

Assessment of Heavy Metal Concentrations in the United Kingdom

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

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	Name	Signature	Date
Author	Keith Vincent and Neil Passant		
Reviewed by	Peter Coleman and John Stedman		
Approved by	John Stedman		

Executive Summary

In preparation for the implementation of the 4th Daughter Directive a detailed assessment of arsenic, cadmium and nickel concentrations in the United Kingdom has been conducted. The assessment reviewed the available monitoring and emission data and through atmospheric dispersion modelling attempted to link the measured concentrations with the emission inventory.

The 4th Daughter Directive has set target values for arsenic, cadmium and nickel of 6 ng m⁻³, 5 ng m⁻³ and 20 ng m⁻³, respectively. Target levels are based on the concept of "unit risk", where the unit risk is defined as the extra risk of developing cancer from an exposure to 1 µg m⁻³ over a lifetime. A review of the available monitoring data has shown that only the target level for nickel was exceeded at the sampling site at Pontardawe in 2003. Exceedence of the target values for arsenic and cadmium did occur before 2003 at a small number of industrial sites but it is expected that the concentrations will continue to decrease as emission abatement technologies are applied. Lead was also considered in the assessment because emissions of lead are better quantified than the other metals.

Ambient concentrations of heavy metals have decreased dramatically since monitoring began reflecting the reductions in emissions. A review of the historic data collected in the urban trace element network shows that the annual mean concentrations were erratic for each metal until the mid 1990's. Nevertheless this network showed that cadmium concentrations have been lower than the target levels since the early 1980's. Nickel concentrations at some urban sites exceeded target levels well into the 1990's.

The annual mean concentrations at sampling sites in rural locations in 2003 were 0.18 ng m⁻³, 0.66 ng m⁻³, 1.65 ng m⁻³ and 7.58 ng m⁻³ for cadmium, arsenic, nickel and lead, respectively. The relatively ranking in concentration is the same as the relative order in anthropogenic emissions.

The dispersion modelling approach followed the same method as used for other national scale assessments such as benzo[a]pyrene and sulphur dioxide modelling. Emissions from point and area sources were modelled separately, then added together and then compared to monitoring data. However, the predicted concentrations were very much less than the measured concentrations- particularly at the industrial locations. So two additional "modelling methods" were investigated to raise the predicted value. The first of these was to assume that a fugitive emission, three times higher than the reported emission, was released from the metal processing plants. The second was to assume that a fraction of the coarse particulate matter arose from the underlying soil. The incorporation of the fugitive emission did increase the modelled concentration near the metal industry plants but without quantification the method can only be seen as a sensitivity test. The second method showed that a significant fraction of the measured arsenic and lead concentration might originate from the soil surface. Levels of nickel in air at Pontardawe are significantly higher than at other monitoring locations across the UK. At this location there have been measurements of nickel in soil at concentrations significantly higher than the typical UK range. However even assuming this local soil concentration the contribution of soil to nickel concentrations is estimated at around 2 ng m⁻³. This is significantly lower than the measured concentrations.

However, a review of the uncertainty in the emission factors showed that these are very uncertain.

A review of the heavy metal modelling work undertaken by the Meteorological Synthesizing Centre – East shows that the heavy metal EMEP modelling methodology is continually revised as understanding of the heavy metal sources increases.

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1 Introduction

This national scale assessment of heavy metals in the United Kingdom aims to inform Defra of the spatial and temporal variations throughout the country. The Fourth Daughter Directive has set target values for arsenic, cadmium and nickel¹. Target values are less stringent than limit values – they would not lead to closure of a particular installation but would require that member states take all cost-effective abatement measures in the relevant sectors. The target values for arsenic, cadmium and nickel are provided in Table 1.1.

Table 1.1: Fourth Daughter Directive target values for arsenic, cadmium and nickel concentrations.

Pollutant	Target value ng m ⁻³
Arsenic	6
Cadmium	5
Nickel	20

In addition to the three heavy metals that are reviewed as part of the Fourth Daughter Directive, this assessment also examines lead concentrations as lead emissions are expected to have less uncertainty than the other heavy metals. A limit value for lead of 0.5 µg m⁻³ is included in the First Daughter Directive².

Section 1.1 presents information on the particle size distributions for particulate matter containing the heavy metals. Section 1.2 summarises the changes in the EMEP modelling source attribution as knowledge regarding the concentration has increased. Section 1.3 provides an estimate of the heavy metal concentration in air arising from the soil. Section 2 discusses the emission inventory and the associated uncertainty. Section 3 reviews the measurement data. Section 4 presents the modelling work and summarises briefly the heavy modelling work for the UK undertaken by EMEP MSC-E.

1.1 PARTICLE SIZE DISTRIBUTIONS

Understanding the size of the aerosol is important for two main reasons. The first relates to how deeply the particles will reach into the respiratory system. The second relates to the deposition velocity, which in turn, relates to the residence time in the atmosphere and hence the potential for long range transport in the atmosphere. A number of studies measuring heavy metal concentrations have been carried out. The results of these studies are presented in Figure 1.1. Ashmore *et al.* (2000) present the size distribution from two studies- the first was in a rural location in Scotland (Auchencorth Moss) and the second for two sites in the West Midlands. Figure 1.1a shows that the cadmium and lead particles in the aerosol were sub micron – at the deposition velocity particularly suited for long-range transport of particulate matter. A similar size range (Figure 1.1b) was found for arsenic and cadmium in particulate matter for samples collected at two locations in Finland (European Communities, 2001). The nickel aerosol was characterised by a multi-

¹ Council Directive 2004/107/EC, of 15 December 2004, relating to arsenic, cadmium, nickel and polycyclic aromatic hydrocarbons in ambient air (The Fourth Daughter Directive). From the Official Journal of the European Communities, 26.1.2005, En Series, L23/3.

² Council Directive 1999/30/EC, of 22 April 1999, relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air (The First Daughter Directive). From the Official Journal of the European Communities, 29.6.1999, En Series, L163/41.

modal distribution. The particles with diameters greater than 10 μm are expected to settle quickly after release. Figure 1.1c also presented a third set of size distributions from an aerosol collected in Germany - showing the same size distribution.

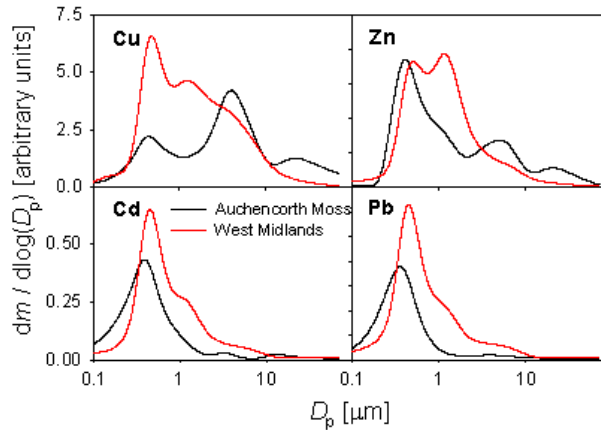


Figure 1.1a: Size distribution of cadmium and lead for rural and urban areas in the United Kingdom (from Ashmore, 2000).

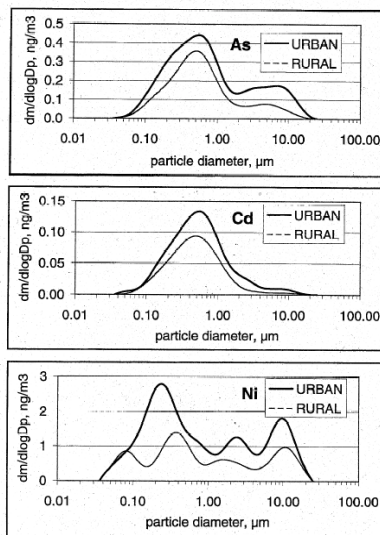


Figure 1.1b Size distribution of arsenic, cadmium and nickel measured at rural and urban locations in Finland (from European Communities, 2001)

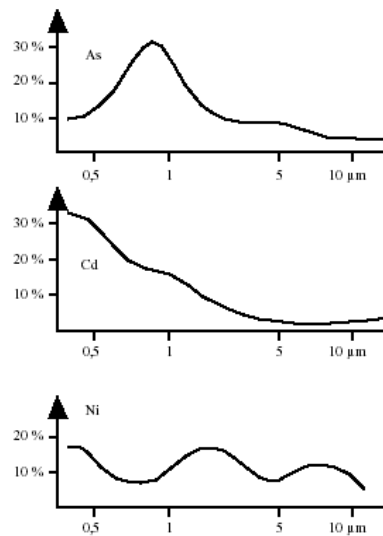


Figure 1.1c: Size distribution of arsenic, cadmium and nickel measured at an urban location in Germany (from European Communities, 2001)

Figure 1.1: Estimated size distributions for heavy metals at a number of locations in Europe

1.2 CONTRIBUTION OF EUROPEAN EMISSIONS AND NATURAL SOURCES TO UNITED KINGDOM DEPOSITIONS

The Position Paper on heavy metals (European Communities, 2001) summarised the then state of knowledge with regards to heavy metal sources, measurements and modelling. Cadmium concentrations were expected to be lower than arsenic concentrations at the European level because the arsenic sources were considered to be combustion sources

and these are considered ubiquitous whereas cadmium emissions sources are considered to be from production processes located in industrial areas. Nickel concentrations are higher than arsenic or cadmium concentrations.

There have been a number of attempts at estimating the relative contribution of anthropogenic, natural and re-suspension sources to the observed concentration. For the Position Paper 86% of the cadmium released from the UK was estimated to deposit within the UK, with only 3% of the observed deposition attributed to reemission of previously deposited material or natural emission.

By 2004, the estimates of the relative contribution of each had been changed. Table 1.2 compares the main sources of transboundary pollution in the United Kingdom as obtained from the Position Paper and MSC-E (2004a). The contribution of the UK to its own deposition had substantially reduced whereas the reemission and natural source component had increased significantly. It should be borne in mind that two different inventories were used in each modelling run, the former using a much higher cadmium emission inventory - shown to reproduce the measured concentration values (see Section 4.5).

Table 1.2: The three largest sources, contribution of own sources and reemission to deposition in the United Kingdom.

Data source	Largest contributor to UK	% age of UK Total	Second largest contributor to UK	% age of UK total	Third largest contributor to UK	% age of UK total	Contribution Of own sources % age	Reemission, natural and global sources % age
EU, 2001	France	3	Poland	2	Germany	1	86	3
MSC-E 2004a	Ireland	3	France	2	Spain	1	32	58

1.2.1 Non anthropogenic cadmium emissions in the UK

The MSC-E (Alexey Ryaboshapko, Meteorological Synthesizing Centre – East, *Personal Communication, 2005*) has provided estimates for natural emission and re-emission of cadmium in the United Kingdom. Natural emission is estimated to be about 1.2 t/yr. Re-emission of previously deposited anthropogenic cadmium is changeable in space and time. The cadmium re-emission value for the UK is estimated to be about 4.2 t/yr. These values are considered to be very uncertain (Oleg Travnikov, Meteorological Synthesizing Centre – East, *Personal Communication*).

1.2.2 Estimated contribution of soil to heavy metal concentrations

Surveys carried out since the 1960's show that soils in urban and industrialised areas contain anomalously high concentrations of heavy metals (Alloway, 1990). It would then be expected that a proportion of the ambient aerosol does contain some material that arose from the re-suspension of particulate matter from the soil surface. Using a typical value for the coarse fraction of the ambient aerosol of $8 \mu\text{g m}^{-3}$ (Table 5.5, APEG, 1999) and assuming that all the coarse material arises from the soil and that the concentration of the metal in the coarse particulate matter is the same as in the soil allows a simple method to calculating the metal concentration in the air. Table 1.3 show a number of estimates of heavy metals in soils and an estimate of heavy metal concentration in ambient air. The highest concentrations are obtained for lead, reflecting the large amount of accumulated lead emission that occurred due to the use of lead additives in petrol.

Cadmium concentrations arising from soils are particularly small suggesting that the observed concentrations are derived from non-natural sources.

Nickel concentrations are about an order of magnitude less than the ambient concentration measured in rural locations.

Levels of nickel in air at Pontardawe are significantly higher than at other monitoring locations across the UK (see Section 3). At this location there have been measurements of nickel in soil at concentrations significantly higher than the typical UK national range. However even using the maximum local soil concentration measured in 1974 from the spoil tips of 250 mg kg⁻¹ (Pattenden 1974) with the other assumptions described above the contribution of soil to nickel concentrations might be 2 ng m⁻³. This is significantly lower than the measured concentrations.

However using a single value of coarse and a limited number of heavy metal concentrations in soils can only provide an indicative value of re-suspension from soils and a further more detailed analysis is recommended.

Table 1.3: Heavy metal concentrations in a range of soil types and an estimate of the heavy metal component of the ambient aerosol assuming that the concentration is derived from a coarse particulate matter fraction (with a coarse particulate matter concentration of 8 µg m⁻³).

Metal		Low estimate	High estimate	Central estimate
Arsenic	Concentration in soil, mg kg ⁻¹	10	424	51
	Source: Alloway (1990), Page 84	Uncontaminated soils	Mineralised soils in SW England	Non mineralised soils in SW England
	Ambient concentration, ng m ⁻³	0.08	3.39	0.41
Cadmium	Concentration in soil, mg kg ⁻¹	0.01	2.4	1.0
	Source: Alloway (1990), Table 6.2	Lowest value in UK agricultural range	Highest value in UK agricultural range	Most frequently occurring value in UK soil survey
	Ambient concentration, ng m ⁻³	< 0.001	0.019	0.008
Nickel	Concentration in soil, mg kg ⁻¹	25	53	40
	Source: Alloway (1990), Table 7.3	Lowest mean	Highest mean	Mean
	Ambient concentration, ng m ⁻³	0.20	0.42	0.32
Lead	Concentration in soil, mg kg ⁻¹	100	1592	700
	Source: Alloway (1990), Chapter 9	Upper value in rural soil range	Industrial	Upper value in range of roadside soils
	Ambient concentration, ng m ⁻³	0.8	12.7	5.6

2 Emissions

2.1 INTRODUCTION

The modelling work described in this report uses emissions data taken from the 2002 version of the National Atmospheric Emissions Inventory (NAEI). Since completion of the work, the 2003 version of the NAEI has been completed. This new version of the inventory included some significant revisions to emission estimates for metals. This chapter includes some discussion of both the 2002 NAEI data used for the modelling work, but also the revised 2003 NAEI figures as well since this has a bearing on our conclusions.

2.2 HISTORIC EMISSIONS OF HEAVY METALS

Emissions of arsenic, cadmium, nickel, and lead during the period 1970-2002 have been estimated in the 2002 version of the NAEI. Table 2.1 shows that significant reductions in emissions are estimated for all four metals over this period.

Table 2.1: Arsenic, cadmium, nickel and lead emissions (tonnes) in 1970 to 2002. Data obtained from the 2002 version of the National Atmospheric Emissions Inventory (NAEI, 2004)

Metal	1970	2002	Percentage reduction from 1970 to 2002
Arsenic	134.3	24.0	82%
Cadmium	26.7	4.5	83%
Nickel	1228.8	97.9	92%
Lead	7465.9	162.3	98%

Figure 2.1 presents the emission trend back to 1970 in Standard Nomenclature for Air Pollutants (SNAP) format. This classification attributes the emission into nine main source sectors.

For arsenic (Figure 2.1a), most of the emission is attributed to three SNAP sectors: combustion in energy and transformation; non-industrial combustion plants; and combustion in manufacturing. Most of the emission from non-industrial combustion plants is from residential properties.

For cadmium (Figure 2.1b), waste treatment and disposal was the dominant source until about 1993, since when emissions from the major contributor, municipal solid waste incineration, have decreased significantly. Subsequently, the dominant cadmium source has been the 'combustion in manufacturing' sector.

For nickel (Figure 2.1c), the major contributor to emissions was the combustion in manufacturing sector up until about 1996 when emissions from combustion in energy and transformation became the dominant source.

For lead (Figure 2.1d), emissions from road transport dominated lead emissions for most of the thirty-two year period. Lead has now been removed from petrol and emissions

from the combustion in manufacturing sector now dominate lead emissions in the United Kingdom.

Figure 2.2 presents an alternative breakdown of emissions which attempts to classify sources into groups sharing similar characteristics. This classification is designed to highlight particular features of the various inventories.

Figure 2.2a (arsenic) shows that emissions from the combustion of solid fossil fuels reduced by an order of magnitude from 1970 to 2002 (105 tonnes to 11 tonnes). A decline in the use of coal by power stations and industry, and the use of coal, coke, and anthracite as a domestic fuel have caused this decrease in emissions, although emissions from power stations and industry have also been reduced through the increasing use of particulate matter abatement systems. Emissions from the combustion of wood treated with copper-chromium-arsenic preservatives was the next largest source (9 tonnes year⁻¹ each year since 1970). A constant emission estimate is used for this source: this reflects a lack of detailed data for this source rather than actual constancy in annual emissions. Other sources, including combustion of oil-based fuels and metal industry sources are relatively unimportant compared with combustion of solid fuels and treated wood which contributed 46% and 37% of UK emissions in 2002 respectively.

Figure 2.2b shows a more complex picture for cadmium emissions. Up until 1992, the largest source was waste incineration (incineration of municipal solid waste and clinical waste) with emissions estimated at 9.5 tonnes annually. After 1992 emissions from this source decreased rapidly to about 3.9 tonnes in 1993, then further to reach 0.4 tonnes in 2002. Metal industry processes such as steel production, non-ferrous metal production and foundry processes have also been significant but declining sources of cadmium with emissions of 8.8 tonnes in 1970 and 2.4 tonnes in 2002. The sector is now the biggest contributor (53%) to emissions. Emissions from both incineration and metal industry processes have declined due to increasing use of particulate matter abatement systems. Fuel combustion is a less important source for cadmium than for some metals but is still important. Coal and oil combustion have declined in importance since 1970 and emissions have decreased accordingly. A 1984 peak in emissions from oil combustion was due to increased use of fuel oil at power stations in that year in response to industrial action by coal miners. Fuel combustion has been a fairly consistent contributor of between a quarter and a third of UK emissions each year.

Figure 2.2c shows the decrease in nickel emission from 1970 to 2002. Almost all of the emissions of nickel occur from combustion of fuel oil and, to a lesser extent, solid fuels. Emissions have decreased due to a sharp decline in the use of fuel oil and coal. Despite this decline in fuel use, emissions from combustion processes have remained above 85% of total UK emissions across the time series since other sources such as the metals industry have also declined.

Figure 2.2d shows that the lead inventory was historically dominated by emissions from the use of leaded petrol. Emissions from this sector decreased from a peak of 8,400 tonnes in 1973 to only 1.5 tonnes in 2002. This decrease is due to increasingly stringent control of the use of lead additives in petrol over the period, culminating in their use being prohibited after 1999. Emissions from other sources were, until about 1986, a relatively minor component of UK emissions, but are now dominant due to the phase-out of leaded petrol. The most significant current sources are coal combustion and metal industry processes.

These four figures show clearly that the inventories for the four metals are significantly different in terms of the relative importance of different sources. The arsenic and nickel inventories are dominated by combustion of coal and fuel oil respectively, while the cadmium inventory is dominated by process emissions. The lead inventory was dominated by emissions related to use of lead-containing chemicals as petrol additives.

There are, however, also some similarities between the inventories – coal combustion and metal industry processes are non-trivial emission sources for all four metals. As previously mentioned, the trend in emissions is also similar with sharp decreases for all metals from a peak in 1970 (1973 for lead) to lows in 2001 or 2002.

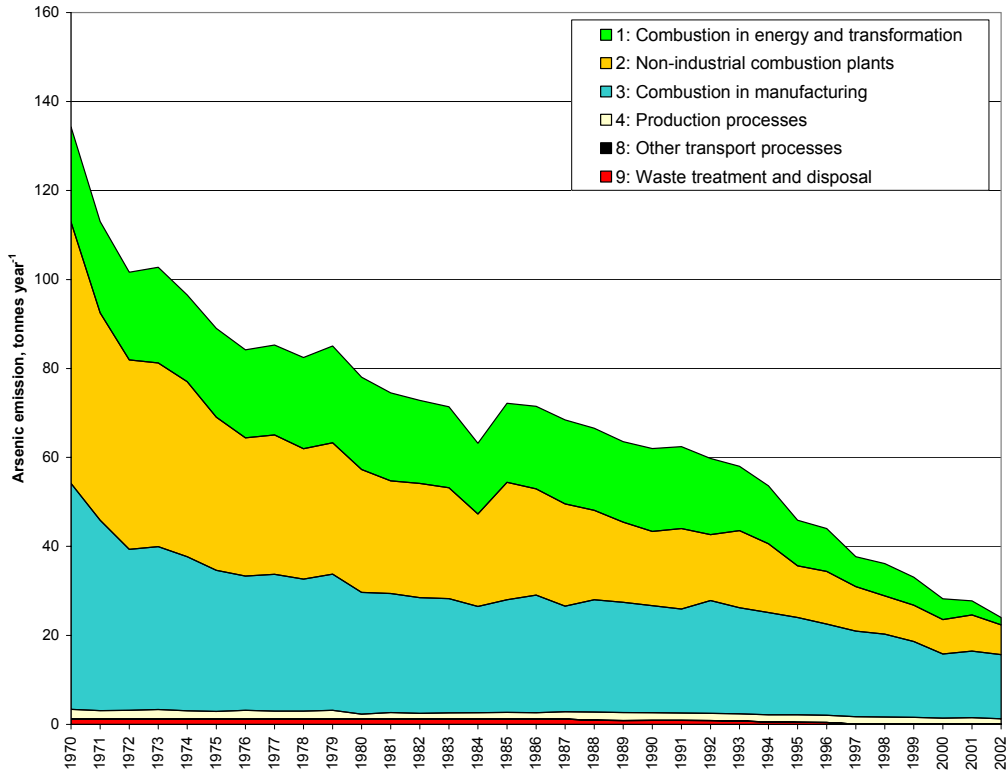


Figure 2.1a: Arsenic emission from 1970 to 2002, tonnes year⁻¹

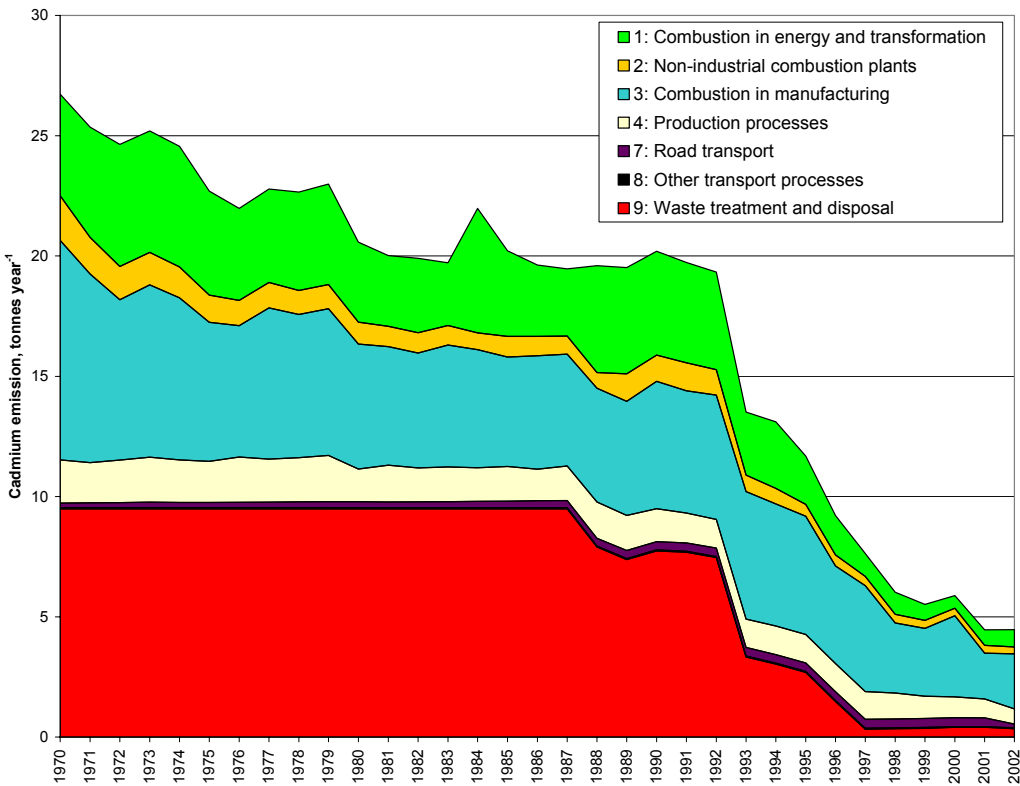


Figure 2.1b: Cadmium emission from 1970 to 2002, tonnes year⁻¹

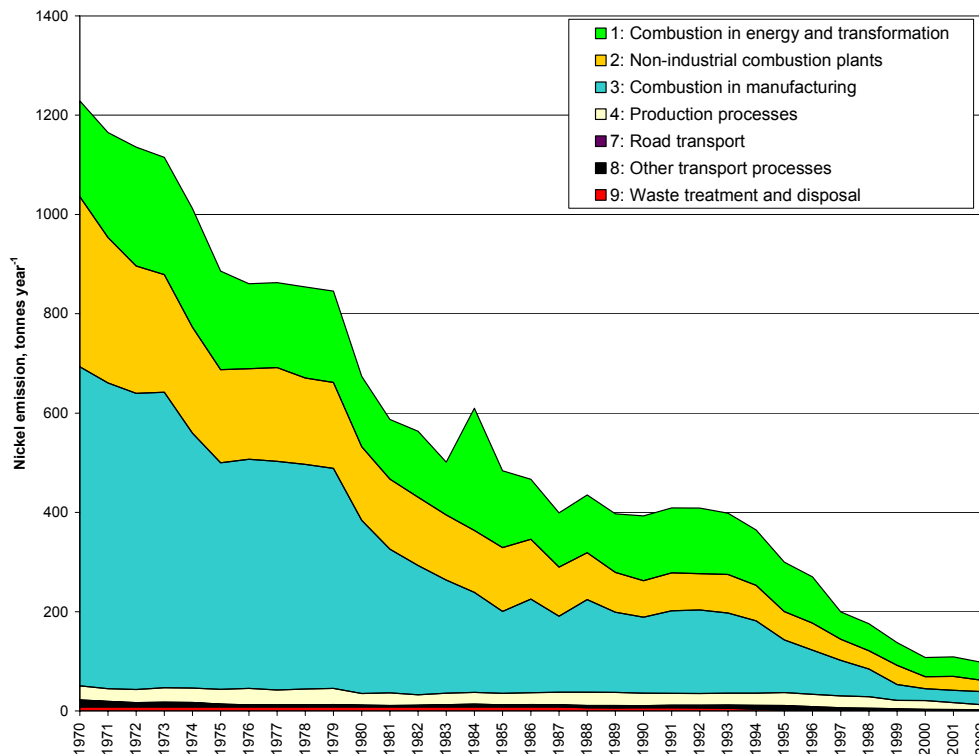


Figure 2.1c: Nickel emission from 1970 to 2002, tonnes year⁻¹

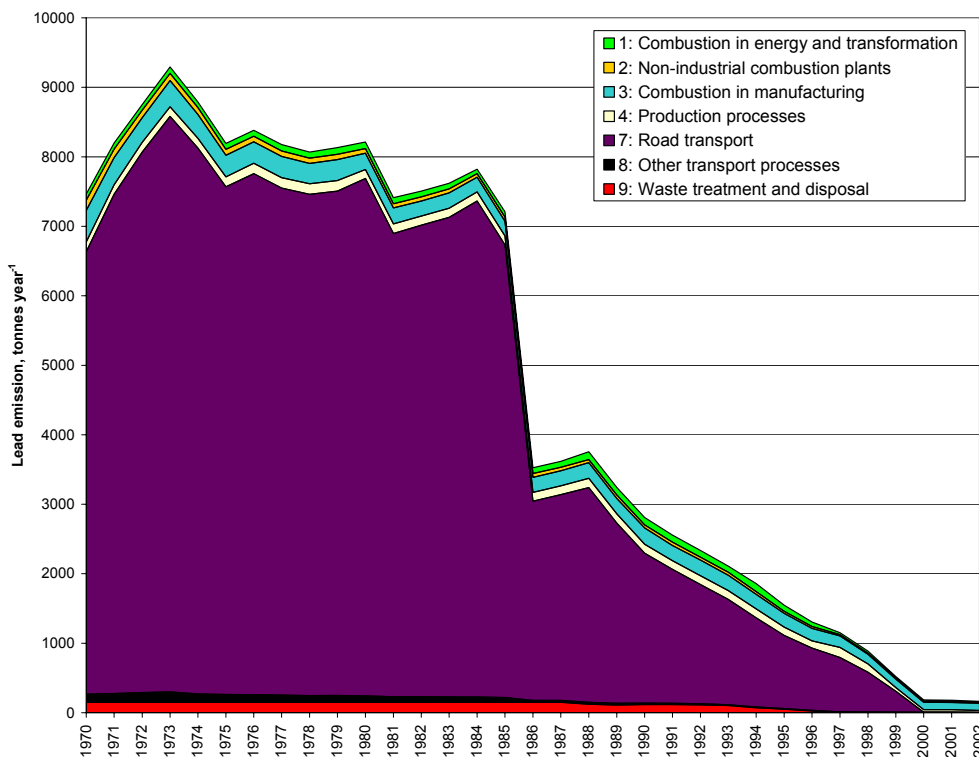


Figure 2.1d: Lead emission from 1970 to 2002, tonnes year⁻¹

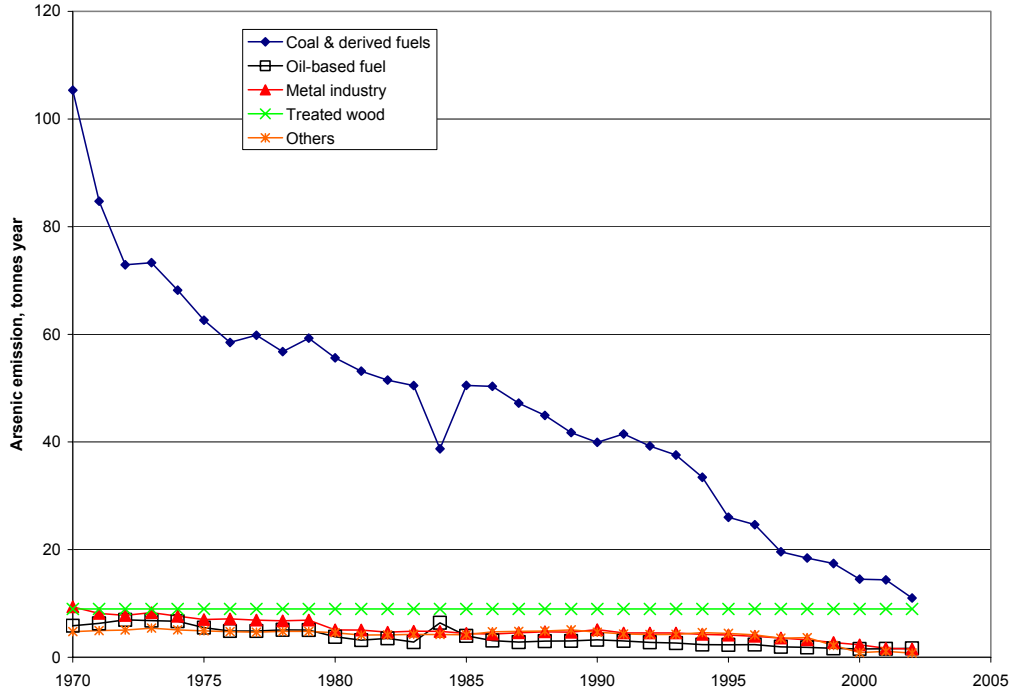


Figure 2.2a: Arsenic emission from 1970 to 2002, tonnes year⁻¹

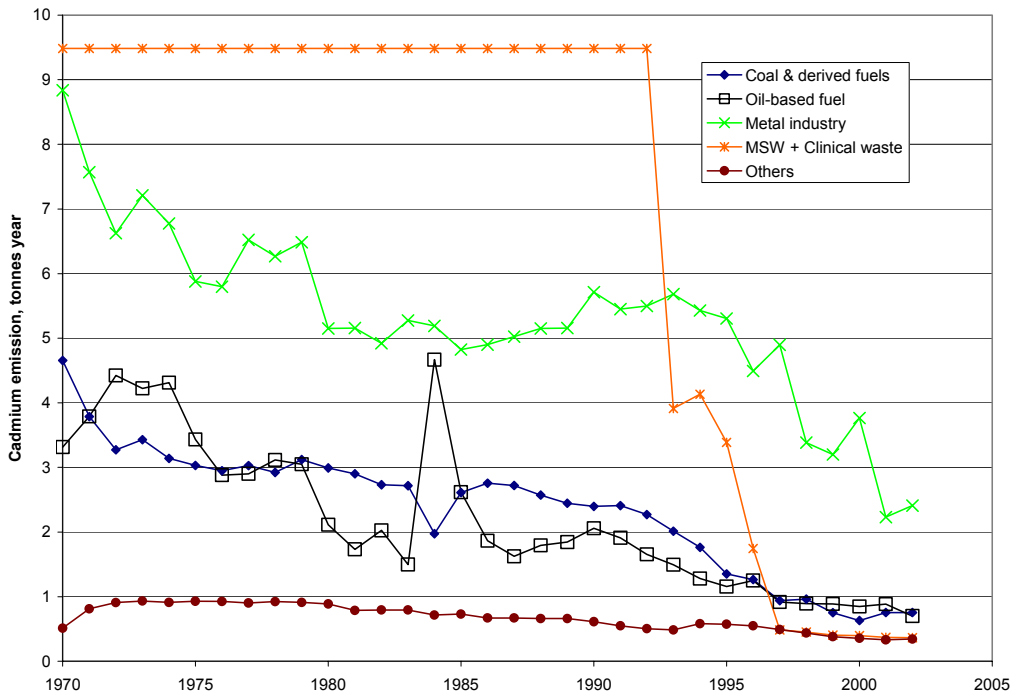


Figure 2.2b: Cadmium emission from 1970 to 2002, tonnes year⁻¹

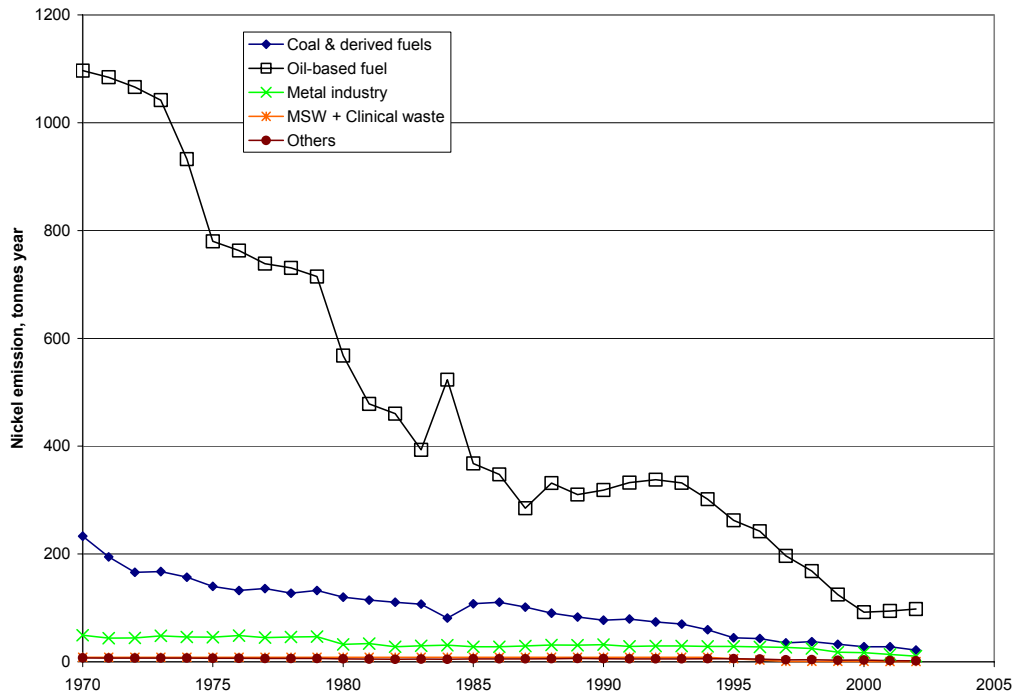


Figure 2.2c: Nickel emission from 1970 to 2002, tonnes year⁻¹

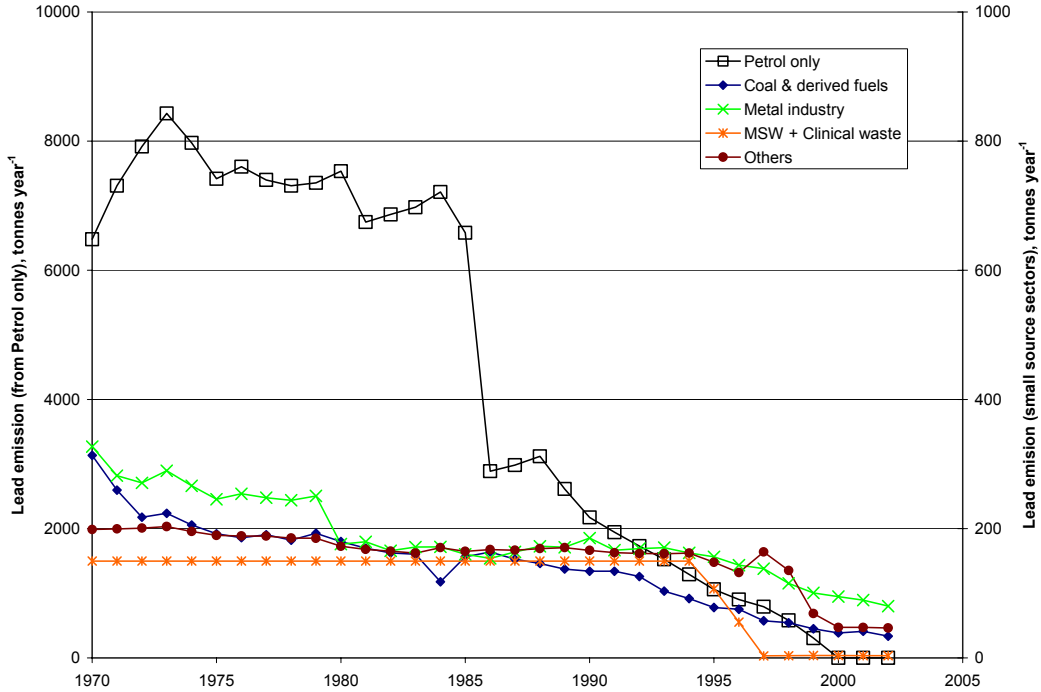


Figure 2.2d: Lead emission from 1970 to 2002, tonnes year⁻¹

2.3 UNCERTAINTY IN EMISSION ESTIMATES

The emission estimates for metals are among the most uncertain of those within the National Atmospheric Emissions Inventory (NAEI). This uncertainty is reflected in the estimates of total UK emissions of the four metals for the year 2000, taken from four successive versions of the NAEI (see Table 2.2).

Table 2.2: Total estimated UK emissions of selected metals during 2000 from four versions of the NAEI (all figures in tonnes)

Pollutant	2000 NAEI	2001 NAEI	2002 NAEI	2003 NAEI
Arsenic	34.6	38.1	28.2	20.9
Cadmium	5.22	7.27	5.91	7.93
Nickel	115	158	141	201
Lead	496	194	185	166

Estimates for all of the metals have changed significantly from year to year as revisions have been made to the emission factors used to calculate emissions, although the large decrease in the lead estimate between the 2000 and 2001 versions of the NAEI is mostly due to the removal of an error in the 2000 estimate. Both the 2002 NAEI data used for this study and the 2003 NAEI estimates were considered very uncertain, as shown by quantitative assessments of uncertainty for each data set, which produced the following estimates for the probable range of emissions:

Metal	2002 NAEI	2003 NAEI
Arsenic	13.1 to 40.9 tonnes	6.98 to 38.9 tonnes
Cadmium	3.61 to 6.27 tonnes	3.28 to 12.9 tonnes
Nickel	54.5 to 176 tonnes	83.2 to 345 tonnes
Lead	123 to 216 tonnes	96.0 to 186 tonnes

The assessment for the 2003 NAEI indicated a wider range of likely emissions for all four metals and suggested much higher emissions were possible for cadmium and nickel compared with the 2002 assessment.

The uncertainty in these inventories is due to a number of factors, some of which apply to all four metals:

- 1) Emission factors for the combustion of liquid and solid fuels are very uncertain, being based on analysis of, at most, a few samples of each fuel. The metal contents of fuels are known to vary considerably. The heavy metal content of UK coals can vary by up to an order of magnitude. The reliance on only a few measurements for each fuel is therefore a source of concern. Fuel combustion is estimated to be a major source of metal emissions and the uncertainty in the factors used translates into a significant uncertainty in the UK total emission estimate.
- 2) Emission estimates for industrial processes such as steel-making, non-ferrous metal production and foundries probably do not all include fugitive emissions, whereas these emissions may be very significant.
- 3) A few other sources are poorly characterised but are estimated to be significant sources of metals. These include disposal by burning of wood treated with copper-chromium-arsenic wood preservatives (estimated to be 9 tonnes a year⁻¹ for all years back to 1970).
- 4) Estimates are not available for a few sources that may give rise to significant emissions of metals. These include accidental/malicious fires (including fires in dwellings, factories and other buildings, and vehicles), demolition, and erosion/corrosion of metal structures.

- 5) The inventory does not include any estimate for re-suspension of previously-deposited metal emissions, or for suspension of naturally occurring metals.

Section 2.1 has shown how the make-up of the inventories for the four metals differ, and so the factors listed above impact on these inventories to differing degrees. Significant revisions to the inventories between the 2002 and 2003 versions also change the relative importance of different factors.

The uncertainty analysis carried out on the NAEI each year includes a 'key source analysis', which is based on the approach recommended for greenhouse gas inventories by the Intergovernmental Panel on Climate Change (IPCC). Key sources are those that contribute most to the uncertainty in an inventory. They may be key sources because they dominate emissions, even if those emissions are relatively well characterised, or they may be key sources because emissions, while estimated to be small, are very poorly characterised.

The key source analyses carried out for the 2002 and 2003 versions of the NAEI gave notably different lists of key sources as shown in Tables 2.3 to 2.6. For example, domestic combustion of anthracite was a key source for all three pollutants according to the analysis on the 2002 NAEI but not a key source for any of the metals according to the analysis on the 2003 NAEI. This resulted from revision of the factors for this source making the source far less significant.

The NAEI metal inventories have been undergoing a process of gradual review over the past 3-4 years, beginning with a review of emission factors for large-scale processes such as steelworks and cement clinker production (Passant *et al*, 2002) and continuing with changes, for example, to the estimates for glass processes (Passant, 2003; 2004), and revisions to the methodology for mercury from crematoria. The latest stage of this process has been a review of fuel combustion emission factors for the 2003 version of the NAEI. This review led to significant changes in the emission estimates as shown by the key source analysis. Given the high level of uncertainty still remaining in the metal inventories, further significant changes are likely in the next few versions of the NAEI.

Table 2.3: Key sources for arsenic emissions in 2002 and 2003

Source	2002 NAEI	2003 NAEI
Domestic combustion of coke	✓	
Domestic combustion of anthracite	✓	
Domestic combustion of solid smokeless fuel	✓	
Industrial combustion of coal	✓	
Industrial combustion of coke	✓	
Industrial combustion of fuel oil		✓
Industrial combustion of waste lubricants	✓	✓
Refineries combustion of fuel oil		✓
Burning of CCA-treated wood	✓	✓
Blast furnaces	✓	✓
Foundries		✓

Table 2.4: Key sources for cadmium emissions in 2002 and 2003

Source	2002 NAEI	2003 NAEI
Domestic combustion of anthracite	✓	
Domestic combustion of wood	✓	
Industrial combustion of fuel oil		✓
Refineries combustion of fuel oil	✓	✓
Public sector combustion of fuel oil		✓
Refineries – catalyst regeneration		✓
Solid smokeless fuel manufacture		✓
Clinical waste incineration	✓	
Sinter plant	✓	✓
Basic oxygen furnaces	✓	✓
Primary aluminium production	✓	
Primary lead/zinc production	✓	
Copper alloy & semis manufacture	✓	
Foundries	✓	✓

Table 2.5: Key sources for nickel emissions in 2002 and 2003

Source	2002 NAEI	2003 NAEI
Domestic combustion of coal	✓	
Domestic combustion of coke	✓	
Domestic combustion of anthracite	✓	
Domestic combustion of solid smokeless fuel	✓	
Industrial combustion of coke	✓	
Industrial combustion of gas oil		✓
Industrial combustion of fuel oil	✓	✓
Refineries combustion of fuel oil	✓	✓
Public sector combustion of fuel oil	✓	✓
Commercial sector combustion of fuel oil	✓	
Refineries combustion of miscellaneous products	✓	
Refineries – catalyst regeneration	✓	
Blast furnaces	✓	✓
Primary aluminium production	✓	✓
Foundries	✓	

Table 2.6: Key sources for lead emissions in 2002 and 2003

Source	2002 NAEI	2003 NAEI
Domestic combustion of anthracite	✓	
Domestic combustion of coal	✓	
Industrial combustion of coal	✓	
Industrial combustion of coke	✓	
Industrial combustion of waste lubricants	✓	✓
Refineries' combustion of fuel oil		✓
Coke ovens		✓
Sinter plants	✓	✓
Electric arc furnaces	✓	✓
Primary lead/zinc production	✓	
Secondary lead production	✓	✓
Foundries	✓	✓
Cement clinker production	✓	✓
Manufacture of alkyl lead chemicals	✓	✓

2.4 EMISSIONS USED IN HEAVY METAL CONCENTRATION MODELLING

The NAEI assigns heavy metal emissions into area and point source types. The emissions in each source type are modelled differently with the area source emission modelled using a dispersion kernel approach and the point sources modelled using the dispersion model ADMS 3.2.

The area emissions were obtained from the NAEI as 1 km x 1 km grids. In general, emissions from point sources are better characterised than emissions from area sources where a range of disaggregation methods are used to distribute the emission throughout the country.

Table 2.7 shows that the arsenic emission inventory is dominated by area sources whereas cadmium and lead are dominated by point source emissions. Nickel emissions are estimated to come in equal measure from area and point sources.

Table 2.7: Breakdown of heavy metal emissions into area and point sources for 2002 (tonnes)

Heavy metal	NAEI 2002 Area grid emission	NAEI 2002 Point emission
Arsenic	20.2	3.9
Cadmium	1.2	3.2
Nickel	47.5	46.9
Lead	55.1	107.3

Due to the relatively sparse set of monitoring data in 2003 it was felt that a more comprehensive assessment would be obtained if emission from point sources were modelled using the maximum emission obtained from the year 1999 to 2003. In this way a modelled concentration could be derived which could be compared with a monitored concentration value.

3 Measurements

3.1 DESCRIPTION OF SAMPLING NETWORKS

Heavy metals have been measured as part of a various monitoring networks since the 1970's. Data from these networks are reviewed in order to put the modelling outputs into context and to assess whether trends in concentrations or emissions can be related or inferred.

Heavy metal concentrations have been measured since the 1970's, as part of the UK Multi-Element Survey (Loader, 1994). This survey started in 1976 with 20 monitoring stations in a number of urban locations throughout the United Kingdom. In 1978 the network was reduced to just five sites (Motherwell, Glasgow, Leeds, Brent and Central London) that had produced relatively high concentrations for one or more of the elements monitored. Samples were collected using the Warren Spring Laboratory designed M-Type sampler. This sampler collected total suspended particulate matter. Concentrations for the years 1999 to 2003 are presented in Tables 3.1 to 3.4 (sites are referred to as Urban Trace Metals). The long-term trends are compared against emissions in Section 3.2.3.

In the light of the then proposed EU limit values for arsenic, cadmium and nickel a comprehensive monitoring campaign was started in 1999 to ascertain the ambient levels of these pollutants close to industrial sources where there was a potential for the concentration to be high (Maggs *et al.*, 2001) Monitoring was conducted weekly at thirty sampling sites on behalf of Defra by Stanger Science and Environment. Samples were collected using the Partisol sampler. This sampler is designed to collect particulate matter within the PM₁₀ fraction. In addition to providing baseline information on the likelihood of complying with the EU limit, the network also provided information regarding AQS objective for lead.

The monitoring programme lasted twelve months- starting in December 1999 and finishing in November 2000. Sampling from a substantially reduced network resumed in the spring of 2002. A number of sites closed in August 2003 with only IMI refiners, INCO Swansea, BZL Hallen, Avesta Pollarit Rotherham, ICI Runcorn and Brookside Bilston Lane providing at least 75% data capture for 2003. Hence it should be borne in mind that the industrial sites have relatively poor annual data capture statistics in 2002 and 2003. The industrial network continued to be operated by Stanger Science and Environment until 2004 when NPL began to operate the network.

Sites not unduly influenced by local urbanisation and industrial activities are found in the North Sea and Rural Trace Element networks. The former network was established in 1986 at coastal locations on the eastern side of Britain and aimed to provide estimates of atmospheric inputs of these pollutants to the North Sea as part of a requirement of the Paris Commission's Comprehensive Atmospheric Monitoring Programme (CAMP). The three sites were at Banchory in Scotland, East Roston in Norfolk and High Muffles in North Yorkshire. Details of the network are provided in Playford and Baker (2000). They found that the measuring of trace metals in air is subject to uncertainty despite the care taken in preparing and handling the sample material. These sites were used in the EMEP modelling assessments.

The Rural Trace Element network has been in operation since 1972. The aim of the network was to assess the impact of control policies on air concentrations and depositions. The three sites were located at Chilton (Oxfordshire), Styrrup

(Nottinghamshire) and Wraymires (Cumbria). This network perhaps provides the longest running trends of heavy metal concentrations in the United Kingdom. Details of the network are provided in Conolly (2003). Samples for the North Sea and Rural Trace Element network were collected using the Harwell sampler. This sampler would have collected the total suspended particulate matter.

At the end of 2002 sampling at the Rural Trace Element and Urban Trace Element stopped and was replaced by a new rural network operated by the Centre for Ecology and Hydrology at Edinburgh. The concentrations presented were obtained from CEH (Alan McDonald, *Personal Communication, 2005*). Samples were collected using a Grasby Anderson sampler (Thermo ESM Andersen FH 95). This sampler is designed to collect particulate matter within the PM₁₀ fraction.

However sampling did not start until March 2003, hence, the data capture is less than 75%. Annual data capture greater than 75% was obtained for Monkswood, Yarner Wood, Auchencorth Moss, Cwmystwyth and Banchory. The data capture at Wytham Woods, Beacon Hill and Heigham Holmes was less than 30%.

In addition there are a number of additional sites, for example, Manchester, London Cromwell Road and Eskdalemuir formed part of Lead in Petrol sites or EC Directive sites that began monitoring multi-elements in the mid 1990's. London Marylebone is a super site monitoring a number of different pollutants.

Sampling has also taken place at Pontardawe close to the INCO nickel works in Swansea (NPTCBC, 2000). Monitoring has taken place here since 1972 when the site formed part of the Trace Element Network. Since 1989 it has been operated by the local authority. Nickel concentrations at this site are the highest measured in the United Kingdom.

3.2 CURRENT CONCENTRATIONS: 1999 TO 2003

Tables 3.1 to 3.4 present the heavy metal concentrations measured at each of the sampling networks.

Table 3.1: Arsenic concentrations measured at a number of locations throughout the United Kingdom (ng m⁻³). 4th Daughter Directive Target Concentration is 6 ng m⁻³

Site	Type	Industry/Network	1999	2000	2001	2002	2003
Castle Cement, Wrexham	Industrial	Cement Manufacture		1.03			
ICI Chemicals and Polymers Plc., Runcorn, Cheshire	Industrial	Chloroalkali		1			
White Rose Environmental, Knostrop, Leeds	Industrial	Clinical Waste Incinerator		3.31		1.65	1.65
Scottish Power - Longannet Power Station, Fife	Industrial	Coal-Fired Power Station (no FGD)		0.70			
NIGEN Ltd. - Kilroot Power Station, Carrickfergus, N.Ireland	Industrial	Coal-Fired Power Station (proposal to burn Orimulsion)		0.47			
National Power Plc. - Drax Power Station, Selby	Industrial	Coal-Fired Power Station (with FGD)		1.16			
A Cohen & Co Ltd., Greenwich, London	Industrial	Copper and Copper Alloy		1.59			
IMI Refiners Ltd., Walsall, W.Midlands	Industrial	Copper and Copper Alloy		8.36		1.92	3.16
Cerro Extruded Metals, West Bromwich	Industrial	Copper and Copper Alloy - Non Ferrous Part B		1.84		1.71	1.36
Sutton Coldfield Crematorium	Industrial	Crematoria		1.15			
Walkers Galvanizing, Walsall, W.Midlands	Industrial	Galvanising		4.22			1.78
Avesta Polarit, Rotherham	Industrial	Industrial metal				2.37	2.11
Brookside Bilston Lane	Industrial	Industrial metal				1.82	2.11
BZL Hallen	Industrial	Industrial metal				4.79	2.71
Corus Steel Rotherham	Industrial	Industrial metal				2.70	2.29
Elswick (6), Newcastle	Industrial	Industrial metal				1.74	1.37
British Steel, Llanwern	Industrial	Industrial metal		1.70			
Sidney Smith, Stourbridge, W.Midlands	Industrial	Integrated Steel		2.30		1.99	1.22
Bruhl UK Ltd., Tipton, W.Midlands	Industrial	Iron Foundry (Cold-Blast Cupola)		2.67		2.53	1.66
Paramount Batteries, Rotherham	Industrial	Iron Foundry (Hot-Blast Cupola)		2.91			
Tungsten Batteries Ltd., Market Harborough, Leicestershire	Industrial	Lead Acid Battery		1.08			
Associated Octel Company Ltd., Ellesmere Port, Wirral	Industrial	Lead Acid Battery		0.95			
Britannia Refined Metals, Gravesend, Kent	Industrial	Lead Anti-Knock Ingredients		1.31			
Britannia Zinc Ltd., Avonmouth, Bristol	Industrial	Lead Producer/Recycle		1.89			
Midland Lead Refiners, Swadlincote, Derbyshire	Industrial	Lead Producer/Recycle		1.78			
Belfast Harbour Estate - Mixed	Industrial	Lead Producer/Recycle		1.01			
Wolverhampton MWI	Industrial	Mixed		3.11			
INCO Europe, Swansea	Industrial	Municipal Waste Incinerator		1.18			
Glacier Vandervell Ltd., Kilmarnock, East Ayrshire	Industrial	Nickel Refinery		0.54			
FE Mottram Ltd., Congleton	Industrial	Non-Ferrous Alloy		1.19			
Esso Petroleum Company Ltd., Fawley, Hampshire	Industrial	Non-Ferrous Part B		0.90			
Coolkeeragh Power Station, Derry, N.Ireland	Industrial	Oil Refinery		0.72			
Cliffe Hill Quarry, Coalville, Leicestershire	Industrial	Oil-Fired Power Station		1.28			
British Steel Engineering, Rotherham	Industrial	Roadstone Coating		3.01			
British Steel Plc., Scunthorpe, Lincolnshire	Industrial	Steel Industry		1.70			
Banchory	Rural	North Sea	0.27	0.27	0.38	0.49	0.45
East Rushton	Rural	North Sea	1.27	0.88	0.64	1.60	
High Muffles	Rural	North Sea	0.62	0.50	0.35	0.67	
Auchencorth Moss	Rural	Rural					0.43
Beacon Hill	Rural	Rural					1.5
Cockley Beck	Rural	Rural					0.63
Cwmystwyth	Rural	Rural					0.38
Eskdalemuir	Rural	Rural					0.3
Heigham Holmes	Rural	Rural					1.3
Monkswood	Rural	Rural					0.93
Wytham Woods	Rural	Rural					0.92
Yarner Wood	Rural	Rural					0.71

Site	Type	Industry/Network	1999	2000	2001	2002	2003
Chilton	Rural	Rural Trace Metal	0.44	0.77	0.8	0.84	
Styrrup	Rural	Rural Trace Metal	2.40	1.30	0.99	0.85	
Wraymires	Rural	Rural Trace Metal	0.42	0.41	0.49	0.42	
Pontardawe	Industrial	Industrial metal	1.1	1			0.7
Manchester	Urban	Urban					1.5
Central London	Urban	Urban Trace Metal					1.5
Glasgow	Urban	Urban Trace Metal					1.2
Leeds	Urban	Urban Trace Metal					1.3
London Brent	Urban	Urban Trace Metal					1.8
London Cromwell Rd	Urban	Urban Trace Metal					1.5
London Marylebone	Urban	Urban Kerbside		1.36	1.68	1.51	1.73
Motherwell	Urban	Urban Trace Metal					0.8

The shaded squares indicated data capture was less than 75% for the year.

Table 3.2: Cadmium concentrations measured at a number of locations throughout the United Kingdom (ng m⁻³). 4th Daughter Directive Target Concentration is 5 ng m⁻³

Site	Type	Industry/Network	1999	2000	2001	2002	2003
Castle Cement, Wrexham	Industrial	Cement Manufacture		0.22			
ICI Chemicals and Polymers Plc., Runcorn, Cheshire	Industrial	Chloroalkali		0.23			
White Rose Environmental, Knostrop, Leeds	Industrial	Clinical Waste Incinerator		0.57			
Scottish Power - Longannet Power Station, Fife	Industrial	Coal-Fired Power Station (no FGD)		0.12			
NIGEN Ltd. - Kilroot Power Station, Carrickfergus, N.Ireland	Industrial	Coal-Fired Power Station (proposal to burn Orimulsion)		0.13			
National Power Plc. - Drax Power Station, Selby	Industrial	Coal-Fired Power Station (with FGD)		0.25			
A Cohen & Co Ltd., Greenwich, London	Industrial	Copper and Copper Alloy		0.55			
IMI Refiners Ltd., Walsall, W.Midlands	Industrial	Copper and Copper Alloy		7.37		2.16	1.40
Cerro Extruded Metals, West Bromwich	Industrial	Copper and Copper Alloy on		0.76		0.69	0.75
Sutton Coldfield Crematorium	Industrial	Crematoria		0.38			
Walkers Galvanizing, Walsall, W.Midlands	Industrial	Galvanising		1.94			
Avesta Polarit, Rotherham	Industrial	Industrial metal				0.94	0.94
Brittania Recycling, Wakefield	Industrial	Industrial metal				5.08	4.29
Brookside Bilston Lane	Industrial	Industrial metal				13.05	3.60
British Steel, Llanwern	Industrial	Industrial metal				3.70	0.19
Sidney Smith, Stourbridge, W.Midlands	Industrial	Integrated Steel		1.40			
Bruhl UK Ltd., Tipton, W.Midlands	Industrial	Iron Foundry		3.50		1.19	0.85
Paramount Batteries, Rotherham	Industrial	Iron Foundry		1.18			
Tungsten Batteries Ltd., Market Harborough, Leicestershire	Industrial	Lead Acid Battery		0.59			
Associated Ocel Company Ltd., Ellesmere Port, Wirral	Industrial	Lead Acid Battery		0.24			
Britannia Refined Metals, Gravesend, Kent	Industrial	Lead Anti-Knock Ingredients		0.17			
Britannia Zinc Ltd., Avonmouth, Bristol	Industrial	Lead Producer/Recycle		0.47			
Midland Lead Refiners, Swadlincote, Derbyshire	Industrial	Lead Producer/Recycle		7.73		8.26	1.84
Belfast Harbour Estate - Mixed	Industrial	Lead Producer/Recycle		0.52			
Wolverhampton MWI	Industrial	Mixed		0.14			
INCO Europe, Swansea	Industrial	Municipal Waste Incinerator		0.82			
Glacier Vandervell Ltd., Kilmarnock, East Ayrshire	Industrial	Nickel Refinery		0.27			
FE Mottram Ltd., Congleton	Industrial	Non-Ferrous Alloy		0.53			
Esso Petroleum Company Ltd., Fawley, Hampshire	Industrial	Non-Ferrous Part B		0.34			
Coolkeeragh Power Station, Derry, N.Ireland	Industrial	Oil Refinery		0.20			
Cliffe Hill Quarry, Coalville, Leicestershire	Industrial	Oil-Fired Power Station		0.13			
British Steel Engineering, Rotherham	Industrial	Roadstone Coating		0.26			
British Steel Plc., Scunthorpe, Lincolnshire	Industrial	Steel Industry		0.81			
British Steel, Llanwern	Industrial	Steel Industry		0.62			
Banchory	Rural	Rural	0.11	0.05	0.01	0.13	0.06
East Rushton	Rural	North Sea	0.29	0.22	0.22	0.45	
High Muffles	Rural	North Sea	0.16	0.22	0.22	0.27	
Auchencorth Moss	Rural	Rural					0.07
Beacon Hill	Rural	Rural					0.21
Cockley Beck	Rural	Rural					0.07
Cwmystwyth	Rural	Rural					0.09
Eskdalemuir	Rural	Rural		0.30	0.10	0.10	0.10
Heigham Holmes	Rural	Rural					0.18
Monkswood	Rural	Rural					0.18
Wytham Woods	Rural	Rural					0.15

Site	Type	Industry/Network	1999	2000	2001	2002	2003
Yarner Wood	Rural	Rural					0.12
Chilton	Rural	Rural Trace Metal	0.27	0.32	0.45	0.35	
Styrrup	Rural	Rural Trace Metal	0.28	0.29	0.34	0.67	
Wraymires	Rural	Rural Trace Metal	0.06	0.11	0.10	0.10	
Pontardawe	Industrial	Industrial metal	0.27	0.21			0.14
Manchester	Urban	Urban					0.30
Central London	Urban	Urban Trace Metal	0.9			0.40	0.40
Glasgow	Urban	Urban Trace Metal	0.5	0.40	0.40	0.20	0.30
Leeds	Urban	Urban Trace Metal	0.5	0.50	0.50	0.50	0.30
London Brent	Urban	Urban Trace Metal	1	0.30	0.50	0.90	0.40
London Cromwell Rd	Urban	Urban Trace Metal	0.9	0.5	0.6	0.3	0.4
London Marylebone	Urban	Urban Kerbside		0.39	0.57	0.41	0.47
Motherwell	Urban	Urban Trace Metal	1	0.3	0.5	0.4	0.2

The shaded squares indicated data capture was less than 75% for the year.

Table 3.3: Nickel concentrations measured at a number of locations throughout the United Kingdom (ng m⁻³). 4th Daughter Directive Target Concentration is 20 ng m⁻³

Site	Type	Industry/Network	1999	2000	2001	2002	2003
Castle Cement, Wrexham	Industrial	Cement Manufacture		0.71			
ICI Chemicals and Polymers Plc., Runcorn, Cheshire	Industrial	Chloroalkali		1.78			
White Rose Environmental, Knostrop, Leeds	Industrial	Clinical Waste Incinerator		2.48			
Scottish Power - Longannet Power Station, Fife	Industrial	Coal-Fired Power Station		1.21			
NIGEN Ltd. - Kilroot Power Station, Carrickfergus, N.Ireland	Industrial	Coal-Fired Power Station		1.25			
National Power Plc. - Drax Power Station, Derby	Industrial	Coal-Fired Power Station		1.88			
A Cohen & Co Ltd., Greenwich, London	Industrial	Copper and Copper Alloy		2.61			
IMI Refiners Ltd., Walsall, W.Midlands	Industrial	Copper and Copper Alloy		7.44		2.13	3.57
Cerro Extruded Metals, West Bromwich	Industrial	Copper and Copper Alloy		1.93			
Sutton Coldfield Crematorium	Industrial	Crematoria		1.15			
Walkers Galvanizing, Walsall, W.Midlands	Industrial	Galvanising		2.61			
Avesta Polarit, Rotherham	Industrial	Industrial metal				16.20	19.37
Brookside Bilston Lane	Industrial	Industrial metal				2.03	2.81
BZL Hallen	Industrial	Industrial metal				1.96	2.48
Elswick (6), Newcastle	Industrial	Industrial metal				1.91	0.96
British Steel, Llanwern	Industrial	Integrated Steel		3.43			
Sidney Smith, Stourbridge, W.Midlands	Industrial	Iron Foundry		1.71			
Bruhl UK Ltd., Tipton, W.Midlands	Industrial	Iron Foundry		13.39		3.05	4.54
Paramount Batteries, Rotherham	Industrial	Lead Acid Battery		3.69			
Tungsten Batteries Ltd., Market Harborough, Leicestershire	Industrial	Lead Acid Battery		1.03			
Associated Octel Company Ltd., Ellesmere Port, Wirral	Industrial	Lead Anti-Knock Ingredients		1.41			
Britannia Refined Metals, Gravesend, Kent	Industrial	Lead Producer/Recycle		2.92			
Britannia Zinc Ltd., Avonmouth, Bristol	Industrial	Lead Producer/Recycle		2.67			
Midland Lead Refiners, Swadincote, Derbyshire	Industrial	Lead Producer/Recycle		1.72			
Belfast Harbour Estate - Mixed	Industrial	Mixed		3.59			
Wolverhampton MWI	Industrial	Municipal Waste Incinerator		1.78			
INCO Europe, Swansea	Industrial	Nickel Refinery		20.64		28.91	18.14
Glacier Vandervell Ltd., Kilmarnock, East Ayrshire	Industrial	Non-Ferrous Alloy		0.85			
FE Mottram Ltd., Congleton	Industrial	Non-Ferrous Part B		1.34			
Esso Petroleum Company Ltd., Fawley, Hampshire	Industrial	Oil Refinery		2.40			
Coolkeeragh Power Station, Derry, N.Ireland	Industrial	Oil-Fired Power Station		2.05			
Cliffe Hill Quarry, Coalville, Leicestershire	Industrial	Roadstone Coating		1.33			
British Steel Engineering, Rotherham	Industrial	Steel Industry		8.25			
British Steel Plc., Scunthorpe, Lincolnshire	Industrial	Steel Industry		2.28			
Banchory	Rural	Rural	0.16	1.08	0.52	0.16	1
East Rushton	Rural	North Sea	0.70	2.60	2.30	1.90	
High Muffles	Rural	North Sea	0.70	2.47	1.20	1.20	
Auchencorth Moss	Rural	Rural					1.8
Beacon Hill	Rural	Rural					1.5
Cockley Beck	Rural	Rural					0.95
Cwmystwyth	Rural	Rural					1.2
Eskdalemuir	Rural	Rural		2.60	0.90	0.60	2.6
Heigham Holmes	Rural	Rural					1.9
Monkswood	Rural	Rural					1.9
Wytham Woods	Rural	Rural					1.4
Yarner Wood	Rural	Rural					2.1

Site	Type	Industry/Network	1999	2000	2001	2002	2003
Cilton	Rural	Rural Trace Metal	1.6	1.1	1.6	1.4	
Styrrup	Rural	Rural Trace Metal	2.2	2.8	3.2	4.7	
Wraymires	Rural	Rural Trace Metal	0.67	0.51	0.86	0.86	
Pontardawe	Industrial	Industrial metal	71.2	44.2	41.4	92.2	42.7
Manchester	Urban	Urban					1.7
Central London	Urban	Urban Trace Metal	4.7			2.2	2.9
Glasgow	Urban	Urban Trace Metal	4.7	4.8	2.3	1.6	1.5
Leeds	Urban	Urban Trace Metal	4.6	4.7	2.9	2.9	1.7
London Brent	Urban	Urban Trace Metal	4.6	5.1	3.4	2.9	2.6
London Cromwell Rd	Urban	Urban Trace Metal	4.7	3.4	3.3	4.4	3.1
London Marylebone	Urban	Urban Kerbside		3.8	3.96	3.4	4.26
Motherwell	Urban	Urban Trace Metal	4.2	3	2.6	1.3	0.9

The shaded squares indicated data capture was less than 75% for the year.

Table 3.4: Lead concentrations measured at a number of locations throughout the United Kingdom (ng m⁻³). 1st Daughter Directive Limit Value is 500 ng m⁻³

Site	Type	Industry/Network	1999	2000	2001	2002	2003
Castle Cement, Wrexham	Industrial	Cement Manufacture		18.08			
ICI Chemicals and Polymers Plc., Runcorn, Cheshire	Industrial	Chloroalkali		16.56			
White Rose Environmental, Knostrop, Leeds	Industrial	Clinical Waste Incinerator		30.63			
Scottish Power - Longannet Power Station, Fife	Industrial	Coal-Fired Power Station		7.55			
NIGEN Ltd. - Kilroot Power Station, Carrickfergus, N.Ireland	Industrial	Coal-Fired Power Station		3.87			
National Power Plc. - Drax Power Station, Derby	Industrial	Coal-Fired Power Station		14.00			
A Cohen & Co Ltd., Greenwich, London	Industrial	Copper and Copper Alloy		55.51			
IMI Refiners Ltd., Walsall, W.Midlands	Industrial	Copper and Copper Alloy		237.18		43.49	46.69
Cerro Extruded Metals, West Bromwich	Industrial	Copper and Copper Alloy		87.30			
Sutton Coldfield Crematorium	Industrial	Crematoria		17.06			
Walkers Galvanizing, Walsall, W.Midlands	Industrial	Galvanising		90.77			
Avesta Polarit, Rotherham	Industrial	Industrial metal				50.74	46.14
Brittania Recycling, Wakefield	Industrial	Industrial metal				151.20	27.15
Brookside Bilston Lane	Industrial	Industrial metal				188.29	102.88
BZL Hallen	Industrial	Industrial metal				245.47	70.97
Elswick (6), Newcastle	Industrial	Industrial metal				162.75	32.91
British Steel, Llanwern	Industrial	Integrated Steel		40.32			
Sidney Smith, Stourbridge, W.Midlands	Industrial	Iron Foundry		36.98			
Bruhl UK Ltd., Tipton, W.Midlands	Industrial	Iron Foundry		62.84			
Paramount Batteries, Rotherham	Industrial	Lead Acid Battery		49.50			
Tungsten Batteries Ltd., Market Harborough, Leicestershire	Industrial	Lead Acid Battery		30.70			
Associated Octel Company Ltd., Ellesmere Port, Wirral	Industrial	Lead Anti-Knock Ingredients		12.76			
Britannia Refined Metals, Gravesend, Kent	Industrial	Lead Producer/Recycle		34.98			
Britannia Zinc Ltd., Avonmouth, Bristol	Industrial	Lead Producer/Recycle		104.29			
Midland Lead Refiners, Swadlincote, Derbyshire	Industrial	Lead Producer/Recycle		72.35			
Belfast Harbour Estate - Mixed	Industrial	Mixed		11.89			
Wolverhampton MWI	Industrial	Municipal Waste Incinerator		54.69			
INCO Europe, Swansea	Industrial	Nickel Refinery		18.04			
Glacier Vandervell Ltd., Kilmarnock, East Ayrshire	Industrial	Non-Ferrous Alloy		29.99			
FE Mottram Ltd., Congleton	Industrial	Non-Ferrous Part B		14.10			
Esso Petroleum Company Ltd., Fawley, Hampshire	Industrial	Oil Refinery		11.58			
Coolkeeragh Power Station, Derry, N.Ireland	Industrial	Oil-Fired Power Station		2.93			
Cliffe Hill Quarry, Coalville, Leicestershire	Industrial	Roadstone Coating		13.41			
British Steel Engineering, Rotherham	Industrial	Steel Industry		146.09			
British Steel Plc., Scunthorpe, Lincolnshire	Industrial	Steel Industry		115.28			
Banchory	Rural	North Sea	2.20	2.10	0.25	0.84	
East Rushton	Rural	North Sea	17.5	10.2	8.1	8	
High Muffles	Rural	North Sea	9.1	7.7	5.7	5.3	
Auchencorth Moss	Rural	Rural					4.1
Beacon Hill	Rural	Rural					15.6
Cockley Beck	Rural	Rural					5.3
Cwmystwyth	Rural	Rural					4.3
Eskdalemuir	Rural	Rural		3	2	3	3
Heigham Holmes	Rural	Rural					10.1
Monkswood	Rural	Rural					10.9
Wytham Woods	Rural	Rural					10.6
Yarner Wood	Rural	Rural					6.6

Site	Type	Industry/Network	1999	2000	2001	2002	2003
Chilton	Rural	Rural Trace Metal	9.8	10.6	7.9	9.7	
Styrrup	Rural	Rural Trace Metal	25.8	23	21	16	
Wraymires	Rural	Rural Trace Metal	3.70	4.50	4.90	4.90	
Pontardawe	Industrial	Industrial metal	14.70	12.10			9.9
Manchester	Urban	Urban	51.00	22.00	23.00	20.00	20
Central London	Urban	Urban Trace Metal	36.00			22.00	21
Glasgow	Urban	Urban Trace Metal	20.00	17.00	25.00	15.00	15
Leeds	Urban	Urban Trace Metal	39	27	31	43	21
London Brent	Urban	Urban Trace Metal	49	24	30	22	25
London Cromwell Rd	Urban	Urban Trace Metal	68	32	31	27	22
London Marylebone	Urban	Urban Kerbside	33	38	36	28	28
Motherwell	Urban	Urban Trace Metal	16	9	16	12	10

The shaded squares indicated data capture was less than 75% for the year.

3.3 A COMPARISON OF LONG TERM TRENDS IN CONCENTRATIONS AND EMISSIONS

3.3.1 Trends in the rural trace element network

Conolly (2003) presented an analysis showing how concentrations have decreased since 1972. The cadmium and lead concentration plots were characterised by large peaks and troughs for years before the 1990's – particularly at Chilton and Styrrup. This may suggest that the annual mean concentration was influenced by large particulate matter contaminating the collected samples (or local sources). The arsenic concentration series at these three sites is probably the longest in the UK. The arsenic concentration trend at Chilton and Styrrup follows the arsenic emission reduction- whereas there is a lot of scatter in the Wraymires arsenic data. At all three sites the nickel concentrations agree well with the emission reductions.

Conolly (2003) summarised the changes in concentrations at the start (average of years 1972 to 1979) and end of the sampling period (average 2000 to 2001). The largest reductions in concentration occurred for lead at all sites (all greater than 90%) and for arsenic and nickel at Wraymires (greater than 80%). The cadmium concentration decreased by more than 80 % at Styrrup.

3.3.2 Trends at North Sea sites

Playford and Baker (2000) calculated four-year averages for a period at the start of the North Sea network and for the four-year period 1996 to 1999. As for the Rural Trace Metal network aggregating the data in multi year chunks removed inter year variability. The reduction in cadmium concentration at High Muffles is largest of any metal – reasons why such reductions in concentration occurred at this site are unclear.

Similar reduction in concentrations occurred at East Ruston and High Muffles, the similarity with the reduction in national nickel emissions may suggest that the nickel emission inventory is reasonably well estimated. The smallest concentrations for each metal are measured at Banchory that also shows the least reduction in concentration - reflecting the distance of this site from the main emission sources.

3.3.3 Trends in the urban network

Loader (1994) summarised the multi element data for the pollution years 1976/77 to 1992/1993. An updated analysis summarising the data in calendar years is presented in this section. The weekly and monthly data were extracted from Netcen's Air Pollution database for years up until 1995. Data after 1995 were obtained from a spreadsheet on the Defra's Air Quality Archive, see (http://www.airquality.co.uk/archive/data/metals/metals_data.xls).

The location where the sampling sites are located are described in Table 3.5.

Table 3.5: Description of the urban trace metal sampling sites

Site Name	Location description
Motherwell	Town centre site. Ravenscraig steel works were 0.5 - 2km to the north east. These closed in 1992
Brent	Close by North Circular Road. Surrounded by light industry/residential area and a park.
Leeds	Commercial district of city centre
Glasgow	1.2km SE of city centre
Central London	Close by Victoria Station. Moved from Vauxhall Bridge Rd in 1990

For the pre 1996 data annual means were calculated for years when the number of valid measurement days exceeded 270 days. Figure 3.1 plots the annual means and a major source sector as presented in Section 2. For cadmium the annual mean concentrations are compared with the change in emissions from coal and derived fuels. There is a considerable year-to-year variability at each sampling site particularly before 1990. After then the inter year variability at decreases and the concentrations at each site vary in a similar way.

For nickel the annual mean concentrations are compared to the reduction in emissions from oil based fuels. The annual mean concentrations at Glasgow and London Vauxhall Bridge Road seem to follow the emission reduction closely. The greatest inter year variability is seen at Motherwell – this may reflect the proximity of the sampling site to the Ravenscraig steel plant.

For lead annual mean concentrations are compared to lead in petrol source sector The annual mean concentrations measured at London Brent follow the emission reduction particularly well – particularly following the large decrease in emission from 1985 to 1986. It is curious why there is so much inter-year variability in the concentration before 1985. Reasons for this may include variations in localised sources that disappeared after 1985, improvements in sampling handling or variations in the amount of lead associated with large particles.

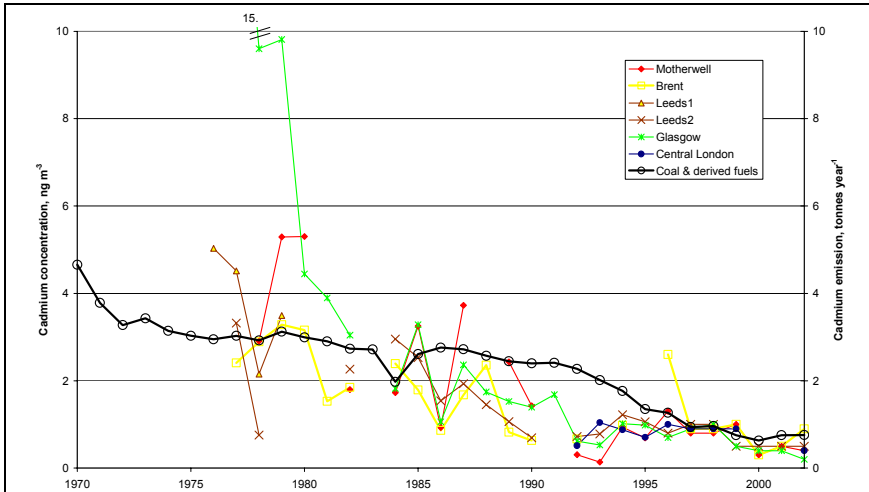


Figure 3.1a: Trends in cadmium concentration at the urban trace metal sites

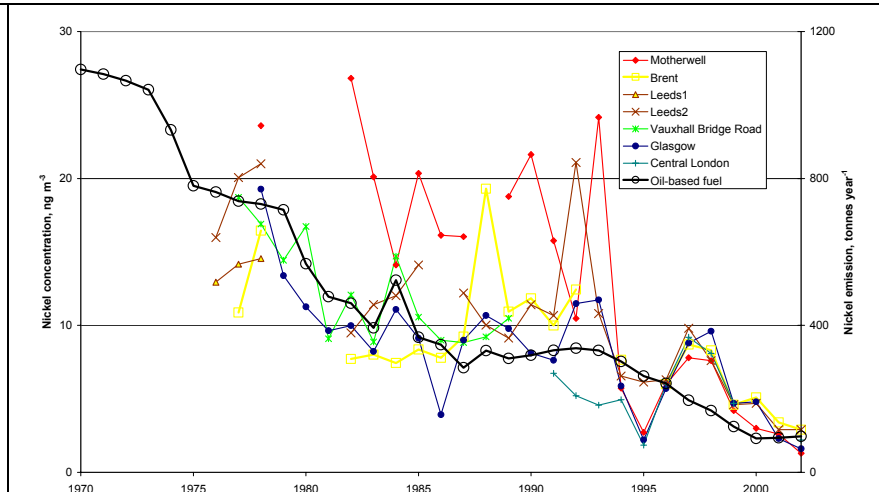


Figure 3.1b: Trends in nickel concentration at the urban trace metal sites

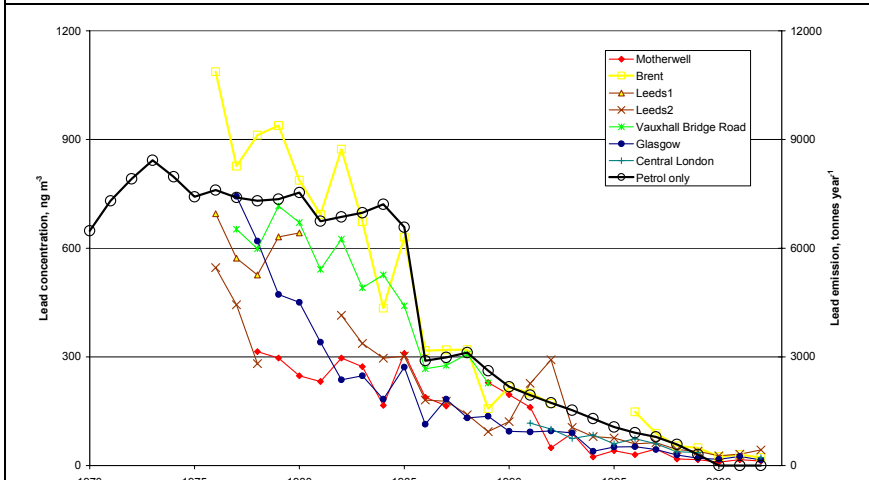


Figure 3.1c: Trends in lead concentration at the urban trace metal sites

Figure 3.1 Trends in heavy metal concentrations at the urban trace metal sampling sites

4 Concentration modelling

4.1 AREA SOURCE MODELLING

The Netcen area source model has been used previously to predict annual sulphur dioxide and BaP concentrations (Abbott and Vincent, 1999 and Coleman *et al.*, 2001). The Netcen area source model incorporates results from the dispersion model, ADMS-3 and calculates the annual average contribution from area sources on a 1 km receptor grid covering the country. Wet and dry deposition for the area source model was ignored on the basis of that they were shown to be insignificant in sensitivity studies (Coleman *et al.*, 2001). The emissions from each square was assumed to be uniformly distributed throughout the square at an initial height of 10 m: i.e., each 1 km square was represented by an emitting volume 1 km × 1 km × 10 m high. The estimate of 10 m is based on the height of a typical house and assumes that emissions will be entrained in the building wake.

4.2 POINT SOURCE MODELLING

Emissions from point sources are modelled using the emissions provided by the Pollution Inventory. Emission data are available for 1999 to 2003. As discussed above there was relatively little monitoring data with the required data capture in 2003. The emissions are modelled using stack release characteristics obtained from the Netcen point source database.

Characterising the amount of heavy metal from industrial plant is notoriously difficult. According to Passant (*personal communication 2005*) approximately three times the reported emission from metal processing industries may be released as a fugitive emission. Preliminary modelling showed a substantial under estimate in concentration around the metal processing sources. To assess the likelihood of fugitive emissions contributing to the observed concentration a sensitivity study was conducted in which three times the reported emission from the point source was modelled as a fugitive emission. The emission release parameters are provided in Table 4.1. Emissions were assumed to be non buoyant.

Table 4.1: Stack release parameters used to characterise fugitive emission release

Parameter	Value
Release height	10 m
Diameter	1 m
Temperature	15 °C

4.3 METEOROLOGICAL DATA

For this current assessment concentrations are predicted using just one meteorological data set. This is because the largest uncertainty in the modelling process is associated with characterising the emission term and a more sophisticated treatment of the meteorological input are unlikely to improve significantly the model prediction. The data set used was the 2002 meteorological dataset for Waddington.

4.4 MODEL VALIDATION

The concentrations of heavy metals are affected both by emissions from local sources and by larger sources some distance away. Furthermore, the top down methods used by the NAEI to disaggregate the emissions from domestic and small industrial sources are inaccurate at the local scale. It is therefore difficult to calibrate the area source model using heavy metal monitoring data. However, NAEI emissions estimates for oxides of nitrogen, mainly from road transport sources, are considered much more reliable and allow calibration of the area source model. Previous work by Abbott and Vincent (1999) concluded that the area source model provides a reasonable estimate of the contribution to annual average concentrations from area sources. Figure 4.1 shows that the modelled NO_x concentration is a reasonable estimate of the measured concentrations in 2002.

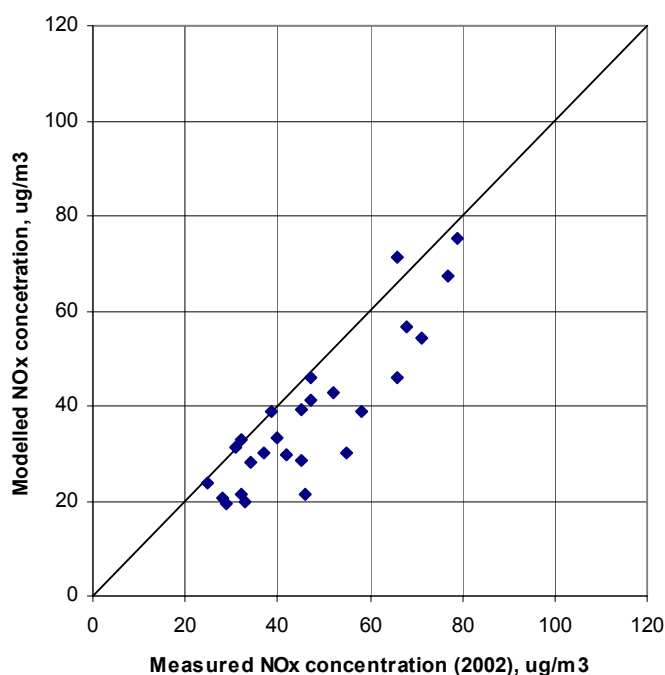


Figure 4.1: A comparison of modelled NO_x emissions (2002 emissions) and 2002 measurement data

Figures 4.2a-d and 4.3a-d compare the measured concentration with the modelled concentration values. The measured concentrations were presented previously in Tables 3.1 to 3.4 and are plotted so that lowest and highest concentration and the average value are shown. The concentrations are used without any regard to the data capture criteria (see shaded areas within Tables 3.1 to 3.4). Data from Figures 4.2 and 4.3 are tabulated in Table 4.2.

The modelled concentrations in Figure 4.2 include the fugitive emission sources for the metal industry plant, the point sources, the area sources and the natural component derived using the soil content presented in Table 1.1. For arsenic, cadmium and nickel a constant soil value (based on the central value) was used, whereas for lead, the soil in lead values characteristic of industrial, rural and urban values were used. Figure 4.3 presents the same data but excludes the fugitive emission. By comparing both sets of figures it can be seen that the additional consideration of the fugitive source does go some way to explaining the high heavy metal concentrations measured at some industrial plants.

For arsenic, the concentrations predicted at BZL Hallen, Associated Octal and Britannia Zinc Limited appear to be significantly over estimated whereas at IMI Refineries and British Steel Engineering the additional fugitive source seems to approach the measured concentration.

For cadmium, there is significant over prediction at BZL, British Steel Engineering and British Steel plc sampling sites. The concentration at IMI Refinery and Britannia Zinc Limited is predicted well.

For nickel, all concentrations are significantly over predicted. For lead, the fugitive source significantly over predicts at Avesta Polarit Rotherham, British Steel Llanwern, Associated Octal Company and British Steel Engineering. Reasonable prediction occurs at IMI Refineries Limited, BZL Hallen, Britannia Zinc Limited and British Steel.

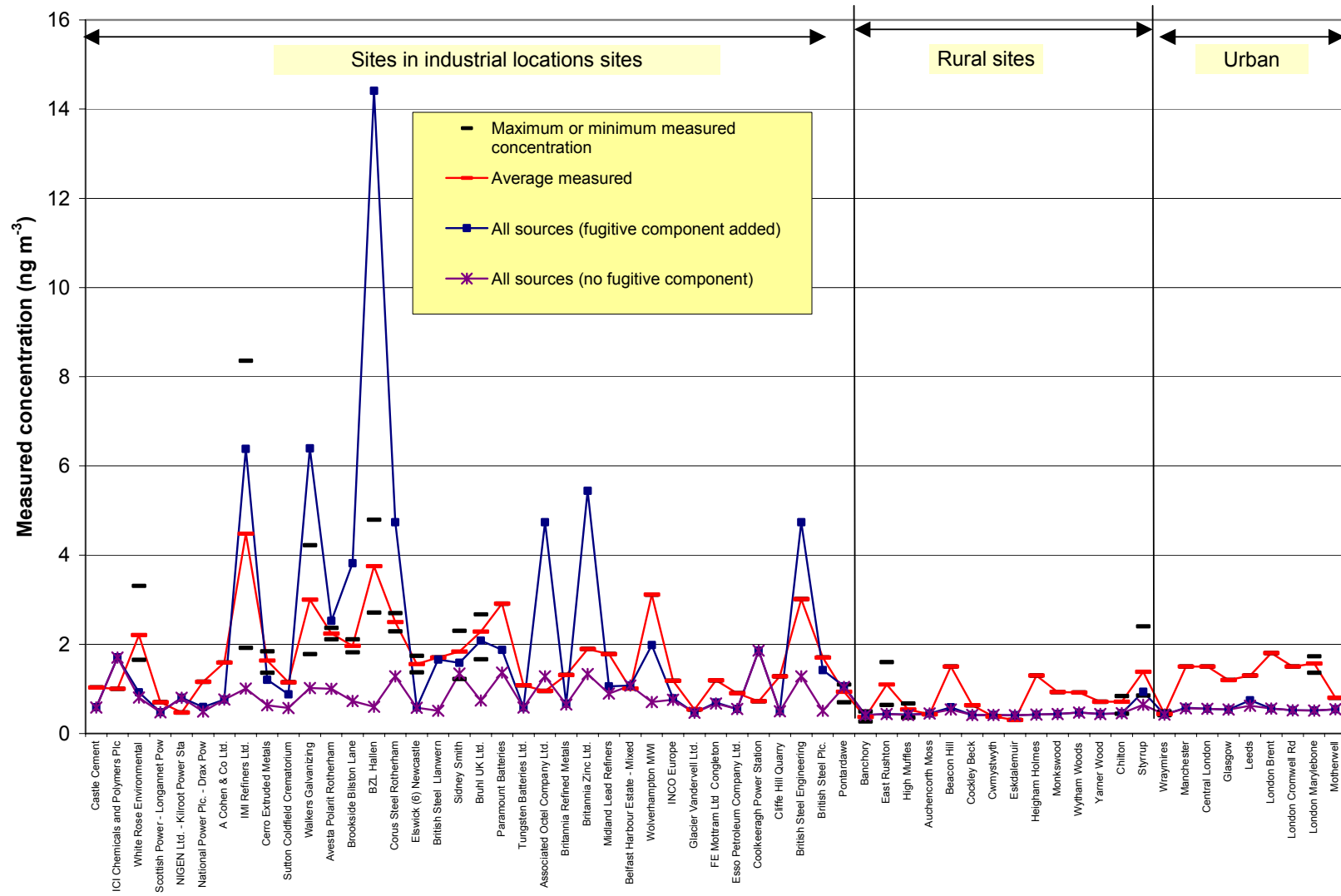


Figure 4.2a: A comparison of modelled and measured Arsenic concentrations (including fugitive emissions)

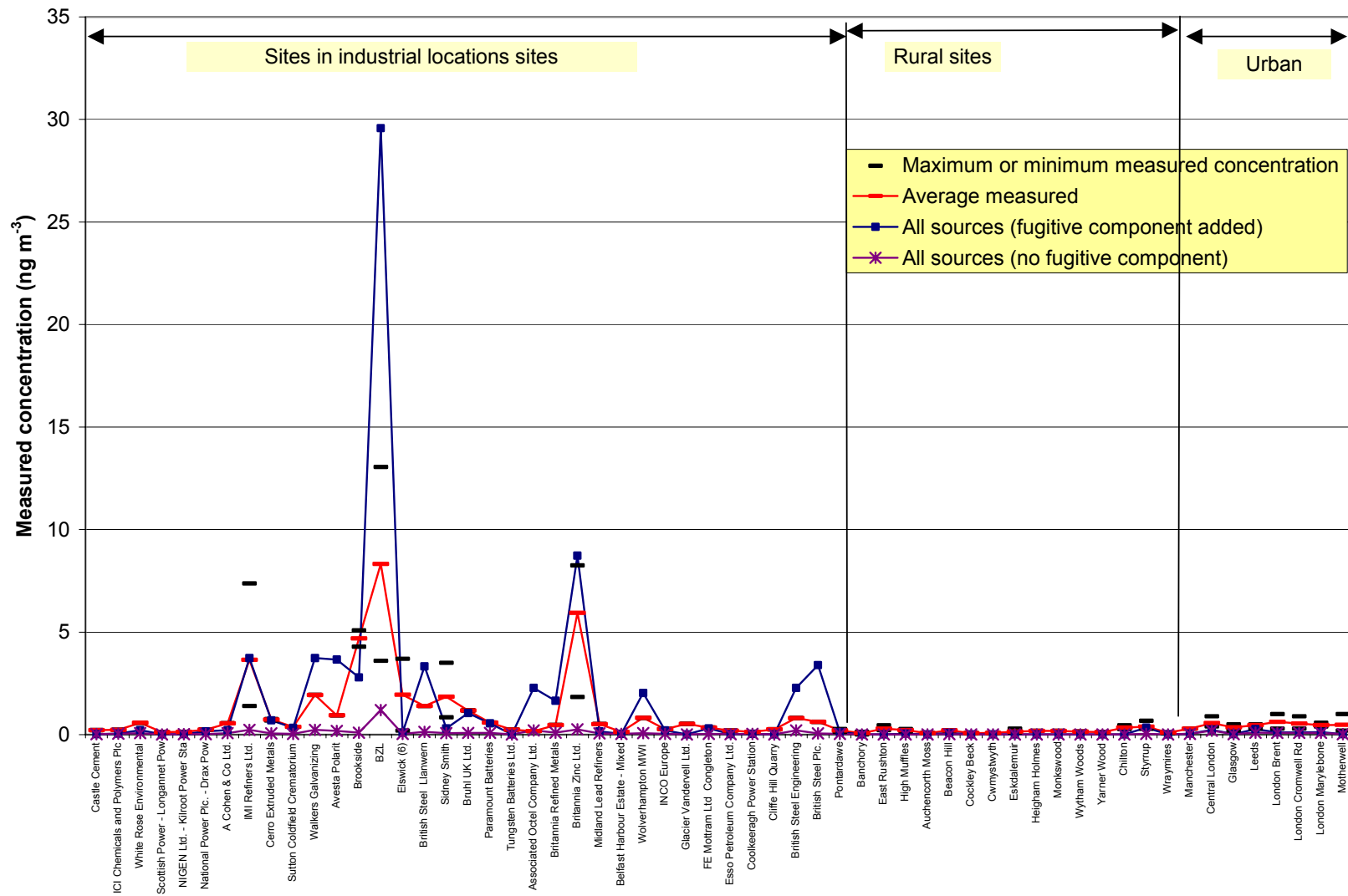


Figure 4.2b: A comparison of modelled and measured Cadmium concentrations (including fugitive emissions)

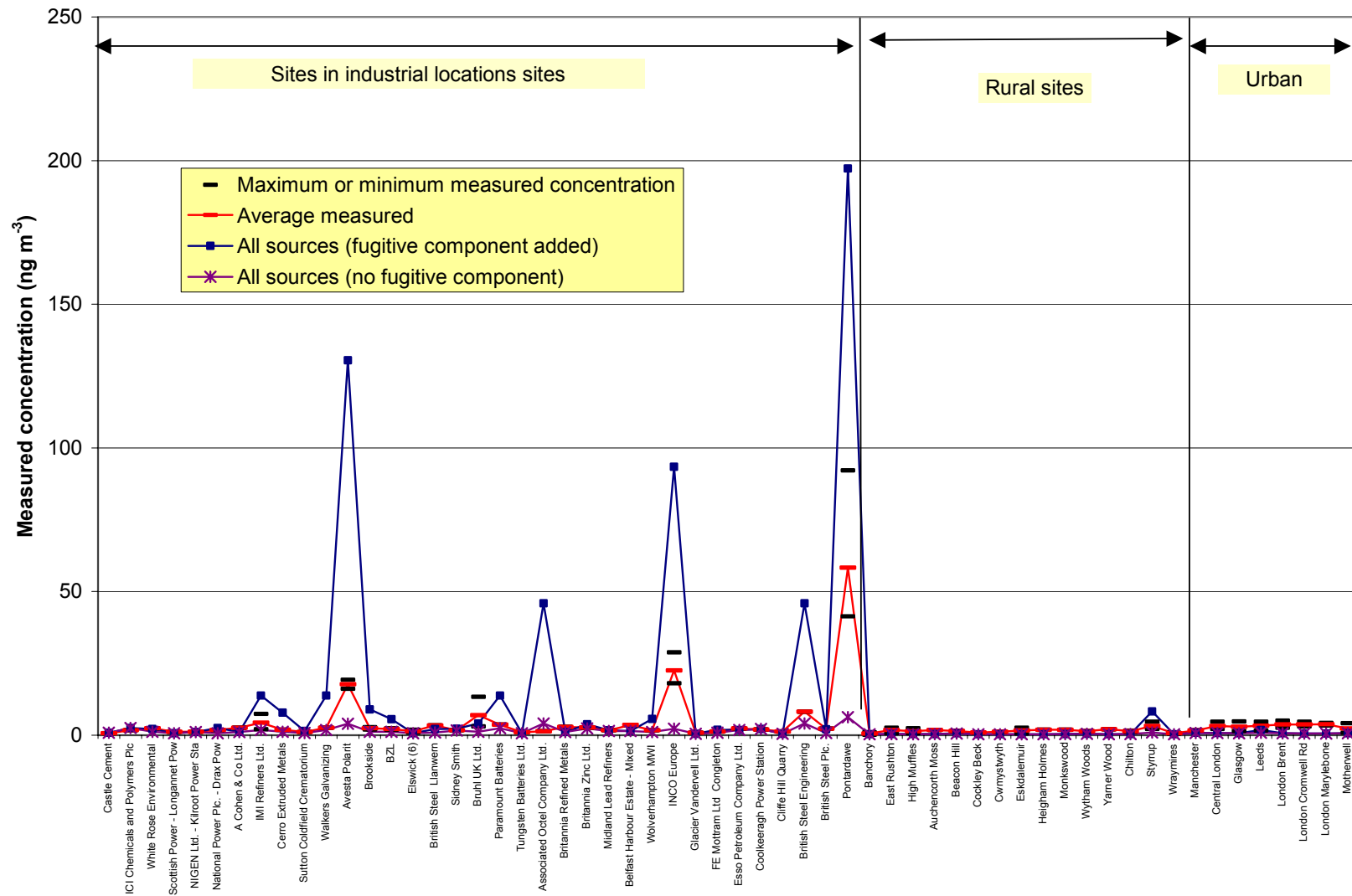


Figure 4.2c: A comparison of modelled and measured Nickel concentrations (including fugitive emissions)

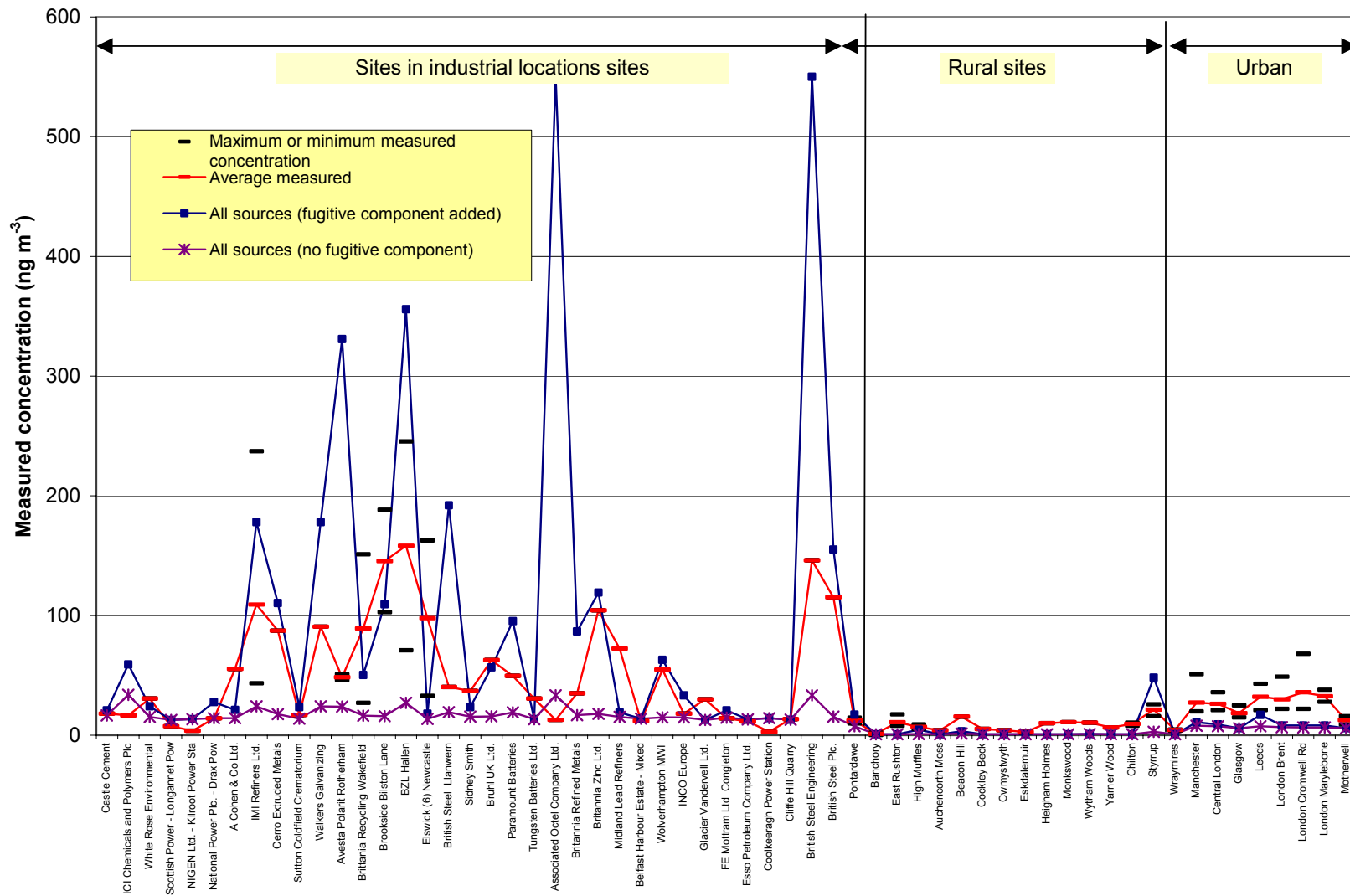


Figure 4.2d: A comparison of modelled and measured Lead concentrations (including fugitive emissions)

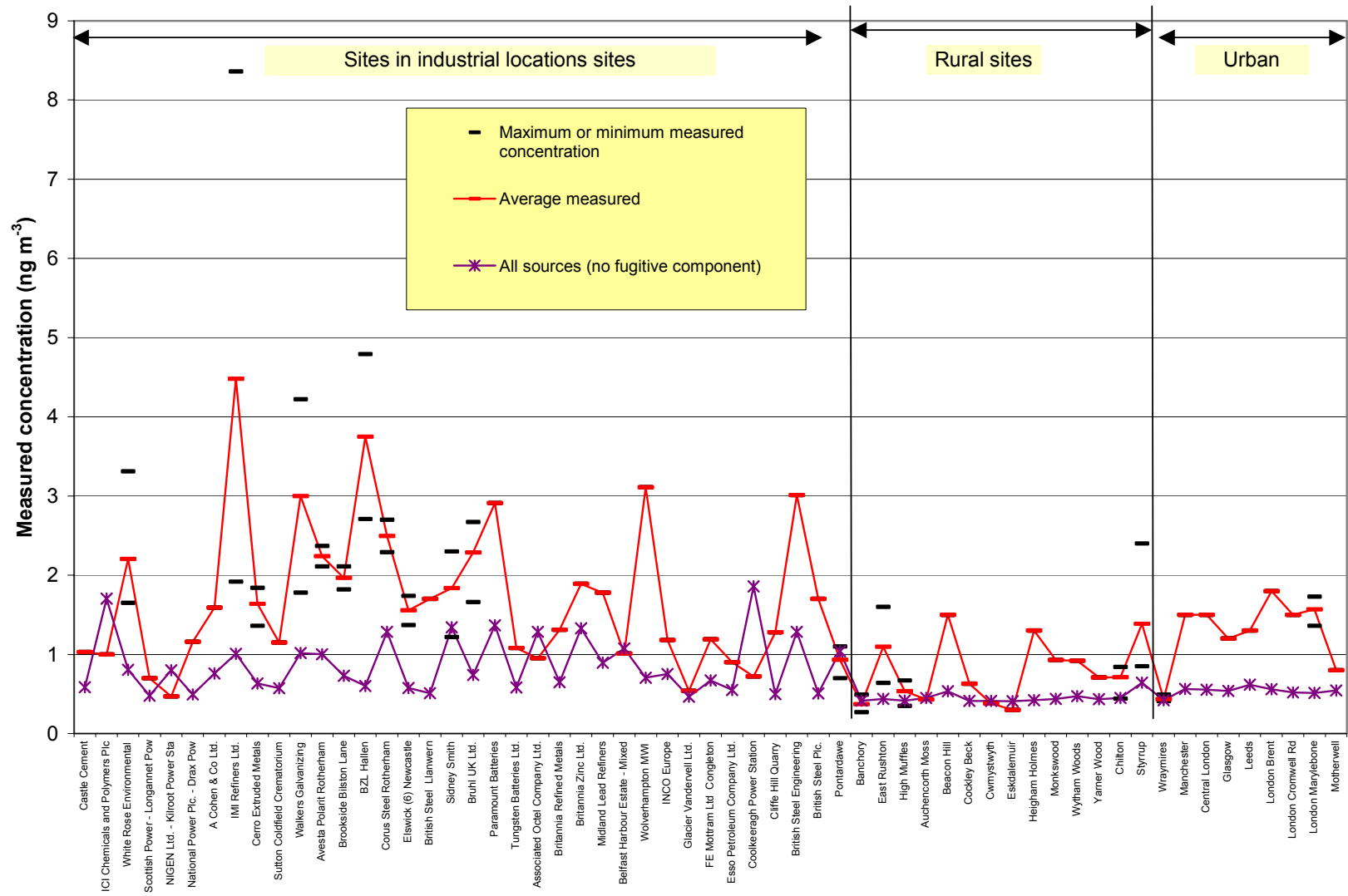


Figure 4.3a: A comparison of modelled and measured Arsenic concentrations (excluding fugitive emissions)

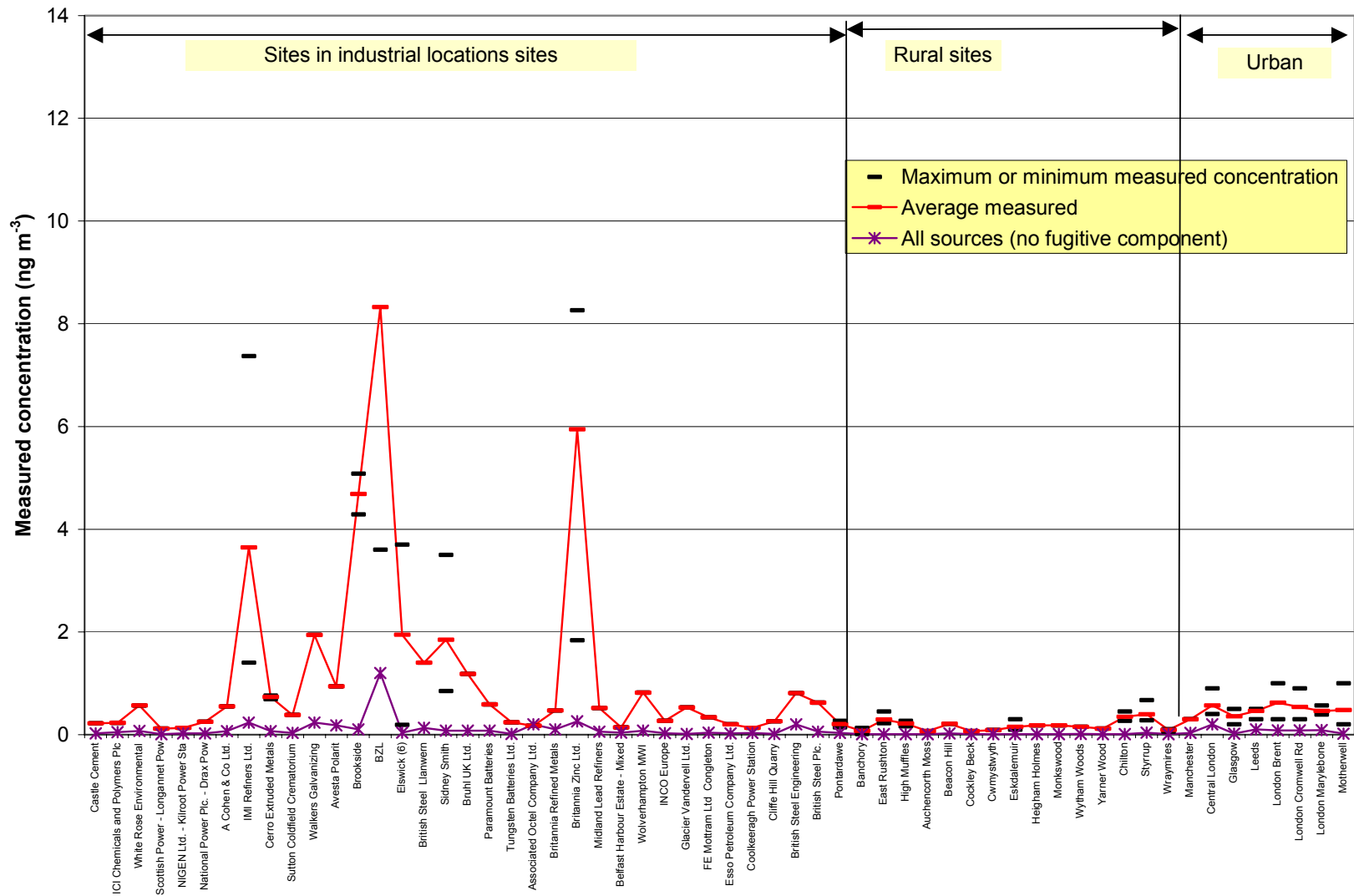


Figure 4.3b: A comparison of modelled and measured Cadmium concentrations (excluding fugitive emissions)

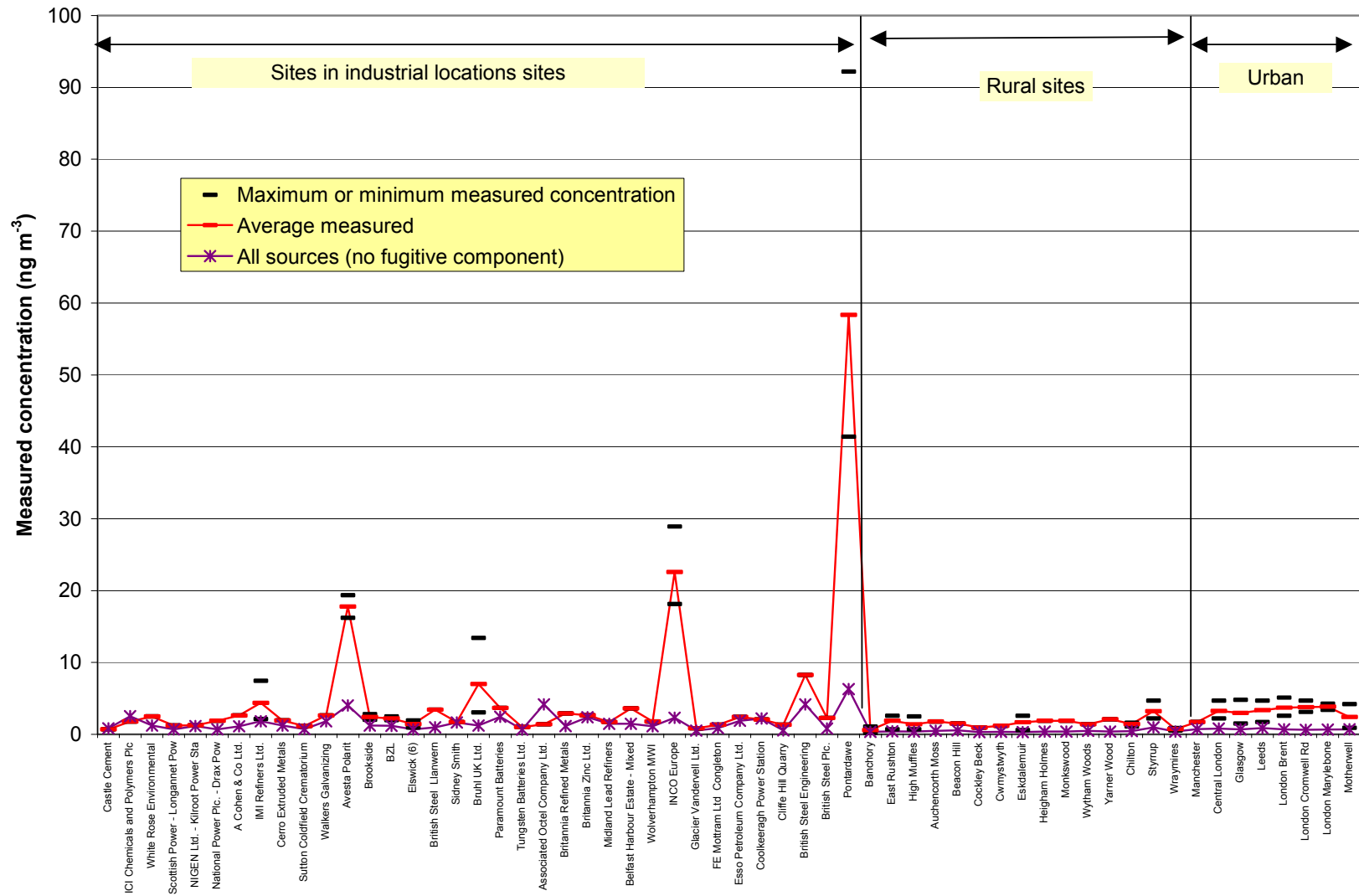


Figure 4.3c: A comparison of modelled and measured Nickel concentrations (excluding fugitive emissions)

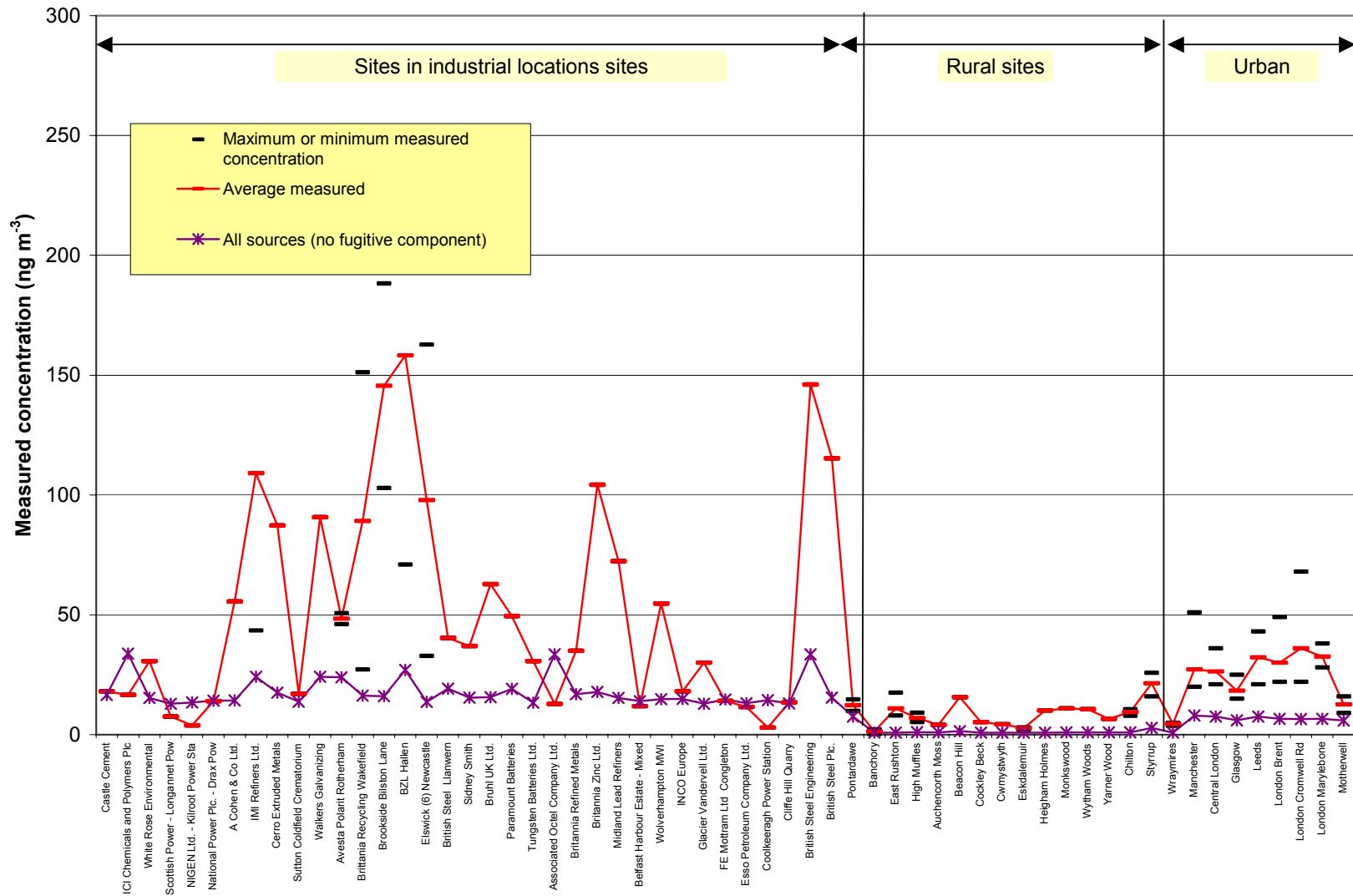


Figure 4.3d: A comparison of modelled and measured Lead concentrations (excluding fugitive emissions)

Table 4.2: A comparison of modelled and measured heavy metal concentrations (including and excluding fugitive emissions)(ng m⁻³)

Site	Arsenic			Cadmium			Nickel			Lead		
	Average measured	All sources (fugitive component added)	All sources (no fugitive component)	Average measured	All sources (fugitive component added)	All sources (no fugitive component)	Average measured	All sources (fugitive component added)	All sources (no fugitive component)	Average measured	All sources (fugitive component added)	All sources (no fugitive component)
Castle Cement, Wrexham	1.03	0.59	0.59	0.22	0.02	0.02	0.71	0.85	0.84	18.08	20.79	16.59
ICI Chemicals and Polymers Plc., Runcorn, Cheshire	1.00	1.71	1.70	0.23	0.05	0.05	1.78	2.56	2.52	16.56	59.24	33.83
White Rose Environmental, Knostrop, Leeds	2.20	0.93	0.81	0.57	0.23	0.07	2.48	2.20	1.21	30.63	24.14	15.35
Scottish Power - Longannet Power Station, Fife	0.70	0.48	0.48	0.12	0.01	0.01	1.21	0.69	0.69	7.55	12.90	12.90
NIGEN Ltd.- Kilroot Power Station, Carrickfergus, N.Ireland	0.47	0.80	0.80	0.13	0.03	0.03	1.25	1.14	1.14	3.87	13.46	13.46
National Power Plc. - Drax Power Station, Selby	1.16	0.59	0.50	0.25	0.16	0.03	1.88	2.56	0.69	14.00	27.80	14.20
A Cohen & Co Ltd., Greenwich, London	1.59	0.76	0.76	0.55	0.22	0.07	2.61	1.13	1.13	55.51	21.16	14.28
IMI Refiners Ltd., Walsall, W.Midlands	4.48	6.38	1.01	3.64	3.73	0.24	4.38	13.85	1.81	109.12	177.99	24.16
Cerro Extruded Metals, West Bromwich	1.64	1.20	0.63	0.73	0.70	0.07	1.93	7.90	1.22	87.30	110.52	17.54
Sutton Coldfield Crematorium	1.15	0.88	0.57	0.38	0.33	0.04	1.15	1.52	0.75	17.06	23.52	13.80
Walkers Galvanizing, Walsall, W.Midlands	3.00	6.39	1.02	1.94	3.73	0.23	2.61	13.85	1.81	90.77	178.04	24.20
Avesta Polarit, Rotherham	2.24	2.53	1.00	0.94	3.66	0.18	17.79	130.50	4.02	48.44	330.91	23.99
Brittania Recycling Wakefield										89.18	50.33	16.30
Brookside Bilston Lane	1.97	3.82	0.73	4.69	2.79	0.10	2.42	9.04	1.24	145.59	109.45	16.06
BZL Hallen	3.75	14.41	0.60	8.33	29.58	1.20	2.22	5.58	1.20	158.22	355.88	27.02
Corus Steel Rotherham	2.50	4.74	1.28									
Elswick (6), Newcastle	1.56	0.59	0.58	1.95	0.10	0.04	1.44	0.72	0.71	97.83	18.06	13.68
British Steel, Llanwern	1.70	1.66	0.51	1.40	3.33	0.13	3.43	2.20	0.99	40.32	192.00	19.24
Sidney Smith, Stourbridge, W.Midlands	1.84	1.58	1.34	1.85	0.31	0.08	1.71	2.28	1.65	36.98	23.59	15.45
Bruhl UK Ltd., Tipton, W.Midlands	2.29	2.09	0.74	1.18	1.05	0.08	6.99	4.12	1.24	62.84	56.58	15.68
Paramount Batteries, Rotherham	2.91	1.88	1.37	0.59	0.55	0.08	3.69	13.79	2.45	49.50	95.21	19.08
Tungsten Batteries Ltd., Market Harborough, Leicestershire	1.08	0.58	0.58	0.24	0.02	0.02	1.03	0.66	0.66	30.70	13.34	13.33
Associated Octel Company Ltd., Ellesmere Port, Wirral	0.95	4.74	1.28	0.17	2.27	0.20	1.41	45.95	4.15	12.76	550.00	33.46
Britannia Refined Metals, Gravesend, Kent	1.31	0.67	0.65	0.47	1.65	0.10	2.92	1.15	1.15	34.98	86.65	16.87
Britannia Zinc Ltd., Avonmouth, Bristol	1.89	5.44	1.33	5.94	8.73	0.26	2.67	3.81	2.38	104.29	119.22	17.86
Midland Lead Refiners, Swadlincote, Derbyshire	1.78	1.06	0.89	0.52	0.16	0.06	1.72	1.78	1.48	72.35	19.05	15.31
Belfast Harbour Estate - Mixed	1.01	1.07	1.07	0.14	0.04	0.04	3.59	1.49	1.49	11.89	13.95	13.95
Wolverhampton MWI	3.11	1.98	0.71	0.82	2.03	0.08	1.78	5.70	1.11	54.69	63.06	14.81
INCO Europe, Swansea	1.18	0.79	0.75	0.27	0.20	0.03	22.56	93.42	2.29	18.04	33.44	14.95
Glacier Vandervell Ltd., Kilmarnock, East Ayrshire	0.54	0.47	0.47	0.53	0.01	0.01	0.85	0.52	0.52	29.99	12.90	12.90
FE Mottram Ltd., Congleton	1.19	0.70	0.67	0.34	0.31	0.04	1.34	1.92	0.88	14.10	20.86	14.74
Esso Petroleum Company Ltd., Fawley, Hampshire	0.90	0.55	0.55	0.20	0.02	0.02	2.40	1.88	1.88	11.58	13.16	13.16
Coolkeeragh Power Station, Derry, N.Ireland	0.72	1.86	1.86	0.13	0.03	0.03	2.05	2.19	2.19	2.93	14.37	14.37
Cliffe Hill Quarry, Coalville, Leicestershire	1.28	0.50	0.50	0.26	0.01	0.01	1.33	0.55	0.55	13.41	12.99	12.99
British Steel Engineering, Rotherham	3.01	4.74	1.28	0.81	2.27	0.20	8.25	45.95	4.15	146.09	550.00	33.46
British Steel Plc., Scunthorpe, Lincolnshire	1.70	1.42	0.51	0.62	3.40	0.06	2.28	2.13	0.81	115.28	155.17	15.47
Banchory	0.37	0.42	0.42	0.07	0.01	0.01	0.58	0.35	0.35	1.35	0.82	0.82
East Rushton	1.10	0.44	0.44	0.30	0.01	0.01	1.88	0.41	0.41	10.95	0.88	0.88
High Muffles	0.54	0.43	0.42	0.22	0.05	0.01	1.39	0.39	0.38	6.95	4.69	1.09
Auchencorth Moss	0.43	0.45	0.45	0.07	0.01	0.01	1.80	0.47	0.47	4.10	0.92	0.92
Beacon Hill	1.50	0.59	0.54	0.21	0.08	0.02	1.50	0.73	0.58	15.60	3.26	1.47

Site	Arsenic			Cadmium			Nickel			Lead		
	Average measured	All sources (fugitive component added)	All sources (no fugitive component)	Average measured	All sources (fugitive component added)	All sources (no fugitive component)	Average measured	All sources (fugitive component added)	All sources (no fugitive component)	Average measured	All sources (fugitive component added)	All sources (no fugitive component)
Cockley Beck	0.63	0.41	0.41	0.07	0.01	0.01	0.95	0.33	0.33	5.30	0.81	0.81
Cwmystwyth	0.38	0.41	0.41	0.09	0.01	0.01	1.20	0.33	0.33	4.30	0.81	0.81
Eskdalemuir	0.30	0.41	0.41	0.15	0.01	0.01	1.68	0.32	0.32	2.75	0.80	0.80
Heigham Holmes	1.30	0.42	0.42	0.18	0.01	0.01	1.90	0.38	0.38	10.10	0.84	0.84
Monkswood	0.93	0.44	0.44	0.18	0.01	0.01	1.90	0.40	0.40	10.90	0.90	0.90
Wytham Woods	0.92	0.47	0.47	0.15	0.01	0.01	1.40	0.48	0.48	10.60	0.99	0.99
Yarner Wood	0.71	0.44	0.44	0.12	0.01	0.01	2.10	0.39	0.39	6.60	0.92	0.92
Chilton	0.71	0.45	0.45	0.35	0.01	0.01	1.43	0.47	0.47	9.50	0.92	0.92
Styrrup	1.39	0.94	0.64	0.40	0.34	0.04	3.23	8.32	0.97	21.45	48.17	2.88
Wraymires	0.44	0.42	0.42	0.09	0.01	0.01	0.73	0.39	0.39	4.50	0.84	0.84
Pontardawe	0.93	1.06	1.04	0.21	0.13	0.04	58.34	197.26	6.28	12.23	17.25	7.60
Manchester	1.50	0.58	0.56	0.30	0.05	0.04	1.70	0.85	0.75	27.20	11.00	8.02
Central London	1.50	0.55	0.55	0.57	0.23	0.20	3.27	0.79	0.79	26.33	8.94	7.55
Glasgow	1.20	0.54	0.54	0.36	0.02	0.02	2.98	0.69	0.69	18.40	5.94	5.94
Leeds	1.30	0.75	0.62	0.46	0.27	0.10	3.36	1.84	0.87	32.20	17.02	7.54
London Brent	1.80	0.56	0.56	0.62	0.11	0.08	3.72	0.70	0.70	30.00	8.29	6.62
London Cromwell Rd	1.50	0.52	0.52	0.54	0.12	0.08	3.78	0.63	0.63	36.00	8.19	6.54
London Marylebone	1.57	0.51	0.51	0.46	0.12	0.09	3.86	0.65	0.65	32.60	8.10	6.58
Motherwell	0.80	0.55	0.55	0.48	0.02	0.02	2.40	0.69	0.69	12.60	5.93	5.93

When the measured arsenic concentrations are compared to the modelled concentrations (Figure 4.3) without the fugitive component most of the industrial metal processing sites are significantly under predicted. The model concentrations at the urban sites are only marginally higher than the concentrations modelled at the rural sites. For cadmium and nickel, the modelled concentration is significantly lower than all measured concentrations suggesting that the emission inventory is underestimated. For lead, the high lead in soil concentrations assigned to the sampling sites in the industrial areas approaches the lower concentrations measured at these sites. At the urban sites, the model significantly under predicts the observed concentration.

4.5 COMPARISON WITH EMEP MODELLING WORK

The European Communities (2001) presented the results of model study in which the cadmium concentrations were presented against the measured concentrations at a number of locations throughout the EMEP modelling domain. The model shows a reasonable prediction of the observed concentration. However the emission inventory used was that of Pacyna (1999) and not National Emission data provided to EMEP. The Pacyna (1999) inventory estimated the cadmium emission in 1996 for the United Kingdom to be 50 ktonnes year⁻¹ whereas the NAEI reported 11 tonnes year⁻¹ in 1996.

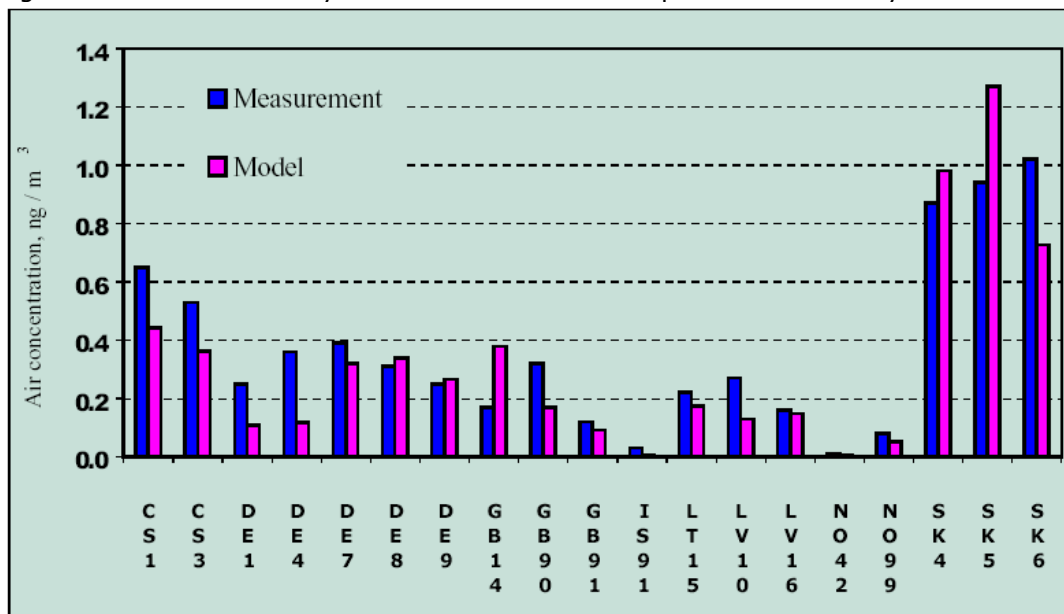


Figure 4.2 A comparison of modelled and measured concentration (ng m⁻³) in 1996 at a number of sites within the EMEP sampling work. The sites labelled GB14, GB90 GB91 are High Muffles, East Ruston and Banchory. Other country codes include CS Czech Republic, DE Germany, IS Iceland, LT Lithuania, LV Latvia, NO Norway and SK Slovakia.

By the time of the 2004 assessment, the MSC-E was using nationally reported data for the modelling work (MSC-E, 2004b). Figure 4.3 shows that the modelled concentration was about half of the measured concentrations. In addition, the EMEP is expected to produce higher concentrations than the dispersion modelling described above because boundary concentrations, equivalent to regional background concentration values, are set. A technical report released in June 2005 presented the boundary concentrations used in the modelling (MSC-E 2005). Figure 4.4 shows the magnitude of the boundary concentrations for lead and cadmium.

The boundary cadmium concentrations are of a similar order to the concentrations measured at Wraymires and Banchory (see Table 3.2 and suggest that most of the cadmium at these sites may be attributed to regional background pollution. A similar conclusion could be made for lead concentrations (see Table 3.4) measured at Eskdalemuir.

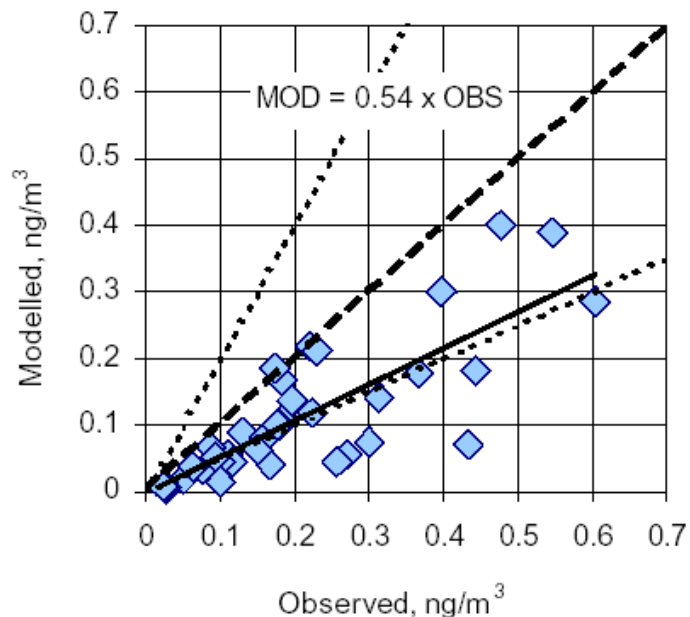


Figure 4.3: A comparison of EMEP modelled and measured cadmium concentration for 2002

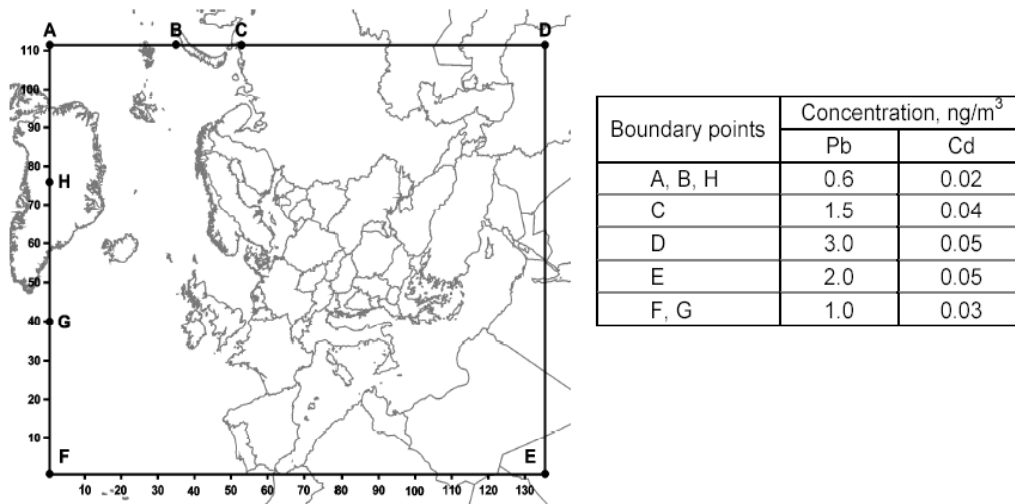


Figure 4.4: Locations of boundary points and concentration values assigned at these points

5 Conclusions and Recommendations

A review of the available monitoring data has shown that only one sampling site in 2003 exceeded the target value for 2012. This occurred for nickel at Pontardawe. Exceedence of the target values for arsenic and cadmium did occur before 2003 at a small number of industrial sites but it is expected that the concentrations will continue to decrease as emission abatement technologies are applied.

Ambient concentrations of heavy metals have decreased dramatically since monitoring began, reflecting the reductions in emissions. A review of the historic data collected in the urban trace element network shows that the annual mean concentrations were erratic for each metal until the mid 1990's. Nevertheless this network showed that cadmium concentrations have been lower than the target levels since the early 1980's. Nickel concentrations at some urban sites exceeded target levels well into the 1990's.

A standard dispersion modelling approach was used to predict the measured concentrations of arsenic, cadmium, nickel and lead at sampling sites located throughout the United Kingdom. The results showed that the modelled concentrations were significantly below the measured concentrations. This modelling and that carried out by EMEP suggests that there is a significant underestimation in the emissions. However, there is still considerable uncertainty in understanding the origin of the metals in the ambient aerosol, for example, EMEP have recently revised significantly upwards the contribution from natural sources and resuspension of previously released material. A similar exercise should be conducted based on UK specific data. A simple modelling approach showed that a significant fraction of measured arsenic and lead could come from the metal contained in soil. A more thorough review using the national soil inventory, if this were available, may improve the predictions.

The work presented here has reinforced the view that the National Atmospheric Emission Inventory for heavy metals is particularly uncertain. Further emission monitoring of a number of key sources should improve the prediction of heavy metal concentrations.

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