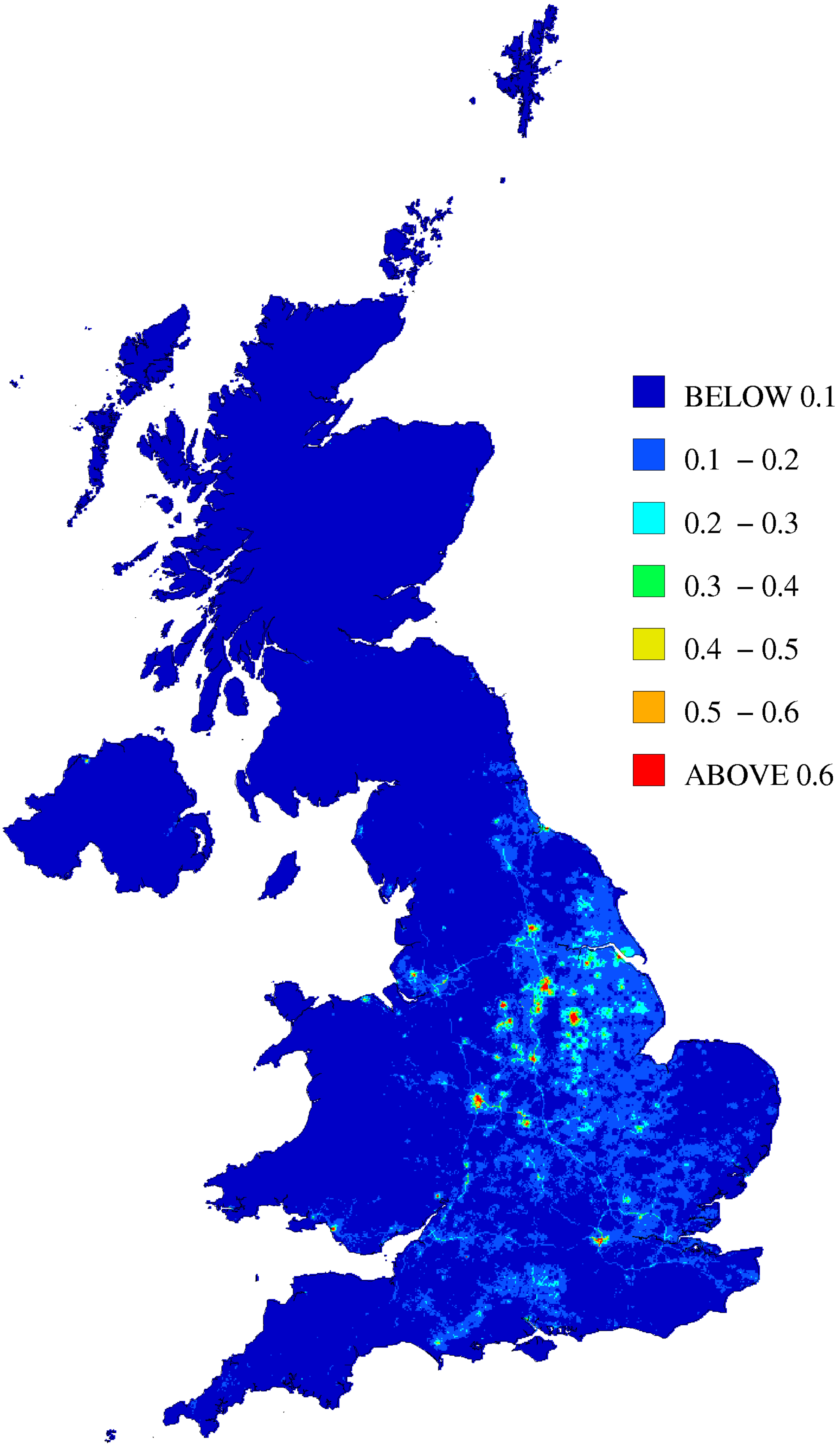


Figure 2.11: Source apportionment for Cd, 2009

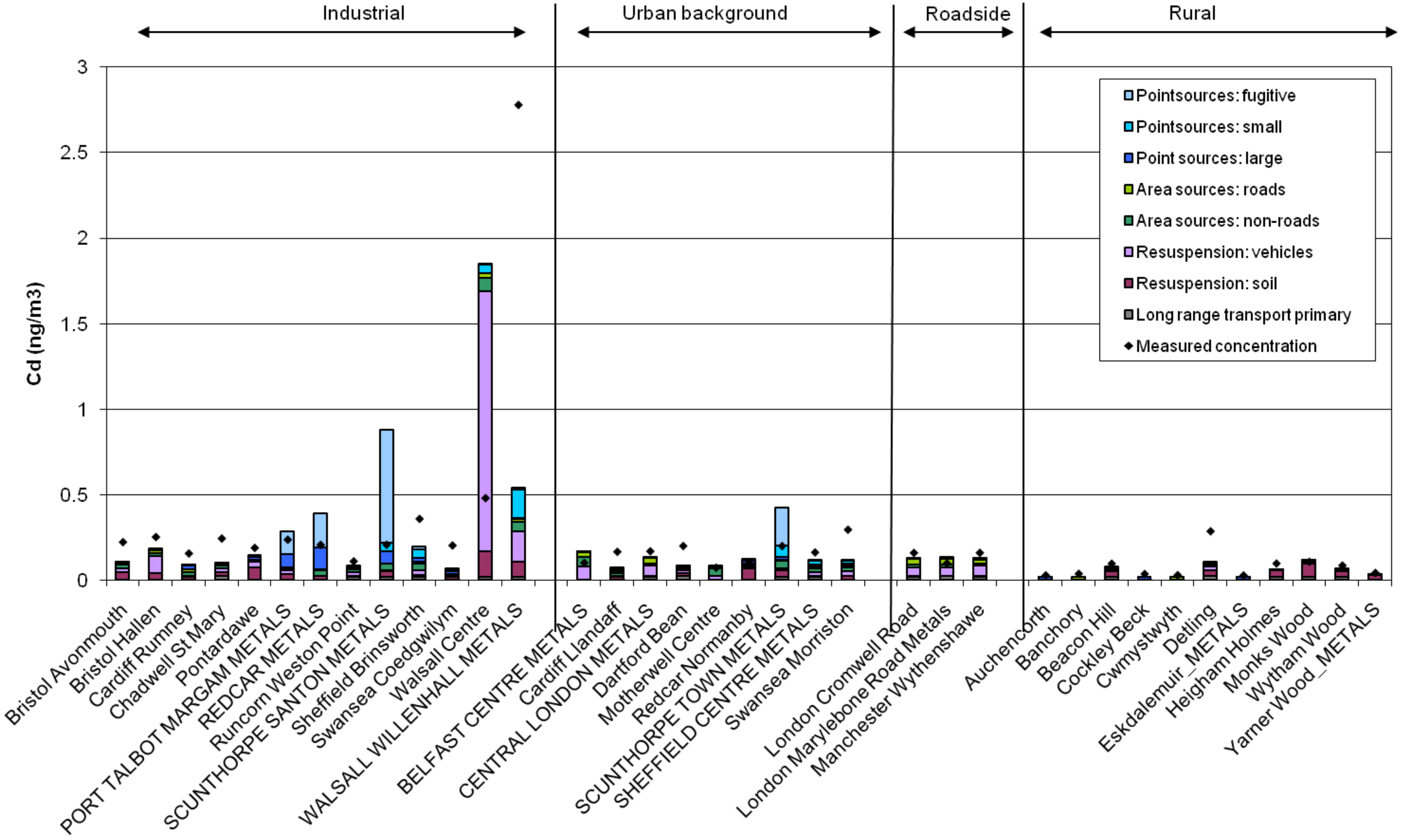


Figure 2.12: Verification of annual mean Cd at Industrial sites

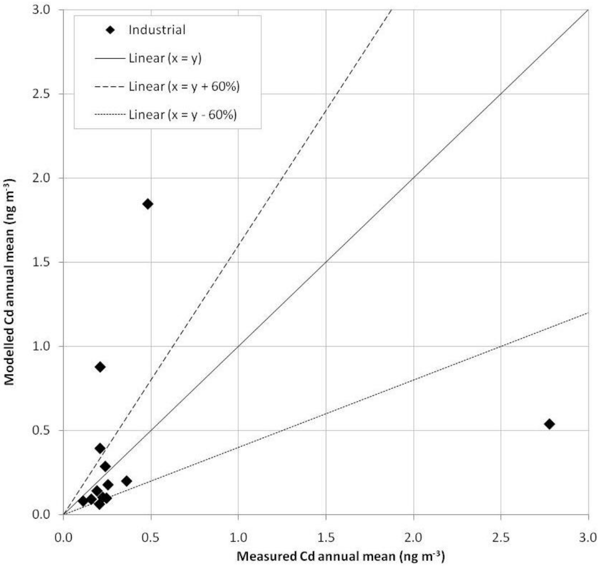


Figure 2.13: Verification of annual mean Cd at urban background sites

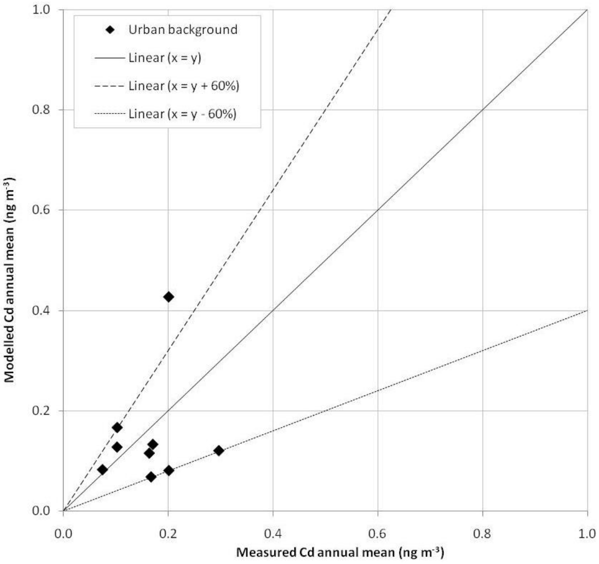


Figure 2.14: Verification of annual mean Cd at roadside sites

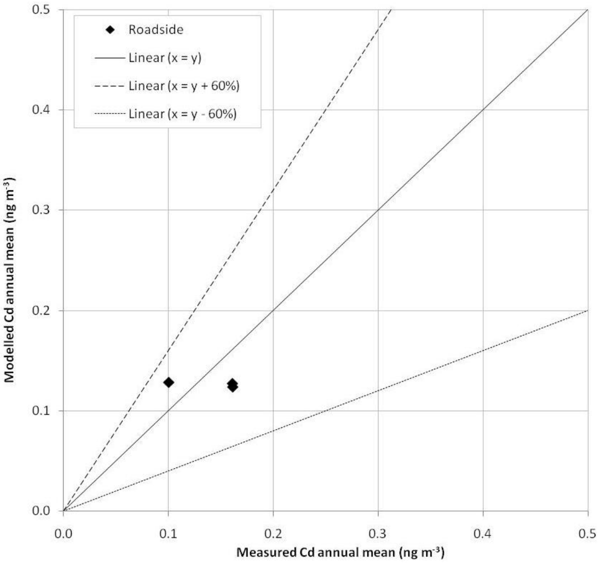


Figure 2.15: Verification of annual mean Cd at rural sites

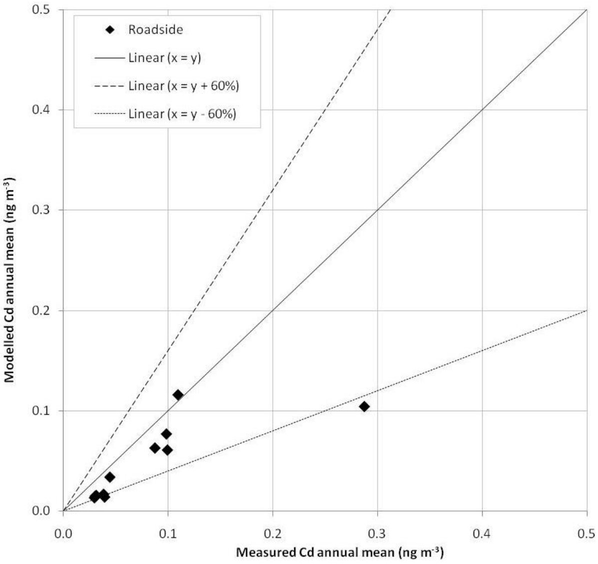


Table 2.6: Summary statistics for comparison between modelled and measured annual mean Cd concentrations at different monitoring sites, 2009

	Mean of measurements (ng/m^3)	Mean of model estimates (ng/m^3)	R^2	% of sites outside DQO of ±60%	Number of sites in assessment
Industrial sites	0.44	0.38	0.04	38.5	13
Urban background sites	0.16	0.15	0.03	22.2	9
Roadside sites	0.14	0.13	0.48	0.0	3
Rural sites	0.08	0.05	0.62	18.2	11

2.7 Nickel

2.7.1 Introduction

The method used to estimate ambient Ni concentrations across the UK is described in Section 2.4.

A cap of 7 ng/m^3 was applied to the contribution generated from the re-suspension of bare soils. This value was chosen as an estimate of the maximum likely concentration generated from this source.

2.7.2 Maps of annual mean concentrations

Figure 2.17 shows the modelled annual mean Ni concentrations. The maximum estimated Ni annual mean concentration was 16.87 ng/m^3.

2.7.3 Source apportionment

Figure 2.18 shows the modelled Ni contribution from different sources at 36 monitoring site locations. Measured concentrations at the sites are also presented, giving an indication of the level of agreement between modelled and measured concentrations. This analysis suggests that the main sources of nickel are point sources including fugitive industrial emissions, non-road area sources and re-suspension processes.

2.7.4 Verification of mapped concentrations

An alternative presentation of the comparisons of modelled and measured annual mean Ni concentrations in 2009 at different monitoring site locations are shown in Figure 2.19 to Figure 2.22. These figures include lines to represent the AQDD4 data quality objective for modelled annual mean Ni concentrations: y=x-60% and y=x+60% (see Section 1.6).

Summary statistics for modelled and measured Ni concentrations are listed in Table 2.7, including the percentage of sites for which the modelled values are outside of the DQOs as well as the total number of sites included in the analysis.

The mean measured and modelled concentrations agree reasonably well for the roadside monitoring sites. The agreements between measured and modelled concentrations on a site-by-site basis (quantified using R^2) are poor for the urban background and industrial monitoring locations. The results for rural sites show slightly better agreement.

It should be noted that non-emission inventory sources (such as fugitive, re-suspension and long range transport of primary PM) result in additional uncertainty when compared with a pollutant such as NO_X, whose source apportionment is better known. The agreement between the measured and modelled annual mean heavy metal concentrations in this current assessment is much better than the assessment presented by Vincent and Passant (2008). This is because the current assessment includes contributions from resuspension processes in addition to emission sources included within the emissions inventory. The agreement is much better at the rural sites in particular, where the previous assessment predicted much lower concentrations.

Table 2.7: Summary statistics for comparison between modelled and measured annual mean Ni concentrations at different monitoring sites, 2009

	Mean of measurements (ng/m^3)	Mean of model estimates (ng/m^3)	R^2	% of sites outside DQO of ±60%	Number of sites in assessment
Industrial sites	4.88	3.96	0.08	69.2	13
Urban background sites	2.07	3.07	0.06	66.7	9
Roadside sites	1.89	2.12	0.67	0.0	3
Rural sites	0.78	1.03	0.30	27.3	11

2.7.5 Detailed comparison of modelled results with the target value

There were no measured exceedences of the TV at any of the monitoring sites within the National Monitoring Network. The tabular results for the supplementary assessment for Ni are presented in Table 2.8, taken from Form 19j of the questionnaire. Exceedences of the TV for the Swansea Urban Area and South Wales zones have been reported based upon the annual mean concentration of 24 ng/m^3 measured at the local authority site at Pontardawe and the detailed local modelling analysis is described below. This monitoring site is within the Swansea Urban Area zone but is very near to the boundary of the South Wales zone.

An exceedence of the annual mean target value of 20 ng/m^3 was measured in 2009 at the Pontardawe monitoring site in South Wales. This site is run by the Local Authority, and is not within the National Network. An annual mean concentration of 24 ng/m^3 was recorded, significantly lower than the 2008 annual mean concentration of 43 ng/m^3.

Since the 2008 assessment (Yap et al., 2009), detailed dispersion modelling has been undertaken using ADMS 4.2 for the area in South Wales where exceedences of the annual mean target value of 20 ng/m^3 have been measured. This small scale modelling has been used to assess the likely magnitude and spatial scale of the exceedence.

The emission of nickel from the relevant industrial point source was taken as 157.57 kg/year, emitted from nine locations across the complex (data provided by industrial operator). Building effects were included in the model, and a 6km x 6km area was extracted from a single 20km x 20km Land-Form PANORAMA® tile to model the topographical effects of the valley. The height of the terrain was specified at the centre of each 50m x 50m grid square.

Figure 2.16 shows the modelled ambient concentration estimates resulting from the point source emissions. The distribution of Ni concentrations from the point source are strongly influenced by the terrain in the area, as can be seen in Figure 2.16 – the Swansea Valley runs south-west to north-east through the village of Pontardawe, where the point source is located.

The conclusions from this dispersion modelling study are that there was an exceedence of the target value for Ni in both the South Wales and Swansea urban area zones in 2009, and this exceedence was likely to have extended over a spatial area of relevance to the directive (at least 250m x 250m for industrial locations).

The source apportionment and scatter graphs in the sections above do not include the contribution to ambient concentrations at the Pontardawe site from the identified local industrial source. The addition of this contribution brings the total modelled concentration up to 32.2 ng/m^3.

Emission abatement at the relevant plant is currently (2010) being improved in order to reduce the impact of these emissions on local ambient air quality. Further modelling work will be undertaken following the completion of the installation of the improved abatement and subsequent emission measurements.

The Pontardawe monitoring site is located south-west of the point source, and a new monitoring location, which will be located downwind of the site under a prevailing south-westerly wind (north-east of the point source), is currently under consideration.

A concentration close to the target value (16 ng/m^3) was measured at the Swansea Coedgwilym national network monitoring site. Further measurement and modelling work is underway in South Wales in order to gain a better understanding the origins of the Ni concentrations in the area.

Figure 2.16: Modelled Ni plume from point source in South Wales where exceedences of the annual mean Ni target value have been measured

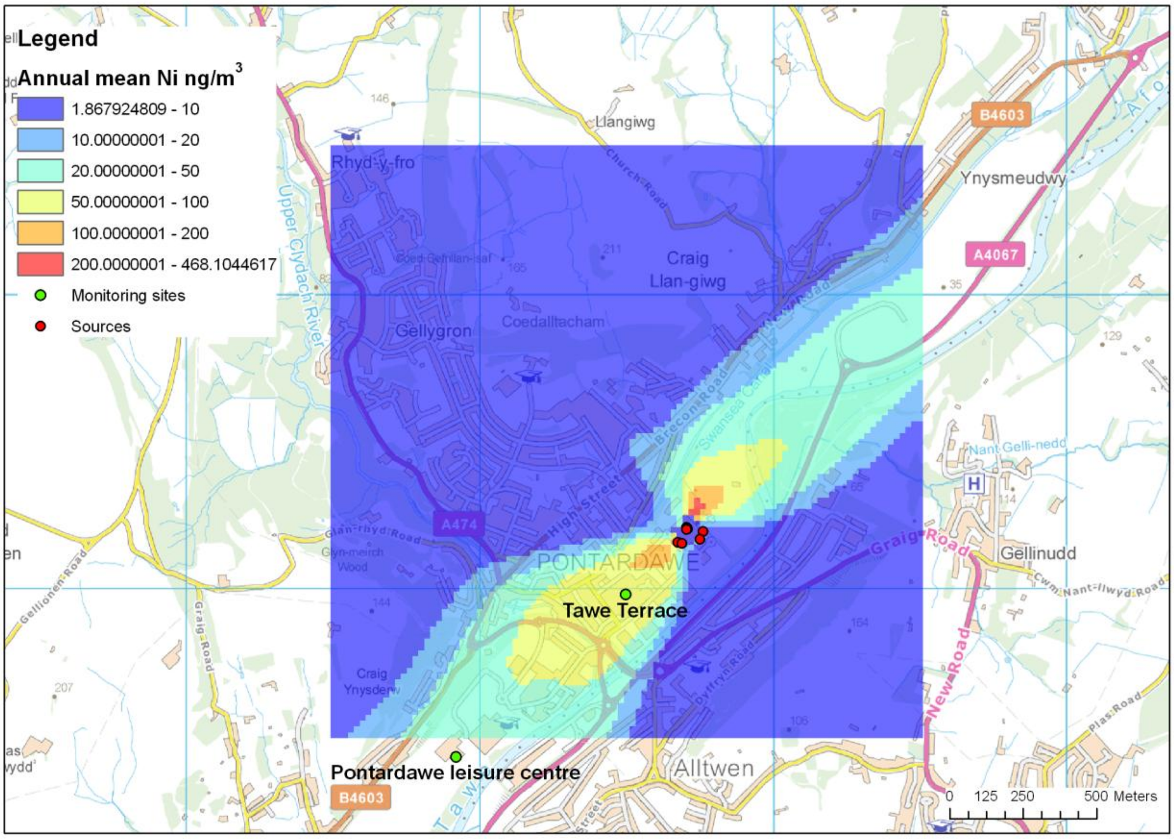


Figure 2.17: Annual mean map of Ni concentrations for comparison with the Ni target value of 20ng/m^3, 2009 (ng/m^3)

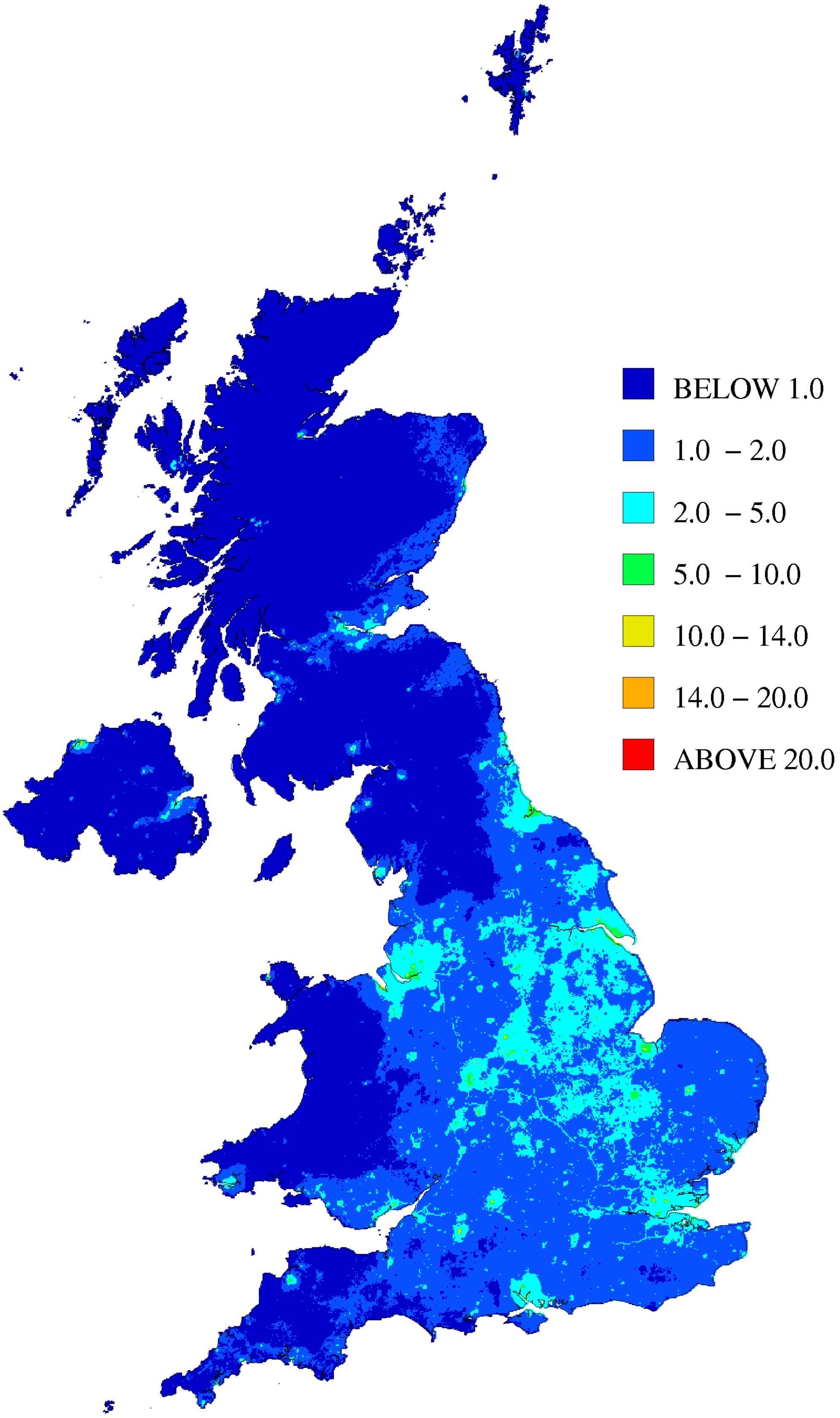


Figure 2.18: Source apportionment for Ni, 2009

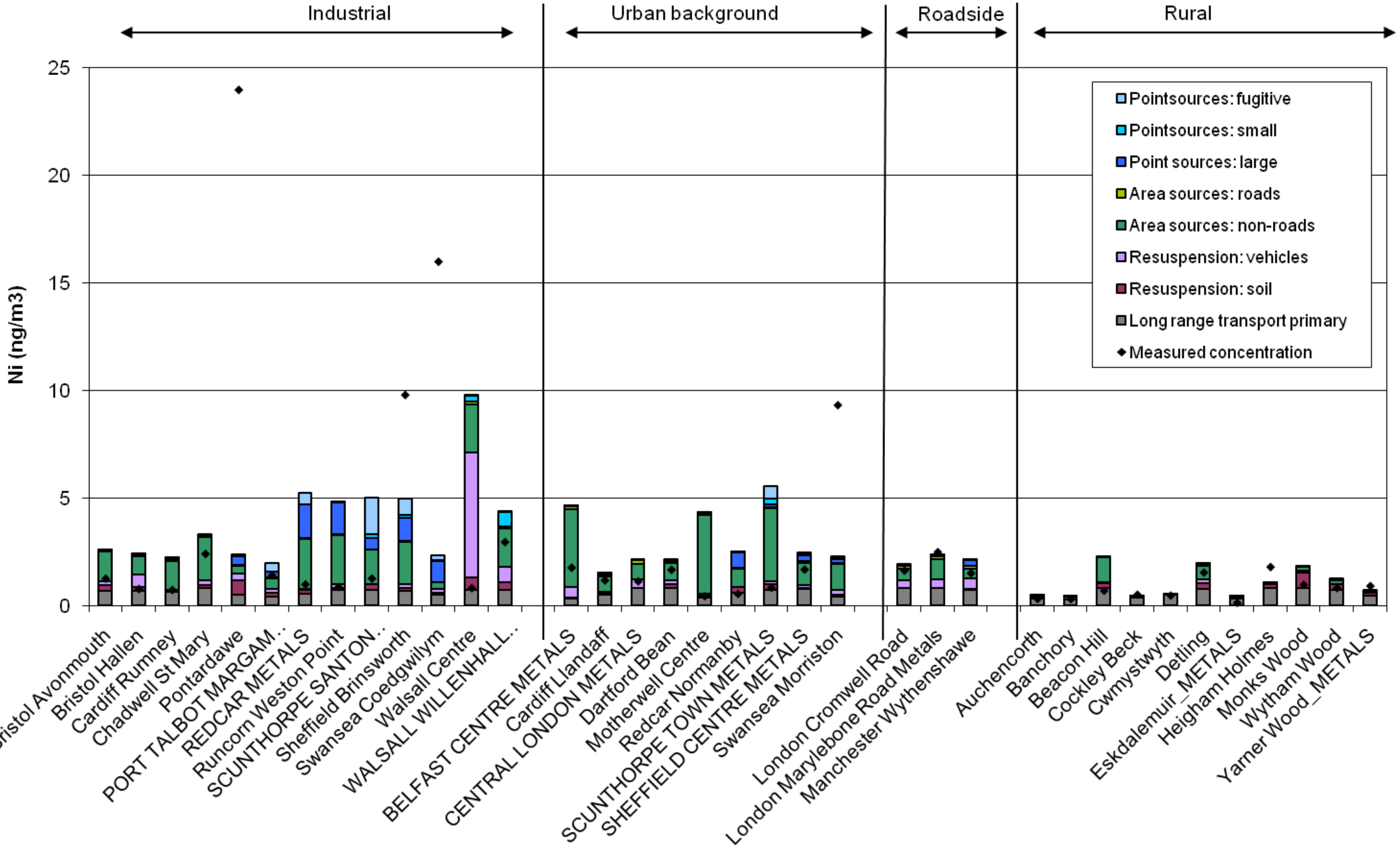


Figure 2.19: Verification of annual mean Ni at Industrial sites

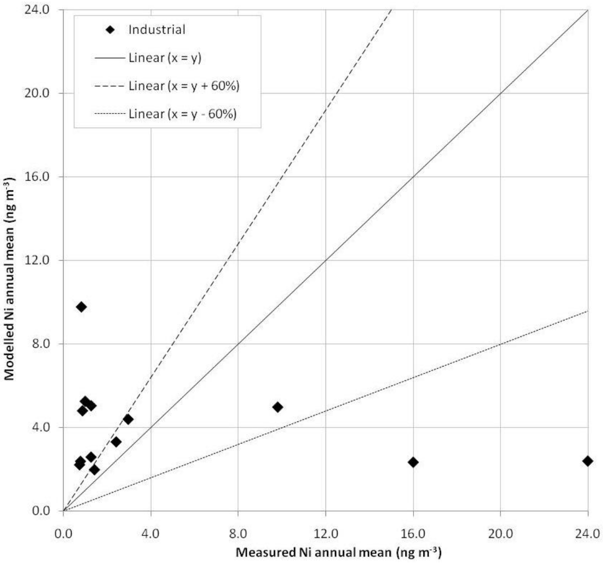


Figure 2.20: Verification of annual mean Ni at urban background sites

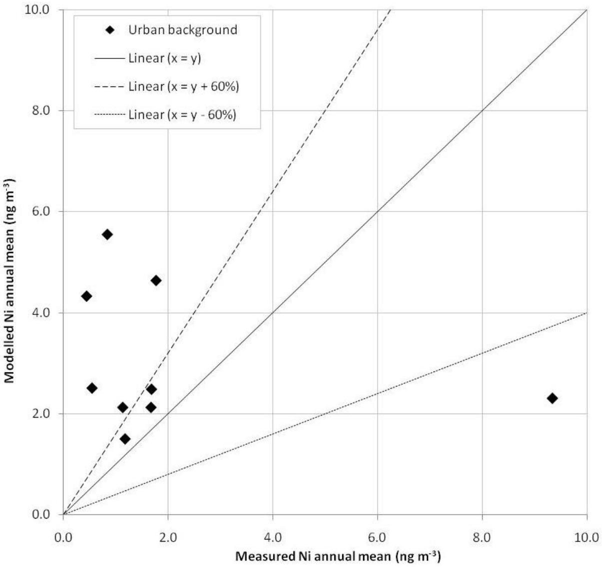


Figure 2.21: Verification of annual mean Ni at roadside sites

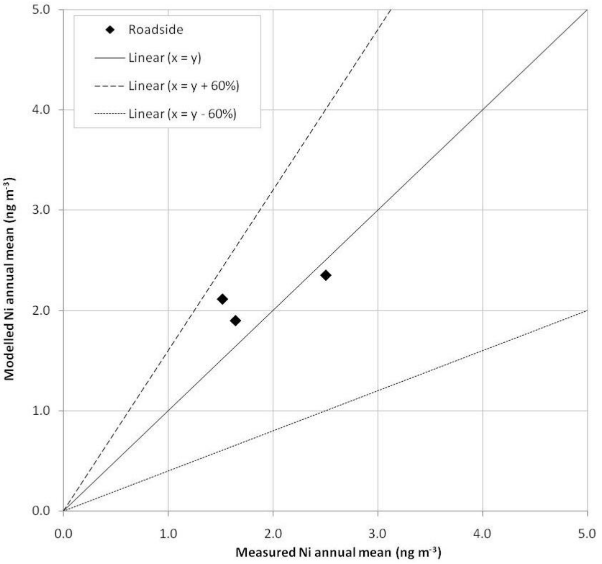


Figure 2.22: Verification of annual mean Ni at rural sites

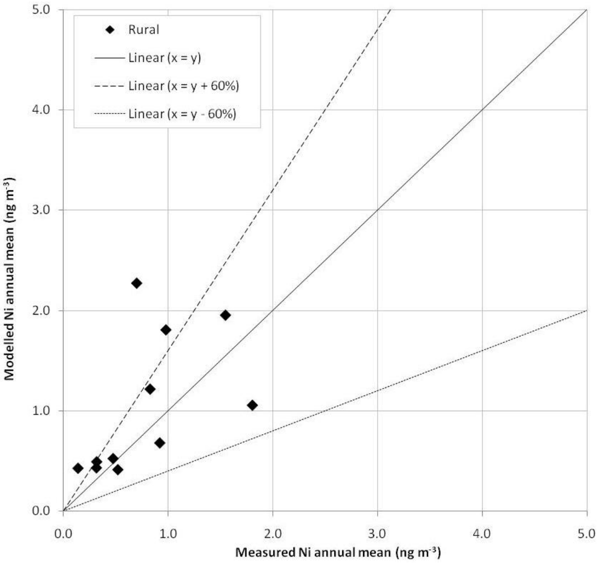


Table 2.8: Tabular results of and methods used for supplementary assessment for Ni

Zone	Zone code	Above TV for health (annual mean)			
		Area		Population exposed	
		km^2	Method	Number	Method
Greater London Urban Area	UK0001	0	B	0	B
West Midlands Urban Area	UK0002	0	B	0	B
Greater Manchester Urban Area	UK0003	0	B	0	B
West Yorkshire Urban Area	UK0004	0	B	0	B
Tyneside	UK0005	0	B	0	B
Liverpool Urban Area	UK0006	0	B	0	B
Sheffield Urban Area	UK0007	0	B	0	B
Nottingham Urban Area	UK0008	0	B	0	B
Bristol Urban Area	UK0009	0	B	0	B
Brighton/Worthing/Littlehampton	UK0010	0	B	0	B
Leicester Urban Area	UK0011	0	B	0	B
Portsmouth Urban Area	UK0012	0	B	0	B
Teesside Urban Area	UK0013	0	B	0	B
The Potteries	UK0014	0	B	0	B
Bournemouth Urban Area	UK0015	0	B	0	B
Reading/Wokingham Urban Area	UK0016	0	B	0	B
Coventry/Bedworth	UK0017	0	B	0	B
Kingston upon Hull	UK0018	0	B	0	B
Southampton Urban Area	UK0019	0	B	0	B
Birkenhead Urban Area	UK0020	0	B	0	B
Southend Urban Area	UK0021	0	B	0	B
Blackpool Urban Area	UK0022	0	B	0	B
Preston Urban Area	UK0023	0	B	0	B
Glasgow Urban Area	UK0024	0	B	0	B
Edinburgh Urban Area	UK0025	0	B	0	B
Cardiff Urban Area	UK0026	0	B	0	B
Swansea Urban Area	UK0027	1	B	1577	B
Belfast Metropolitan Urban Area	UK0028	0	B	0	B
Eastern	UK0029	0	B	0	B
South West	UK0030	0	B	0	B
South East	UK0031	0	B	0	B
East Midlands	UK0032	0	B	0	B
North West & Merseyside	UK0033	0	B	0	B
Yorkshire & Humberside	UK0034	0	B	0	B
West Midlands	UK0035	0	B	0	B
North East	UK0036	0	B	0	B
Central Scotland	UK0037	0	B	0	B
North East Scotland	UK0038	0	B	0	B
Highland	UK0039	0	B	0	B
Scottish Borders	UK0040	0	B	0	B
South Wales	UK0041	1	B	484	B
North Wales	UK0042	0	B	0	B
Northern Ireland	UK0043	0	B	0	B
Total		2		2061	

Method ‘B’ is the modelling methodology described in this report.

3 Benzo(a)pyrene

3.1 Introduction

Benzo(a)pyrene, (B(a)P) concentrations were modelled for 2005 by Vincent el al. (2007) to inform the UK Preliminary Assessment for AQDD4 (Bush, 2007) and were modelled for 2008 as part of a full air quality assessment in support of the Directive requirements. 2009 is the second year for which a full air quality assessment is required and national modelling of B(a)P has been undertaken in order to assess compliance with the target value of 1 ng/m^{-3} set out in the Directive.

3.2 Monitoring sites

The monitoring sites operational during 2009 for the purposes of AQDD4 reporting are listed in Form 3 of the questionnaire (CDR 2010). In previous years a combination of two different monitoring instruments has been used (Andersen and Digitel instruments). In 2009, only Digitel instruments were operating. A summary of the monitoring data for 2009 is presented Table 3.1.

Table 3.1: Summary of B(a)P monitoring data for 2009

EoI code	**Site name**	**Site type**	**Instrument type**	**Annual Mean B(a)P**	
				DC %	**ng/m^3**
GB0932A	Auchencorth Moss A	Rural	Digitel	91%	0.04
GB0933A	Auchencorth Moss B*	Rural	Digitel (PUF)	19%	0.03
GB0934A	Ballymena Ballykeel	Urban background	Digitel	93%	1.60
GB0866A	Birmingham Tyburn (PAH)	Urban background	Digitel	91%	0.26
GB0700A	Bolsover	Urban background	Digitel	98%	0.32
GB0869A	Cardiff Lakeside	Urban background	Digitel	96%	0.19
GB0944A	Derry Brandywell	Urban background	Digitel	97%	0.22
GB0870A	Edinburgh St Leonards (PAH)	Urban background	Digitel	98%	0.19
GB0701A	Glasgow Centre (PAH)	Urban background	Digitel	88%	1.00
GB0936A	Harwell A	Rural	Digitel	93%	0.26
GB0937A	Harwell B*	Rural	Digitel (PUF)	98%	0.13
GB0702A	Hazelrigg (PAH)	Rural	Digitel	100%	0.19
GB0850A	Hove (PAH)	Urban background	Digitel	100%	0.09
GB0705A	Kinlochleven	Urban background	Digitel	31%	0.09
GB0867A	Leeds Millshaw	Urban background	Digitel	73%	0.08
GB0706A	Lisburn Dunmurry High School	Urban background	Digitel	94%	0.18
GB0848A	Liverpool Speke (PAH)	Urban background	Digitel	88%	0.30
GB0849A	London Brent (PAH)	Urban background	Digitel	96%	0.31
GB0847A	London Crystal Palace Parade	Urban background	Digitel	86%	0.90
GB0938A	London Marylebone Road (PAH)	Urban background	Digitel	99%	0.24
GB0939A	Lynemouth	Industrial	Digitel	94%	0.55
GB0945A	Middlesbrough (PAH)	Industrial	Digitel	100%	0.39
GB0773A	Newcastle Centre (PAH)	Urban background	Digitel	99%	0.15
GB0962A	Newport	Urban background	Digitel	89%	0.22

EoI code	Site name	Site type	Instrument type	Annual Mean B(a)P	
				DC %	ng/m^3
GB0711A	Port Talbot (PAH)	Industrial	Digitel	95%	0.39
GB0940A	Royston	Industrial	Digitel	95%	1.00
GB0660A	Salford Eccles	Urban background	Digitel	99%	2.40
GB0941A	Scunthorpe Santon	Industrial	Digitel	99%	1.80
GB0868A	Scunthorpe Town (PAH)	Industrial	Digitel	94%	0.87
GB0942A	South Hiendley	Industrial	Digitel	85%	0.21
GB0004R	Stoke Ferry (PAH)	Rural	Digitel	96%	0.14
GB0943A	Swansea Cwm Level Park	Urban background	Digitel	89%	0.24

*** Digitel instrument with particulate filter and vapour capture. Despite the difference in monitoring technique, this method provides comparable quality data to the standard Digitel data. Observations are made less frequently using the PUF – AQDD4 specifies a minimum requirement of 14% but in the UK this is typically exceeded.**

3.3 Emissions

Emissions estimates for B(a)P are published annually in the National Atmospheric Emissions Inventory (NAEI). The latest available inventory year is 2008, details of which are given in Murrells et al., 2010. Projections of emissions estimates for 2010, 2015 and 2020 have been derived from the 2008 NAEI estimates using the Updated Energy Projections (UEP 38) provided by the Department of Energy and Climate Change (DECC). The emissions estimates for 2008, 2010, 2015 and 2020 by SNAP code are shown in Figure 3.1. Values for intermediate years have been interpolated in this figure.

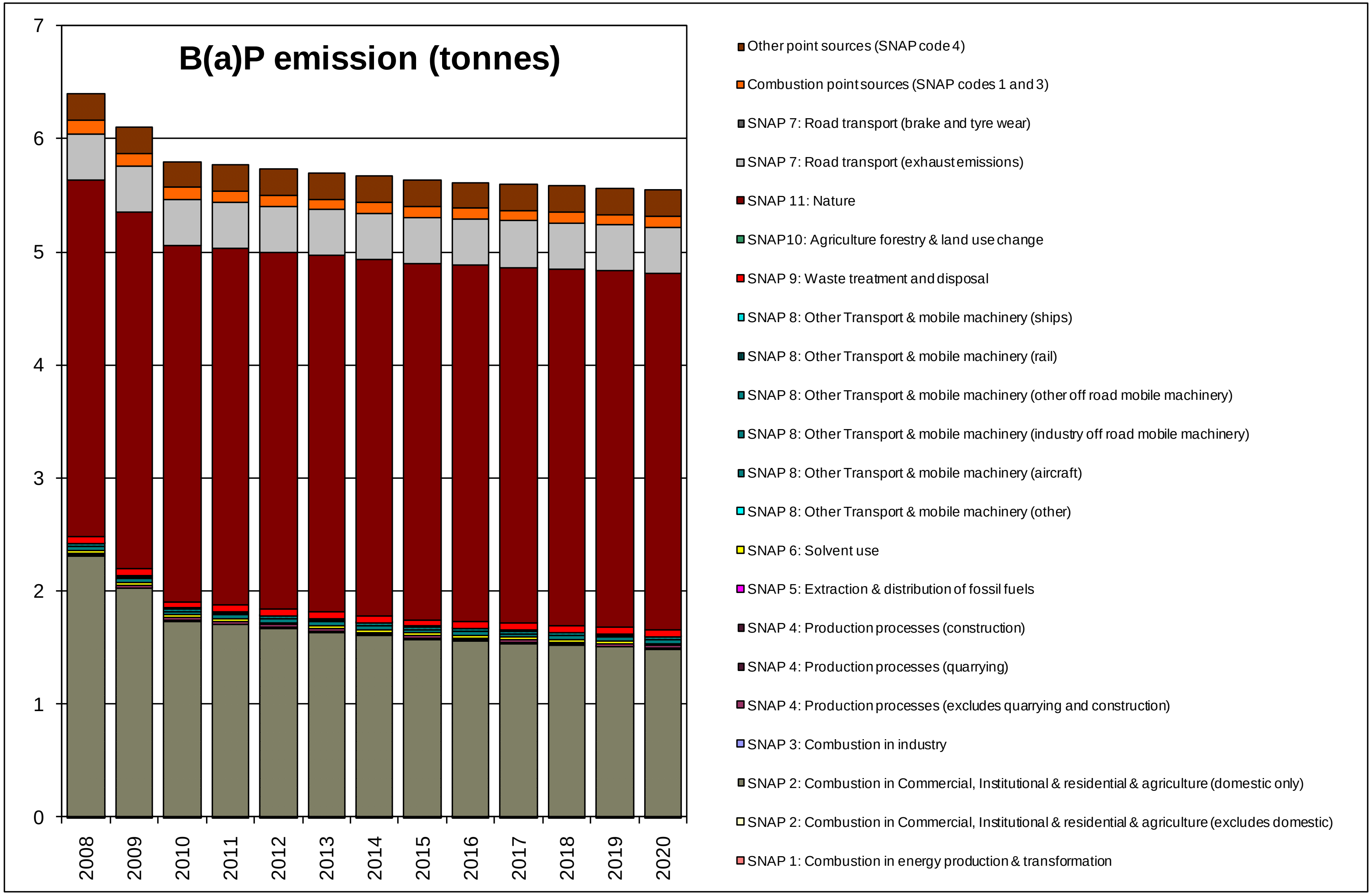
Point source emissions are emissions of a known amount from a known location, such as power stations. Area source emissions are ‘diffuse emissions’ from many unspecified locations, such as the emissions from domestic heating.

Figure 3.1 shows that emissions from B(a)P are expected to decline from 2008 to 2015 with the sharpest decline until 2010. From 2010 onwards the projected decline in emissions is anticipated to be steady but less significant. A contributory factor for this more gradual decline is that some of the most significant sources of B(a)P emissions are outside of regulatory controls. For example, the single largest source is SNAP 11: ‘Nature’, which refers to B(a)P emissions from combustion in the natural environment such as forest fires. Despite the relatively high emissions contribution from this source sector, the method for distribution of these emissions used in the NAEI ensures that natural combustion is spread evenly across the UK and does not unduly affect the modelled ambient concentrations in any particular area.

Another significant source of emission is the combustion of solid fuels for domestic heating as shown in Figure 3.1. This is a particularly important source in rural areas (particularly in Northern Ireland and Scotland) where there may be a heavy dependency on solid fuels instead of natural gas due to limitations of the gas supply infrastructure in more remote locations. The emissions inventory provides maps of emissions in a 1km x 1km grid, which is likely to be too coarse to incorporate very local variations in emissions from sources such as domestic heating, where there may be considerable in-square variation due to differences in fuel use. Updates to the mapped NAEI emissions inventory for 2008 used in this modelling included new information on the spatial distribution of domestic gas use (last updated for the 2004 inventory) for all areas except Northern Ireland.

Maps of emissions from area sources in 2009 have been derived from the 2008 inventory maps using specific scaling factors for each combination of source and activity (typically fuel type) which have been derived from these projections. Emissions from point sources have not been scaled and the emissions for 2008 have been assumed to apply in 2009.

Figure 3.1: UK total B(a)P emissions for 2008 and emissions projections up to 2020 by SNAP code (NAEI 2008)



3.4 The model

Ground level annual mean concentrations of B(a)P are considered to consist of:

- Point sources from industrial processes
- Area source emissions

A significant change to the modelling methodology since the 2005 assessment (Vincent el al., 2007) has been the decision to implement a calibration based on monitoring data from the national network. This decision was made to ensure that the model result was realistically consistent with the measurements which were unexpectedly elevated during 2008 as a result of meteorological conditions. The methodology has been continued into the modelling for 2009. Particular consideration was given to appropriate application of calibration factors to the model, and for this reason separate calibration factors were derived for the area and point source components of the model.

3.4.1 Area sources

The modelled uncalibrated area source contribution has been calculated by applying an ADMS 4.2 derived dispersion kernel to calculate the contribution to ambient concentrations at a central receptor location from area source emissions within a 33km x 33km square surrounding each receptor. Hourly sequential meteorological data from Waddington in 2009 has been used to construct the dispersion kernels, as described in Appendix 1.

A calibration has been applied to the modelled B(a)P area source component (Figure 3.2). This has been calculated by plotting the uncalibrated area source component from the model against measured concentrations that have been adjusted to represent background (non-industrial) concentrations only (i.e. measured concentrations at background sites minus modelled point source contributions at those locations). The modelled area source contribution was multiplied by the coefficient (5.9137) to calculate the calibrated area source contribution for each grid square in the country.

As part of the calibration process concentration caps have been applied to certain sectors. This is because the use of surrogate statistics for mapping area source emissions sometimes results in unrealistically large concentrations in some grid squares for a given sector. The concentration caps applied are given in Table 3.2. These caps have been applied to emissions based on expert judgement of the model results in order to address known artefacts in the area source emissions grids and to reconcile the model results with the measured data at each monitoring site. The application of these caps is annually reported back to the NAEI as part of the quality checking process to ensure that continual improvements are made in the emissions grids.

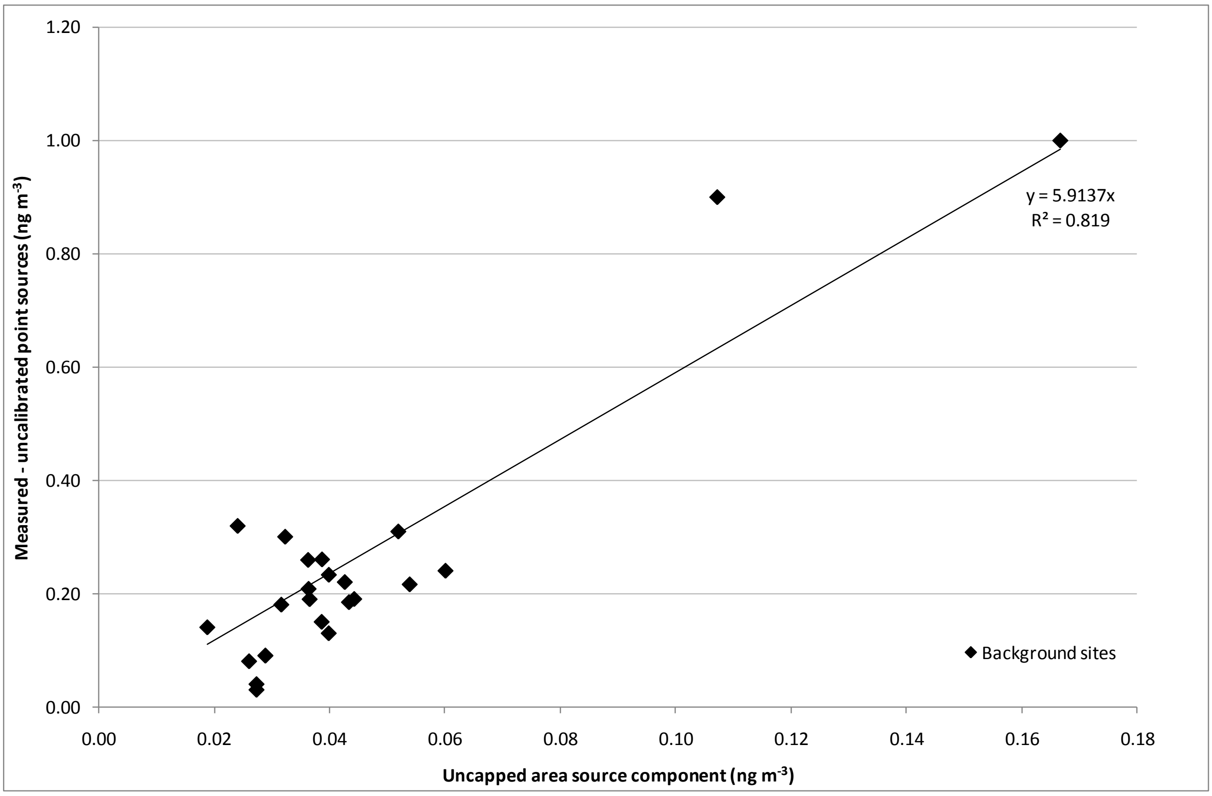
Table 3.2 - Concentration caps applied to B(a)P sector grids

SNAP code	Description	*Cap applied (ng m^{-3})**
SNAP 2	Combustion in Commercial, Institutional & residential & agriculture (domestic only)**	*0.76*
SNAP 4	Production Processes	*0.66*

*Caps listed are for calibrated concentrations.

**Cap applied outside Northern Ireland only, no cap applied in Northern Ireland where high emissions reflect heavy reliance on solid fuel combustion for domestic heating.

Figure 3.2: Calibration of area source model for B(a)P



3.4.2 Point sources

Contributions to ground level annual mean B(a)P concentrations from point sources in 2008 NAEI were estimated by modelling each source explicitly using an atmospheric dispersion model (ADMS 4.2) and sequential meteorological data for 2009 from Waddington.

Industrial point sources of B(a)P are either fugitive (as from coking plants) or from clearly defined stacks for other sources. The emission amount is derived either from direct measurement or by emission factors. Release characteristics were obtained from the NAEI point sources database and included parameters such as:

- Stack height
- Stack diameter
- Discharge velocity
- Discharge temperature

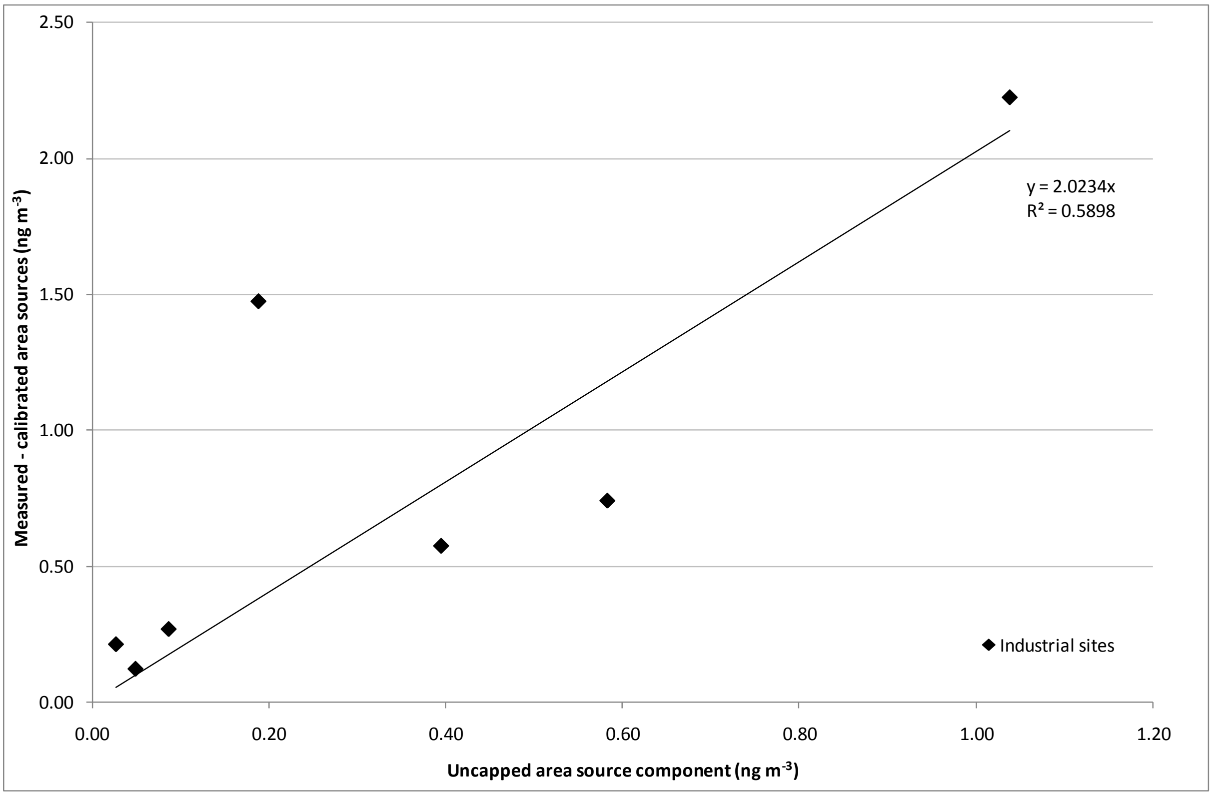
A total of 118 large points sources were modelled for B(a)P of which 8 were modelled using specifically tailored modelling parameters to accommodate non-standard stack arrangements. These included:

- Anglesey anode baking processes which uses a dual flue concentric stack arrangement
- Coke works at Barnsley, Teesside, Port Talbot and Scunthorpe which were all modelled as line sources

Specific emission information for coking plants was provided by Peter Coleman (personal communication, 2009) and covered Barnsley (Monkton coke oven), Teesside (Redcar and South Bank coke ovens and sinter plant), Port Talbot (Morfa coke works and sinter plant) and Scunthorpe (Dawes Lane and Appleby coke ovens and sinter plant).

In order to obtain a model result that was consistent with measured concentrations, the model was calibrated using monitoring data from the national network. Industrial sites only were used to calibrate the point source contribution (Figure 3.3). Measured industrial concentrations were adjusted by subtracting the calibrated modelled area source concentration so that the measured value represented the industrial component only. There is an element of circularity involved in the calibration of both area and point sources because the calibration process for each requires the subtraction of the other in order to isolate the component being calibrated. A decision was made to calibrate the area source component first using the uncalibrated modelled point source component and then to use the calibrated area source component to subtract from the measured industrial concentrations in the calibration of the point sources. This is reasonable since the contribution from point sources at non-industrial monitoring sites is very small. A multiple regression analysis for all monitoring sites was considered but was rejected because it would be likely to over fit to the data and not provide realistic coefficients.

Figure 3.3: Calibration of point source model for B(a)P



The modelled point source contribution was multiplied by the coefficient (2.0234) to calculate the calibrated point source contribution.

During the course of this modelling an error was discovered in the assignment of receptors for consideration within the previous assessments (Vincent and Passant (2008); Yap et al. (2009)). This affected the coking plant at Redcar and Southbank in Teesside and has resulted in modelled exceedences of the target value in the North East Zone and Teesside Urban Area that were not identified in previous modelling assessments.

3.5 Results

3.5.1 Map of annual mean concentrations

Figure 3.4 shows the modelled annual mean B(a)P concentrations. The maximum estimated B(a)P annual mean concentration was 4.98 ng/m^3.

3.5.2 Source apportionment

A source apportionment graph has been plotted in Figure 3.5 to present the B(a)P contribution from different sources at monitoring site locations. Measured concentrations at the sites are also presented, giving an indication of the level of agreement between modelled and measured concentrations.

3.5.3 Verification of mapped concentrations

An alternative presentation of the comparison between modelled and measured annual mean B(a)P concentrations in 2009 at different monitoring site locations are shown in Figure 3.6 to Figure 3.8. These figures include lines to represent the AQDD4 data quality objective for modelled annual mean B(a)P concentrations: y=x-60% and y=x+60% (see Section 1.6).

Figure 3.4: Annual mean map of B(a)P concentrations for comparison with the B(a)P target value of 1 ng/m^3, 2009 (ng/m^3)

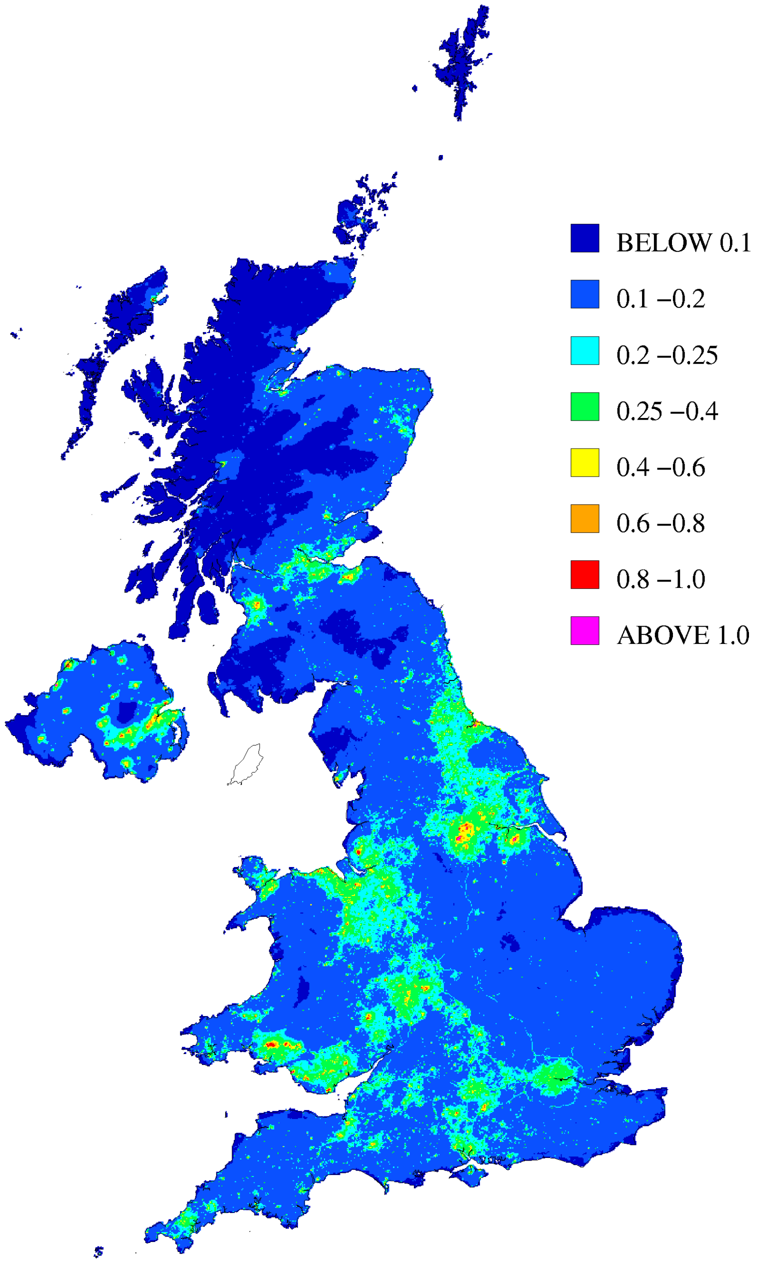


Figure 3.5: Source apportionment for B(a)P

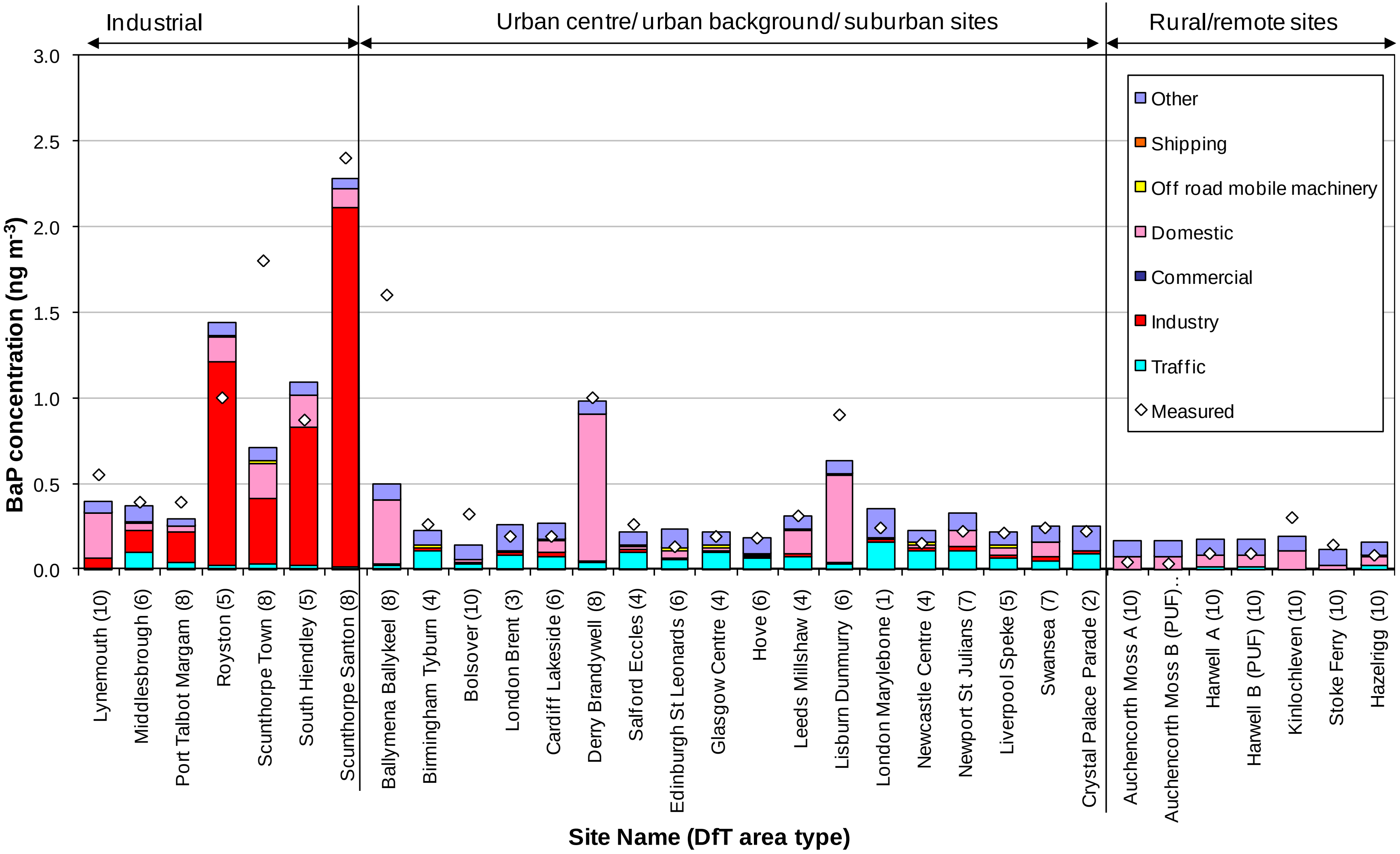


Figure 3.6: Verification of annual mean B(a)P at industrial sites

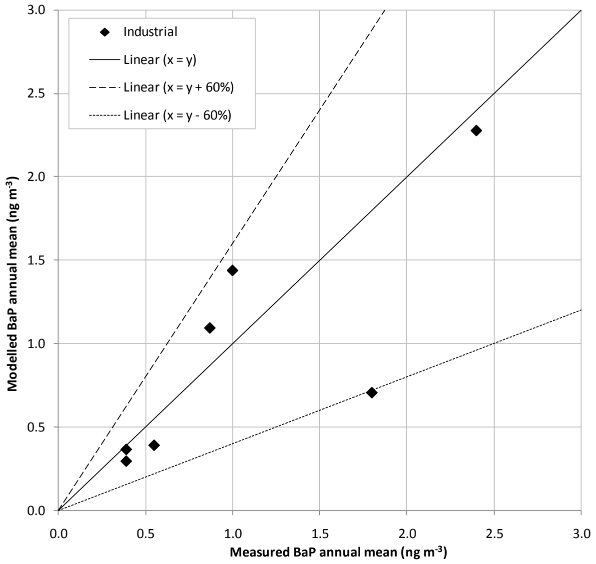


Figure 3.7: Verification of annual mean B(a)P at urban background sites

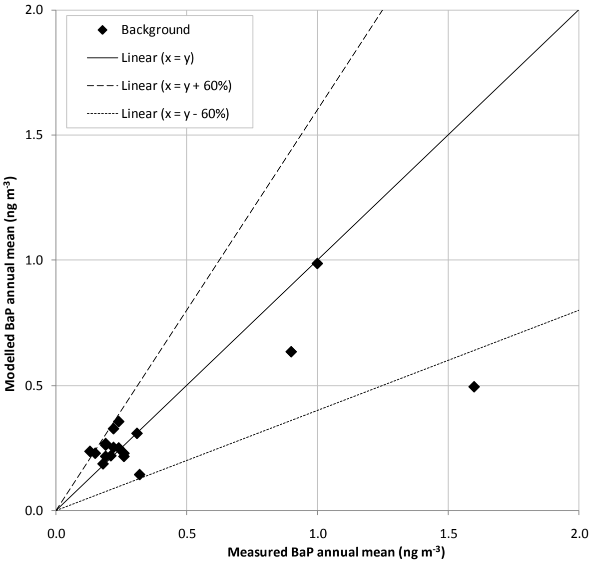
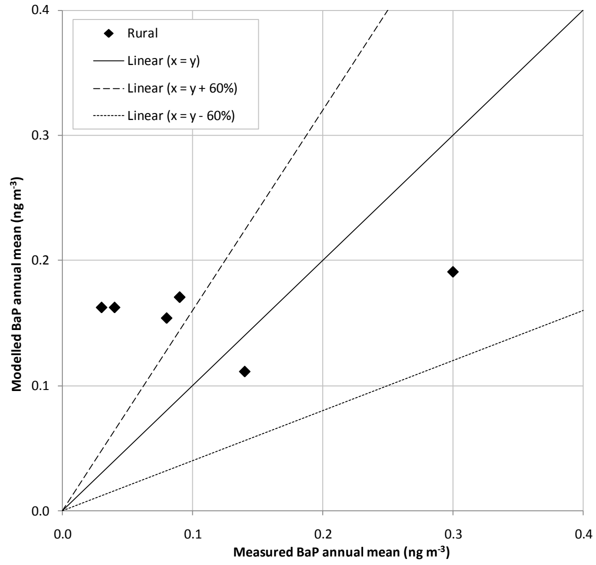


Figure 3.8: Verification of annual mean B(a)P at rural sites



Summary statistics for modelled and measured B(a)P concentrations are listed in Table 3.3, including the percentage of sites at which modelled concentrations are outside of the data quality objectives (DQOs), and the total number of sites included in the analysis.

The calculated means of measured compared with modelled concentrations are in good agreement for urban background and rural sites. The agreement between measured and modelled concentrations at industrial sites is less good. It is likely that variation of B(a)P concentrations in close proximity to these major sources is not as well represented in the model. The R^2 values are high for industrial and urban background sites but poor for rural sites. This is because the model results are principally driven by the calibration process in which industrial and urban background sites are prominent in defining the relationship.

Table 3.3: Summary statistics for comparison between modelled and measured annual mean B(a)P concentrations at different monitoring sites, 2009

	Mean of measurements (ng/m^3)	Mean of model estimates (ng/m^3)	R^2	% of sites outside DQO of ±60%	Number of sites in assessment
Industrial sites	1.06	0.94	0.63	14	7
Urban background sites	0.38	0.32	0.52	11	18
Rural sites	0.11	0.16	0.08	71	7

3.5.4 Comparison of modelling and measurement results with the target value

Tabular results for the supplementary assessment for B(a)P are presented in Table 3.4.

Exceedences of the 1 ng/m^3 target value have been modelled for six zones. The exceedences in the Swansea Urban Area and South Wales zones were associated with coking operations at Port Talbot. The exceedences in the Yorkshire & Humberside zone were associated with coking operations at Monkton and Scunthorpe and domestic solid fuel use. The exceedances in the Teesside Urban Area and North East zone were associated with coking operations at Redcar and Southbank. The exceedences in the Northern Ireland zone were associated with domestic solid fuel use.

Measured concentrations also exceeded the target value in the Yorkshire & Humberside and Northern Ireland zones. The measured exceedences for these zones have therefore been reported in the air quality assessment. A measured exceedence was also reported for the Teesside zone for which there were no modelled exceedences.

Table 3.4: Tabular results of and methods used for supplementary assessment for B(a)P

Zone	Zone code	Above TV for health (annual mean)			
		Area		Population exposed	
		Km^2	Method	Number	Method
Greater London Urban Area	UK0001	0	B	0	B
West Midlands Urban Area	UK0002	0	B	0	B
Greater Manchester Urban Area	UK0003	0	B	0	B
West Yorkshire Urban Area	UK0004	0	B	0	B
Tyneside	UK0005	0	B	0	B
Liverpool Urban Area	UK0006	0	B	0	B
Sheffield Urban Area	UK0007	0	B	0	B
Nottingham Urban Area	UK0008	0	B	0	B
Bristol Urban Area	UK0009	0	B	0	B
Brighton/Worthing/Littlehampton	UK0010	0	B	0	B
Leicester Urban Area	UK0011	0	B	0	B
Portsmouth Urban Area	UK0012	0	B	0	B
Teesside Urban Area	UK0013	4	B	283	B
The Potteries	UK0014	0	B	0	B
Bournemouth Urban Area	UK0015	0	B	0	B
Reading/Wokingham Urban Area	UK0016	0	B	0	B
Coventry/Bedworth	UK0017	0	B	0	B
Kingston upon Hull	UK0018	0	B	0	B
Southampton Urban Area	UK0019	0	B	0	B
Birkenhead Urban Area	UK0020	0	B	0	B
Southend Urban Area	UK0021	0	B	0	B
Blackpool Urban Area	UK0022	0	B	0	B
Preston Urban Area	UK0023	0	B	0	B
Glasgow Urban Area	UK0024	0	B	0	B
Edinburgh Urban Area	UK0025	0	B	0	B
Cardiff Urban Area	UK0026	0	B	0	B
Swansea Urban Area	UK0027	1	B	24	B
Belfast Urban Area	UK0028	0	B	0	B
Eastern	UK0029	0	B	0	B
South West	UK0030	0	B	0	B
South East	UK0031	0	B	0	B
East Midlands	UK0032	0	B	0	B
North West & Merseyside	UK0033	0	B	0	B
Yorkshire & Humberside	UK0034	13	B	6714	B
West Midlands	UK0035	0	B	0	B
North East	UK0036	1	B	10	B
Central Scotland	UK0037	0	B	0	B
North East Scotland	UK0038	0	B	0	B
Highland	UK0039	0	B	0	B
Scottish Borders	UK0040	0	B	0	B
South Wales	UK0041	1	B	19	B
North Wales	UK0042	0	B	0	B
Northern Ireland	UK0043	7	B	20630	B
Total		27		27680	

Method ‘B’ is the modelling methodology described in this report.

4 Results of the air quality assessments

The results of the air quality assessments for As, Cd, Ni, and B(a)P are listed in Table 4.1. These tables present information from Form 9b of the questionnaire.

The tables have been completed as follows:

- Where all measurements were within the relevant target values in 2009, the table shows this as “OK”
- Where compliance was determined by modelling only, this is shown as “OK (m)”
- Where locations were identified as exceeding a target value this is identified as “>TV”
- Where an exceedence was determined by modelling, this is indicated by (m)

Zones that complied with the relevant target values are shaded blue, while those that did not are shaded red.

If both measurements and model estimates show that a threshold has been exceeded then the measurements are regarded as the primary basis for compliance status. Where locations have been identified as exceeding from modelling this indicates that modelled concentrations were higher than measured concentrations, or on rare occasions that measurements were not available or not required for that zone (measurements are not required where the Article 5 Assessment illustrates that concentrations are lower than the Lower Assessment Threshold) and modelled values were therefore used. Modelled concentrations may be higher than measured concentrations because the modelling studies provide estimates of concentrations over the entire zone. It is possible that the locations of the monitoring sites do not correspond to the location of the highest concentration in the zone. Compliance can be determined by modelling where measurements are not available for a zone.

Table 4.1: List of zones and agglomerations where levels exceed or do not exceed target values for arsenic, cadmium, nickel and benzo(a)pyrene (2004/1007/EC, Annex I)

Zone	Zone code	As TV	Cd TV	Ni TV	B(a)P TV
Greater London Urban Area	UK0001	OK	OK	OK	OK (m)
West Midlands Urban Area	UK0002	OK	OK	OK	OK
Greater Manchester Urban Area	UK0003	OK	OK	OK	OK
West Yorkshire Urban Area	UK0004	OK (m)	OK (m)	OK (m)	OK
Tyneside	UK0005	OK (m)	OK (m)	OK (m)	OK
Liverpool Urban Area	UK0006	OK (m)	OK (m)	OK (m)	OK
Sheffield Urban Area	UK0007	OK	OK	OK	OK (m)
Nottingham Urban Area	UK0008	OK (m)	OK (m)	OK (m)	OK (m)
Bristol Urban Area	UK0009	OK	OK	OK	OK (m)
Brighton/Worthing/Littlehampton	UK0010	OK (m)	OK (m)	OK (m)	OK
Leicester Urban Area	UK0011	OK (m)	OK (m)	OK (m)	OK (m)
Portsmouth Urban Area	UK0012	OK (m)	OK (m)	OK (m)	OK (m)
Teesside Urban Area	UK0013	OK	OK	OK	> TV (m)
The Potteries	UK0014	OK (m)	OK (m)	OK (m)	OK (m)
Bournemouth Urban Area	UK0015	OK (m)	OK (m)	OK (m)	OK (m)
Reading/Wokingham Urban Area	UK0016	OK (m)	OK (m)	OK (m)	OK (m)
Coventry/Bedworth	UK0017	OK (m)	OK (m)	OK (m)	OK (m)
Kingston upon Hull	UK0018	OK (m)	OK (m)	OK (m)	OK (m)
Southampton Urban Area	UK0019	OK (m)	OK (m)	OK (m)	OK (m)
Birkenhead Urban Area	UK0020	OK (m)	OK (m)	OK (m)	OK (m)
Southend Urban Area	UK0021	OK (m)	OK (m)	OK (m)	OK (m)
Blackpool Urban Area	UK0022	OK (m)	OK (m)	OK (m)	OK (m)
Preston Urban Area	UK0023	OK (m)	OK (m)	OK (m)	OK (m)
Glasgow Urban Area	UK0024	OK	OK	OK	OK
Edinburgh Urban Area	UK0025	OK (m)	OK (m)	OK (m)	OK
Cardiff Urban Area	UK0026	OK	OK	OK	OK
Swansea Urban Area	UK0027	OK	OK	> TV (m)	> TV (m)
Belfast Urban Area	UK0028	OK	OK	OK	OK
Eastern	UK0029	OK	OK	OK	OK
South West	UK0030	OK	OK	OK	OK (m)
South East	UK0031	OK	OK	OK	OK
East Midlands	UK0032	OK	OK	OK	OK
North West & Merseyside	UK0033	OK	OK	OK	OK
Yorkshire & Humberside	UK0034	OK	OK	OK	> TV
West Midlands	UK0035	OK (m)	OK (m)	OK (m)	OK (m)
North East	UK0036	OK	OK	OK	> TV (m)
Central Scotland	UK0037	OK	OK	OK	OK
North East Scotland	UK0038	OK	OK	OK	OK (m)
Highland	UK0039	OK (m)	OK (m)	OK (m)	OK
Scottish Borders	UK0040	OK	OK	OK	OK (m)
South Wales	UK0041	OK	OK	> TV (m)	> TV (m)
North Wales	UK0042	OK (m)	OK (m)	OK (m)	OK (m)
Northern Ireland	UK0043	OK (m)	OK (m)	OK (m)	> TV

5 Acknowledgements

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Appendices

Appendix 1: Dispersion kernels for area source model

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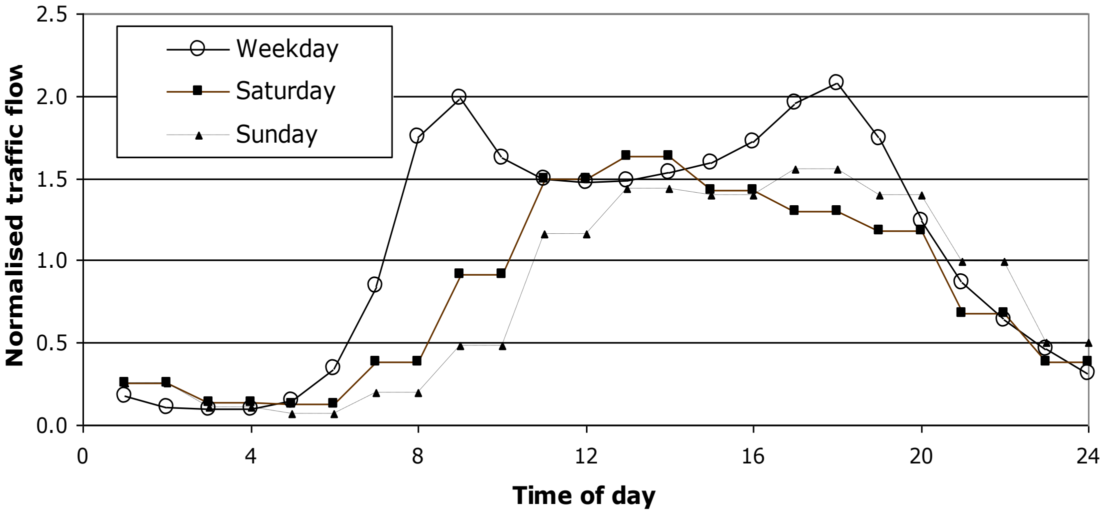
Dispersion kernels for area source model

Dispersion kernels for calculating the annual mean contribution of emissions from area sources to ambient annual mean concentrations were calculated using ADMS 4.2. Separate kernels were calculated for traffic and other area sources (which were assumed to have a constant temporal profile of emissions). Kernels were generated for 2009 using sequential meteorological data from Waddington. The dispersion parameters used to calculate the kernels are listed in Table A1.1. The emission profile used to represent traffic emissions for the traffic kernels is shown in Figure A1.1. This was obtained from a distribution of all traffic in the United Kingdom by time of day (DETR, 2000).

Figure A1.1. Temporal profile of traffic emissions



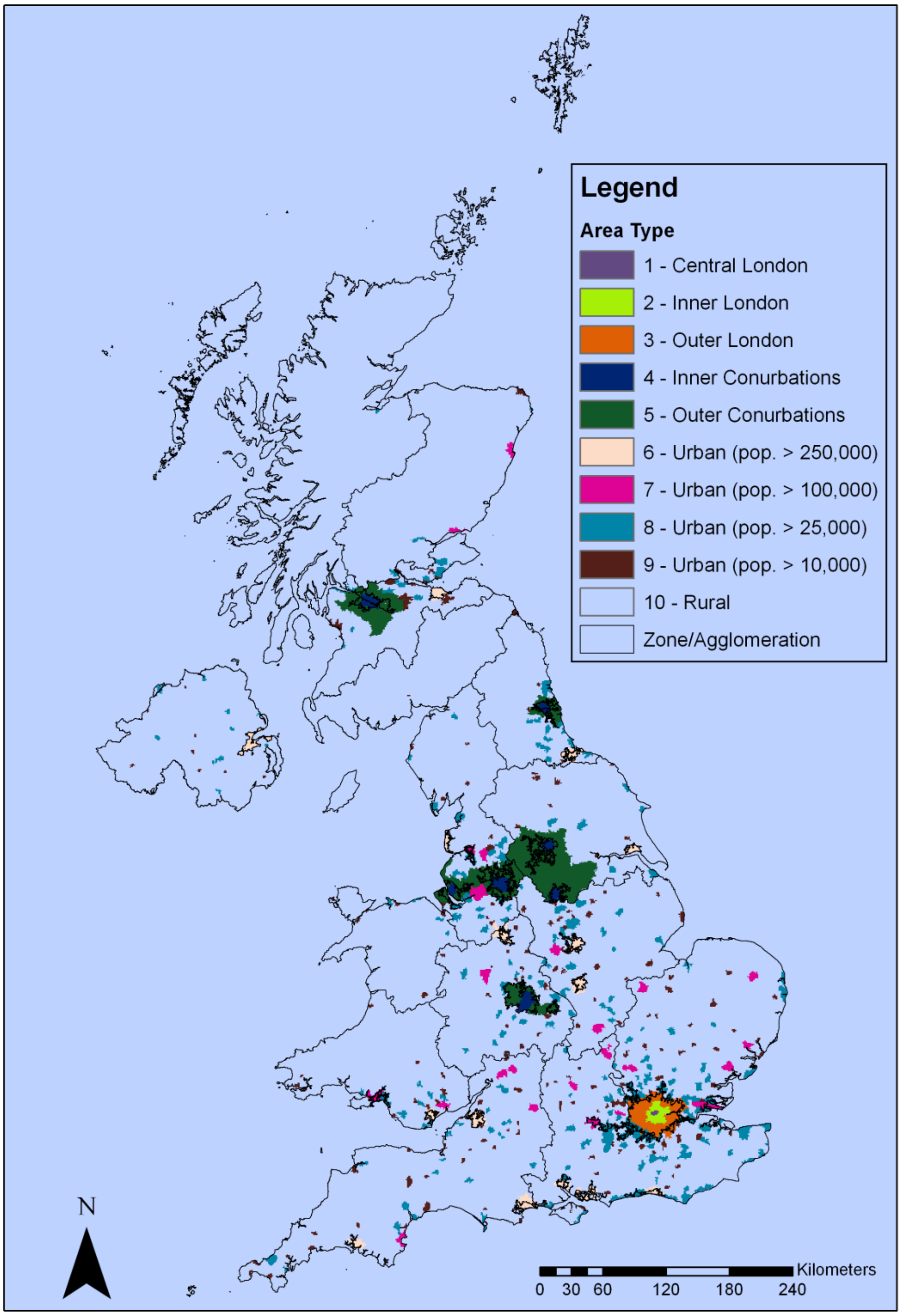
The dispersion kernels were revised for the 2007 modelling for all pollutants and the same method was applied for 2009. For NO_x, PM_{10}, benzene and CO the kernels are now on a 1km x 1km resolution matrix and are made using ADMS 4.2 (rather than the 3km x 3km resolution matrix used in previous years). The centre squares have been scaled to remove the impact of sources within 50 m of the receptor location in that square on the basis that background sites are not located very close to specific sources such as major roads. Different kernels have been made for different area types, to take into account different dispersion conditions in urban areas of different sizes. Previously this was accounted for in the PCM models by the application of different empirical calibration coefficients in inner conurbations and other locations. The kernels have been made specific to different types of location by varying minimum Monin Obukhov Length (LMO). The location of the different area types are shown in Figure A1.2 and surface roughness due to different land use. This has replaced the use of different calibration coefficients for inner conurbations and elsewhere.

ADMS 4.2 recommends using a minimum Monin Obukhov Length (LMO) of 30m for an urban area. However, sensitivity testing indicated that an LMO of 20m produced a more realistic fit using ADMS 4.2.

Table A1.1. Summary of inverted dispersion kernel parameters

Kernel name	**Area types**	**Type of location**	**LMO (m)**	**Surface roughness (m)**		**Height (m) of volume source**	**Variable emission profile?**	**Emission rate (g m^{-3} s^{-1})**
				Dispersion site	**Met site**			
Non road transport	1,2,4	Conurbation	25	0.5	0.02	30	N	3.33E-08
Non road transport	3,4,5,6,7,8	Smaller urban	20	0.5	0.02	30	N	3.33E-08
Non road transport	9,10	Rural	10	0.5	0.02	30	N	3.33E-08
Road transport	1,2,4	Conurbation	25	0.5	0.02	10	Y	1.0E-7
Road transport	3,4,5,6,7,8	Smaller urban	20	0.5	0.02	10	Y	1.0E-7
Road transport	9,10	Rural	10	0.5	0.02	10	Y	1.0E-7

Figure A1.2. Map of UK area types



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