

NPL REPORT AS 23

**UK Non-Automatic Hydrocarbon
Network:**

Annual Report for 2007

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Kevin Whiteside and
Paul Quincey**

NOT RESTRICTED

April 2008

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Approved on behalf of Managing Director, NPL
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Executive Summary

This report summarises operational matters and the data obtained by the Non-Automatic Hydrocarbon Network in the year 2007.

The background, methods used and site locations are given in Sections 1 and 2. Restructuring of the Network in 2007 has led to several site changes, and the discontinuation of the 1,3-butadiene measurements within the Network during the year.

Annual average data for benzene and 1,3-butadiene, and data capture, are given in Section 3. No sites exceeded the European Union Limit Value for benzene or the UK Air Quality Objectives for benzene and 1,3-butadiene.

No notable anomalous measurements were observed during the year.

Section 4 examines long term trends for benzene and 1,3-butadiene and compares them with the trends expected from the UK National Atmospheric Emissions Inventory. Trends in concentration over the period 1994 to 2002 are significantly downward and agree well between the two data sets. Trends in benzene since 2002 are generally downward, especially at sites measuring higher concentrations.

Comparability with data from the Automatic Hydrocarbon Network and other sources are discussed.

Section 5 compares recent Network benzene data with modelled data, supplied by AEA Technology. Agreement is generally good, with a tendency for the model to underestimate benzene concentration, and substantial disagreements only at traffic- or industrially-affected sites.

UK Non-Automatic Hydrocarbon Network

Annual Report for 2007

1. Introduction

1.1 General Background, History and Methods

The Hydrocarbon Networks exist within the framework of Defra's Air Quality Science Programme, the aims of which are to determine the magnitude of sources, exposure and effects of air pollutants on human health and the natural environment, to develop a better understanding of underlying processes, and to underpin the development and implementation of national and international strategies in order to reduce the impacts of air pollution. The Programme includes a combination of monitoring Networks, emission inventories, atmospheric modelling, strategic evaluation, scientific research and dissemination to assist in these aims.

The Automatic and Non-Automatic Hydrocarbon Networks were established in 2002, following on from the previous Hydrocarbon Network, which measured 25 species of hydrocarbon on an hourly basis at 13 sites. As more benzene monitoring sites were needed to comply with regulations, the Non-Automatic Network was set up using a less expensive method to produce benzene measurements as fortnightly averages at 35 sites. Some of the sites are at the same location as the previous Hydrocarbon Network sites, so that long term trends can be evaluated.

The benzene monitoring method involves pumping ambient air at a rate of about 10 ml/min through duplicate tubes containing the sorbent Carbopack X, with subsequent laboratory analysis of the benzene content of the tubes. This method was validated over a year-long pilot study, whose results are available through the Defra website:

http://www.airquality.co.uk/archive/reports/cat05/0407061411_btex_npl_pilot_final.pdf

The method is described in the paper:

Studies using the sorbent Carbopack X for measuring environmental benzene with Perkin-Elmer-type pumped and diffusive samplers, Nicholas A Martin, David J Marlow, Malcolm H Henderson, Brian A Goody and Paul G Quincey: Atmospheric Environment 37 (2003) 871-879.

In addition to the benzene measurements, 1,3-butadiene is measured at 10 sites using a diffusive technique, also using Carbopack X as the sorbent. The method is described in the paper:

Studies using the sorbent Carbopack X for measuring environmental 1,3-butadiene with pumped and diffusive samplers, Nicholas A Martin, Philippa Duckworth, Malcolm H Henderson, Nigel R W Swann, Simon T Granshaw, Robert P Lipscombe, Brian A Goody: Atmospheric Environment 39 (2005) 1069-1077.

1.2 Regulatory Background

The current ambient benzene legislation is set out in The Air Quality Strategy for England, Scotland, Wales and Northern Ireland, Cm 7169 (July 2007). The requirements are based on those of the EU Directive 2000/69/EC, in which the relevant information for benzene is given in Table 1 below:

Benzene

	<i>Averaging period</i>	<i>Limit value</i>	<i>Margin of tolerance</i>	<i>Date by which limit value is to be met</i>
Limit value for the protection of human health	Calendar year	5 $\mu\text{g}/\text{m}^3$	5 $\mu\text{g}/\text{m}^3$ reducing on 1st January 2006 and every 12 months thereafter by 1 $\mu\text{g}/\text{m}^3$ to reach 0 $\mu\text{g}/\text{m}^3$ by 1st January 2010	1st January 2010

Table 1: benzene limit value and associated information

The concentration 5 $\mu\text{g}/\text{m}^3$ is to be expressed at 293 K and 101.3 kPa, and is equivalent to 1.54 ppb.

The Margin of Tolerance means that Member States can exceed the Limit Value for a limited period if necessary. EU Directive 2000/69/EC is soon to be replaced by the Ambient Air Quality and Cleaner Air for Europe Directive, but the requirements for benzene will remain the same.

As part of the National Air Quality Strategy there are also Air Quality Objectives, which can be stricter than the Limit Value, and which also include 1,3-butadiene.

The benzene Objective for England and Wales is the same as that given above.

The benzene Objective for Scotland and Northern Ireland is an annual average of 3.25 $\mu\text{g}/\text{m}^3$ (1 ppb), by 1/1/2010.

1,3-Butadiene does not feature in EU legislation except as an ozone precursor in the Ozone Directive 2002/3/EC. The annual average 1,3-butadiene Objective in the National Air Quality Strategy is 2.25 $\mu\text{g}/\text{m}^3$ (1 ppb).

Standard methods for measuring benzene concentration, which include the method used in the Network, have been published by CEN as EN 14662 Parts 1 to 5.

1.3 Units of Measurement

Regulations in the United Kingdom have in the past expressed concentrations of gases in units of molar parts per billion (1,000,000,000) - ppb. This is the number of benzene molecules, for example, within a billion molecules in the volume of air of interest. These units have the advantage that if the temperature or pressure of the air changes, the value remains the same.

Current UK and European legislation sets limit value concentrations as micrograms of pollutant per cubic metre of air ($\mu\text{g.m}^{-3}$). When these units are used without correcting to a standard temperature and pressure, the same “packet” of air will have a different concentration as these properties of the air change. The legislation specifies that the air volume must be corrected to be at a standard temperature of 293 K (about 20°C), and a pressure of 101.3 kPa (about average atmospheric pressure at sea level).

Both sets of units are used in this report.

The relationships between the two sets of units are:

for benzene	$1 \text{ ppb} = 3.25 \mu\text{g.m}^{-3}$
for 1,3-butadiene	$1 \text{ ppb} = 2.25 \mu\text{g.m}^{-3}$.

2. Network sites during 2007

2.1 *Start of the year*

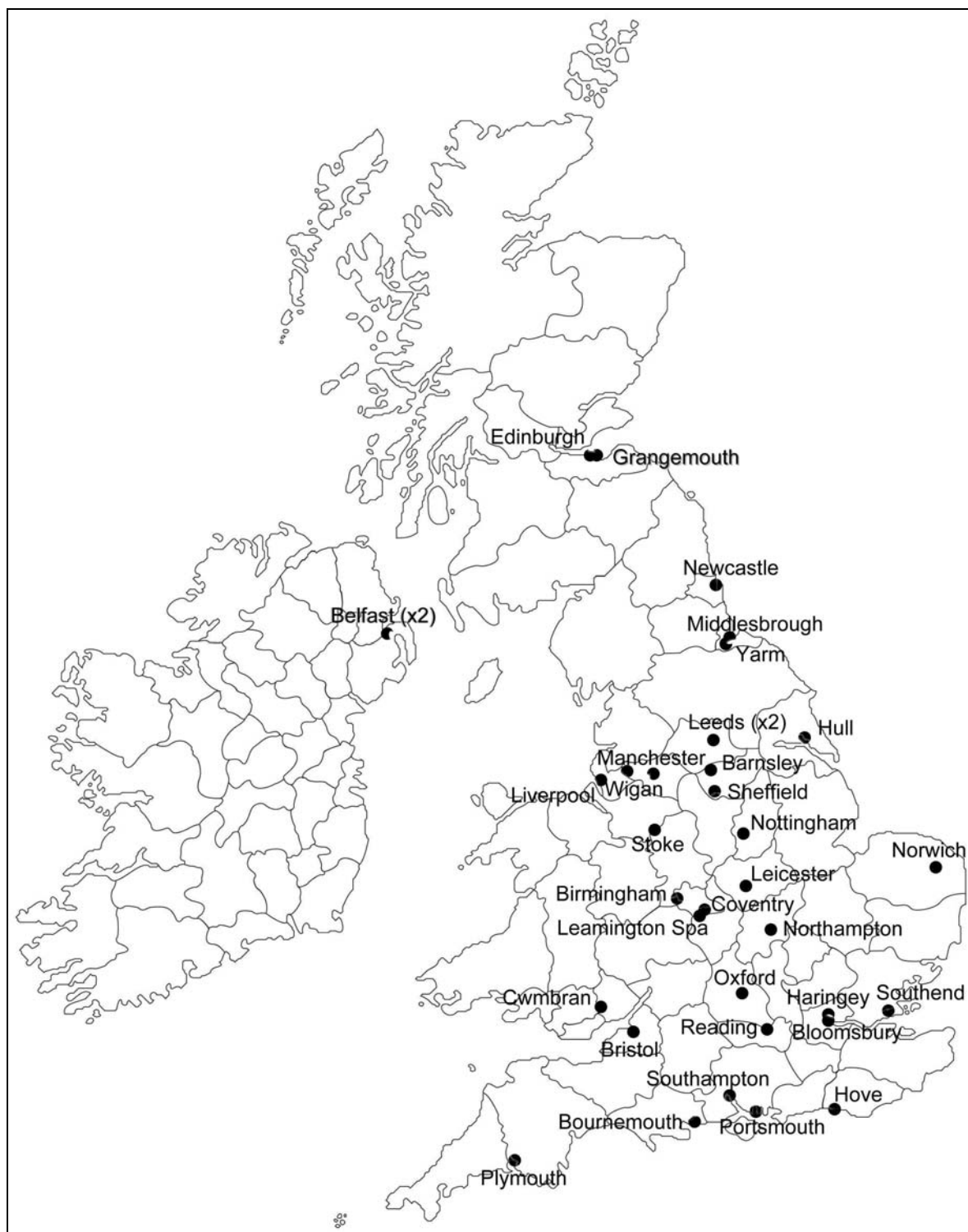


Figure 1: map of sites across the United Kingdom at the start of 2007

At the beginning of 2007, the sites in the Network were located as in Figure 1.

Table 2 lists the sites with their Local Site Operators and whether they also measured 1,3-butadiene.

Site Name	Type	Local Site Operator	1,3-butadiene
Barnsley Gawber	Roadside	Barnsley Council	Y
Belfast centre		Belfast City Council	
Belfast roadside		Belfast City Council	
Birmingham roadside		Birmingham City Council	
Bloomsbury	Roadside	Casella Stanger	Y
Bournemouth		Bournemouth Borough C	
Bristol Old Market		Bristol City Council	
Coventry Memorial Park		Coventry City Council	
Cwmbran	Industrial	Torfaen CBC	Y
Edinburgh St Leonard's		City of Edinburgh Council	
Grangemouth		Falkirk Council	
Haringey roadside		King's College London	
Hove roadside	Roadside	Brighton and Hove City C	Y
Hull Freetown	Roadside	Hull City Council	
Leamington Spa		Warwick District Council	
Leeds centre		Leeds City Council	
Leeds roadside	Roadside	Leeds City Council	Y
Leicester centre		Leicester City Council	
Liverpool Speke		Faber Maunsell	
Manchester Piccadilly		Manchester City Council	
Middlesbrough	Industrial	Middlesbrough Borough C	Y
Newcastle		Newcastle City Council	
Northampton		Northampton Borough C	
Norwich centre		Faber Maunsell	
Nottingham centre	Roadside	Nottingham City Council	Y
Oxford centre		Oxford City Council	
Plymouth		Plymouth City Council	
Portsmouth		Portsmouth City Council	
Reading	Roadside	Reading Borough Council	Y
Sheffield		Sheffield City Council	
Southampton		Southampton City Council	
Southend-on-sea		Southend-on-Sea BC	
Stoke centre	Roadside	City of Stoke on Trent	Y
Wigan centre		Wigan Metropolitan BC	
Yarm		Stockton on Tees BC	

Table 2: Network sites at the start of 2007

All sites in Table 2 are Urban Background except where stated in the Type column. Further details on these sites can be found on the UK Automatic Urban and Rural Network Site Information Archive at:

<http://www.stanger.co.uk/siteinfo/>

2.2 Changes during 2007

In anticipation of the siting requirements in the new Air Quality Directive, some of the site locations in the Network were changed in 2007. These changes involved the closure of 10 existing sites and the opening of 11 new sites for benzene monitoring in the UK. In 2007 all 10 sites listed in Table 3 were closed and 2 of the sites listed in Table 4 had the benzene sampler installed. 6 of the remaining 9 sites were installed by 09/04/08 and Chesterfield Roadside will be installed shortly. Suitable locations for 2 sites are still to be identified and samplers will be installed as soon as the site details have been finalised.

Site	Date
Belfast Roadside	09/10/2007
Portsmouth	25/10/2007
Bournemouth	26/10/2007
Southend on Sea	30/10/2007
Cwmbran	31/10/2007
Hull Freetown	14/11/2007
Edinburgh	27/11/2007
Reading	04/12/2007
Hove	05/12/2007
Leeds Roadside	11/12/2007

Table 3 Sites closed in 2007

Site	Start Date
Camden Kerbside	19/12/07
Birmingham Tyburn	18/12/07
Oxford St Ebbes	30/01/08
Bury Roadside	17/01/08
Cambridge Roadside	04/02/08
Bath Roadside	28/01/08
York Fishergate	13/02/08
Carlisle Caldewgate	09/04/08
Chesterfield Roadside	TBA
West Midlands Roadside	AEAT to find a site
South East Roadside	AEAT to find a site

Table 4 New benzene monitoring sites

As part of the restructuring of the Network, the monitoring of 1,3-butadiene within this Network ceased during September 2007.

3. Data and Data Capture for 2007

3.1 Benzene: comparison with Limit Values and Objectives

Site	ppb	ug.m ⁻³
Barnsley Gawber	0.18	0.58
Belfast Centre	0.19	0.62
Belfast Roadside	0.39	1.26
Birmingham Roadside	0.52	1.68
Bloomsbury	0.33	1.07
Bournemouth	0.16	0.52
Bristol Old Market	0.41	1.33
Coventry Memorial Park	0.18	0.58
Cwmbran	0.15	0.49
Edinburgh St Leonard's	0.16	0.52
Grangemouth	0.34	1.10
Haringey Roadside	0.47	1.52
Hove Roadside	0.27	0.87
Hull Freetown	0.25	0.81
Leamington Spa	0.24	0.78
Leeds Centre	0.24	0.78
Leeds Roadside	0.47	1.52
Leicester Centre	0.26	0.84
Liverpool Speke	0.29	0.94
Manchester Piccadilly	0.31	1.00
Middlesbrough	0.36	1.17
Newcastle	0.19	0.62
Northampton	0.19	0.62
Norwich Centre	0.24	0.78
Nottingham Centre	0.26	0.84
Oxford Centre	0.24	0.78
Plymouth	0.20	0.65
Portsmouth	0.20	0.65
Reading	0.22	0.71
Sheffield	0.29	0.94
Southampton	0.31	1.00
Southend-on-Sea	0.19	0.62
Stoke Centre	0.32	1.04
Wigan Centre	0.21	0.68
Yarm	0.56	1.81

Table 5: Benzene annual average concentrations for 2007

The annual average concentration of benzene at each site over the calendar year 2007 is given in Table 5. It should be noted that some of the later data is unratified, but it is not expected that it will change significantly. For those sites that closed during the year, the average for the period of operation is given. In all cases this covers more than 75% of the year.

Annual average concentrations at all sites were below the Limit Value of $5 \mu\text{g.m}^{-3}$ set by the European Directive 2000/69/EC (the same as those in the new Ambient Air Quality Directive).

As mentioned above, within the UK Air Quality Strategy the Objectives for benzene are:

- for England and Wales, an annual average of $5 \mu\text{g/m}^3$ to be achieved by 31 December 2010;
- for Scotland and Northern Ireland, a running annual mean of $3.25 \mu\text{g/m}^3$ to be achieved by 31 December 2010.

These Objectives were met in 2007 for all sites.

Data capture figures less than 95% are given in Table 6.

Site	Data capture, %
Portsmouth	73
Reading	87
Bournemouth	88
Bloomsbury	90
Hove Roadside	90
Middlesbrough	90
Haringey Roadside	90
Southend-on-Sea	93
Birmingham Roadside	94
Cwmbran	94

Table 6: 2007 Benzene data capture for sites < 95%

Reasons for data loss at those sites with less than 90% data capture were:

Portsmouth (73%)

No tubes were changed after the site closure was announced on 03/08/07. The site closed on 25/10/07.

Reading (87%)

The tubes exposed between 24/04/07 and 08/05/07 were lost in the post during their return to NPL.

Leaking tube elbows affected the sampling period 11/10/07 to 06/11/07.

Bournemouth (88%)

Leaking tube elbows affected the sampling period 15/05/07 to 29/05/07.

No tubes were exposed between 16/10/07 and 26/10/07 due to the imminent site closure.

3.2 1,3-Butadiene: comparison with Objectives

Annual average concentrations and data capture for 1,3-butadiene are given in Table 7.

Site	ppb	$\mu\text{g.m}^{-3}$	Data capture, %
Grangemouth	0.16	0.36	100
Birmingham Roadside	0.08	0.18	95
Bristol Old Market	0.06	0.14	98
Haringey Roadside	0.05	0.11	98
Leeds Roadside	0.05	0.11	99
Middlesbrough	0.05	0.11	92
Belfast Centre	0.04	0.09	92
Belfast Roadside	0.04	0.09	98
Leeds Centre	0.04	0.09	100

Table 7: 2007 1,3-butadiene annual average and data capture

The method is ascribed a large measurement uncertainty below 0.05 ppb, so that the values near or below the red line should be treated with caution.

All measured concentrations are below the United Kingdom Air Quality Strategy Objective of $2.25 \mu\text{g/m}^3$ (1 ppb). There is no European Union Limit Value for 1,3-butadiene.

No sites had a data capture below 90%

The interferent peak that has previously appeared on the Bristol Old Market 1,3-butadiene gas chromatograph traces was not detected this year.

3.3 Episodes and anomalous results

The only fortnightly value recorded above 1.6 ppb ($5 \mu\text{g}/\text{m}^3$) for benzene was at Plymouth during the last sample of 2006, for the period covering 19 December 2006 to 4 January 2007, when 3.46 ppb ($11.2 \mu\text{g}/\text{m}^3$) was measured. No reason has been found. Concentrations have returned to normal in 2007.

3.4 Annual variation

The concentrations were generally highest at the start and end of the year, with lower concentrations over the summer. The data for London Haringey, given below, was typical:

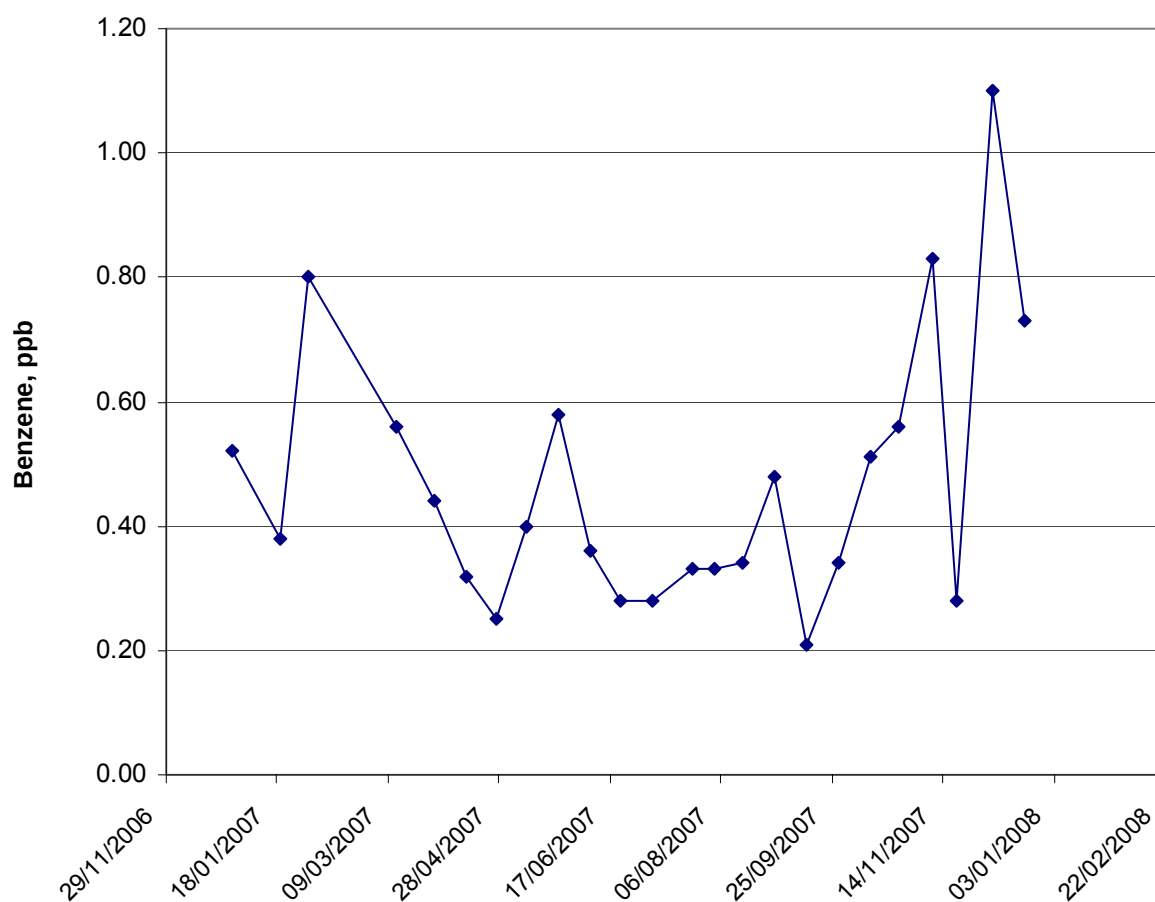


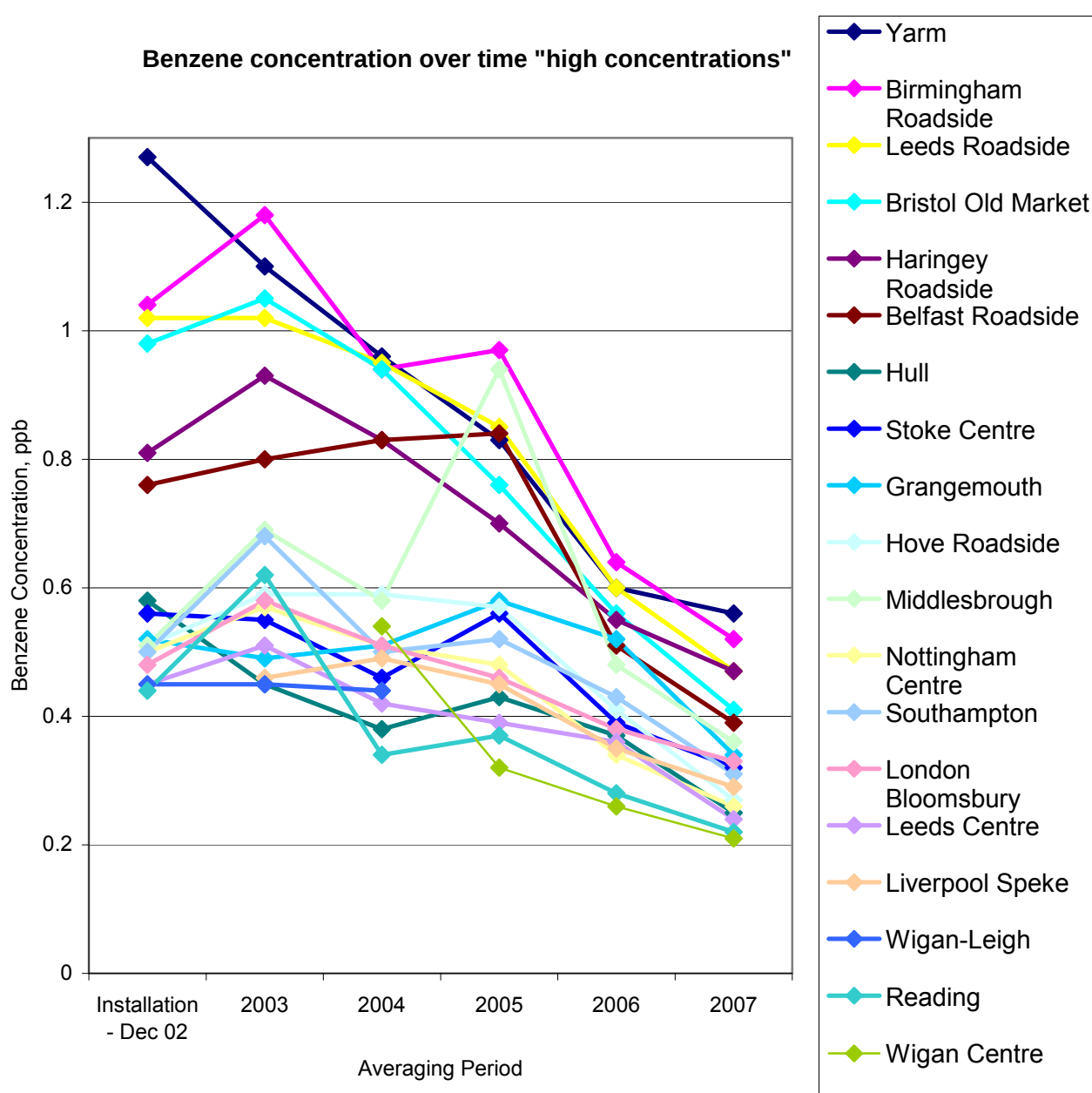
Figure 2: Benzene concentrations for London Haringey throughout 2007

4. Long term trends and comparisons with the UK emission inventory and other data

4.1 Benzene

4.1.1 Long term trends and Emissions Inventory

Benzene data from the seven years of operation of the pumped samplers is shown in Figure 3. For clarity the sites have been divided into two graphs according to concentration in the first year. Benzene concentrations have generally dropped substantially over the history of the Network. The reductions in concentration are more notable at the higher concentration (typically traffic influenced) sites.



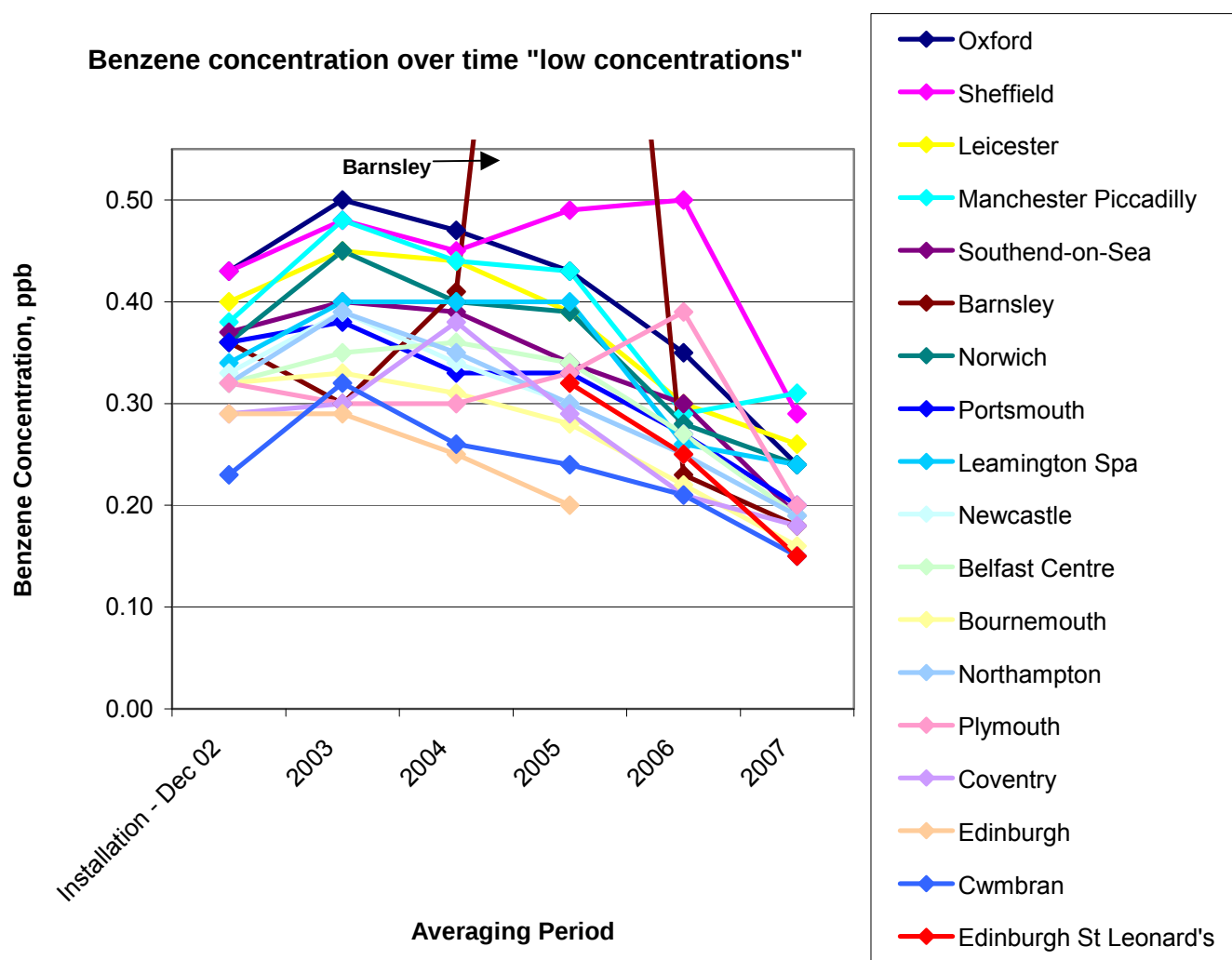


Figure 3 (also previous page): Recent annual average benzene concentrations

The anomalous increase in concentration at Middlesbrough in 2005, and at Barnsley in 2004 and 2005, were attributed to local sources.

Longer term trends can be gauged from data at sites that were monitoring benzene in the previous Hydrocarbon Network. These are shown in Figure 4.

This long term benzene trend is well matched by the trend predicted by the National Atmospheric Emissions Inventory, shown in Figure 5.

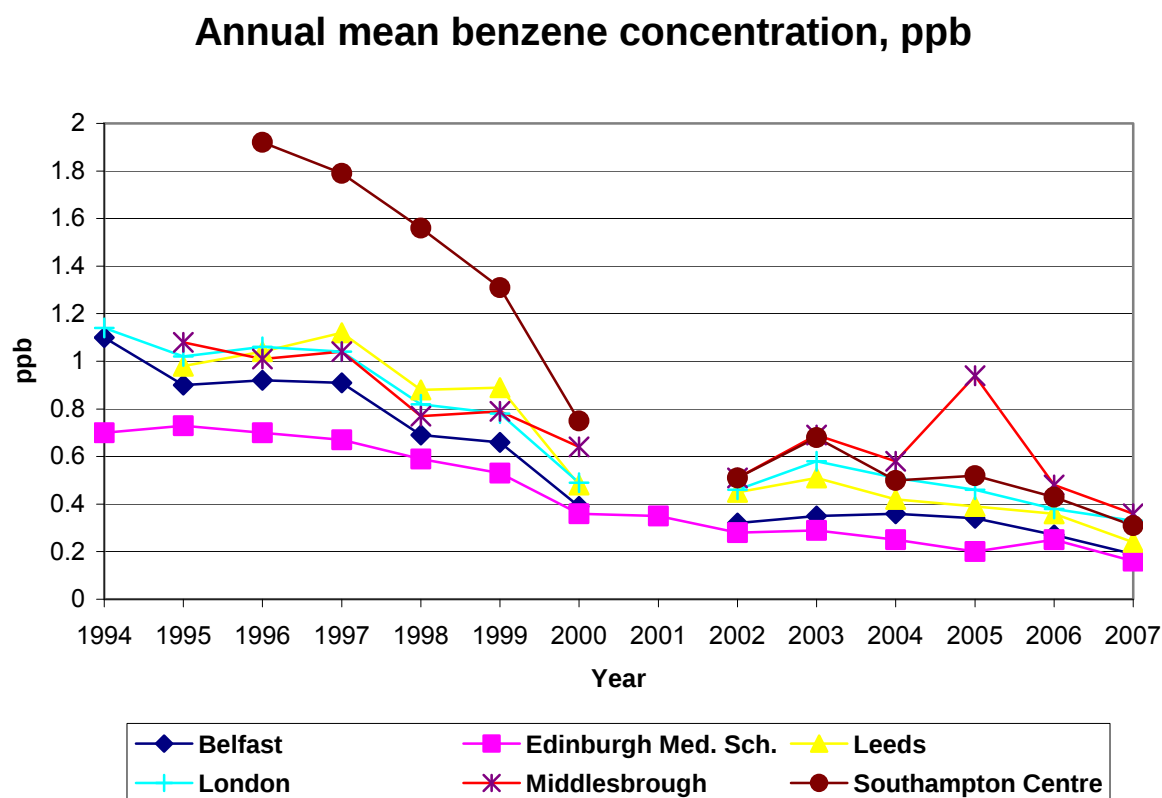


Figure 4: Long Term Trends in Benzene Concentration

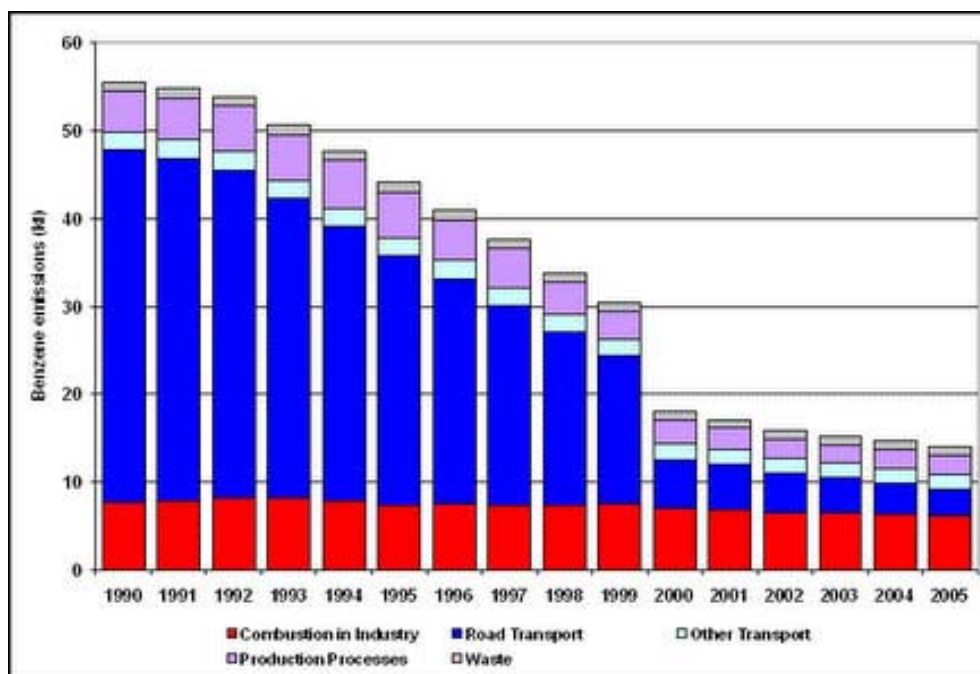


Figure 5: Emission Inventory Trend for Benzene

4.1.2 Automatic Hydrocarbon Network

Parallel measurements with an NPL pumped system and the Automatic Hydrocarbon Network instrument were made at Marylebone Road throughout 2007, and the results are shown in the Table below. There is no simple relationship between the two sets of data, but the results indicate that in general the automatic system records lower concentrations than the pump box system.

Measurement period	Pump box $\mu\text{g.m}^{-3}$	Automatic method $\mu\text{g.m}^{-3}$
10/01/07 - 24/01/07	2.24	
24/01/07 - 07/02/07	2.33	
07/02/07 - 21/02/07	2.56	
21/02/07 - 08/03/07	1.46	
08/03/07 - 21/03/07	2.04	
21/03/07 - 04/04/07	1.78	
04/04/07 - 18/04/07	2.04	
18/04/07 - 02/05/07	0.91	1.39
02/05/07 - 16/05/07	1.94	1.51
16/05/07 - 30/05/07	1.56	1.20
30/05/07 - 13/06/07	2.07	0.98
13/06/07 - 27/06/07	1.75	1.62
27/06/07 - 11/07/07	1.94	1.55
25/07/07 - 08/08/07	1.65	1.10
08/08/07 - 22/08/07	1.56	0.87
22/08/07 - 05/09/07	1.46	
05/09/07 - 19/09/07	2.33	
19/09/07 - 03/10/07	2.19	2.05
03/10/07 - 17/10/07	1.52	
17/10/07 - 31/10/07	2.66	
31/10/07 - 14/11/07	1.75	
14/11/07 - 28/11/07	2.71	1.56
28/11/07 - 12/12/07	1.96	1.51
12/12/07 - 27/12/07	2.53	2.29
Average (valid pairs only)	1.90	1.47

Table 8: Comparison between pumped and automatic benzene data at Marylebone Road

Missing data from the automatic method corresponds to measurement periods where the data capture for the automatic method was below 75%.

The available 2007 annual average concentrations for benzene on the Automatic Hydrocarbon Network were $0.91 \mu\text{g/m}^3$ at London Eltham, $0.97 \mu\text{g/m}^3$ at Glasgow Kerbside and $0.33 \mu\text{g/m}^3$ at Harwell. These are all compatible with the measurements on the Non-Automatic Network.

4.1.3 Grangemouth survey

NPL carries out a regular survey of both background and industrially-influenced hydrocarbon concentrations around Grangemouth on behalf of Ineos Manufacturing (Scotland) Ltd, using diffusive samplers. Annual average benzene concentrations at background sites for 2007 were all in the range 0.2 – 0.4 ppb, while the two industrially-influenced sites recorded 0.5 and 1.1 ppb. This is comparable with the Network concentration for the semi-industrial Grangemouth site of 0.34 ppb.

4.2 1,3-Butadiene

Figure 6 shows recent 1,3-butadiene data at the five sites where long term measurements are available. The downward trend broadly follows the trend predicted by the National Atmospheric Emissions Inventory, shown in Figure 7.

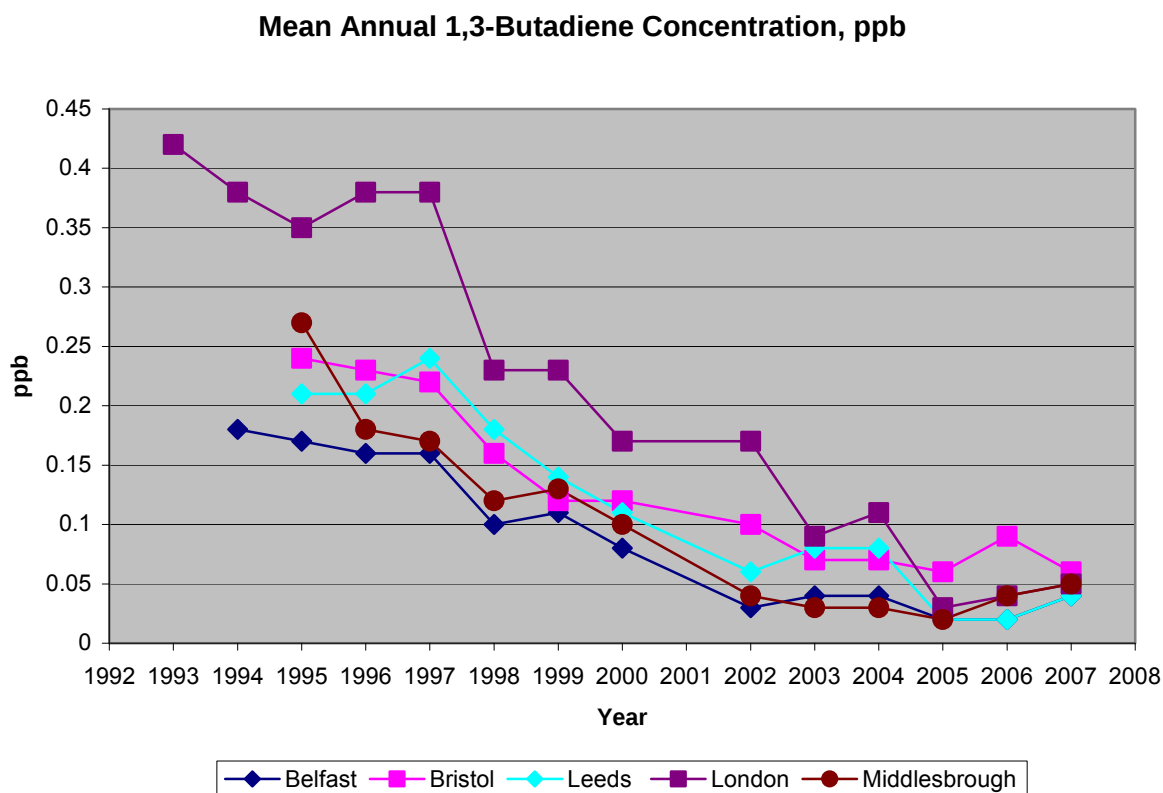


Figure 6: Long Term Trends in 1,3-Butadiene Concentration

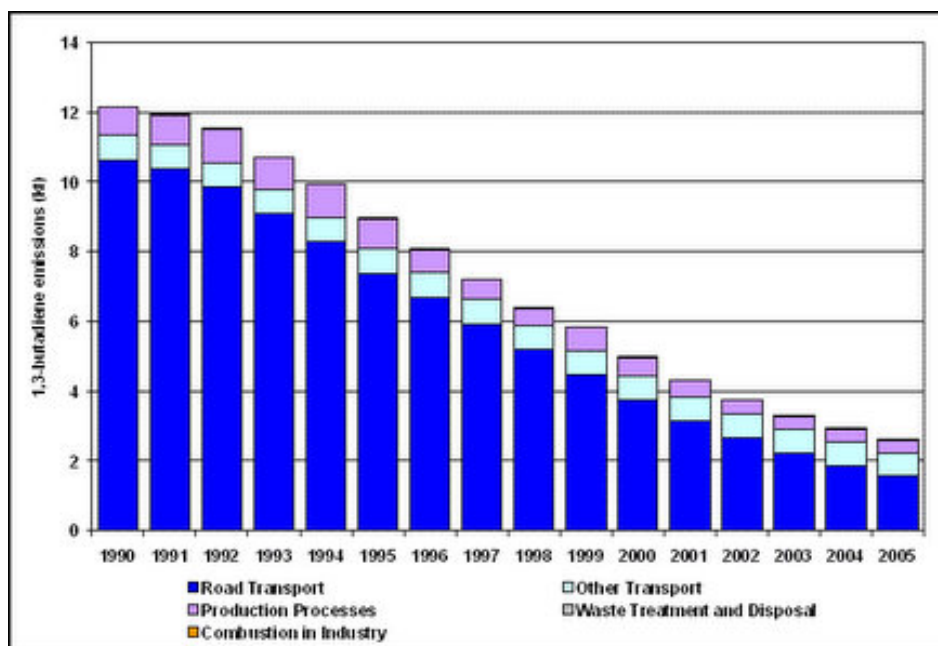


Figure 7: Emission Inventory Trend for 1,3-Butadiene

4.2.1 Automatic Hydrocarbon Network

The available 2007 annual average concentrations for 1,3-butadiene on the Automatic Hydrocarbon Network were $0.36 \mu\text{g}/\text{m}^3$ at Marylebone Road, $0.10 \mu\text{g}/\text{m}^3$ at London Eltham, $0.15 \mu\text{g}/\text{m}^3$ at Glasgow Kerbside, and $0.01 \mu\text{g}/\text{m}^3$ at Harwell. These are all compatible with comparable measurements on the Non-Automatic Network.

4.2.2 Grangemouth survey

NPL carries out a regular survey of both background and industrially-influenced hydrocarbon concentrations around Grangemouth on behalf of Ineos Manufacturing (Scotland) Ltd, using diffusive samples. Reported annual average 1,3-butadiene concentrations at background sites for 2007 ranged from $<0.05 \text{ ppb}$ to 0.08 ppb , while the two industrially-influenced sites recorded 0.36 and 0.52 ppb . This is comparable with the Network concentration for the semi-industrial Grangemouth site of 0.16 ppb .

5. Comparison with benzene modelling data

In 2007, AEA Technology supplied NPL with modelled benzene data for the locations of all the Network sites in 2006. It is understood that the data represents background concentrations, so would not be expected to account for traffic sources at roadside sites, or nearby industrial sources.

Table 9 gives the modelled data in the left hand column. The next three columns give the Network data for the years 2005, 2006 and 2007, with the mean of these in the next column. The empty boxes for Barnsley Gawber and Middlesbrough are when a very local source caused anomalously high benzene concentrations. The difference between the modelled data and the measured average is in the penultimate column.

SITE (all concs in $\mu\text{g}/\text{m}^3$)	2006 modelled benzene	Measured benzene 2005	Measured benzene 2006	Measured benzene 2007	Mean measured 2005-07	Difference	Model implic- ation
Barnsley Gawber	0.98		0.75	0.58	0.67	-0.31	High
Belfast Centre	0.83	1.11	0.88	0.62	0.87	0.04	
Belfast Roadside	0.54	2.73	1.66	1.26	1.88	1.34	V Low
Birmingham Roadside	0.89	3.15	2.08	1.68	2.30	1.42	V Low
Bloomsbury	1.33	1.50	1.24	1.07	1.27	-0.06	
Bournemouth	0.56	0.91	0.72	0.52	0.72	0.16	
Bristol Old Market (rdsd)	0.92	2.47	1.82	1.33	1.87	0.96	Low
Coventry Memorial Park	0.75	0.94	0.68	0.58	0.73	-0.02	
Cwmbran	0.63	0.78	0.68	0.49	0.65	0.02	
Edinburgh St Leonards	0.69	1.04	0.81	0.52	0.79	0.11	
Grangemouth (industrial)	3.52	1.89	1.69	1.1	1.56	-1.96	V High
Haringey Roadside	0.82	2.28	1.79	1.52	1.86	1.05	V Low
Hove Roadside	0.78	1.85	1.33	0.87	1.35	0.57	Low
Hull Freetown	1.07	1.40	1.20	0.81	1.14	0.07	
Leamington Spa	0.76	1.30	0.85	0.78	0.98	0.21	
Leeds Centre	1.22	1.27	1.17	0.78	1.07	-0.14	
Leeds Roadside	0.90	2.76	1.95	1.52	2.08	1.17	V Low
Leicester Centre	1.06	1.27	0.98	0.84	1.03	-0.03	
Liverpool Speke	0.59	1.46	1.14	0.94	1.18	0.59	Low
Manchester Piccadilly	1.18	1.40	0.94	1	1.11	-0.07	
Middlesbrough (industr.)	0.88		1.56	1.17	1.37	0.49	Low
Newcastle Centre	0.92	0.98	0.81	0.62	0.80	-0.11	
Northampton	0.62	0.98	0.81	0.62	0.80	0.19	
Norwich Centre	0.78	1.27	0.91	0.78	0.99	0.21	
Nottingham Centre	0.92	1.56	1.11	0.84	1.17	0.25	
Oxford Centre	0.71	1.40	1.14	0.78	1.11	0.40	Low
Plymouth Centre	0.49	1.07	1.27	0.65	1.00	0.51	Low
Portsmouth	0.81	1.07	0.88	0.65	0.87	0.06	
Reading	0.82	1.20	0.91	0.71	0.94	0.12	
Sheffield Centre	1.05	1.59	1.63	0.94	1.39	0.33	Low
Southampton Centre	0.78	1.69	1.40	1	1.36	0.58	Low
Southend-on-Sea	0.72	1.11	0.98	0.62	0.90	0.18	
Stoke-on-Trent Centre	0.79	1.82	1.27	1.04	1.38	0.59	Low
Wigan Centre	0.67	1.04	0.85	0.68	0.86	0.18	
Yarm (roadside)	0.50	2.70	1.95	1.81	2.15	1.65	V Low

Table 9: comparison between recent benzene data and modeled data

The final column gives a grading to the difference between the modelled and measured data, where differences greater than $0.3 \mu\text{g}/\text{m}^3$ are noted as implying the model predictions are “high” or “low”, while differences greater than $1.0 \mu\text{g}/\text{m}^3$ are graded “very high” or “very low”.

It is notable that the substantial downward trend over the three measurement years used to form the average makes the timing of the model a critical factor. The trend means that the Barnsley Gawber “high” grade can be attributed to the 2005 measurement being missing from the Table.

In general the modelled data appears somewhat lower than the measured average. The mean value for the non-roadside, non-industrial sites is $0.83 \mu\text{g}/\text{m}^3$ for the modelled data and $1.00 \mu\text{g}/\text{m}^3$ for the measured data. This can be interpreted as the model anticipating reductions in benzene emissions at these sites about eight months early.

As expected, roadside concentrations are significantly underestimated by the model.

The one significant anomaly is Grangemouth, where the industrial sources contributed much less to the measured concentration than the model predicted.

Annex 1 – Fortnightly data

Benzene

Site	Start Date	End Date	Benzene Concentration, ppb
Barnsley Gawber	10/01/2007	23/01/2007	0.22
	23/01/2007	07/02/2007	0.21
	07/02/2007	21/02/2007	0.21
	21/02/2007	07/03/2007	0.13
	07/03/2007	20/03/2007	0.18
	20/03/2007	02/04/2007	0.25
	02/04/2007	18/04/2007	0.31
	18/04/2007	02/05/2007	0.10
	02/05/2007	16/05/2007	0.11
	16/05/2007	31/05/2007	0.10
	31/05/2007	13/06/2007	0.22
	13/06/2007	26/06/2007	0.13
	26/06/2007	10/07/2007	0.06
	10/07/2007	25/07/2007	0.11
	25/07/2007	07/08/2007	0.07
	07/08/2007	21/08/2007	0.11
	21/08/2007	05/09/2007	0.10
	05/09/2007	18/09/2007	0.15
	18/09/2007	31/10/2007	0.15
	31/10/2007	14/11/2007	0.25
	14/11/2007	29/11/2007	0.30
	29/11/2007	12/12/2007	0.17
	12/12/2007	27/12/2007	0.35
Belfast Centre	09/01/2007	23/01/2007	0.39
	23/01/2007	06/02/2007	0.31
	06/02/2007	20/02/2007	0.23
	20/02/2007	06/03/2007	0.17
	06/03/2007	20/03/2007	0.19
	20/03/2007	03/04/2007	0.31
	03/04/2007	17/04/2007	0.19
	17/04/2007	01/05/2007	0.10
	01/05/2007	15/05/2007	0.10
	15/05/2007	29/05/2007	0.12
	29/05/2007	12/06/2007	0.13

Site	Start Date	End Date	Benzene Concentration, ppb
Belfast Roadside	24/07/2007	07/08/2007	0.11
	07/08/2007	21/08/2007	0.13
	21/08/2007	04/09/2007	0.09
	04/09/2007	18/09/2007	0.11
	18/09/2007	02/10/2007	0.11
	02/10/2007	16/10/2007	0.17
	16/10/2007	30/10/2007	0.20
	30/10/2007	13/11/2007	0.16
	13/11/2007	27/11/2007	0.20
	27/11/2007	11/12/2007	0.26
	11/12/2007	24/12/2007	0.37
	09/01/2007	23/01/2007	0.78
Birmingham Roadside	23/01/2007	06/02/2007	0.63
	06/02/2007	20/02/2007	0.46
	20/02/2007	06/03/2007	0.31
	06/03/2007	20/03/2007	0.36
	20/03/2007	03/04/2007	0.53
	03/04/2007	17/04/2007	0.43
	17/04/2007	01/05/2007	0.19
	01/05/2007	15/05/2007	0.20
	15/05/2007	29/05/2007	0.32
	29/05/2007	12/06/2007	0.38
	12/06/2007	26/06/2007	0.43
	26/06/2007	10/07/2007	0.33
Birmingham Roadside	10/07/2007	24/07/2007	0.31
	24/07/2007	07/08/2007	0.32
	07/08/2007	21/08/2007	0.39
	21/08/2007	04/09/2007	0.36
	04/09/2007	18/09/2007	0.42
	18/09/2007	02/10/2007	0.28
	02/10/2007	09/10/2007	0.41
	04/01/2007	18/01/2007	0.46
	18/01/2007	15/02/2007	0.56
	15/02/2007	01/03/2007	0.51
	01/03/2007	15/03/2007	0.24
	15/03/2007	29/03/2007	0.72
	29/03/2007	13/04/2007	0.68
Birmingham Roadside	13/04/2007	27/04/2007	0.38
	27/04/2007	10/05/2007	0.37
	10/05/2007	24/05/2007	0.45

Site	Start Date	End Date	Benzene Concentration, ppb
Birmingham Tyburn	24/05/2007	07/06/2007	0.51
	07/06/2007	21/06/2007	0.47
	13/07/2007	19/07/2007	0.42
	19/07/2007	02/08/2007	0.40
	02/08/2007	16/08/2007	0.32
	16/08/2007	30/08/2007	0.44
	30/08/2007	13/09/2007	0.41
	13/09/2007	27/09/2007	0.28
	27/09/2007	11/10/2007	0.73
	11/10/2007	25/10/2007	0.70
	25/10/2007	08/11/2007	0.77
	08/11/2007	22/11/2007	0.78
	22/11/2007	06/12/2007	0.33
	06/12/2007	20/12/2007	1.11
	20/12/2007	03/01/2008	0.52
	18/12/2007	03/01/2008	0.38
Bloomsbury	22/01/2007	07/02/2007	0.39
	07/02/2007	21/02/2007	0.26
	21/02/2007	06/03/2007	0.22
	06/03/2007	21/03/2007	0.26
	21/03/2007	03/04/2007	0.40
	03/04/2007	17/04/2007	0.39
	17/04/2007	01/05/2007	0.20
	01/05/2007	15/05/2007	0.13
	15/05/2007	29/05/2007	0.24
	29/05/2007	12/06/2007	0.29
	06/07/2007	08/08/2007	0.19
	08/08/2007	21/08/2007	0.18
	21/08/2007	05/09/2007	0.24
	05/09/2007	18/09/2007	0.24
	18/09/2007	03/10/2007	0.23
	03/10/2007	18/10/2007	0.28
	18/10/2007	01/11/2007	0.37
	01/11/2007	13/11/2007	0.51
	13/11/2007	26/11/2007	0.43
	26/11/2007	11/12/2007	0.23
Bournemouth	11/12/2007	20/12/2007	0.98
	09/01/2007	23/01/2007	0.26
	23/01/2007	06/02/2007	0.27

Site	Start Date	End Date	Benzene Concentration, ppb
Bristol Old Market	06/02/2007	20/02/2007	0.21
	20/02/2007	06/03/2007	0.12
	06/03/2007	20/03/2007	0.19
	20/03/2007	03/04/2007	0.32
	03/04/2007	17/04/2007	0.22
	17/04/2007	01/05/2007	0.16
	01/05/2007	15/05/2007	0.05
	29/05/2007	12/06/2007	0.11
	12/06/2007	26/06/2007	0.09
	26/06/2007	10/07/2007	0.07
	10/07/2007	24/07/2007	0.08
	24/07/2007	07/08/2007	0.09
	07/08/2007	21/08/2007	0.08
	21/08/2007	04/09/2007	0.15
	04/09/2007	18/09/2007	0.26
	18/09/2007	02/10/2007	0.14
	02/10/2007	16/10/2007	0.22
	10/01/2007	24/01/2007	0.36
	24/01/2007	07/02/2007	0.68
	07/02/2007	21/02/2007	0.43
	21/02/2007	07/03/2007	0.31
	07/03/2007	21/03/2007	0.38
	21/03/2007	03/04/2007	0.52
	03/04/2007	18/04/2007	0.72
	18/04/2007	03/05/2007	0.29
	03/05/2007	16/05/2007	0.20
	16/05/2007	30/05/2007	0.29
	30/05/2007	13/06/2007	0.31
	13/06/2007	27/06/2007	0.23
	27/06/2007	11/07/2007	0.17
	11/07/2007	25/07/2007	0.24
	25/07/2007	08/08/2007	0.25
	08/08/2007	22/08/2007	0.29
	22/08/2007	05/09/2007	0.29
	05/09/2007	19/09/2007	0.37
	19/09/2007	03/10/2007	0.30
	03/10/2007	17/10/2007	0.42
	17/10/2007	01/11/2007	0.45
	01/11/2007	14/11/2007	0.48
	14/11/2007	26/11/2007	0.82
	26/11/2007	12/12/2007	0.37

Site	Start Date	End Date	Benzene Concentration, ppb
Coventry Memorial Park	12/12/2007	27/12/2007	0.94
	11/01/2007	23/01/2007	0.17
	23/01/2007	06/02/2007	0.38
	06/02/2007	21/02/2007	0.21
	21/02/2007	06/03/2007	0.13
	06/03/2007	20/03/2007	0.19
	03/04/2007	17/04/2007	0.32
	17/04/2007	01/05/2007	0.14
	01/05/2007	15/05/2007	0.06
	15/05/2007	30/05/2007	0.13
	30/05/2007	12/06/2007	0.17
	12/06/2007	27/06/2007	0.09
	27/06/2007	10/07/2007	0.05
	10/07/2007	24/07/2007	0.10
	24/07/2007	07/08/2007	0.09
	07/08/2007	21/08/2007	0.12
	21/08/2007	18/09/2007	0.11
	18/09/2007	02/10/2007	0.10
	02/10/2007	17/10/2007	0.14
	17/10/2007	30/10/2007	0.25
	30/10/2007	13/11/2007	0.24
	13/11/2007	27/11/2007	0.22
	27/11/2007	11/12/2007	0.16
	11/12/2007	27/12/2007	0.52
Cwmbran	02/01/2007	18/01/2007	0.37
	18/01/2007	05/02/2007	0.14
	05/02/2007	22/02/2007	0.31
	22/02/2007	08/03/2007	0.15
	08/03/2007	27/03/2007	0.22
	27/03/2007	11/04/2007	0.24
	11/04/2007	23/04/2007	0.14
	23/04/2007	08/05/2007	0.13
	08/05/2007	21/05/2007	0.10
	21/05/2007	06/06/2007	0.14
	06/06/2007	21/06/2007	0.10
	21/06/2007	06/07/2007	0.05
	06/07/2007	24/07/2007	0.06
	24/07/2007	08/08/2007	0.08
	08/08/2007	24/08/2007	0.07
	24/08/2007	10/09/2007	0.10

Site	Start Date	End Date	Benzene Concentration, ppb
Edinburgh St Leonard's	10/09/2007	26/09/2007	0.06
	26/09/2007	15/10/2007	0.20
	11/01/2007	25/01/2007	0.20
	25/01/2007	08/02/2007	0.24
	08/02/2007	22/02/2007	0.26
	22/02/2007	08/03/2007	0.16
	08/03/2007	22/03/2007	0.20
	22/03/2007	05/04/2007	0.24
	05/04/2007	19/04/2007	0.22
	19/04/2007	03/05/2007	0.11
	03/05/2007	17/05/2007	0.07
	17/05/2007	31/05/2007	0.10
	31/05/2007	14/06/2007	0.19
	14/06/2007	28/06/2007	0.10
	28/06/2007	12/07/2007	0.13
	12/07/2007	26/07/2007	0.08
	26/07/2007	09/08/2007	0.11
	09/08/2007	24/08/2007	0.11
	24/08/2007	06/09/2007	0.12
	06/09/2007	20/09/2007	0.10
Grangemouth	04/01/2007	25/01/2007	0.23
	25/01/2007	05/02/2007	0.14
	06/02/2007	07/03/2007	0.28
	07/03/2007	23/03/2007	0.23
	23/03/2007	13/04/2007	0.65
	13/04/2007	27/04/2007	0.38
	27/04/2007	18/05/2007	0.62
	22/05/2007	11/06/2007	0.67
	11/06/2007	05/07/2007	0.55
	05/07/2007	23/07/2007	0.19
	23/07/2007	06/08/2007	0.14
	06/08/2007	23/08/2007	0.41
	23/08/2007	06/09/2007	0.12
	06/09/2007	20/09/2007	0.09
	20/09/2007	10/10/2007	0.41
	25/10/2007	23/11/2007	0.28
	27/11/2007	11/12/2007	0.27
Haringey Roadside	29/12/2006	19/01/2007	0.52
	19/01/2007	01/02/2007	0.38

Site	Start Date	End Date	Benzene Concentration, ppb
Hove Roadside	01/02/2007	20/02/2007	0.80
	13/03/2007	30/03/2007	0.56
	30/03/2007	13/04/2007	0.44
	13/04/2007	27/04/2007	0.32
	27/04/2007	10/05/2007	0.25
	10/05/2007	25/05/2007	0.40
	25/05/2007	08/06/2007	0.58
	08/06/2007	22/06/2007	0.36
	22/06/2007	06/07/2007	0.28
	06/07/2007	24/07/2007	0.28
	24/07/2007	03/08/2007	0.33
	03/08/2007	16/08/2007	0.33
	16/08/2007	30/08/2007	0.34
	30/08/2007	14/09/2007	0.48
	14/09/2007	28/09/2007	0.21
	28/09/2007	12/10/2007	0.34
	12/10/2007	25/10/2007	0.51
	25/10/2007	09/11/2007	0.56
	09/11/2007	20/11/2007	0.83
	20/11/2007	06/12/2007	0.28
	06/12/2007	21/12/2007	1.10
Hull Freetown	19/01/2007	02/02/2007	0.53
	02/02/2007	21/02/2007	0.26
	21/02/2007	15/03/2007	0.23
	15/03/2007	05/04/2007	0.40
	05/04/2007	23/04/2007	0.23
	23/04/2007	03/05/2007	0.28
	03/05/2007	21/05/2007	0.23
	21/05/2007	14/06/2007	0.22
	14/06/2007	28/06/2007	0.17
	28/06/2007	12/07/2007	0.17
	12/07/2007	25/07/2007	0.16
	25/07/2007	08/08/2007	0.23
	08/08/2007	21/08/2007	0.22
	21/08/2007	05/09/2007	0.32
	05/09/2007	19/09/2007	0.28
	19/09/2007	03/10/2007	0.32
	03/10/2007	31/10/2007	0.38
	31/10/2007	20/11/2007	0.32
Hull Freetown	18/01/2007	01/02/2007	0.25

Site	Start Date	End Date	Benzene Concentration, ppb
Leamington Spa	01/02/2007	01/03/2007	0.35
	01/03/2007	15/03/2007	0.59
	15/03/2007	29/03/2007	0.34
	29/03/2007	12/04/2007	0.23
	12/04/2007	26/04/2007	0.19
	26/04/2007	10/05/2007	0.20
	10/05/2007	24/05/2007	0.28
	24/05/2007	07/06/2007	0.15
	07/06/2007	21/06/2007	0.21
	21/06/2007	05/07/2007	0.17
	05/07/2007	19/07/2007	0.18
	19/07/2007	02/08/2007	0.13
	02/08/2007	16/08/2007	0.15
	16/08/2007	30/08/2007	0.09
	30/08/2007	13/09/2007	0.18
	13/09/2007	27/09/2007	0.12
	27/09/2007	11/10/2007	0.25
	11/10/2007	25/10/2007	0.33
	25/10/2007	08/11/2007	0.49
	08/11/2007	14/11/2007	0.30
Leamington Spa	08/01/2007	23/01/2007	0.36
	23/01/2007	05/02/2007	0.43
	05/02/2007	19/02/2007	0.29
	19/02/2007	05/03/2007	0.24
	05/03/2007	19/03/2007	0.23
	19/03/2007	02/04/2007	0.30
	02/04/2007	16/04/2007	0.20
	16/04/2007	30/04/2007	0.10
	30/04/2007	14/05/2007	0.09
	14/05/2007	29/05/2007	0.20
	29/05/2007	11/06/2007	0.16
	25/06/2007	09/07/2007	0.13
	09/07/2007	23/07/2007	0.13
	23/07/2007	06/08/2007	0.13
	06/08/2007	20/08/2007	0.13
	20/08/2007	03/09/2007	0.13
	03/09/2007	10/09/2007	0.17
	10/09/2007	01/10/2007	0.12
	01/10/2007	15/10/2007	0.22
	15/10/2007	30/10/2007	0.22
	30/10/2007	12/11/2007	0.41

Site	Start Date	End Date	Benzene Concentration, ppb
Leeds Centre	12/11/2007	26/11/2007	0.42
	26/11/2007	10/12/2007	0.14
	10/12/2007	21/12/2007	0.65
	03/01/2007	17/01/2007	0.27
	17/01/2007	31/01/2007	0.34
	31/01/2007	14/02/2007	0.34
	14/02/2007	28/02/2007	0.39
	28/02/2007	14/03/2007	0.19
	14/03/2007	28/03/2007	0.30
	28/03/2007	11/04/2007	0.22
	11/04/2007	25/04/2007	0.14
	25/04/2007	09/05/2007	0.22
	09/05/2007	23/05/2007	0.26
	23/05/2007	06/06/2007	0.17
	06/06/2007	20/06/2007	0.16
	20/06/2007	04/07/2007	0.18
	04/07/2007	18/07/2007	0.17
	18/07/2007	01/08/2007	0.13
	01/08/2007	15/08/2007	0.19
	15/08/2007	29/08/2007	0.14
	29/08/2007	14/09/2007	0.14
	14/09/2007	26/09/2007	0.18
	26/09/2007	10/10/2007	0.20
	10/10/2007	24/10/2007	0.28
	24/10/2007	07/11/2007	0.31
	07/11/2007	21/11/2007	0.20
	21/11/2007	05/12/2007	0.31
	05/12/2007	19/12/2007	0.60
	19/12/2007	02/01/2008	0.28
Leeds Roadside	02/01/2007	18/01/2007	0.29
	18/01/2007	06/02/2007	0.77
	06/02/2007	22/02/2007	1.23
	22/02/2007	15/03/2007	0.35
	15/03/2007	05/04/2007	0.51
	05/04/2007	19/04/2007	0.43
	19/04/2007	01/05/2007	0.41
	01/05/2007	17/05/2007	0.39
	17/05/2007	01/06/2007	0.47
	01/06/2007	19/06/2007	0.49
	19/06/2007	06/07/2007	0.37

Site	Start Date	End Date	Benzene Concentration, ppb
Leicester Centre	06/07/2007	17/07/2007	0.32
	17/07/2007	31/07/2007	0.29
	31/07/2007	15/08/2007	0.28
	15/08/2007	30/08/2007	0.37
	30/08/2007	20/09/2007	0.46
	20/09/2007	05/10/2007	0.37
	05/10/2007	19/10/2007	0.58
	19/10/2007	02/11/2007	0.74
	02/11/2007	20/11/2007	0.33
	20/11/2007	11/12/2007	0.37
	04/01/2007	19/01/2007	0.37
	19/01/2007	30/01/2007	0.33
	30/01/2007	15/02/2007	0.43
	15/02/2007	01/03/2007	0.47
	01/03/2007	15/03/2007	0.21
	15/03/2007	28/03/2007	0.35
	28/03/2007	11/04/2007	0.26
	11/04/2007	25/04/2007	0.25
	25/04/2007	09/05/2007	0.14
	09/05/2007	23/05/2007	0.26
	23/05/2007	04/06/2007	0.17
	04/06/2007	20/06/2007	0.21
	20/06/2007	04/07/2007	0.15
	04/07/2007	18/07/2007	0.17
	18/07/2007	01/08/2007	0.13
	01/08/2007	15/08/2007	0.18
	15/08/2007	29/08/2007	0.18
	29/08/2007	14/09/2007	0.19
	14/09/2007	26/09/2007	0.12
	26/09/2007	10/10/2007	0.22
	10/10/2007	24/10/2007	0.49
	24/10/2007	07/11/2007	0.38
	07/11/2007	23/11/2007	0.25
	23/11/2007	05/12/2007	0.29
	05/12/2007	19/12/2007	0.31
Liverpool Speke	03/01/2007	16/01/2007	0.48
	16/01/2007	01/02/2007	0.23
	01/02/2007	15/02/2007	0.45
	15/02/2007	01/03/2007	0.26
	01/03/2007	14/03/2007	0.38

Site	Start Date	End Date	Benzene Concentration, ppb
Manchester Piccadilly	14/03/2007	26/03/2007	0.34
	26/03/2007	10/04/2007	0.31
	10/04/2007	23/04/2007	0.32
	23/04/2007	09/05/2007	0.19
	09/05/2007	21/05/2007	0.29
	21/05/2007	07/06/2007	0.19
	07/06/2007	18/06/2007	0.18
	18/06/2007	04/07/2007	0.19
	04/07/2007	17/07/2007	0.19
	17/07/2007	31/07/2007	0.23
	31/07/2007	14/08/2007	0.33
	14/08/2007	30/08/2007	0.13
	30/08/2007	10/09/2007	0.09
	10/09/2007	24/09/2007	0.24
	24/09/2007	16/10/2007	0.20
	16/10/2007	01/11/2007	0.33
	01/11/2007	13/11/2007	0.27
	13/11/2007	27/11/2007	0.47
	27/11/2007	11/12/2007	0.41
	11/12/2007	21/12/2007	0.33
	04/01/2007	18/01/2007	0.38
	18/01/2007	01/02/2007	0.22
	01/02/2007	15/02/2007	0.61
	15/02/2007	01/03/2007	0.29
	01/03/2007	15/03/2007	0.18
	15/03/2007	29/03/2007	0.39
	29/03/2007	12/04/2007	0.27
	12/04/2007	26/04/2007	0.15
	26/04/2007	10/05/2007	0.19
	10/05/2007	24/05/2007	0.25
	24/05/2007	07/06/2007	0.20
	07/06/2007	21/06/2007	0.15
	21/06/2007	05/07/2007	0.36
	05/07/2007	19/07/2007	0.22
	19/07/2007	02/08/2007	0.28
	02/08/2007	16/08/2007	0.16
	16/08/2007	30/08/2007	0.22
	30/08/2007	13/09/2007	0.34
	13/09/2007	27/09/2007	0.26
	27/09/2007	11/10/2007	0.50
	11/10/2007	25/10/2007	0.34

Site	Start Date	End Date	Benzene Concentration, ppb
Marylebone Rd	25/10/2007	08/11/2007	0.63
	08/11/2007	22/11/2007	0.37
	22/11/2007	06/12/2007	0.15
	06/12/2007	20/12/2007	0.58
	20/12/2007	03/01/2008	0.38
	10/01/2007	24/01/2007	0.69
	24/01/2007	07/02/2007	0.72
	07/02/2007	21/02/2007	0.79
	21/02/2007	08/03/2007	0.45
	08/03/2007	21/03/2007	0.63
	21/03/2007	04/04/2007	0.55
	04/04/2007	18/04/2007	0.63
	18/04/2007	02/05/2007	0.28
	02/05/2007	16/05/2007	0.60
	16/05/2007	30/05/2007	0.48
	30/05/2007	13/06/2007	0.64
	13/06/2007	27/06/2007	0.54
	27/06/2007	11/07/2007	0.60
	25/07/2007	08/08/2007	0.51
	08/08/2007	22/08/2007	0.48
	22/08/2007	05/09/2007	0.45
	05/09/2007	19/09/2007	0.72
	19/09/2007	03/10/2007	0.68
	03/10/2007	17/10/2007	0.47
	17/10/2007	31/10/2007	0.82
	31/10/2007	14/11/2007	0.54
	14/11/2007	28/11/2007	0.83
	28/11/2007	12/12/2007	0.60
	12/12/2007	27/12/2007	0.78
Middlesbrough	02/01/2007	16/01/2007	0.22
	16/01/2007	30/01/2007	0.37
	30/01/2007	13/02/2007	0.31
	13/02/2007	27/02/2007	0.35
	27/02/2007	13/03/2007	0.20
	13/03/2007	27/03/2007	0.44
	27/03/2007	10/04/2007	0.43
	10/04/2007	24/04/2007	0.31
	24/04/2007	08/05/2007	0.55
	08/05/2007	21/05/2007	0.45
	21/05/2007	05/06/2007	0.34

Site	Start Date	End Date	Benzene Concentration, ppb
Newcastle	05/06/2007	19/06/2007	0.81
	19/06/2007	03/07/2007	0.31
	03/07/2007	17/07/2007	0.16
	17/07/2007	31/07/2007	0.33
	31/07/2007	14/08/2007	0.27
	19/09/2007	25/09/2007	0.09
	25/09/2007	09/10/2007	0.86
	09/10/2007	23/10/2007	0.29
	23/10/2007	06/11/2007	0.38
	06/11/2007	20/11/2007	0.24
	20/11/2007	04/12/2007	0.18
	04/12/2007	18/12/2007	0.31
	18/12/2007	02/01/2008	0.34
	02/01/2007	16/01/2007	0.20
	16/01/2007	30/01/2007	0.19
	30/01/2007	13/02/2007	0.26
	13/02/2007	27/02/2007	0.32
	27/02/2007	13/03/2007	0.15
	13/03/2007	27/03/2007	0.23
	27/03/2007	10/04/2007	0.19
	10/04/2007	24/04/2007	0.12
	24/04/2007	08/05/2007	0.14
	08/05/2007	22/05/2007	0.17
	22/05/2007	05/06/2007	0.14
	05/06/2007	19/06/2007	0.16
	19/06/2007	02/07/2007	0.16
	02/07/2007	16/07/2007	0.11
	17/07/2007	31/07/2007	0.09
	31/07/2007	14/08/2007	0.14
	14/08/2007	28/08/2007	0.08
	28/08/2007	10/09/2007	0.08
	11/09/2007	26/09/2007	0.09
	26/09/2007	09/10/2007	0.31
	09/10/2007	23/10/2007	0.17
	23/10/2007	06/11/2007	0.37
	06/11/2007	20/11/2007	0.21
	20/11/2007	04/12/2007	0.15
	04/12/2007	18/12/2007	0.31
Northampton	12/01/2007	25/01/2007	0.23
	25/01/2007	09/02/2007	0.36

Site	Start Date	End Date	Benzene Concentration, ppb
	09/02/2007	22/02/2007	0.17
	22/02/2007	08/03/2007	0.15
	08/03/2007	22/03/2007	0.22
	22/03/2007	05/04/2007	0.28
	05/04/2007	19/04/2007	0.31
	19/04/2007	03/05/2007	0.08
	03/05/2007	17/05/2007	0.07
	17/05/2007	31/05/2007	0.14
	31/05/2007	14/06/2007	0.18
	14/06/2007	28/06/2007	0.09
	28/06/2007	12/07/2007	0.09
	12/07/2007	26/07/2007	0.11
	26/07/2007	10/08/2007	0.13
	10/08/2007	23/08/2007	0.11
	23/08/2007	06/09/2007	0.14
	06/09/2007	20/09/2007	0.14
	20/09/2007	04/10/2007	0.16
	04/10/2007	18/10/2007	0.16
	18/10/2007	01/11/2007	0.24
	01/11/2007	15/11/2007	0.28
	15/11/2007	29/11/2007	0.34
	29/11/2007	13/12/2007	0.24
	13/12/2007	27/12/2007	0.33
Norwich Centre	02/01/2007	18/01/2007	0.27
	18/01/2007	29/01/2007	0.39
	29/01/2007	12/02/2007	0.34
	12/02/2007	26/02/2007	0.30
	26/02/2007	13/03/2007	0.27
	13/03/2007	28/03/2007	0.35
	28/03/2007	11/04/2007	0.25
	11/04/2007	24/04/2007	0.12
	24/04/2007	11/05/2007	0.14
	11/05/2007	24/05/2007	0.21
	24/05/2007	08/06/2007	0.13
	08/06/2007	22/06/2007	0.17
	22/06/2007	06/07/2007	0.13
	06/07/2007	20/07/2007	0.18
	20/07/2007	02/08/2007	0.11
	02/08/2007	15/08/2007	0.23
	15/08/2007	30/08/2007	0.12
	30/08/2007	28/09/2007	0.13

Site	Start Date	End Date	Benzene Concentration, ppb
Nottingham Centre	28/09/2007	12/10/2007	0.18
	12/10/2007	25/10/2007	0.33
	25/10/2007	09/11/2007	0.28
	09/11/2007	23/11/2007	0.28
	23/11/2007	11/12/2007	0.25
	11/12/2007	21/12/2007	0.60
	03/01/2007	17/01/2007	0.33
	17/01/2007	31/01/2007	0.24
	31/01/2007	14/02/2007	0.48
	14/02/2007	28/02/2007	0.31
	28/02/2007	15/03/2007	0.19
	15/03/2007	28/03/2007	0.34
	28/03/2007	11/04/2007	0.30
	11/04/2007	25/04/2007	0.28
	25/04/2007	09/05/2007	0.14
	09/05/2007	23/05/2007	0.24
	23/05/2007	06/06/2007	0.19
	06/06/2007	20/06/2007	0.24
	20/06/2007	05/07/2007	0.17
	05/07/2007	18/07/2007	0.20
	18/07/2007	01/08/2007	0.17
	01/08/2007	16/08/2007	0.17
	16/08/2007	30/08/2007	0.17
	30/08/2007	12/09/2007	0.19
	12/09/2007	26/09/2007	0.17
	26/09/2007	10/10/2007	0.27
	10/10/2007	24/10/2007	0.36
	24/10/2007	14/11/2007	0.29
	14/11/2007	28/11/2007	0.34
	28/11/2007	11/12/2007	0.23
	11/12/2007	27/12/2007	0.41
Oxford Centre	02/01/2007	15/01/2007	0.17
	15/01/2007	29/01/2007	0.18
	29/01/2007	12/02/2007	0.53
	12/02/2007	26/02/2007	0.28
	26/02/2007	12/03/2007	0.24
	12/03/2007	26/03/2007	0.31
	26/03/2007	11/04/2007	0.35
	11/04/2007	26/04/2007	0.19
	26/04/2007	14/05/2007	0.10

Site	Start Date	End Date	Benzene Concentration, ppb
Plymouth	14/05/2007	04/06/2007	0.19
	04/06/2007	18/06/2007	0.16
	18/06/2007	02/07/2007	0.19
	02/07/2007	19/07/2007	0.13
	19/07/2007	07/08/2007	0.22
	07/08/2007	17/08/2007	0.23
	17/08/2007	30/08/2007	0.17
	30/08/2007	17/09/2007	0.19
	17/09/2007	08/10/2007	0.15
	08/10/2007	26/10/2007	0.30
	26/10/2007	12/11/2007	0.43
	12/11/2007	26/11/2007	0.39
	26/11/2007	13/12/2007	0.17
	04/01/2007	16/01/2007	0.20
	16/01/2007	30/01/2007	0.22
	30/01/2007	13/02/2007	0.34
	13/02/2007	27/02/2007	0.18
	27/02/2007	13/03/2007	0.18
	13/03/2007	27/03/2007	0.31
	27/03/2007	10/04/2007	0.27
	10/04/2007	24/04/2007	0.17
	24/04/2007	08/05/2007	0.14
	08/05/2007	23/05/2007	0.13
	23/05/2007	06/06/2007	0.17
	06/06/2007	22/06/2007	0.10
	22/06/2007	03/07/2007	0.12
	03/07/2007	17/07/2007	0.12
	17/07/2007	01/08/2007	0.12
	01/08/2007	15/08/2007	0.13
	15/08/2007	30/08/2007	0.10
	30/08/2007	11/09/2007	0.16
	11/09/2007	26/09/2007	0.11
	26/09/2007	25/10/2007	0.24
	25/10/2007	06/11/2007	0.34
	06/11/2007	20/11/2007	0.21
	20/11/2007	04/12/2007	0.21
	04/12/2007	18/12/2007	0.24
	18/12/2007	03/01/2008	0.38
Portsmouth	12/01/2007	31/01/2007	0.24
	31/01/2007	13/02/2007	0.37

Site	Start Date	End Date	Benzene Concentration, ppb
Reading	13/02/2007	21/03/2007	0.20
	21/03/2007	04/04/2007	0.32
	04/04/2007	26/04/2007	0.13
	26/04/2007	18/05/2007	0.09
	18/05/2007	08/06/2007	0.18
	08/06/2007	03/07/2007	0.13
	03/07/2007	17/07/2007	0.10
	17/07/2007	03/08/2007	0.19
	02/01/2007	16/01/2007	0.25
	16/01/2007	30/01/2007	0.21
	30/01/2007	13/02/2007	0.52
	13/02/2007	27/02/2007	0.25
	27/02/2007	13/03/2007	0.16
	13/03/2007	27/03/2007	0.34
	27/03/2007	10/04/2007	0.30
	10/04/2007	24/04/2007	0.14
	08/05/2007	22/05/2007	0.13
	22/05/2007	05/06/2007	0.18
	05/06/2007	19/06/2007	0.13
	19/06/2007	02/07/2007	0.12
	02/07/2007	17/07/2007	0.11
	17/07/2007	31/07/2007	0.11
	31/07/2007	14/08/2007	0.18
	14/08/2007	28/08/2007	0.11
	28/08/2007	11/09/2007	0.17
	11/09/2007	25/09/2007	0.14
	25/09/2007	11/10/2007	0.32
	06/11/2007	20/11/2007	0.58
	20/11/2007	04/12/2007	0.18
Sheffield	11/01/2007	29/01/2007	0.36
	29/01/2007	08/02/2007	0.58
	08/02/2007	20/02/2007	0.41
	20/02/2007	08/03/2007	0.24
	08/03/2007	21/03/2007	0.39
	21/03/2007	03/04/2007	0.49
	03/04/2007	18/04/2007	0.51
	18/04/2007	08/05/2007	0.58
	08/05/2007	16/05/2007	0.16
	16/05/2007	30/05/2007	0.15
	30/05/2007	12/06/2007	0.34

Site	Start Date	End Date	Benzene Concentration, ppb
Southampton	12/06/2007	28/06/2007	0.19
	28/06/2007	11/07/2007	0.11
	11/07/2007	25/07/2007	0.17
	25/07/2007	08/08/2007	0.11
	08/08/2007	22/08/2007	0.15
	22/08/2007	05/09/2007	0.11
	05/09/2007	19/09/2007	0.19
	19/09/2007	03/10/2007	0.23
	03/10/2007	18/10/2007	0.23
	18/10/2007	01/11/2007	0.28
	01/11/2007	13/11/2007	0.21
	13/11/2007	28/11/2007	0.37
	28/11/2007	13/12/2007	0.23
	13/12/2007	24/12/2007	0.49
	02/01/2007	16/01/2007	0.22
	16/01/2007	30/01/2007	0.33
	30/01/2007	13/02/2007	0.43
	13/02/2007	27/02/2007	0.40
	27/02/2007	13/03/2007	0.21
	13/03/2007	27/03/2007	0.37
	27/03/2007	10/04/2007	0.35
	10/04/2007	24/04/2007	0.18
	24/04/2007	08/05/2007	0.17
	08/05/2007	22/05/2007	0.20
	22/05/2007	05/06/2007	0.19
	05/06/2007	19/06/2007	0.18
	19/06/2007	02/07/2007	0.22
	02/07/2007	17/07/2007	0.19
	17/07/2007	31/07/2007	0.17
	31/07/2007	14/08/2007	0.26
	14/08/2007	28/08/2007	0.16
	28/08/2007	11/09/2007	0.26
	11/09/2007	25/09/2007	0.17
	25/09/2007	09/10/2007	0.38
	09/10/2007	25/10/2007	0.36
	25/10/2007	06/11/2007	0.70
	06/11/2007	20/11/2007	0.47
	20/11/2007	04/12/2007	0.23
	04/12/2007	18/12/2007	0.46
	18/12/2007	02/01/2008	0.76
Southend-on-Sea			

Site	Start Date	End Date	Benzene Concentration, ppb
	02/01/2007	16/01/2007	0.15
	16/01/2007	30/01/2007	0.23
	30/01/2007	13/02/2007	0.57
	13/02/2007	23/02/2007	0.18
	23/02/2007	12/03/2007	0.16
	12/03/2007	27/03/2007	0.34
	27/03/2007	11/04/2007	0.30
	11/04/2007	24/04/2007	0.13
	24/04/2007	08/05/2007	0.18
	08/05/2007	22/05/2007	0.17
	22/05/2007	05/06/2007	0.16
	05/06/2007	19/06/2007	0.15
	19/06/2007	03/07/2007	0.13
	03/07/2007	17/07/2007	0.13
	17/07/2007	31/07/2007	0.09
	31/07/2007	14/08/2007	0.14
	14/08/2007	28/08/2007	0.11
	28/08/2007	11/09/2007	0.14
	11/09/2007	25/09/2007	0.10
	25/09/2007	09/10/2007	0.25
Stoke Centre	03/01/2007	17/01/2007	0.24
	17/01/2007	15/02/2007	0.71
	15/02/2007	28/02/2007	0.34
	28/02/2007	14/03/2007	0.26
	14/03/2007	28/03/2007	0.38
	28/03/2007	11/04/2007	0.36
	11/04/2007	25/04/2007	0.40
	25/04/2007	10/05/2007	0.15
	10/05/2007	23/05/2007	0.31
	23/05/2007	06/06/2007	0.22
	06/06/2007	20/06/2007	0.25
	20/06/2007	04/07/2007	0.24
	04/07/2007	18/07/2007	0.19
	18/07/2007	01/08/2007	0.21
	01/08/2007	15/08/2007	0.24
	15/08/2007	29/08/2007	0.27
	29/08/2007	12/09/2007	0.37
	12/09/2007	26/09/2007	0.25
	26/09/2007	10/10/2007	0.52
	10/10/2007	24/10/2007	0.33
	24/10/2007	07/11/2007	0.43

Site	Start Date	End Date	Benzene Concentration, ppb
Wigan Centre	07/11/2007	21/11/2007	0.25
	21/11/2007	05/12/2007	0.34
	05/12/2007	19/12/2007	0.36
	19/12/2007	02/01/2008	0.32
	11/01/2007	25/01/2007	0.24
	25/01/2007	09/02/2007	0.40
	09/02/2007	28/02/2007	0.28
	23/02/2007	09/03/2007	0.15
	09/03/2007	22/03/2007	0.22
	22/03/2007	05/04/2007	0.24
	05/04/2007	19/04/2007	0.31
	19/04/2007	30/04/2007	0.15
	30/04/2007	15/05/2007	0.16
	15/05/2007	04/06/2007	0.11
	04/06/2007	15/06/2007	0.20
	15/06/2007	26/06/2007	0.10
	27/06/2007	09/07/2007	0.09
	09/07/2007	26/07/2007	0.17
	26/07/2007	06/08/2007	0.14
	06/08/2007	23/08/2007	0.12
	23/08/2007	05/09/2007	0.24
	05/09/2007	21/09/2007	0.17
	21/09/2007	01/10/2007	0.14
	01/10/2007	25/10/2007	0.25
	25/10/2007	05/11/2007	0.31
	05/11/2007	21/11/2007	0.21
	21/11/2007	04/12/2007	0.26
	04/12/2007	17/12/2007	0.24
	17/12/2007	03/01/2008	0.38
Yarm	05/01/2007	17/01/2007	0.41
	17/01/2007	31/01/2007	0.46
	31/01/2007	14/02/2007	1.26
	14/02/2007	28/02/2007	0.61
	28/02/2007	14/03/2007	0.49
	14/03/2007	03/04/2007	0.51
	03/04/2007	16/04/2007	0.63
	16/04/2007	01/05/2007	0.24
	01/05/2007	15/05/2007	0.56
	15/05/2007	29/05/2007	0.35
	29/05/2007	12/06/2007	0.62

Site	Start Date	End Date	Benzene Concentration, ppb
	12/06/2007	05/07/2007	0.70
	05/07/2007	18/07/2007	0.50
	18/07/2007	01/08/2007	0.45
	01/08/2007	15/08/2007	0.51
	15/08/2007	29/08/2007	0.35
	29/08/2007	12/09/2007	0.37
	12/09/2007	26/09/2007	0.29
	26/09/2007	10/10/2007	1.00
	10/10/2007	29/10/2007	0.84
	29/10/2007	12/11/2007	0.49
	12/11/2007	28/11/2007	0.70
	28/11/2007	12/12/2007	0.39
	12/12/2007	02/01/2008	0.59

1,3-butadiene

Site	Start Date	End Date	1,3-butadiene concentration, ppb
Belfast Centre	09/01/2007	23/01/2007	0.07
	23/01/2007	06/02/2007	0.02
	06/02/2007	20/02/2007	0.01
	20/02/2007	06/03/2007	0.01
	06/03/2007	20/03/2007	0.03
	20/03/2007	03/04/2007	0.06
	03/04/2007	17/04/2007	0.04
	17/04/2007	01/05/2007	0.05
	01/05/2007	15/05/2007	0.03
	15/05/2007	29/05/2007	0.02
	29/05/2007	12/06/2007	0.01
	12/06/2007	26/06/2007	0.01
	10/07/2007	24/07/2007	0.02
	24/07/2007	07/08/2007	0.18
	07/08/2007	21/08/2007	0.01
	21/08/2007	04/09/2007	0.04
	04/09/2007	18/09/2007	0.06
Belfast Roadside	09/01/2007	23/01/2007	0.01
	23/01/2007	06/02/2007	0.07
	06/02/2007	20/02/2007	0.01

Site	Start Date	End Date	1,3-butadiene concentration, ppb
Birmingham Roadside	20/02/2007	06/03/2007	0.01
	06/03/2007	20/03/2007	0.02
	20/03/2007	03/04/2007	0.10
	03/04/2007	17/04/2007	0.09
	17/04/2007	01/05/2007	0.06
	01/05/2007	15/05/2007	0.05
	15/05/2007	29/05/2007	0.01
	29/05/2007	12/06/2007	0.01
	12/06/2007	26/06/2007	0.01
	26/06/2007	10/07/2007	0.01
	10/07/2007	24/07/2007	0.03
	24/07/2007	07/08/2007	0.03
	07/08/2007	21/08/2007	0.04
	21/08/2007	04/09/2007	0.07
	04/09/2007	18/09/2007	0.08
	04/01/2007	18/01/2007	0.01
	18/01/2007	15/02/2007	0.03
	15/02/2007	01/03/2007	0.02
Bristol Old Market	01/03/2007	15/03/2007	0.03
	15/03/2007	29/03/2007	0.13
	29/03/2007	13/04/2007	0.12
	13/04/2007	27/04/2007	0.11
	27/04/2007	10/05/2007	0.09
	10/05/2007	24/05/2007	0.07
	24/05/2007	07/06/2007	0.10
	07/06/2007	21/06/2007	0.02
	13/07/2007	19/07/2007	0.09
	19/07/2007	02/08/2007	0.11
	02/08/2007	16/08/2007	0.06
	16/08/2007	30/08/2007	0.17
	30/08/2007	13/09/2007	0.14
	13/09/2007	27/09/2007	0.12
	10/01/2007	24/01/2007	0.02
	24/01/2007	07/02/2007	0.15
	07/02/2007	21/02/2007	0.06
	21/02/2007	07/03/2007	0.01
	07/03/2007	21/03/2007	0.08
	21/03/2007	03/04/2007	0.11
	03/04/2007	18/04/2007	0.08
	18/04/2007	03/05/2007	0.08

Site	Start Date	End Date	1,3-butadiene concentration, ppb
Grangemouth	03/05/2007	16/05/2007	0.04
	16/05/2007	30/05/2007	0.03
	30/05/2007	13/06/2007	0.03
	13/06/2007	27/06/2007	0.03
	27/06/2007	11/07/2007	0.06
	11/07/2007	25/07/2007	0.03
	25/07/2007	08/08/2007	0.07
	08/08/2007	22/08/2007	0.07
	22/08/2007	05/09/2007	0.13
	05/09/2007	19/09/2007	0.12
	04/01/2007	25/01/2007	0.01
	25/01/2007	05/02/2007	0.02
	06/02/2007	07/03/2007	0.23
	07/03/2007	23/03/2007	0.08
	23/03/2007	13/04/2007	0.31
	13/04/2007	27/04/2007	0.36
	27/04/2007	22/05/2007	0.29
	22/05/2007	11/06/2007	0.36
	11/06/2007	05/07/2007	0.01
	05/07/2007	23/07/2007	0.05
Haringey Roadside	23/07/2007	06/08/2007	0.01
	06/08/2007	23/08/2007	0.25
	23/08/2007	06/09/2007	0.15
	29/12/2006	19/01/2007	0.01
	19/01/2007	01/02/2007	0.01
	01/02/2007	20/02/2007	0.01
	20/02/2007	13/03/2007	0.07
	13/03/2007	30/03/2007	0.05
	30/03/2007	13/04/2007	0.11
	13/04/2007	27/04/2007	0.09
	27/04/2007	10/05/2007	0.04
	10/05/2007	25/05/2007	0.06
	25/05/2007	08/06/2007	0.03
	08/06/2007	22/06/2007	0.02
	22/06/2007	06/07/2007	0.03
	06/07/2007	24/07/2007	0.01
	24/07/2007	03/08/2007	0.03
	03/08/2007	16/08/2007	0.07
	16/08/2007	30/08/2007	0.06
	30/08/2007	14/09/2007	0.08

Site	Start Date	End Date	1,3-butadiene concentration, ppb
Leeds Centre	14/09/2007	28/09/2007	0.07
	03/01/2007	17/01/2007	0.01
	17/01/2007	31/01/2007	0.01
	31/01/2007	14/02/2007	0.01
	14/02/2007	28/02/2007	0.01
	28/02/2007	14/03/2007	0.03
	14/03/2007	28/03/2007	0.05
	28/03/2007	11/04/2007	0.06
	11/04/2007	25/04/2007	0.05
	25/04/2007	09/05/2007	0.10
	09/05/2007	23/05/2007	0.12
	23/05/2007	06/06/2007	0.03
	06/06/2007	20/06/2007	0.01
	20/06/2007	04/07/2007	0.01
	04/07/2007	18/07/2007	0.01
	18/07/2007	01/08/2007	0.04
	01/08/2007	15/08/2007	0.01
	15/08/2007	29/08/2007	0.01
	29/08/2007	14/09/2007	0.05
Leeds Roadside	02/01/2007	18/01/2007	0.01
	18/01/2007	06/02/2007	0.12
	06/02/2007	22/02/2007	0.01
	22/02/2007	15/03/2007	0.04
	15/03/2007	05/04/2007	0.09
	05/04/2007	19/04/2007	0.11
	19/04/2007	01/05/2007	0.11
	01/05/2007	17/05/2007	0.04
	17/05/2007	01/06/2007	0.07
	01/06/2007	19/06/2007	0.01
	19/06/2007	06/07/2007	0.01
	06/07/2007	17/07/2007	0.02
	17/07/2007	31/07/2007	0.04
	31/07/2007	15/08/2007	0.01
	15/08/2007	30/08/2007	0.07
Middlesbrough	02/01/2007	16/01/2007	0.01
	16/01/2007	30/01/2007	0.02
	30/01/2007	13/02/2007	0.01
	13/02/2007	27/02/2007	0.01
	27/02/2007	13/03/2007	0.01

Site	Start Date	End Date	1,3-butadiene concentration, ppb
	13/03/2007	27/03/2007	0.08
	27/03/2007	10/04/2007	0.07
	10/04/2007	24/04/2007	0.10
	24/04/2007	08/05/2007	0.13
	08/05/2007	21/05/2007	0.17
	21/05/2007	05/06/2007	0.02
	05/06/2007	19/06/2007	0.01
	19/06/2007	03/07/2007	0.02
	03/07/2007	17/07/2007	0.01
	17/07/2007	31/07/2007	0.13
	31/07/2007	14/08/2007	0.01
	04/09/2007	11/09/2007	0.13
	11/09/2007	19/09/2007	0.20

Annex 2 – Audit schedule

Site	Date	Date	Date
Barnsley Gawber	20/03/2007	17/10/2007	
Belfast Centre	25/04/2007	09/10/2007	
Belfast Roadside	25/04/2007	09/10/2007	
Birmingham Roadside	07/03/2007	13/07/2007	22/08/2007
Birmingham Tyburn	18/12/2007		
Bloomsbury	29/06/2007	06/07/2007	16/11/2007
Bournemouth	10/04/2007	26/10/2007	
Bristol Old Market	23/05/2007	14/11/2007	
Camden Kerbside	19/12/2007		
Coventry Memorial Park	03/04/2007	19/10/2007	
Cwmbran	22/05/2007	31/10/2007	
Edinburgh St Leonard's	01/05/2007	27/11/2007	
Grangemouth	01/05/2007	27/11/2007	
Haringey Roadside	11/04/2007	01/11/2007	
Hove Roadside	18/04/2007	05/12/2007	
Hull Freetown	19/06/2007	16/11/2007	
Leamington Spa	03/04/2007	18/10/2007	
Leeds Centre	27/03/2007	19/09/2007	
Leeds Roadside	27/03/2007	19/09/2007	11/12/2007
Leicester Centre	08/06/2007	12/12/2007	
Liverpool Speke	13/02/2007	08/10/2007	
Manchester Piccadilly	12/02/2007	03/09/2007	
Marylebone Rd	09/01/2007	06/07/2007	07/12/2007
Middlesbrough	19/06/2007	19/09/2007	
Newcastle	26/06/2007	11/12/2007	
Northampton	03/04/2007	18/10/2007	
Norwich Centre	16/05/2007	08/11/2007	
Nottingham Centre	21/03/2007	23/10/2007	
Oxford Centre	05/07/2007	06/12/2007	
Plymouth	06/06/2007	13/11/2007	
Portsmouth	14/03/2007	25/10/2007	
Reading	12/07/2007	04/12/2007	
Sheffield	27/03/2007	22/09/2007	
Southampton	13/03/2007	18/09/2007	
Southend-on-Sea	11/04/2007	30/10/2007	
Stoke Centre	20/03/2007	05/09/2007	
Wigan Centre	13/02/2007	03/09/2007	
Yarm	20/06/2007	11/12/2007	

Birmingham Tyburn and Camden Kerbside were only visited once in 2007, as they were new site installations.