

Air Quality Monitoring in Jersey 2009

Report to Public Health Services, States of Jersey

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AEA group
551.11 Harwell Business Centre
DIDCOT
Oxfordshire
OX11 0QJ

t: 0870 190 6518
f: 0870 190 6377

AEA is a business name of AEA Technology plc

AEA is certificated to ISO9001 and ISO14001

Author	Name	Alison Loader
Approved by	Name	Brian Stacey
	Signature	
	Date	Mar 2010

Executive summary

This report presents the results for 2009 of an ongoing programme of air quality monitoring in Jersey, carried out by AEA on behalf of the Public Health Services and Planning and Environment Department of the States of Jersey.

An automatic monitoring station for nitrogen dioxide (NO₂) was located in the Central Market, Halkett Place, St Helier. This has been in operation since January 2008, so this is its second full year of monitoring. In addition, non-automatic diffusion tube samplers were used for indicative monitoring of nitrogen dioxide (NO₂) at 12 sites, and a suite of four hydrocarbons (benzene, toluene, ethylbenzene and xylenes) at a further six sites. Monitoring sites included areas likely to be affected by specific emission sources (such as petrol stations or the waste incinerator), as well as general background locations. This non-automatic monitoring programme continued a long-term monitoring programme that has operated in Jersey for the past 13 years.

NO₂ and hydrocarbon diffusion tubes were exposed for twelve periods approximating to calendar months. The tubes were supplied and analysed by Gradko International Ltd, and changed by Technical Officers of Jersey's Environmental Health Section.

The automatic monitoring site at Halkett Place met the EC Directive Limit Value (and AQS Objective) for both the 1-hour mean NO₂ concentration and the annual mean NO₂ concentration.

Annual mean concentrations of NO₂ at all twelve diffusion tube monitoring sites were within the EC Directive Limit Value, and were generally comparable with the previous year's results.

Data from long-running diffusion tube sites confirm that levels of NO₂ at urban roadside and kerbside sites continued to decrease in 2009. NO₂ concentrations at residential and rural background sites do not appear to show any upward or downward trend, but are already low.

The diurnal pattern in concentrations of oxides of nitrogen at Halkett Place showed a clear peak in the early morning (0600 – 0800). This is thought to reflect the early morning activity of market retailers arriving to set up for the day, and of daily refuse collections.

Five of the six hydrocarbon monitoring sites met the EC Directive Limit Value for benzene (5 µg m⁻³ as an annual mean, to be achieved by 2010). The sixth site, Springfield Garage, was located on the forecourt of a petrol station and had no relevant exposure. This site was re-located in June 2009 to Faux Bie Terrace (the nearest housing). The five-month mean for January to May 2009 at Springfield Garage was 5.5 µg m⁻³. The seven-month mean for the remainder of the year, measured at Faux Bie, was 1.3 µg m⁻³, well within the EC Limit Value and comparable with other urban benzene monitoring sites.

Hydrocarbon concentrations (particularly that of benzene) are typically lower than during the earlier years of the survey.

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1 Introduction

1.1 Background

AEA, on behalf of the States of Jersey Public Health Services, has undertaken a further programme of air quality monitoring on the island of Jersey in 2009. This is the thirteenth in a series of extensive annual monitoring programmes that began in 1997, and has since provided a long-term dataset of pollutant concentrations.

The pollutants measured were nitrogen dioxide (NO₂), and a range of hydrocarbon species (benzene, toluene, ethyl benzene and three xylene compounds). An automatic monitoring station at Halkett Place was used to monitor NO₂. This was supplemented by indicative monitoring of NO₂ using low cost passive samplers (Palmer type diffusion tubes) at 12 sites on the island. In addition, the suite of four hydrocarbons was monitored using “BTEX” diffusion tubes at six sites.

This report presents the results obtained in the 2009 survey, and compares the data from Jersey with relevant air quality Limit Values, Objectives and guidelines, data from selected UK monitoring stations and previous years' monitoring programmes.

1.2 Objectives

This survey follows on from those in the years 1997 to 2008^{1,2,3,4,5,6,7,8,9,10,11,12}. The objective, as in previous surveys, was to monitor at sites where pollutant concentrations were expected to be high, and compare these with background locations. The monitoring sites consisted of a mixture of urban and rural background sites, together with some locations where higher pollutant concentrations might be expected, such as roadside and kerbside sites, and some close to specific emission sources.

2 Details of Monitoring Programme

2.1 Pollutants Monitored

2.1.1 NO₂

A mixture of nitrogen dioxide (NO₂) and nitric oxide (NO) is emitted by combustion processes. This mixture of oxides of nitrogen is termed NO_x. NO is subsequently oxidised to NO₂ in the atmosphere. NO₂ is an irritant to the respiratory system, and can affect human health. Ambient concentrations of NO₂ are likely to be highest in the most built-up areas, especially where traffic is congested, or where buildings either side of the street create a “canyon” effect, impeding the dispersion of vehicle emissions. The units used for NO₂ concentration in this report are microgrammes per cubic metre ($\mu\text{g m}^{-3}$). Some earlier reports in this series have used parts per billion (ppb): to convert from $\mu\text{g m}^{-3}$ to ppb for comparison with the earlier reports if required, the following relationship should be used:

1 $\mu\text{g m}^{-3}$ = 0.523 ppb for nitrogen dioxide at 293K (20°C) and 1013mb.

2.1.2 Hydrocarbons

There are many sources of hydrocarbon emissions. Methane, for example, is a naturally occurring gas, while xylene compounds are synthetic and used in many applications, for example as a solvent in paint. A range of hydrocarbons is found in vehicle fuel, and occur in vehicle emissions. In most urban areas, vehicle emissions constitute the major source of hydrocarbons, in particular benzene. Also, there is the potential that they may be released to the air from facilities where fuels are stored or handled (such as petrol stations).

A wide range of hydrocarbons is emitted from both fuel storage and handling, and from fuel combustion in vehicles. It is not easy to measure all of these hydrocarbon species (particularly the most volatile) without expensive continuous monitoring systems. However, there are four species associated with fuels and vehicle emissions which, though not the largest constituent of such emissions, are easy to monitor using passive samplers due to their moderate volatility. These are benzene, toluene, ethyl benzene and xylene. Diffusion tubes are available for monitoring this group of organic compounds, and are known as “BTEX” tubes (BTEX being an acronym for the compounds measured).

(i) Benzene

Of the organic compounds measured in this study, benzene is the one of most concern, as it is a known human carcinogen; long-term exposure can cause leukaemia. It is found in petrol and other liquid fuels, in small concentrations. In urban areas, the major source is vehicle emissions. In the UK, annual mean benzene concentrations in ambient air are typically less than $3 \mu\text{g m}^{-3}$. In this report, concentrations of benzene are expressed in microgrammes per cubic metre ($\mu\text{g m}^{-3}$). Some earlier reports in the series used parts per billion (ppb): to convert to ppb to if necessary, the following relationship should be used:

1 $\mu\text{g m}^{-3}$ = 0.307 ppb for benzene at 293K (20°C) and 1013mb.
(only applicable to benzene).

(ii) Toluene

Toluene is also found in petrol in small concentrations. Its primary use is as a solvent in paints and inks; it is also a constituent of tobacco smoke. It has been found to adversely affect human health. Typical ambient concentrations range from trace to $3.8 \mu\text{g m}^{-3}$ in rural areas, up to $204 \mu\text{g m}^{-3}$ in urban areas, and higher near industrial sources. There are no recommended limits for ambient toluene concentrations, although there are occupational limits for workplace exposure¹³. The best estimate for the odour threshold of toluene has been reported as 0.16ppm ($613 \mu\text{g m}^{-3}$)¹⁴. In the present report,

concentrations are expressed in microgrammes per cubic metre ($\mu\text{g m}^{-3}$). Some earlier reports in the series used parts per billion (ppb): to convert to ppb to if necessary, the following relationship should be used:

$1 \mu\text{g m}^{-3} = 0.261 \text{ ppb}$ for toluene at 293K (20°C) and 1013mb.
(only applicable to toluene).

(iii)ethyl benzene

Again, there are no limits for ambient concentration of ethyl benzene, and although there are occupational limits relating to workplace exposure¹³, as discussed in previous reports in this series, they are several orders of magnitude higher than typical outdoor ambient concentrations.

(iv)xylene

Xylene exists in ortho (o), para (p) and meta (m) isomers. Occupational limits relating to workplace exposure, are 100 ppm over 8 hours, and 150 ppm over 10 minutes. Xylene, like toluene, can cause odour nuisance near processes (such as vehicle paint spraying), which emit it. Its odour threshold varies according to the isomer, but the best estimate for the odour threshold of mixed xylenes is 0.016ppm (16 ppb or $70 \mu\text{g m}^{-3}$)¹⁴.

In this report, concentrations of ethylbenzene and xylenes are expressed in microgrammes per cubic metre ($\mu\text{g m}^{-3}$). Some earlier reports in this series used parts per billion (ppb): to convert to ppb to if required, the following relationship should be used:

$1 \mu\text{g m}^{-3} = 0.226 \text{ ppb}$ for ethyl benzene or xylenes at 293K (20°C) and 1013mb.
(applicable to ethylbenzene, m-, p- and o-xylene).

2.2 Air Quality Limit Values And Objectives

This report compares the results of the monitoring survey with air quality Limit Values and Objectives applicable worldwide, in Europe and the UK. These are summarized in Appendix 1 and below.

2.2.1 World Health Organisation

In 2000, the World Health Organisation published revised air quality guidelines¹⁵ for pollutants including NO₂. These were set using currently available scientific evidence on the effects of air pollutants on health and vegetation. The WHO guidelines are advisory only, and do not carry any mandatory status. They are summarised in Appendix 1. There are WHO guidelines for ambient NO₂ concentrations (hourly and annual means) but not benzene. The WHO non-mandatory guideline¹⁴ for NO₂ is that the annual mean should not exceed $40 \mu\text{g m}^{-3}$.

2.2.2 European Community

Throughout Europe, ambient air quality is regulated by the EC Directive on Ambient Air Quality and Cleaner Air for Europe (2008/50/EC)¹⁶. This Directive sets Limit Values, which are mandatory, and other requirements for the protection of human health and ecosystems. Both NO₂ and benzene are covered by this Directive. The States of Jersey have agreed to meet the EU health limits.

The EC Directive on Ambient Air Quality and Cleaner Air for Europe¹⁶ contains Limit Values for NO₂ as follows:

- $200 \mu\text{g m}^{-3}$ as an hourly mean, not to be exceeded more than 18 times per calendar year. To be achieved by 1st January 2010.
- $40 \mu\text{g m}^{-3}$ as an annual mean, for protection of human health. To be achieved by 1st January 2010.

- There is also a limit for annual mean total oxides of nitrogen (NO_x), of 30 µg m⁻³, for protection of vegetation (relevant in rural areas).

The EC Directive on Ambient Air Quality and Cleaner Air for Europe¹⁶ sets a limit of 5 µg m⁻³ for annual mean benzene, to be achieved by 2010.

2.2.3 UK Air Quality Strategy

The UK Air Quality Strategy (AQS) contains standards and objectives for a range of pollutants including NO₂ and benzene¹⁷. These are also summarised in Appendix 1. Only those Objectives relating to the whole UK (as opposed to specifically England, Wales, etc.) are applicable to Jersey, and the AQS does not at present have mandatory status in the States of Jersey.

The UK Air Quality Strategy's objectives for NO₂ are very similar to the EC Directive limits above: the only difference being that they had to be achieved by 31st December 2005

The UK Air Quality Strategy¹⁷ sets the following objectives for benzene:

- 16.25 µg m⁻³ (for the running annual mean), to have been achieved by 31st December 2003
- 3.25 µg m⁻³ (for the calendar year mean in Scotland and Northern Ireland), to be achieved by 31st December 2010.
- 5 µg m⁻³ (for the calendar year mean in England and Wales), to be achieved by 31st December 2010.

Both the 2010 benzene objectives apply to specific parts of the UK only, so strictly speaking do not apply in Jersey. However, the objective of 5 µg m⁻³ applicable to England and Wales is the same as the EC Directive Limit Value, which is applicable.

2.3 Methodologies

Oxides of nitrogen were monitored using a chemiluminescent analyser, located at the Central Market, Halkett Place, St Helier. This automatic monitoring site started operation in January 2008.

The chemiluminescent NO_x analyser provides a continuous output, proportional to the pollutant concentration. This output is recorded and stored every 10 seconds, and averaged to 15-minute average values by internal data loggers. The analysers are connected to a modem and interrogated by telephone to download the data to AEA. Data are downloaded daily and uploaded onto the publicly available website www.jerseymet.gov.je

The automatic monitoring site at Halkett Place was supplemented by indicative monitoring, using diffusion tubes, for NO₂ and BTEX hydrocarbons. Diffusion tubes are "passive" samplers, i.e. they work by absorbing the pollutants direct from the surrounding air and need no power supply.

Palmes-type diffusion tubes were used for NO₂. These consist of a small plastic tube, approximately 7 cm long. During sampling, one end is open and the other closed. The closed end contains an absorbent for the gaseous species to be monitored, in this case NO₂. The tube is mounted vertically with the open end at the bottom. Ambient NO₂ diffuses up the tube during exposure, and is absorbed as nitrite. The average ambient pollutant concentration for the exposure period is calculated from the amount of pollutant absorbed.

BTEX diffusion tubes are different in appearance to NO₂ tubes. They are longer, thinner, and made of metal rather than plastic. These tubes are fitted at both ends with brass Swagelok fittings. A separate "diffusion cap" is supplied. Immediately before exposure, the Swagelok end fitting is replaced with the diffusion cap. The cap is removed after exposure, and is replaced with the Swagelok fitting. BTEX diffusion tubes are very sensitive to interference by solvents.

Diffusion tubes were prepared and analysed by Gradko International Ltd. They were supplied to local Technical Officers of Jersey's Public Health Services, who carried out the tube changing. The tubes

were supplied in sealed condition prior to exposure. The tubes were exposed at the sites for a set period of time. After exposure, the tubes were again sealed and returned to Gradko for analysis. The year was divided into twelve exposure periods approximating to calendar months. The duration of the exposure periods varied between four and five weeks.

Diffusion tubes are an indicative technique, and the results therefore have a greater uncertainty than those of more sophisticated automatic methods. The laboratory states that the margins of uncertainty on the diffusion tube analyses are typically $\pm 3.5\%$ for NO_2 and $\pm 9\%$ for BTEX hydrocarbons. However, uncertainties arising from the exposure phase also contribute to the overall uncertainty: it is usually estimated that the overall uncertainty on diffusion tube measurements is approximately $\pm 25\%$ for NO_2 and $\pm 25\%$ for BTEX hydrocarbons.

The limits of detection in ambient air depend on the tube uptake rate and the exposure time, and therefore vary to some extent from month to month. Typically the detection limit for NO_2 has been equivalent to $0.4 \mu\text{g m}^{-3}$, and the detection limit for benzene around $0.05 \mu\text{g m}^{-3}$.

It should be noted that tube results that are less than 10 x the limit of detection will have a higher level of uncertainty associated with them. In the case of the NO_2 sites, this is rarely a problem as ambient concentrations are above this threshold at all but the most rural locations. However, ambient concentrations of BTEX hydrocarbons are closer to the lower limit of detection using diffusion tubes: the non-urban sites have in the past regularly measured concentrations of $0.5 \mu\text{g m}^{-3}$ and less.

The Local Air Quality Management Technical Guidance LAQM.TG(09)¹⁸ states that when using diffusion tubes for indicative NO_2 monitoring, correction should be made where applicable for any systematic bias (i.e. over-read or under-read compared to the automatic chemiluminescent technique, which is the reference method for NO_2). By co-locating diffusion tubes with the automatic monitoring site at Halkett Place, it was possible to calculate a bias adjustment factor, which could then be applied to the annual mean diffusion tube measurements in this survey. ***The NO_2 diffusion tube results in this report are uncorrected except where clearly specified.*** The BTEX results have not been bias adjusted.

Each monthly batch of diffusion tubes was accompanied by a “travel blank” NO_2 and BTEX tube. These tubes were taken with the exposure tubes to the site, but were not exposed. They were returned to the site operator’s premises, and were kept in a sealed bag in a cupboard. When the exposed tubes were collected, the “travel blank” tubes were taken by the operator to the site. The travel blanks were sent with the exposed tubes for analysis. The purpose of these tubes was to indicate if any contamination of the tubes had occurred. This was particularly relevant in the case of the BTEX tubes, which can easily be contaminated by exposure to solvents.

The travel blank results were not used to apply any correction to the results from the exposed tubes – only to highlight possible contamination issues.

2.4 Monitoring Sites

Automatic monitoring of oxides of nitrogen was carried out at the Central Market, Halkett Place, in St Helier (Figure 1). This site represents a roadside site where levels of NO_2 were expected to be high, and where members of the public are regularly exposed for periods of one hour or more.

Figure 1 Automatic NO_x Monitoring Site, Halkett Place, St Helier



Figure 1 shows the location of the monitoring site. The inlet funnel is just visible as a white tube protruding from the building façade above the hanging basket just beyond the yellow shop front. It is at a height of about 5m.

Figure 2 shows the chemiluminescent NO_x analyser itself, which is located within the building. The analyser is calibrated monthly by the States of Jersey's Health Protection Team. Details of the calibration procedure, and an example of the calibration form used, are provided in Appendix 2.

Figure 2 Automatic NO_x Analyser at Halkett Place, St Helier



As explained in section 2.3, diffusion tubes were also used to monitor NO₂ at twelve sites in a range of different environments around Jersey. Table 1 lists the NO₂ diffusion tube sites, and Figures 3a and 3b show their locations.

Diffusion tubes are also co-located with the automatic monitoring site at Halkett Place, and the results of this co-located monitoring are used to assess the precision and accuracy of the diffusion tubes, relative to the automatic chemiluminescent analyser, which is defined within Europe as the reference method for NO₂. The tubes at this site are exposed in triplicate, to allow assessment of precision. All other diffusion tube sites are single tube sites.

Table 1 NO₂ Monitoring Sites in Jersey

Site Name	Grid Reference	Method	Description
Central Market, Halkett Place	653 486	Automatic analyser Diffusion tubes in triplicate	Halkett Pl., St Helier – co-located with automatic site.
Le Bas Centre	658 489	Diffusion tube	Urban Background
Les Quennevais	579 496	Diffusion tube	Residential Background
Rue des Raisies	689 529	Diffusion tube	Rural Background
Weighbridge	651 483	Diffusion tube	Roadside at bus station near centre of St Helier
Georgetown	661 480	Diffusion tube	Kerbside on major road
Beaumont	597 516	Diffusion tube	Kerbside
The Parade *	648 489	Diffusion tube	Roadside site at General Hospital
Broad Street	652 486	Diffusion tube	Urban background
Union Street	653 486	Diffusion tube	Kerbside in St Helier – corner of Union St. & New St.
New Street	653 485	Diffusion tube	Kerbside in St Helier
Liberation Station	652 485	Diffusion tube	Kerbside opposite entrance to new bus station

*The Parade site was moved to its current roadside location at the end of 2000.

Kerbside: less than 1m from kerb of a busy road.

Roadside: 1-5m from kerb of a busy road.

Background: > 50m from the kerb of any major road.

Note: all grid references are from OS 1:25000 Leisure Map of Jersey and are given to the nearest 100m.

Figure 3a Site Locations Outside St Helier

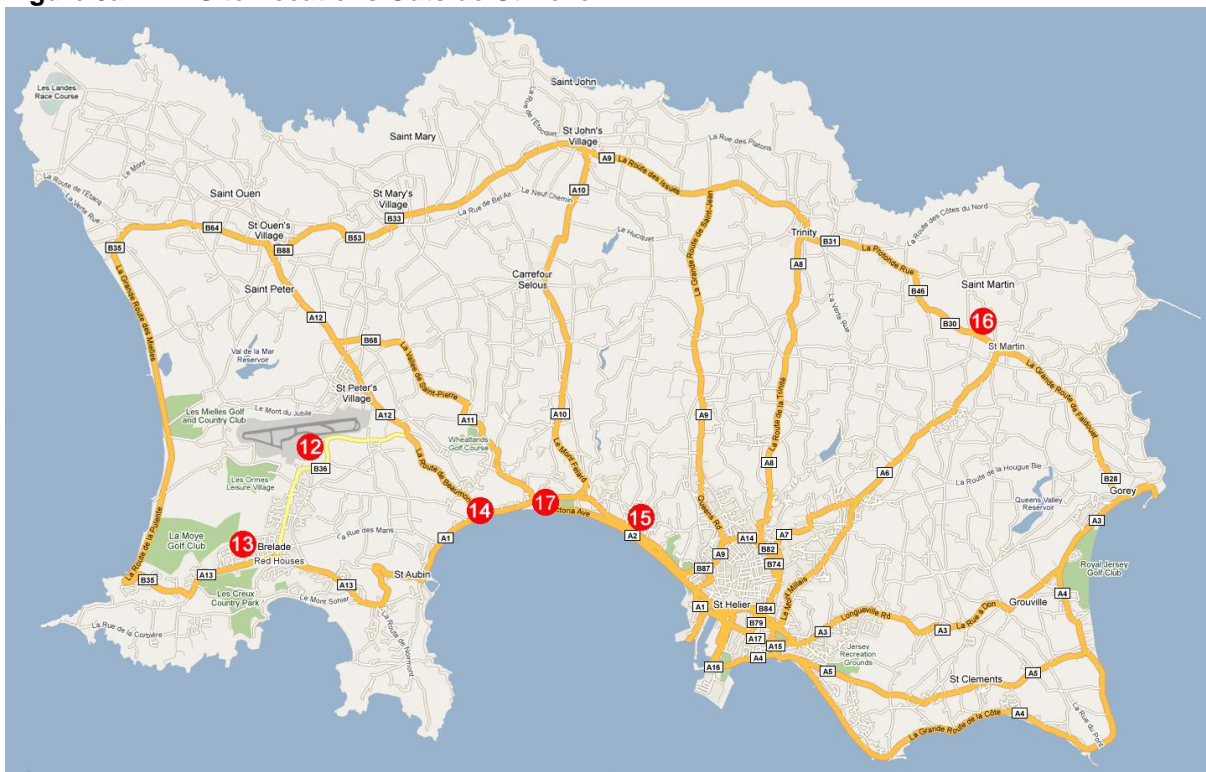
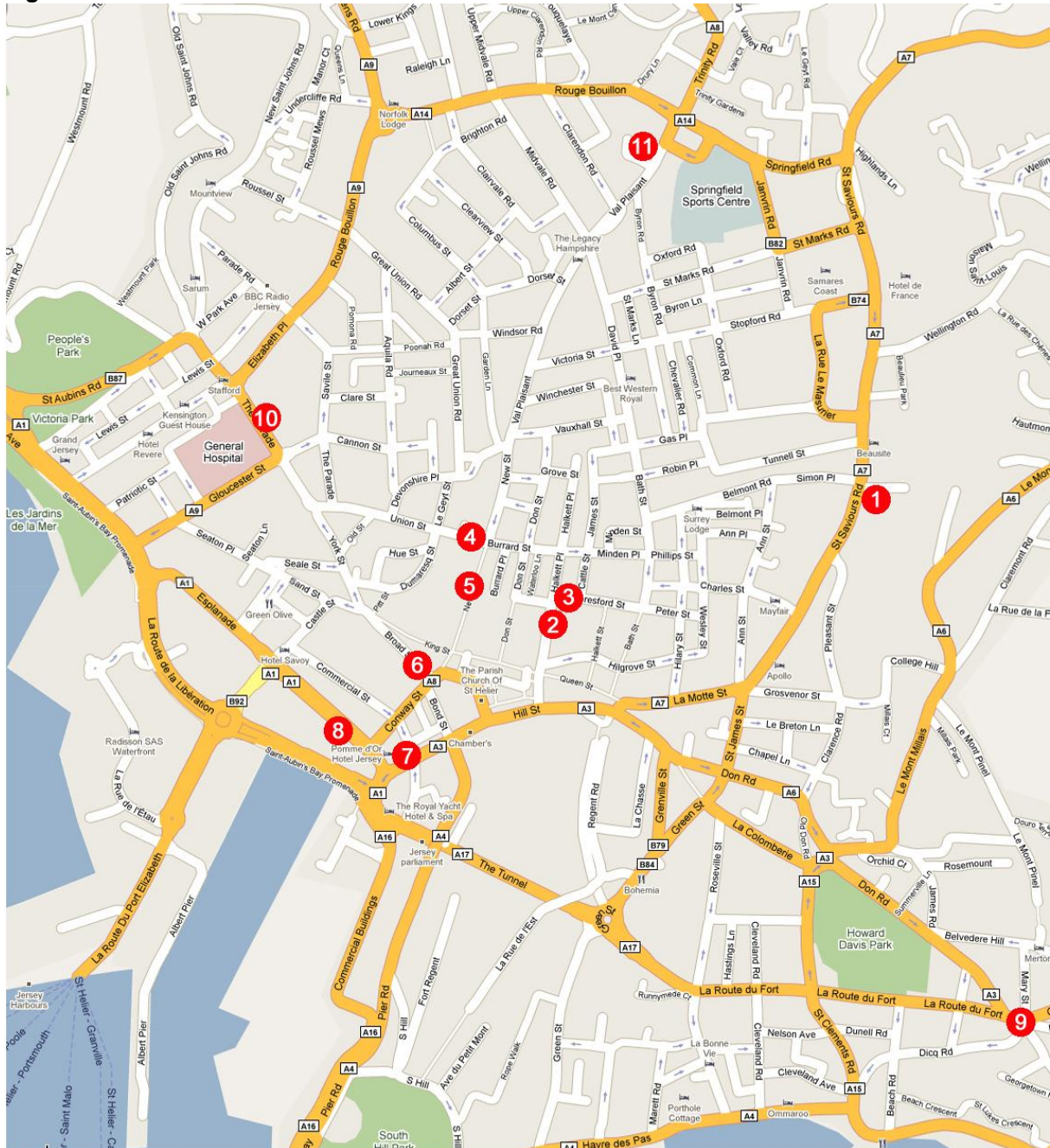


Figure 3b Sites in St Helier town



Key:	Name	Pollutants
1	Le Bas Centre	NO ₂ , BTEX
2	Central Market	NO ₂ , (diffusion tube and automatic)
3	Beresford Street	NO ₂ , BTEX
4	Union Street	NO ₂
5	New Street	NO ₂
6	Broad Street	NO ₂
7	Weighbridge	NO ₂
8	Liberation Station	NO ₂
9	Georgetown	NO ₂
10	The Parade	NO ₂
11	Faux Bie / Springfields Garage	BTEX
12	Airport	BTEX
13	Les Quennevais	NO ₂
14	Beaumont	NO ₂
15	Clos St Andre	NO ₂ , BTEX
16	Rue Des Raisies	NO ₂
17	Handsford Lane	BTEX

BTEX hydrocarbons were monitored at six sites during 2009. These sites are shown in Table 2. The aim was to investigate sites likely to be affected by different emission sources, and compare these with background sites. The sites at Beresford Street and Le Bas Centre are intended to monitor hydrocarbon concentrations at an urban roadside and urban background location respectively.

The Handsford Lane site is close to a paint spraying process – a potential source of hydrocarbon emissions, especially toluene and xylenes. This site replaced a similar site in Elizabeth Lane, which ceased operation when the process closed down in October 2003.

The Faux Bie site replaced the former Springfield Garage site at the beginning of June 2009. This was located at a fuel filling station, a potential source of hydrocarbon emissions including benzene. The old site was close to the forecourt: the new site is located at a nearby house, and is intended to be more representative of public exposure. As of December 2003, the fuel supplier has used vapour recovery when filling the tanks.

The Clos St Andre site is located near the Bellozanne Valley waste incinerator, and the Airport site is located at Jersey Airport, overlooking the airfield.

Table 2 BTEX Diffusion Tube Monitoring sites

Site Name	Grid Reference	Description
Beresford Street	653 486	Urban Roadside
Le Bas Centre	658 489	Urban Background
Faux Bie	658 495	Urban background near fuel filling station
Clos St Andre	638 499	Residential area near Bellozanne Valley refuse incinerator.
Airport	587 509	Jersey Airport, on arrivals hall building overlooking car park.
Handsford Lane	633 499	Urban background near a paint spraying process.

2.5 Calendar of Diffusion Tube Exposure Periods

The calendar of exposure periods used for the NO₂ and BTEX diffusion tubes is shown in Table 3 below. They were intended to approximate to calendar months.

Table 3 Diffusion Tube Exposure Periods

<i>Month</i>	<i>Start Date</i>	<i>End Date</i>
January	07/01/2009	04/02/2009
February	04/02/2009	03/03/2009
March	03/03/2009	01/04/2009
April	01/04/2009	29/04/2009
May	29/04/2009	03/06/2009
June	03/06/2009	01/07/2009
July	01/07/2009	29/07/2009
August	29/07/2009	02/09/2009
September	02/09/2009	30/09/2009
October	30/09/2009	04/11/2009
November	04/11/2009	02/12/2009
December	02/12/2009	07/01/2010

3 Quality Assurance and Data Capture

3.1 Quality Assurance And Quality Control

A full intercalibration audit of the Jersey Halkett Place air quality monitoring site takes place annually. In addition to instrument and calibration standard checking, the air intake sampling system is cleaned and all other aspects of site infrastructure are checked.

Following the instrument and calibration gas checking, and the subsequent scaling and ratification of the data, the overall accuracy and precision figures for the pollutants monitored at Jersey can be summarised as in Table 4:

Table 4 Estimated Accuracy and Precision of the Data Presented

Pollutant	Precision	Accuracy %
NO	±5 ppb	±15%
NO ₂	±5 ppb	±15%

3.2 Data Capture

Overall data capture statistics for the monitoring site are given in Table 5. A data capture rate of 90% or greater for ratified data is recommended in the Defra Technical Guidance LAQM.TG(09)¹⁸.

Table 5 Jersey Halkett Place - Data Capture Statistics 2009

Site	NO	NO ₂	NO _x
Jersey Halkett Place	98.4 %	98.4 %	98.4 %

Data capture of 90% was achieved for NO₂: thus the data capture target of LAQM.TG(09) was met. However, the following significant gap in data capture occurred during the year, as shown in Table 6:

Table 6 Data Gaps 2009

Site	Pollutant	Period	No. of Days	Reason
Jersey Halkett Place	All NO _x	27 th – 30 th Nov	4	Analyser temporarily re-located within the market: power interruption.

4 Results and Discussion

4.1 Presentation of Results

4.1.1 Automatic NO₂ Monitoring Results

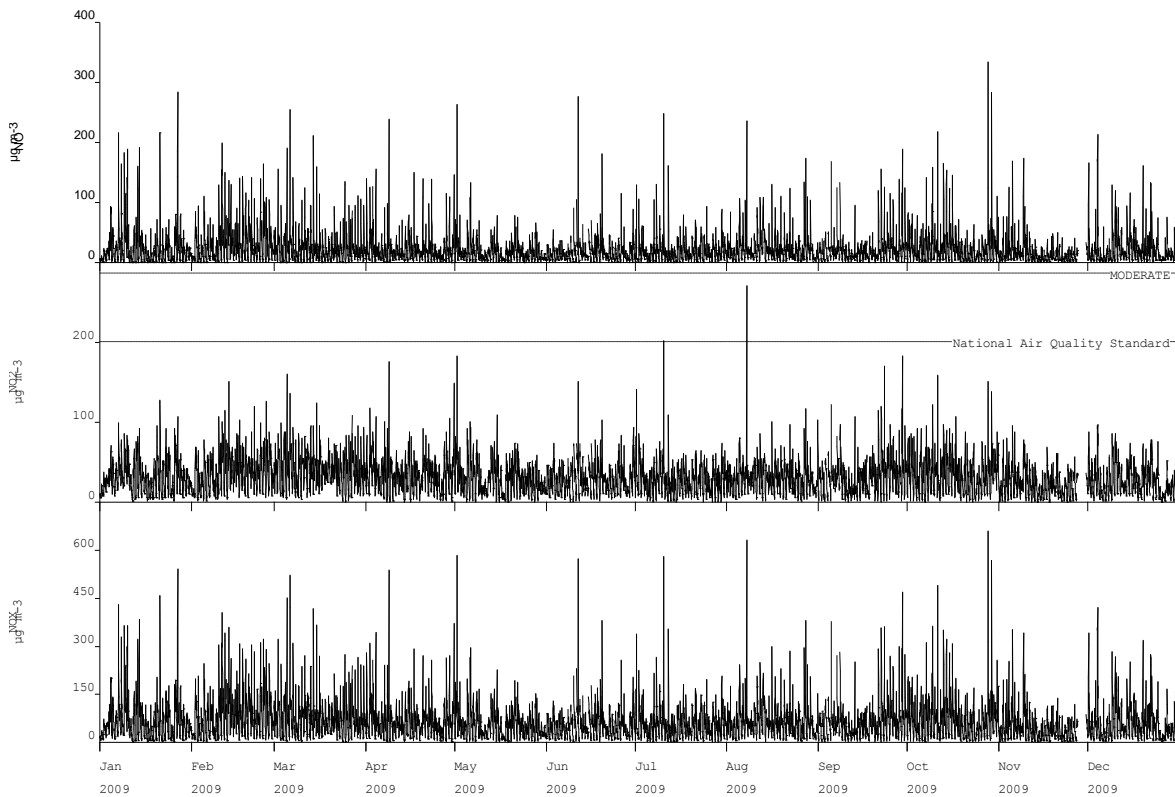
Table 7 shows the key statistics for oxides of nitrogen measured by the automatic analyser at Halkett Place. Figure 4 shows timeseries plots of hourly mean NO, NO₂ and NO_x concentrations.

Table 7 Oxides of Nitrogen: Air Quality Statistics for 2009

POLLUTANT	NO µg m ⁻³	NO ₂ µg m ⁻³	NO _x µg m ⁻³
Maximum 15-minute mean	623	441	1247
Maximum hourly mean	334	271	661
Maximum running 8-hour mean	120	82	265
Maximum running 24-hour mean	63	57	145
Maximum daily mean	56	56	140
Average	21	31	62
Data capture	98.4 %	98.4 %	98.4 %

All mass units are at 20 Celsius and 101.3 kPa.

Figure 4 Time series plots of hourly mean pollutant concentrations at Halkett Place, 2009



4.1.2 NO₂ Diffusion Tube Results

NO₂ diffusion tube results are presented in Table 8 and Figure 5. Although reported by the analyst to two decimal places, the monthly mean results reported here have been rounded to the nearest integer, in view of the estimated uncertainty of $\pm 25\%$ on diffusion tube measurements.

Individual monthly mean NO₂ results ranged from 4 $\mu\text{g m}^{-3}$ (in August at the rural background Rue de Raisies site), to 52 $\mu\text{g m}^{-3}$ (in April at the kerbside Beaumont site).

The May result at Rue des Raisies was extremely high at 43 $\mu\text{g m}^{-3}$, given the rural location of the site. It was concluded that this result was very unlikely to be genuine, and it has been rejected.

The February results at some, though not all, of the sites were suspiciously low. For example, the Le Bas Centre site usually gives monthly mean concentrations in the range 20 – 30 $\mu\text{g m}^{-3}$ but the February 2009 result was just 6.1 $\mu\text{g m}^{-3}$. At Halkett Place, where diffusion tubes are co-located in triplicate with an automatic analyser, the tubes gave a monthly mean of 9 $\mu\text{g m}^{-3}$ but the automatic method gave a monthly mean of 40 $\mu\text{g m}^{-3}$. This was checked with the analyst, who confirmed they had been correctly calculated. Whilst it is inadvisable to reject any data simply because they are higher or lower than expected, the co-location result casts doubt on the validity of the February diffusion tubes not only at Halkett Place but also at other sites which showed similarly low results. As the results from various sites showed this anomaly to different extents, it was difficult to determine which should be retained and which rejected. Therefore, the decision was taken to reject all the February diffusion tube results.

Two tubes went missing from the sites: February's tube at Les Quennevais and February's tube at Union Street.

Results from the Halkett Place site (where diffusion tubes are co-located with an automatic analyser) were used to calculate a bias adjustment factor of 0.9 - see Appendix 3.

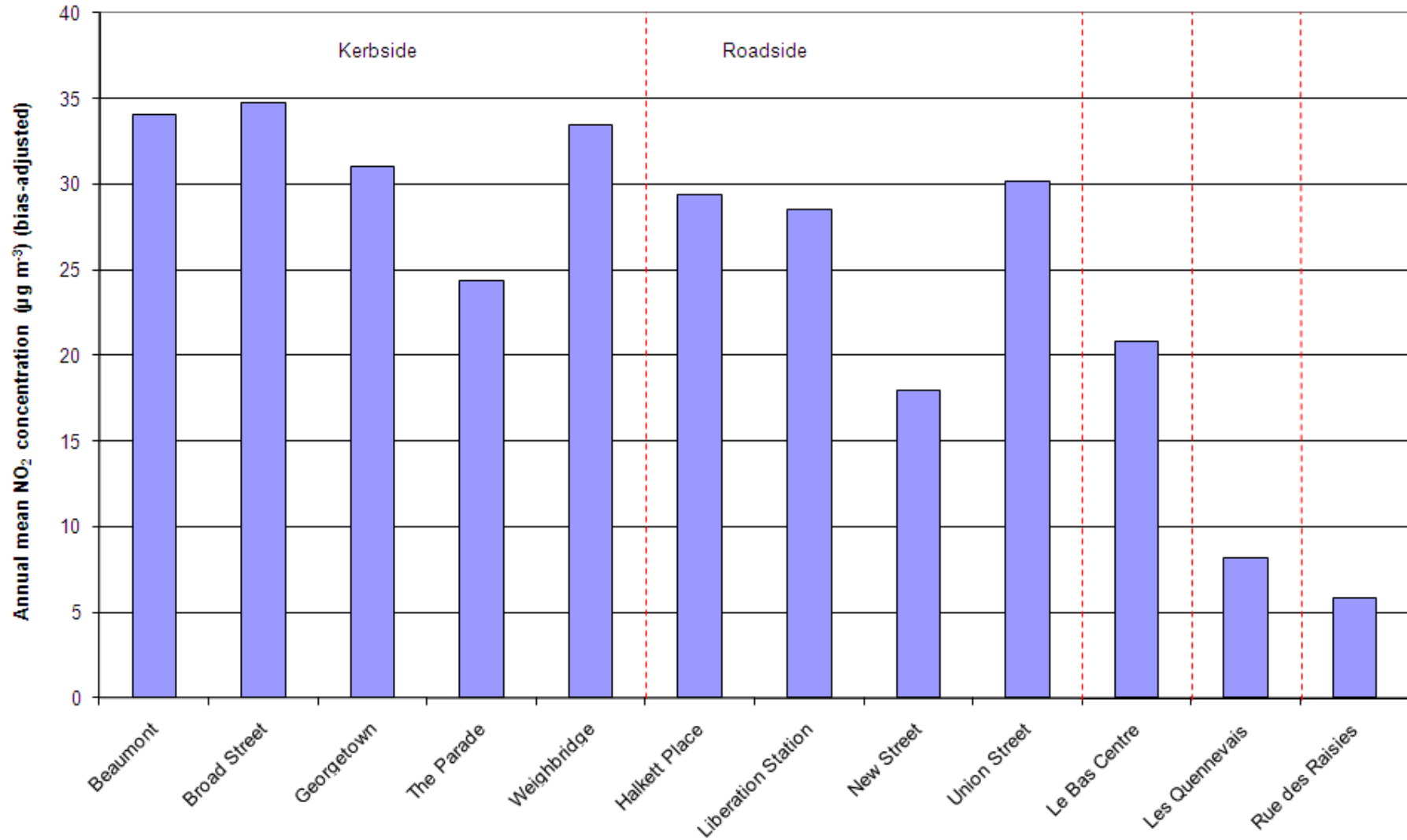
Annual mean NO₂ concentrations (after application of this bias adjustment factor) ranged from 6 $\mu\text{g m}^{-3}$ (at the rural Rue des Raisies site) to 35 $\mu\text{g m}^{-3}$ at the Broad Street site in the centre of St Helier.

Table 8 NO₂ Diffusion Tube Results 2009, Jersey. Concentrations (rounded to nearest integer) in µg m⁻³ .

Site	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09	Mean	Bias adjusted
Beaumont (K)	38	(29)	39	52	46	45	29	29	46	37	25	31	38	34
Broad Street (K)	43	(40)	37	46	39	33	48	39	30	37	44	31	39	35
Georgetown (K)	38	(23)	39	45	35	39	30	30	34	32	26	32	34	31
The Parade (K)	31	(22)	32	32	26	27	24	27	26	25	24	24	27	24
Weighbridge (K)	39	(18)	39	49	37	34	39	34	32	35	40	30	37	33
Halkett Place tube 1 (R)	35	(9)	42	39	30	31	33	28	33	35	28	31		
Halkett Place tube 2 (R)	38	(10)	38	41	30	28	32	30	31	32	28	28		
Halkett Place tube 3 (R)	29	(9)	37	40	30	32	33	31	34	35	28	30		
Halkett Place mean (R)	36	(9)	39	40	30	30	32	30	33	34	28	30	33	29
Liberation Station (R)	25	(24)	33	40	31	34	31	30	40	33	24	29	32	29
New Street (R)	26	(17)	22	22	17	15	17	18	18	19	24	22	20	18
Union Street (R)	39	* n/a	35	41	30	31	36	30	26	33	36	33	34	30
Le Bas Centre (UB)	30	(6)	26	27	23	20	22	20	19	25	22	21	23	21
Les Quennevais (RB)	* n/a	(7)	11	10	8	8	4	7	10	13	8	12	9	8
Rue des Raisies (Rural)	11	(6)	8	7	(reject)	6	7	4	6	7	4	6	6	6

K = Kerbside, R = Roadside, UB = Urban Background, RB = Residential Background, Rural = Rural Background.
 All February data rejected as suspect.

Figure 5 Comparison of Annual Mean Nitrogen Dioxide Concentrations at All Jersey Sites, 2009 (Bias Adjustment Factor Applied)



4.1.3 Precision and Accuracy of NO₂ Diffusion Tubes

Diffusion tubes are an indicative monitoring technique: although they are economical and easy to use, they do not give the same level of precision and accuracy as more expensive automatic monitoring methods. For this reason, as explained in section 2.3 above, the Local Air Quality Management Technical Guidance LAQM.TG(09)¹⁸ states that when using diffusion tubes for indicative NO₂ monitoring, correction should be made where applicable for any systematic bias (i.e. over-read or under-read) compared to the automatic chemiluminescent technique, which is the reference method for NO₂.

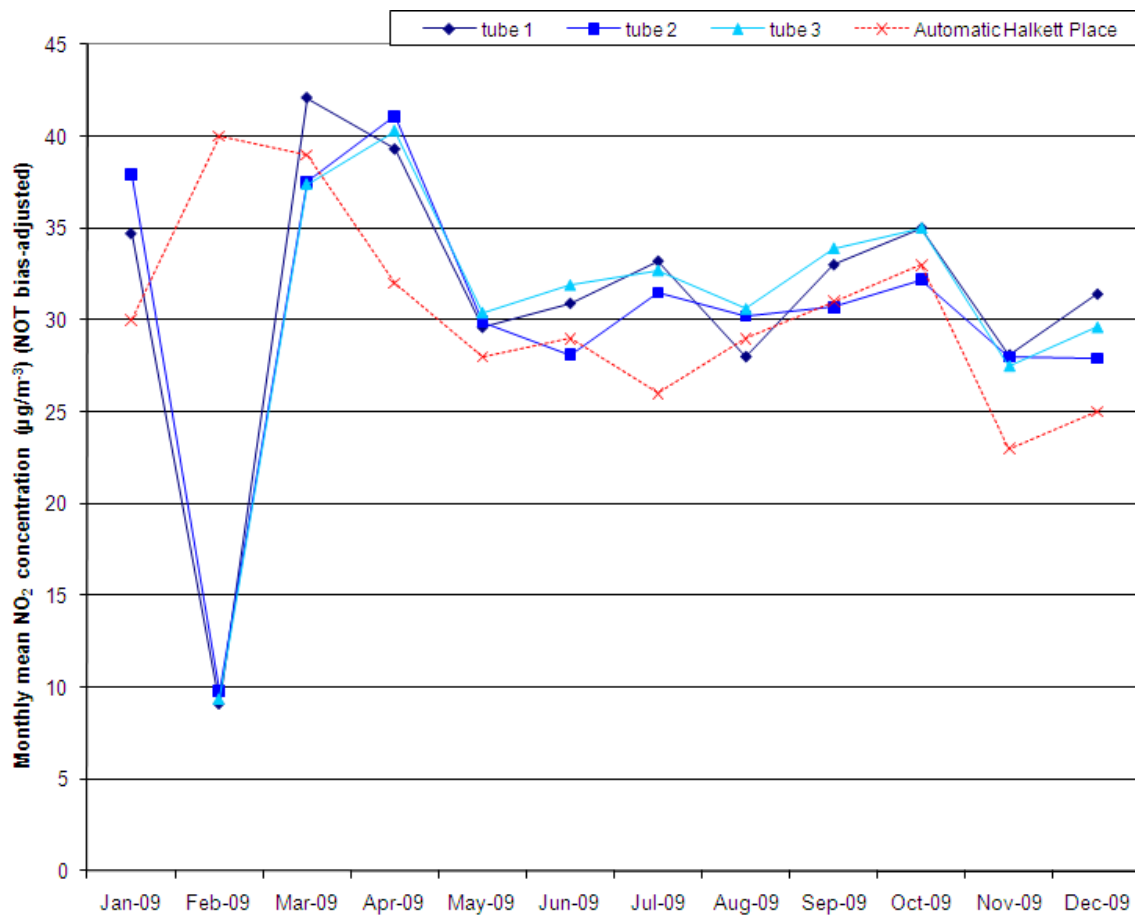
This is usually done by co-locating diffusion tubes with a chemiluminescent analyser and comparing the results of the two methods. The co-location site in this study was Halkett Place. By exposing diffusion tubes in triplicate at this site, it was possible to compare their precision and accuracy with that of the automatic monitor, and to calculate a “bias adjustment factor” which could be applied to the annual mean NO₂ concentrations measured at the other diffusion tube sites, in order to correct for any “bias”.

Exposing tubes in triplicate allowed an investigation of diffusion tube precision. Precision may be expressed in terms of the coefficient of variation (CV) of the three replicate measurements. This parameter, also known as the relative standard deviation, is the standard deviation expressed as a percentage of the mean. For diffusion tubes exposed in triplicate, the CV is usually expected to be within 10% on average. This is based purely on experience of what a competent laboratory is typically able to achieve, although it can be affected by conditions at the site. It is not uncommon for diffusion tube precision to occasionally be poor; this is not a cause for concern if the precision over the rest of the year is consistently good. At Central Market, the CV of the monthly tube triplets ranged from 1% to 14%, with a mean of 5%. There was one month when this value was particularly high. In January, the three results were 29 $\mu\text{g m}^{-3}$, 35 $\mu\text{g m}^{-3}$ and 38 $\mu\text{g m}^{-3}$. However, as none of the three values could clearly be identified as an outlier, none have been rejected from the dataset.

The mean NO₂ concentration as measured by the diffusion tubes was 33 $\mu\text{g m}^{-3}$. Although the bias exhibited by the diffusion tubes varied considerably from month to month, the annual mean concentrations as measured by the automatic analyser and the diffusion tubes were within 1 $\mu\text{g m}^{-3}$. The “bias adjustment factor” was 0.9

As highlighted in section 4.1.2, several sites, including Halkett Place, recorded suspiciously low results in February 2009, and it was considered prudent to reject the whole month’s dataset.

Figure 6 shows the monthly mean NO₂ concentrations, as measured by diffusion tubes and by the automatic analyser, at Halkett Place. Figure 6 shows the rejected February tube results, illustrating that they are clearly much lower than the automatic analyser measurement. In the other months the two methods showed good agreement.

Figure 6 Co-location Results at Halkett Place (including rejected February tube results)

4.2 Comparison with NO₂ Guidelines, Limit Values, and Objectives

Limit Values, AQS Objectives and WHO guidelines for NO₂ are shown in Appendix 1. These are based on the hourly and annual means.

The WHO non-mandatory guideline¹⁵ for NO₂ is that the annual mean should not exceed 40 µg m⁻³. The EC Directive on Ambient Air Quality and Cleaner Air for Europe¹⁶ contains Limit Values for NO₂ as follows:

- 200 µg m⁻³ as an hourly mean, not to be exceeded more than 18 times per calendar year. To be achieved by 1st January 2010.
- 40 µg m⁻³ as an annual mean, for protection of human health. To be achieved by 1st January 2010.
- There is also a limit for annual mean total oxides of nitrogen (NO_x), of 30 µg m⁻³, for protection of vegetation (relevant in rural areas).

The UK Air Quality Strategy¹⁷ contains Objectives for NO₂, which are very similar to the EC Directive limits above: the only difference being that they had to be achieved by 31st December 2005.

The 1-hour mean at the Halkett Place automatic monitoring site exceeded 200 µg m⁻³ on two occasions during 2009. This is within the maximum of 18 permitted exceedences, therefore this site has met the hourly mean EC Directive Limit Value and AQS Objective for this parameter, by the due date. The annual mean concentration of 31 µg m⁻³ as measured by the automatic analyser at Halkett Place is within the EC Limit Value of 40 µg m⁻³.

Because of the long sampling period of diffusion tubes, it is only possible to compare the results from the diffusion tube sites in this study against limit values relating to the annual mean. Annual mean NO₂

concentrations did not exceed $40\mu\text{g m}^{-3}$ at any sites in 2009. The highest annual mean concentration of $35\mu\text{g m}^{-3}$ (after bias adjustment) was measured at Broad Street. This urban kerbside site in the centre of St Helier has recorded relatively high annual mean NO_2 concentrations throughout previous years of this survey. Therefore, all sites met the Limit Value for annual mean NO_2 concentration by the due date. However, as annual mean NO_2 concentrations can vary considerably from year to year due to meteorological and other factors, it is possible that exceedences could occur in future years.

The $30\mu\text{g m}^{-3}$ limit for protection of vegetation is only applicable at rural sites, and is therefore only relevant to Rue des Raisies. The annual mean NO_2 concentration of $6\mu\text{g m}^{-3}$ at this rural site was well within the Limit Value.

4.3 Diurnal and Seasonal Variation in NO_2 Concentration

4.3.1 Diurnal variation in NO_2 concentration at Halkett Place

Figure 7 shows how concentrations of nitrous oxide (NO) and nitrogen dioxide (NO_2) typically varied over the course of the day, as measured by the automatic monitor at Halkett Place.

The curve for NO (which is a primary pollutant, i.e. directly emitted from source, and arises from road vehicles and other combustion sources) shows a very sharp morning peak at 0600 - 0800. Concentrations decrease during the middle of the day, with an afternoon "plateau" before concentrations fall at around 1800. There is barely any afternoon or evening rush-hour peak.

For NO_2 , which has both primary (directly emitted) and secondary (due to oxidation of NO) components, there is again a pronounced morning rush-hour peak, only slightly lower than for NO. There is no real afternoon peak.

Based on AEA's experience with data from the Automatic Urban and Rural Network, the morning peak in NO and NO_2 is typical for urban sites, reflecting the increased levels of these pollutants associated with morning rush-hour traffic. However, at Halkett Place it is particularly early and particularly sharp. This may be explained by the fact that there is a market at Halkett Place every day except Sundays: the peak coincides with the time at which the market traders arrive and set up for the day. In addition, a skip lorry arrives at this time to collect the previous day's refuse. It is believed that vehicle emissions from these activities are responsible for the distinctive morning pattern at Halkett Place.

Halkett Place does not exhibit an afternoon or evening rush-hour peak (as observed at many roadside AURN sites). This is unusual for an urban site: in the afternoon, concentrations of oxidising agents, particularly ozone, in the atmosphere tend to increase, leading to enhanced oxidation of NO to NO_2 . This typically causes the afternoon NO_2 peak at many urban sites to be higher than the morning NO_2 peak. However, this is not the case at Halkett Place.

4.3.2 Seasonal variation in NO_2 concentration

Figure 8 shows the monthly mean NO_2 concentrations measured at the diffusion tube sites and at Halkett Place. This shows the means of the five kerbside and four roadside sites, and the monthly means measured at the single urban background site (Le Bas Centre), urban residential site (Les Quennevais) and rural site (Rue des Raisies). Monthly means (based on the same periods as the diffusion tube exposures) are also shown for the Halkett Place automatic site.

The typical pattern in urban areas is for NO_2 concentrations to be generally higher in the winter and lower in the summer. In 2009, the highest concentrations at the diffusion tube sites were typically measured in March and April. There was no clear seasonal pattern.

Figure 7 Diurnal Variation in concentrations of oxides of nitrogen, Halkett Place

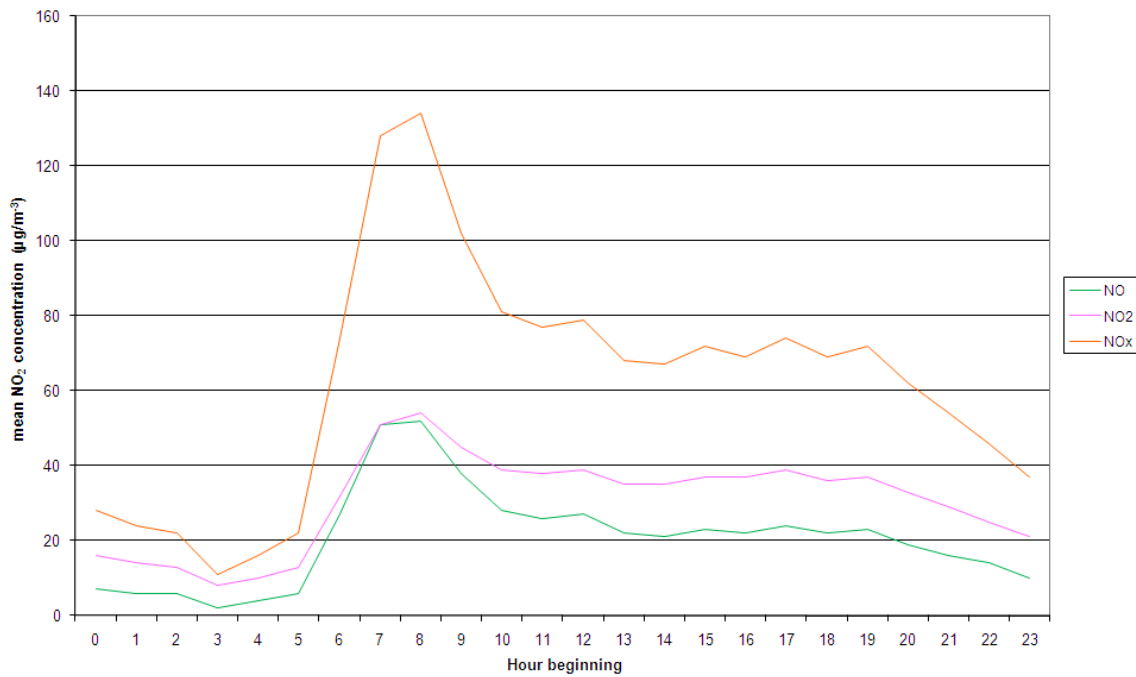
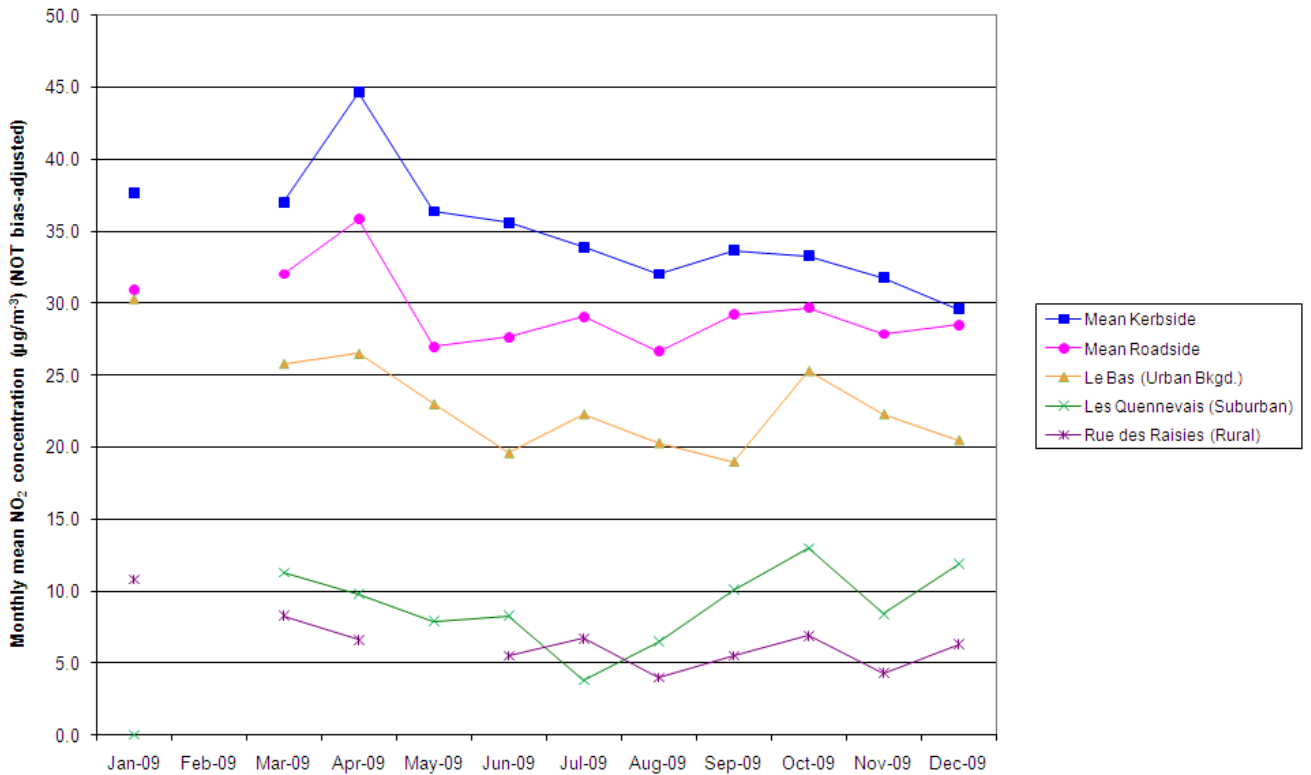


Figure 8 Monthly Mean NO₂ Concentrations at Diffusion Tube Sites and Halkett Place



4.3.3 Comparison with UK NO₂ data

Table 9 compares the NO₂ concentrations measured at Halkett Place with those measured at a selection of UK air quality monitoring stations using automatic (chemiluminescent) NO₂ analysers. The automatic data have been fully ratified. The sites used for comparison are as follows:

- Exeter Roadside – a roadside site in the centre of Exeter, Devon.
- Brighton Roadside – a roadside site in the coastal city of Brighton, Sussex.
- Brighton Preston Park – an urban background site in Brighton.
- Southend on Sea – an urban background site in the coastal town of Southend, Essex.
- Lullington Heath - a rural site on the South Coast of England near the town of Eastbourne.
- Harwell - a rural site in the south of England, within 10km of a power station.

Table 9 Comparison of NO₂ in Jersey with UK Automatic Sites

Site	2009 Annual average NO ₂ , µg m ⁻³
Exeter Roadside	40
Brighton Roadside	37
Brighton Preston Park	19
Southend on Sea	23
Lullington Heath	10.5
Harwell	10.0
Halkett Place (auto.)	31

The bias adjusted annual mean NO₂ concentrations measured at the kerbside and roadside sites in Jersey (rounded to the nearest integer) ranged from 18 to 35 µg m⁻³. The annual means at Exeter Roadside and Brighton Roadside were just above this range, and both were higher than the annual mean at the Halkett Place automatic site (and co-located diffusion tubes). The Jersey urban background site at Le Bas Centre had a (bias adjusted) annual mean NO₂ concentration of 21 µg m⁻³; this is comparable to the annual means from the urban background sites in Southend and Brighton Preston Park. The residential background site at Les Quennevais had a bias-adjusted annual mean NO₂ concentration of 8 µg m⁻³ - more comparable with rural sites such as Lullington Heath and Harwell. The bias-adjusted annual mean of 6 µg m⁻³ at the Jersey rural background site, Rue des Raisies, as in previous years, was considerably lower than that measured at either Harwell or Lullington Heath.

4.3.4 Trends in Nitrogen Dioxide at Long-Running Sites

There are eight sites in the survey which have been in operation since 2000. The annual mean NO₂ concentrations are shown in Table 10 and illustrated in Figure 9. **These data are not adjusted for diffusion tube bias; prior to 2002 there was no reliable information on which to carry out bias adjustment, so for consistency, unadjusted data are used in this section.**

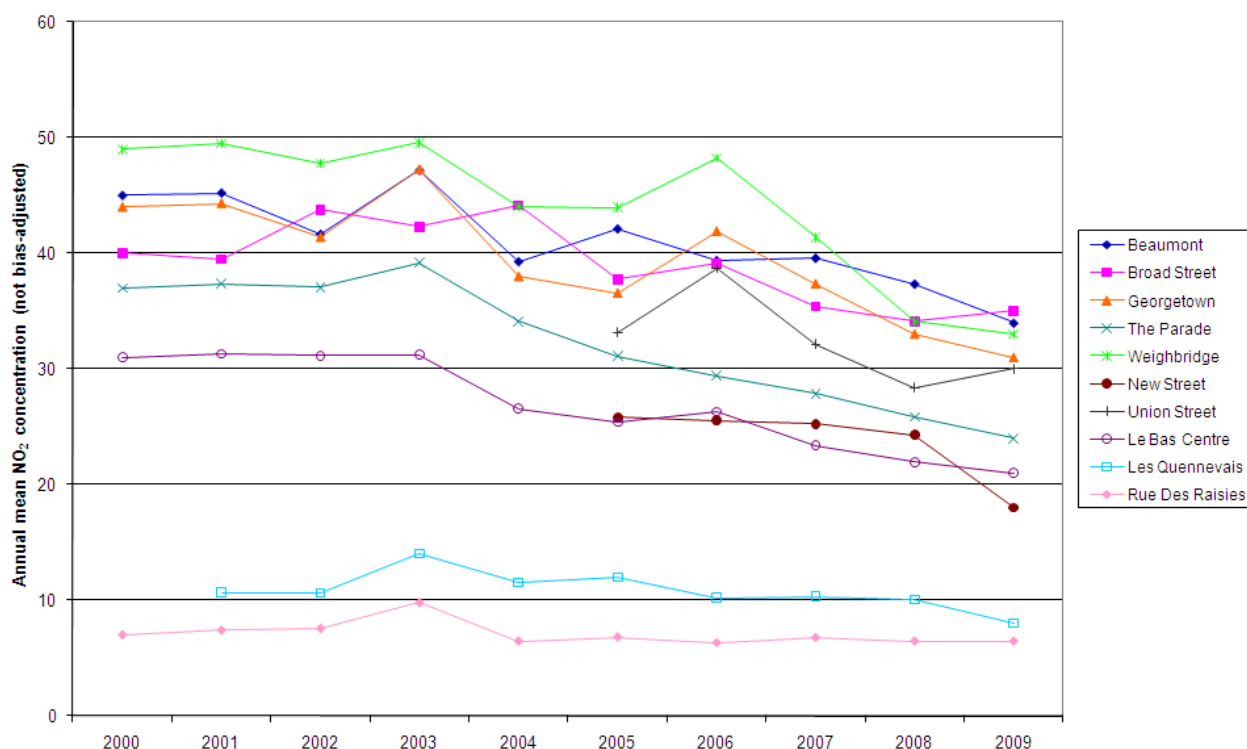
Annual mean NO₂ concentrations at the kerbside, roadside and urban background sites (Weighbridge, Georgetown, Beaumont, the Parade, Broad Street, and Le Bas) gave cause for concern in the early years of the study (2000 to 2003). Many were above the EC Directive Limit Value of 40 µg m⁻³, and there was no sign of concentrations decreasing. However, from 2004 onwards, concentrations began to decrease, and all are now within the Limit Value (although exceedences in future years cannot be ruled out, as NO₂ concentrations vary from year to year due to meteorological and other factors).

The residential background and rural sites at Les Quennevais and Rue des Raisies do not show any consistent upward or downward trend in NO₂ concentration: but levels here are already low so this is not of concern.

Table 10 Annual mean NO₂ concentrations, µg m⁻³ (not bias adjusted)

Site	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Weighbridge	49	49	48	50	44	44	48	41	38	34
Georgetown	44	44	41	47	38	37	42	37	33	35
Beaumont	45	45	42	47	39	42	39	40	37	31
The Parade	37	37	37	39	34	31	29	28	26	24
Broad Street	40	39	44	42	44	38	39	35	34	33
Le Bas Centre	31	31	31	31	27	25	26	23	22	18
Les Quennevais	-	11	11	14	12	12	10	10	10	30
Rue Des Raisies	7	7	8	10	6	7	6	7	7	21

Figure 9 Annual Mean NO₂ Concentrations (not adjusted for diffusion tube bias).



The New Street site has shown a substantial decrease in 2009 compared to 2008 and earlier years. This is thought to be due to a reduction in traffic flow: New Street is now open to access traffic only. By contrast, Union Street is reported to be carrying a greater quantity of traffic, which may possibly account for the observed increase in NO₂ concentration.

4.4 Hydrocarbons

Full monthly results of the hydrocarbon survey for the six sites are shown in Appendix 4, Tables A3.1 to A3.7. Graphical representations are shown in Figures 10 to 15. A summary of annual average hydrocarbon concentrations is shown in Table 11.

Table 11 Summary of Average Hydrocarbon Concentrations, Jersey, 2009

Site	Benzene, $\mu\text{g m}^{-3}$	Toluene, $\mu\text{g m}^{-3}$	Ethyl Benzene, $\mu\text{g m}^{-3}$	m+p Xylene, $\mu\text{g m}^{-3}$	o Xylene, $\mu\text{g m}^{-3}$
Beresford Street	1.8	6.9	1.5	5.2	2.0
Le Bas Centre	1.4	5.4	1.4	3.9	1.5
Handsford Lane (<i>paint spraying</i>)	1.1	4.9	2.0	8.5	2.4
Springfield Garage (<i>petrol station</i>) Jan – May only	5.5	31.9	5.3	18.4	6.7
Faux Bie (<i>Houses near petrol station</i>) Jun – Dec only	1.3	5.5	1.1	3.4	1.3
Clos St Andre	0.8	1.7	0.5	1.4	0.5
Airport	0.6	2.0	0.5	0.9	0.4
Travel Blanks	1.3	5.6	2.8	4.0	6.2

Full data capture was achieved at all sites.

Each batch of tubes is accompanied by a travel blank, whose purpose is explained in section 2.3. These were analysed alongside the exposed tubes, and the results (expressed as equivalent concentrations) have been included in Table 11. Travel blank tubes would normally be expected to give very low results compared with exposed tubes. However, in the 2009 study, the results from the BTEX travel blanks were consistently high. The annual mean blank concentrations (expressed as equivalent ambient concentrations) were comparable to those measured at urban locations such as Beresford Street and Le Bas Centre, and higher than those measured at the Clos St Andre and Airport sites. This indicates that the travel blanks – and possibly all the BTEX tubes – have been exposed to contamination.

This called into question the validity of the entire BTEX dataset for 2009. However, as

- (i) the results from the exposed tubes were consistent with those seen in previous years, when BTEX blanks were not high, and
- (ii) the results from Clos St Andre and the Airport were as low as usual (and on average substantially lower than the travel blanks)

- it has been concluded that the source of contamination has affected the blanks only, and not the exposed tubes. BTEX tubes are very vulnerable to contamination by solvents in common items such as felt-tipped pens. In addition to the sealed bag in which they are supplied, it may be helpful to store them in a sealed container such as a plastic lunchbox.

Springfield Garage monitoring site has always recorded the highest annual mean concentrations of all five BTEX compounds. However, it was located on the forecourt of a fuel filling station, and not truly representative of the exposure of the neighbouring residents. Therefore, at the start of June 2009 the site was re-located to Faux Bie Terrace, in order to more accurately reflect population exposure. Based on the 7-month means for June – December 2009, levels of hydrocarbons at Faux Bie are much lower than those on the forecourt, and are consistent with those measured at Beresford Street and Le Bas Centre. The results for Springfield Garage and Faux Bie have been plotted on the same axes to illustrate this: there is a clear step change when the tubes were re-sited.

The Handsford Lane site (near a paint spraying process) measured highest levels of xylenes than all sites except Springfield Garage, as it typically has in previous years. However, benzene and toluene concentrations at Handsford Lane were no higher than those at Beresford Street or Le Bas; the nearby paint spraying process is not a significant source of benzene or toluene. The Airport site, and Clos St Andre, which are in rural surroundings, recorded the lowest annual mean concentrations of all the BTEX hydrocarbons.

Figure 10 Monthly mean hydrocarbon concentrations at Beresford Street, 2009

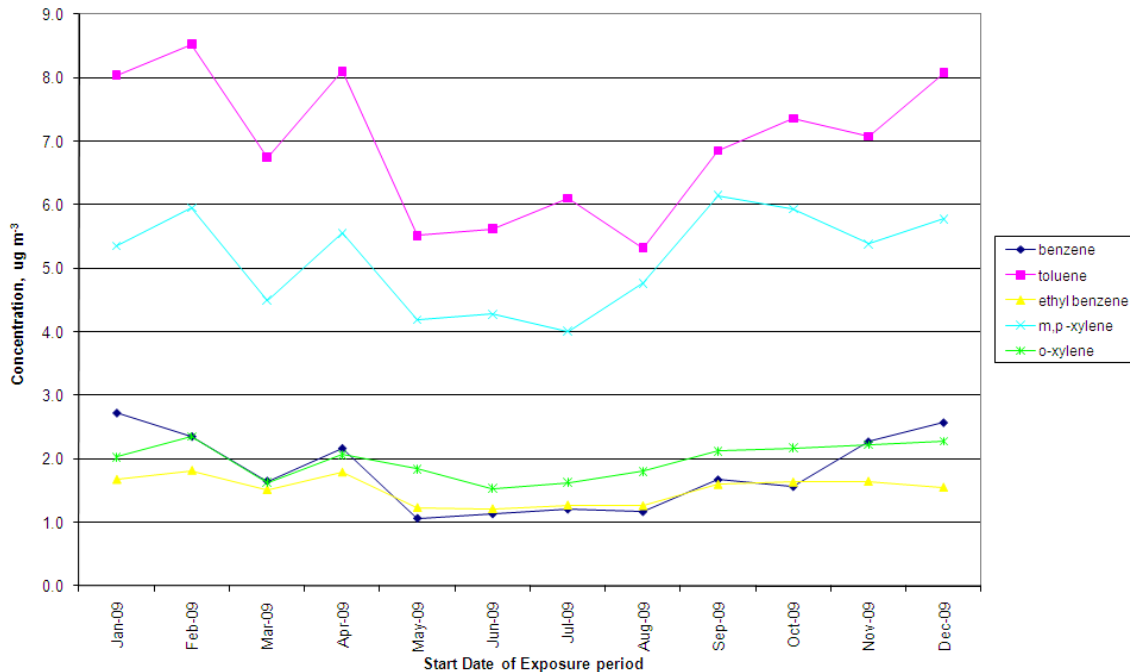


Figure 11 Monthly mean hydrocarbon concentrations at Le Bas Centre, 2009

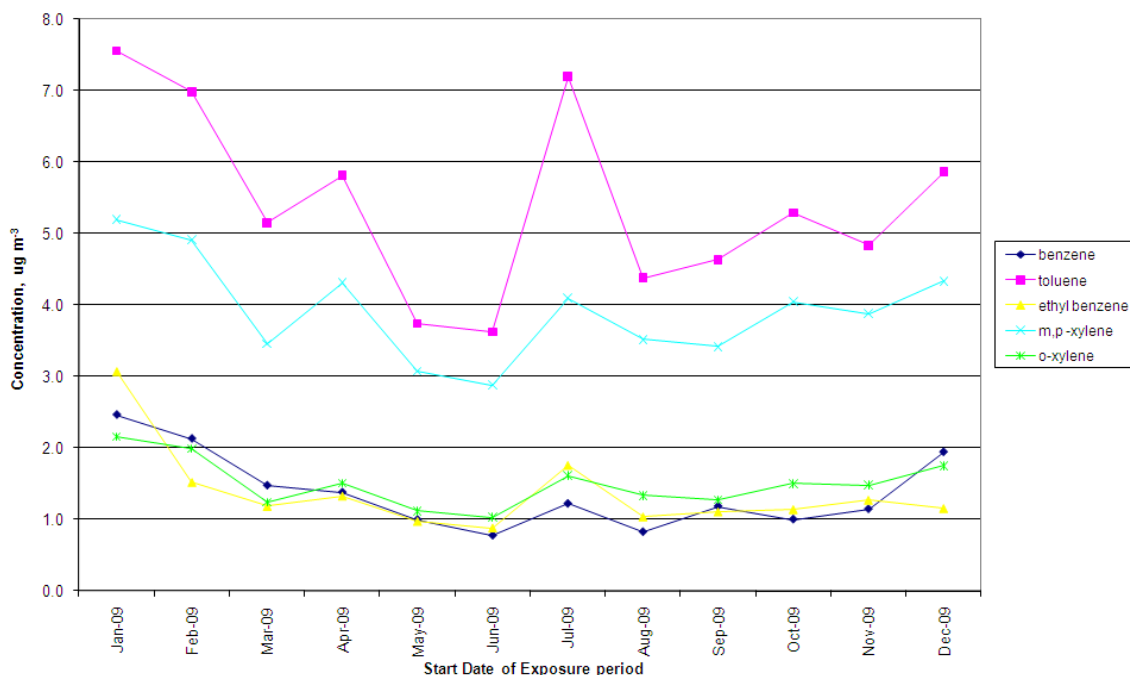


Figure 12 Monthly mean hydrocarbon concentrations at Handsford Lane, 2009

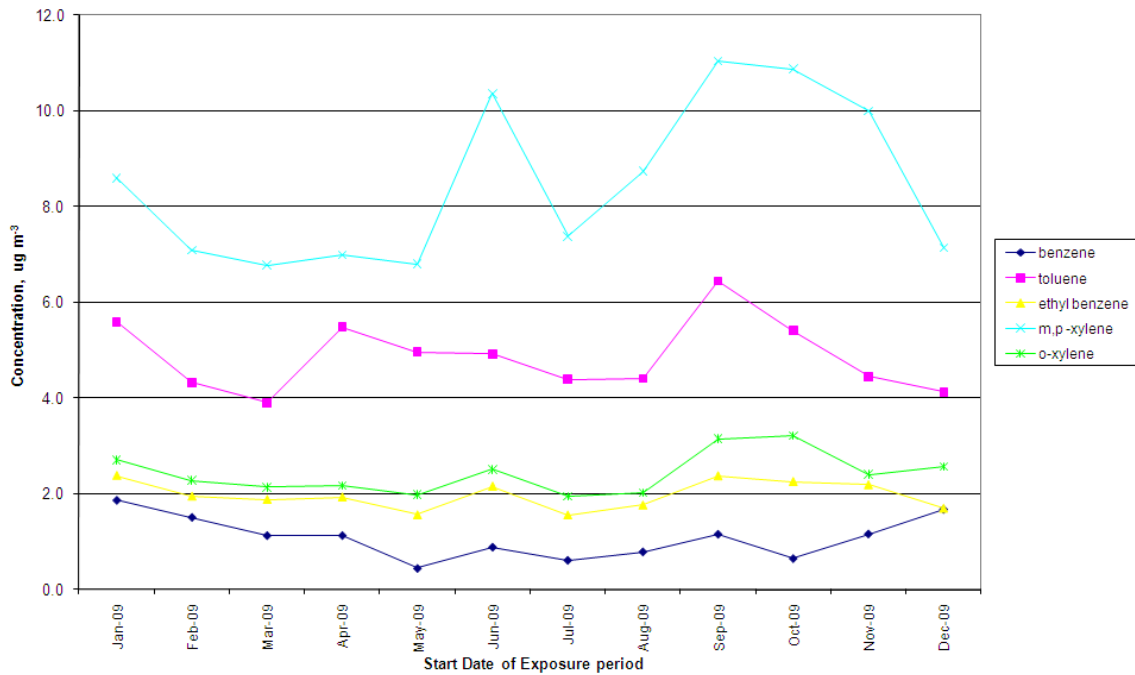


Figure 13 Monthly mean hydrocarbon concentrations at Springfield Garage and Faux Bie, 2009 (change to Faux Bie from June 2009)

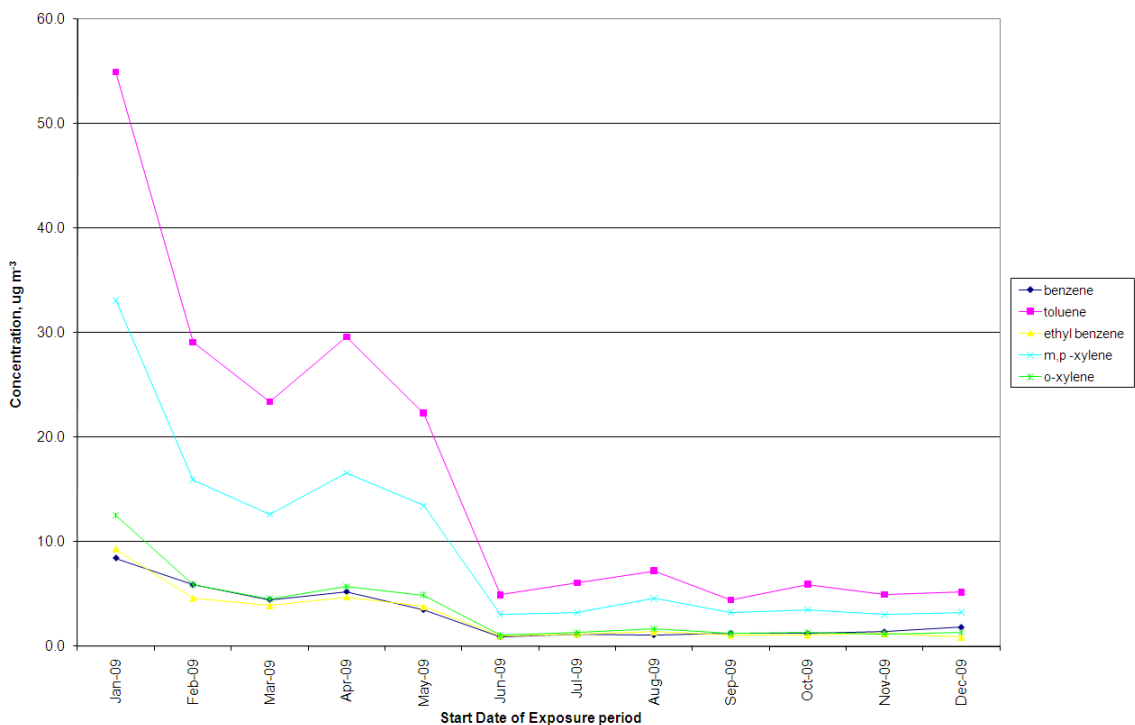


Figure 14 Monthly mean hydrocarbon concentrations at Clos St Andre, 2009

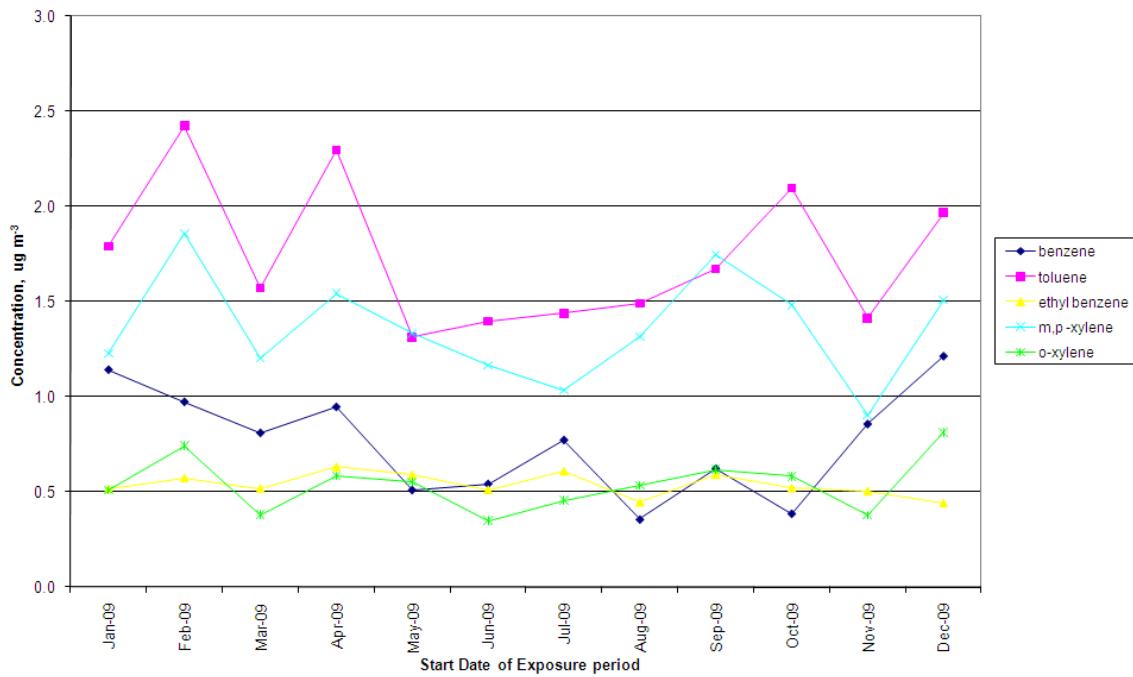
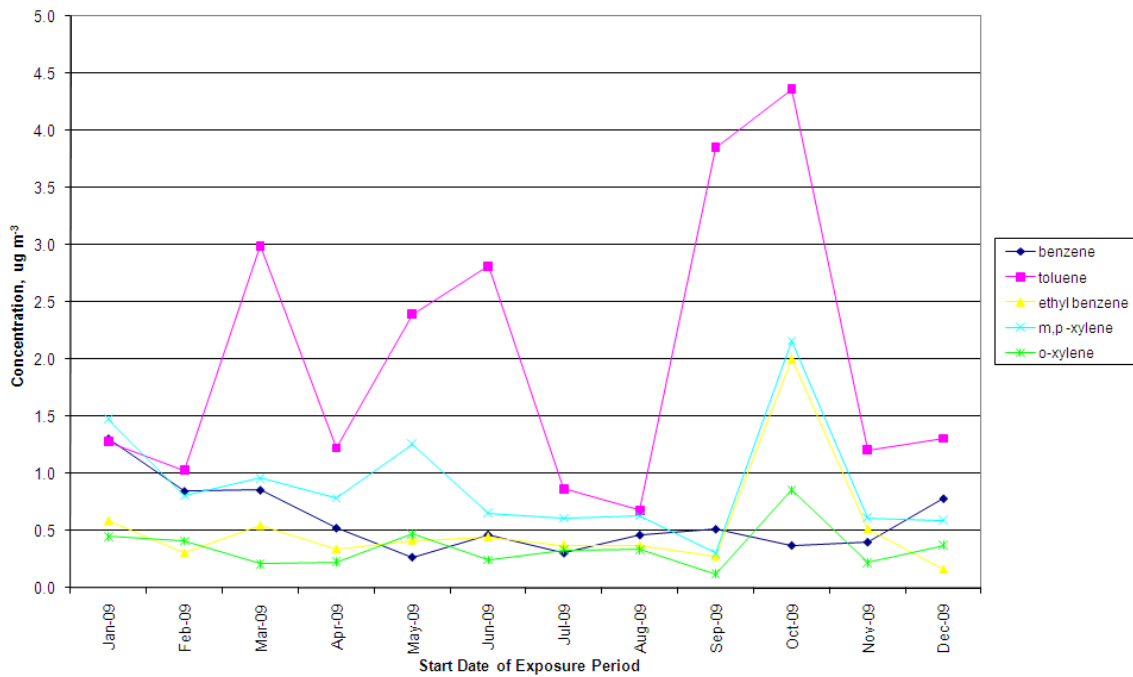


Figure 15 Monthly mean hydrocarbon concentrations at the Airport, 2009



4.4.1 Comparison With Limit Values and Objectives

Of the hydrocarbon species monitored, only benzene is the subject of any applicable air quality standards. The EC Directive on Ambient Air Quality and Cleaner Air for Europe¹⁶ sets a limit of $5 \mu\text{g m}^{-3}$ for annual mean benzene, to be achieved by 2010. All sites met this limit in 2009.

The UK Air Quality Strategy¹⁷ sets the following objectives for benzene:

- $16.25 \mu\text{g m}^{-3}$ (for the running annual mean), to have been achieved by 31st December 2003
- $5 \mu\text{g m}^{-3}$ (for the calendar year mean), to be achieved by 31st December 2010 in England and Wales. This is the same as the EC Limit Value.
- $3.25 \mu\text{g m}^{-3}$ (for the calendar year mean), to be achieved by 31st December 2010 in Scotland and Northern Ireland.

These AQS Objectives are not at present mandatory in Jersey.

The annual mean benzene concentration (which can be considered a good indicator of the running annual mean) did not exceed the 2003 Objective of $16.25 \mu\text{g m}^{-3}$ at any of the Jersey sites. Springfield Garage had a mean benzene concentration of $5.5 \mu\text{g m}^{-3}$, based on January – May data. This is greater than the 2010 EU Limit Value of $5 \mu\text{g m}^{-3}$. However, there is no relevant public exposure at this location, hence the relocation of the site to Faux Bie. On the basis of the seven-month (June – December 2009), the new site appears likely to meet the EC Limit Value for benzene.

4.4.2 Comparison with UK Benzene Data

Benzene was measured using pumped-tube samplers at a large UK-wide network of 36 UK sites in 2008. The pumped tube sampler is defined within Europe as the reference method. Annual mean concentrations from these sites ranged from $0.39 \mu\text{g m}^{-3}$ (at Norwich Lakenfields) to $1.44 \mu\text{g m}^{-3}$ (at Birmingham Roadside.)

Table 12 compares benzene data from the Jersey sites, with two UK monitoring stations, located in cities on the south coast of England and one urban background site in central Birmingham. The comparison sites are:

- Plymouth – an urban background site in the coastal city of Plymouth, Devon
- Southampton – a roadside site in the city of Southampton
- London Bloomsbury – an urban background site in central London

It should be noted that these sites use a different technique (pumped tubes) for measuring benzene than the Jersey sites. Therefore this comparison should be treated as indicative only.

Table 12 Comparison with Benzene Concentrations at Other UK Sites, 2009

Site	Benzene, $\mu\text{g m}^{-3}$
Jersey Sites	
Beresford Street	1.8
Le Bas Centre	1.4
Handsford Lane (<i>paint spraying</i>)	1.1
Faux Bie (<i>petrol station</i>)	1.3
Clos St Andre	0.8
Airport	0.6
Mainland UK sites	
Plymouth	0.67
Southampton	0.79
Birmingham Roadside	1.44

The annual mean benzene concentration at Jersey’s urban sites was typically higher than the UK Network sites, including the roadside site at Southampton and Plymouth. Prior to 2006 it was reported that benzene levels at Clos St Andre and the Airport were lower than typical UK urban levels; however, UK urban levels have decreased and this is no longer the case.

4.4.3 Comparison with Previous Years' Hydrocarbon Results

Figures 16 – 21 show how annual mean hydrocarbon concentrations at the six Jersey sites have changed over the years of monitoring. These data are also provided in tabular form in Appendix 4.

Annual mean levels of hydrocarbons in 2009 were comparable with those measured in 2008 and recent years. It is important to remember that pollutant concentrations are expected to show considerable year-to-year variation, due to meteorological and other factors. Year-to-year changes are therefore of less importance than the observation of long-term trends, which are discussed below.

Figure 16 Trends in Benzene Concentration

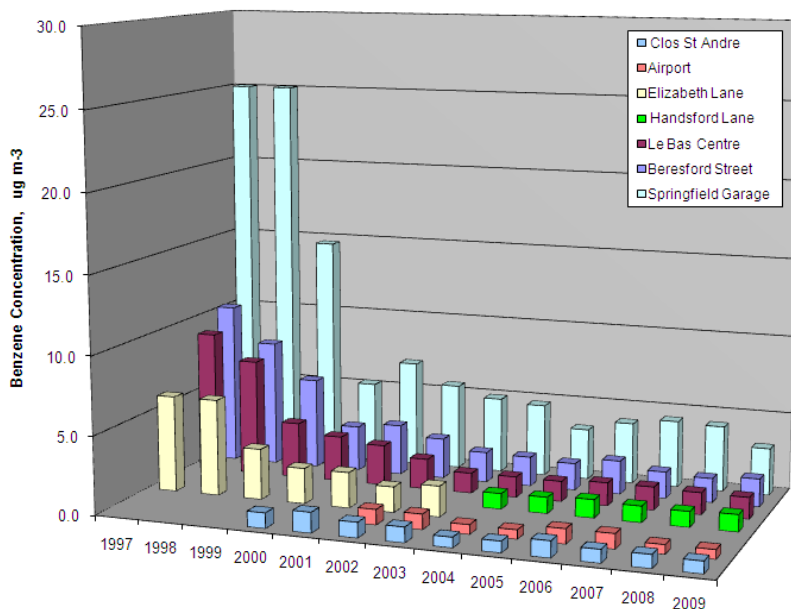


Figure 17 Trends in Toluene Concentration

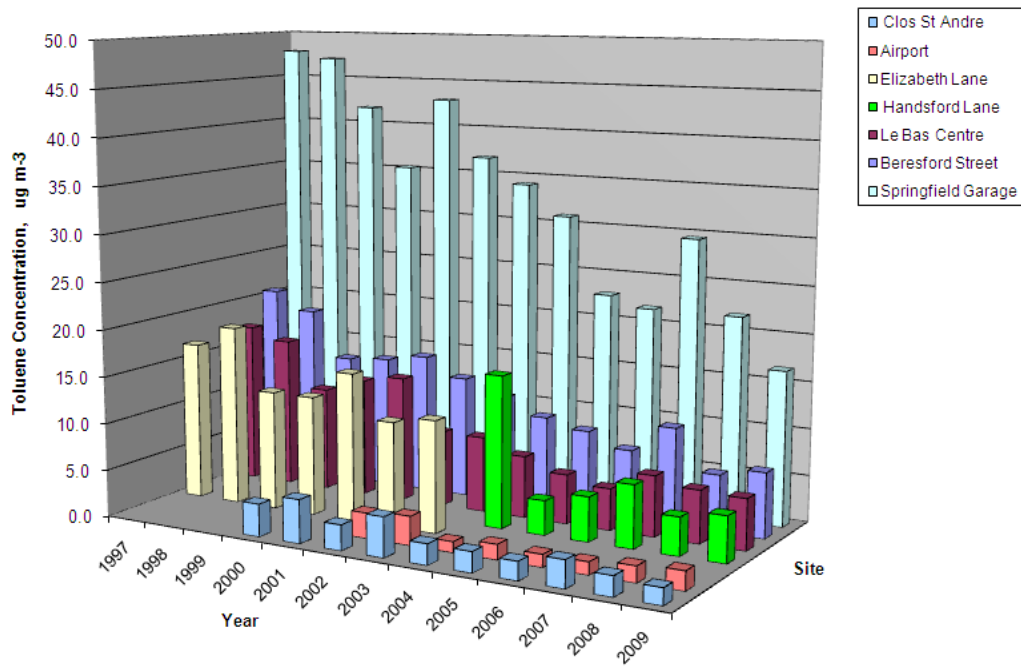


Figure 18 Trends in Ethylbenzene Concentration

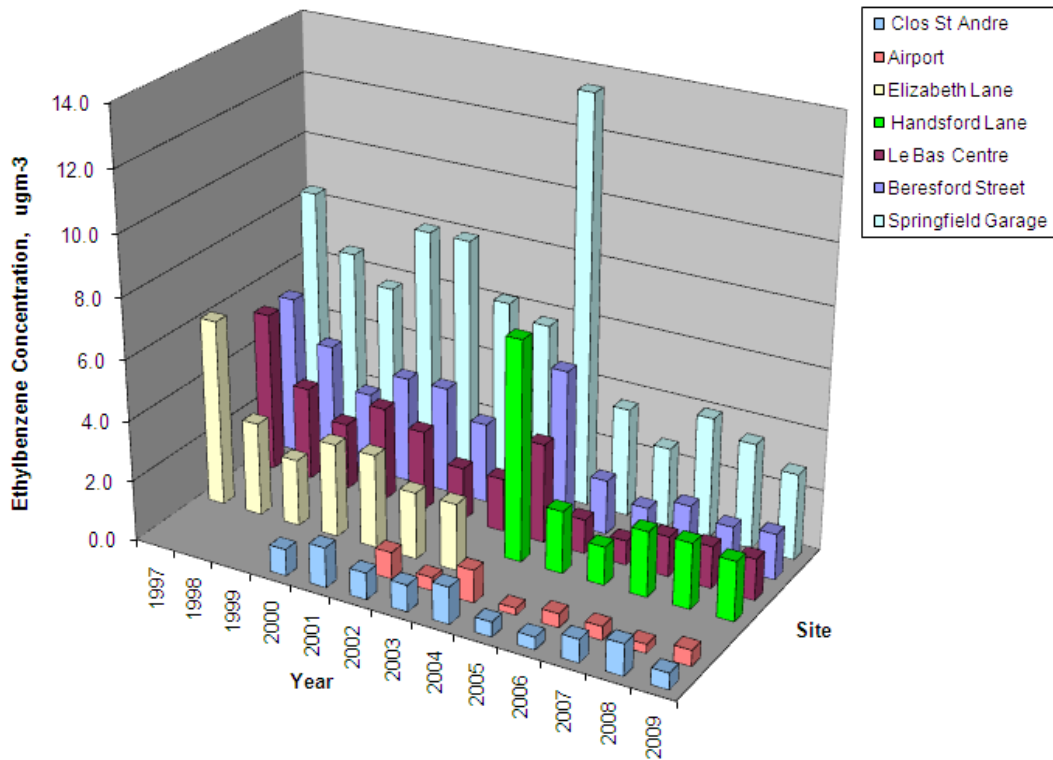


Figure 20 Trends in m+p- Xylene Concentration

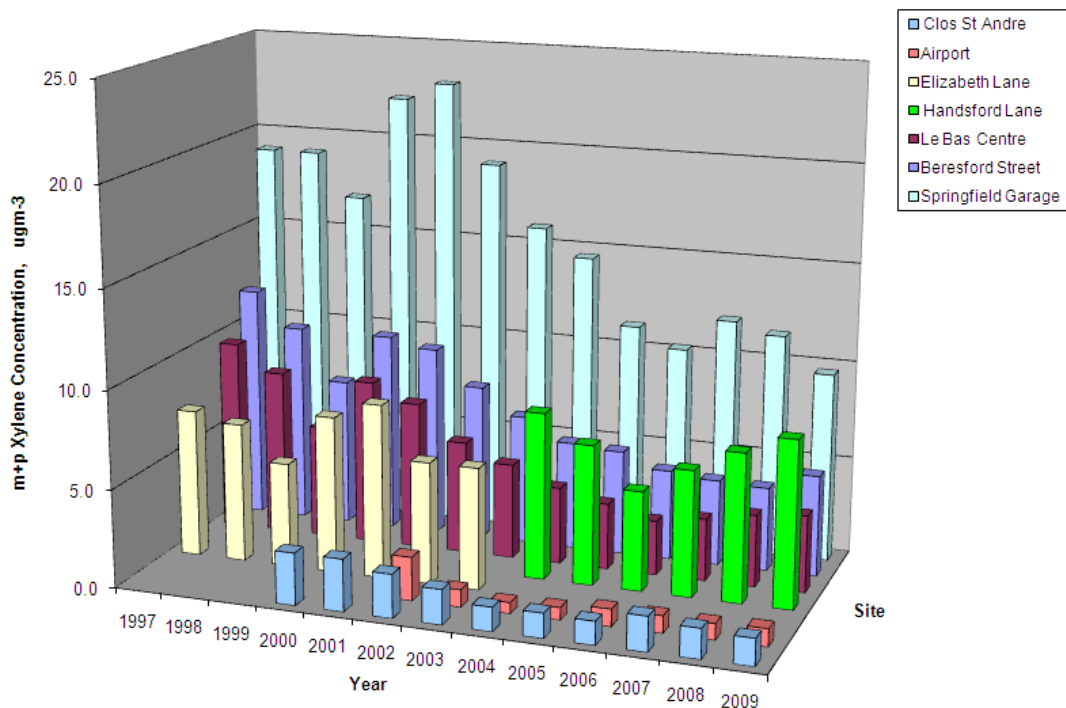
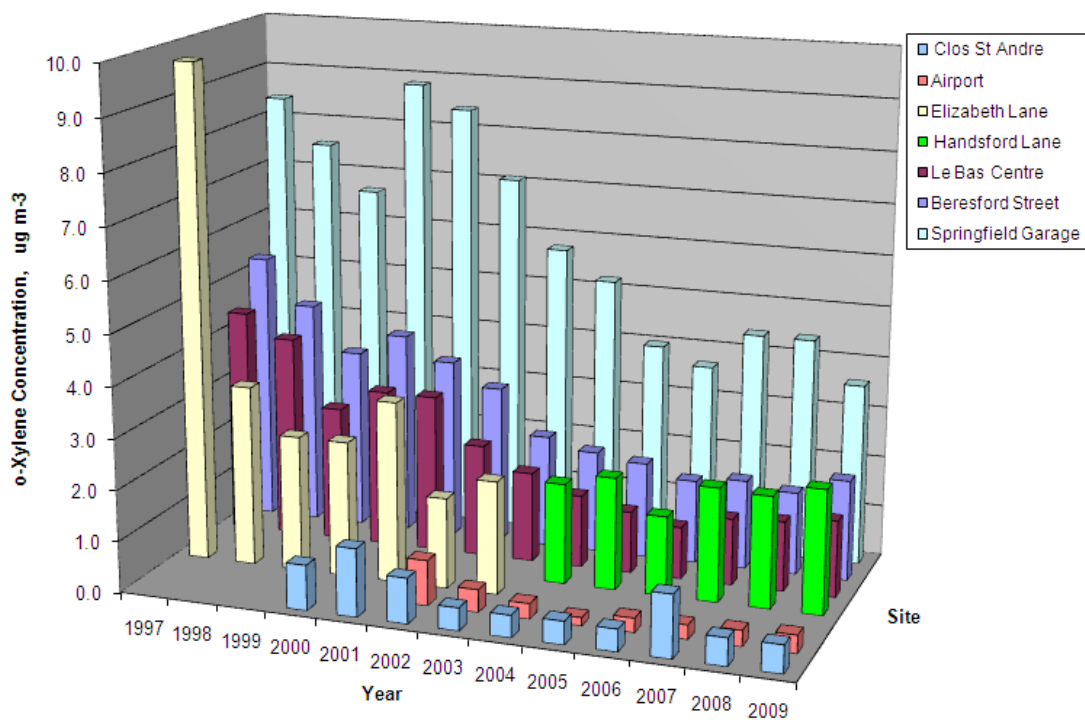


Figure 21 Trends in o-Xylene Concentration



Most hydrocarbon species appear to have decreased over the ten years of monitoring, being in most cases lower now than in the late 1990s. Key observations include:

- Benzene showed a marked drop in 2000, especially at Springfield Garage: this is due to the maximum permitted benzene content of petrol sold in the UK being reduced from 2% in unleaded (5% in super unleaded), to 1% as of 1st January 2000. Concentrations have remained stable (with small fluctuations) since around 2004. However, there is no relevant public exposure at this site, hence its relocation in 2009.
- Toluene concentrations show a downward trend over the earlier years of the survey (1997-2004) but little consistent change thereafter.
- Ethylbenzene concentrations have generally decreased, despite an unexplained increase in 2004.
- Concentrations of m+p xylene, and of o-xylene, are now generally lower than in the early years of the survey.
- At Handsford Lane (near a paint spraying process), concentrations of m+p xylene appear to have risen year-on-year since 2006, after having decreased in the early years of monitoring at this site.

5 Conclusions

AEA has continued the ongoing air quality monitoring programme in Jersey during 2009, on behalf of the States of Jersey Public Health Services. 2009 was the thirteenth year of monitoring. Oxides of nitrogen were monitored at one automatic monitoring station, located in a roadside position at the Central Market, Halkett Place in St Helier, which was supplemented by diffusion tubes for indicative monitoring of NO₂ at 12 sites around the island. Diffusion tubes were co-located (in triplicate) with the automatic site at Halkett Place.

Hydrocarbons (benzene, toluene, ethyl benzene and xylenes, collectively termed BTEX) were measured at 6 sites, also using diffusion tubes. The sites were located at a range of different locations on the island, many of which have been in operation since 2000, and some since 1997. Conclusions of the monitoring programme were as follows:

NO₂ results

1. The maximum hourly mean NO₂ concentration at the Halkett Place automatic monitoring station was 271 $\mu\text{g m}^{-3}$. The site exceeded the EC Directive Limit Value (and AQS Objective) of 200 $\mu\text{g m}^{-3}$ for 1-hour mean NO₂ concentration on just two occasions in 2009. The maximum permitted number of exceedences is 18 per calendar year, so this site meets the Limit Value and Objective.
2. The annual mean NO₂ concentration at Halkett Place was 31 $\mu\text{g m}^{-3}$, as measured by the automatic analyser. This is well within the EC Directive Limit Value and AQS Objective of 40 $\mu\text{g m}^{-3}$.
3. Diffusion tubes exposed in triplicate alongside the automatic analyser showed good agreement with the reference method, giving an annual mean of 33 $\mu\text{g m}^{-3}$.
4. Annual mean NO₂ concentrations at all 12 diffusion tube monitoring sites were within the EC Limit Value, and were generally comparable with previous year's results.
5. Eight diffusion tube sites have been in operation since 2000. These indicate that while in the early years of the survey (2000 – 2004) annual mean NO₂ concentrations at kerbside and roadside sites showed little change, they now appear to be decreasing.
6. There does not appear to be any clear trend in NO₂ concentrations at the long running urban background site (Le Bas Centre), urban residential site (Les Quennevais) or rural site (Rue des Raisies); these appear to be remaining stable. However, as they are all well below the Limit Value and AQS Objective, this is not a cause for great concern.

Hydrocarbon diffusion tube results

7. No sites had annual mean benzene concentrations greater than the UK Air Quality Strategy Objective of 16.25 $\mu\text{g m}^{-3}$, which was to be achieved by the end of 2003.
8. Springfield Garage had a five-month (January to May) mean benzene concentration greater than the EC Directive Limit Value of 5 $\mu\text{g m}^{-3}$ (which is to be achieved by 2010). However, this site has no relevant public exposure and was therefore re-located to Faux Bie in June 2009.
9. Annual mean concentrations of BTEX hydrocarbons were comparable with those measured in recent years.
10. Concentrations of all BTEX hydrocarbons (especially benzene) are considerably lower than in the early years of the survey. However, there has been little consistent change in the most recent years.
11. In 2009, the results of the BTEX travel blank were consistently high. One possible explanation is that they have been contaminated by solvents. Although the BTEX tubes have always been stored in sealed bags, it is suggested these be placed in a sealed container (e.g. a plastic sandwich box) and kept away from items such as felt-tip pens and markers, which contain solvents.

6 Acknowledgements

AEA gratefully acknowledges the help and support of the staff of the States of Jersey Health Protection Services, in the completion of this monitoring study.

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Appendices

Appendix 1: Air Quality Limit Values, Objectives and Guidelines

Appendix 2: Calibration Procedures for Automatic Analyser

Appendix 3: Nitrogen Dioxide Diffusion Tubes: Bias Adjustment Factor

Appendix 4: BTEX Diffusion Tubes: Monthly Dataset

Appendix 1

Air Quality Limit Values, Objectives and Guidelines

Air Pollution Guidelines Used in this Report.

UK and International Ambient Air Quality Limit Values, Objectives and Guidelines

Nitrogen Dioxide

Guideline Set By	Description	Criteria Based On	Value ⁽¹⁾ / $\mu\text{g m}^{-3}$ (ppb)
The Air Quality Strategy ⁽²⁾ Set in regulations ⁽³⁾ for all UK: Not intended to be set in regulations:	Objective for Dec. 31 st 2005, for protection of human health	1-hour mean	200 (105) Not to be exceeded more than 18 times per calendar year.
	Objective for Dec. 31 st 2005, for protection of human health	Annual mean	40 (21)
	Objective for Dec. 31 st 2000, for protection of vegetation.	Annual mean NO _x (NO _x as NO ₂)	30 (16)
European Community 1985 NO₂ Directive ⁽⁴⁾ Limit remains in force until fully repealed 01/01/2010.	Limit Value	Calendar year of data: 98%ile of hourly means.	200 (105)
ED Directive on Ambient Air Quality and Cleaner Air for Europe ⁽⁵⁾	Limit Value for protection of human health. To be achieved by Jan. 1 st 2010	1 hour mean	200 (105) not to be exceeded more than 18 times per calendar year
	Limit Value for protection of human health. To be achieved by Jan. 1 st 2010	Calendar year mean	40 (21)
	Limit Value (total NO _x) for protection of vegetation. To be achieved by Jul. 19 th 2001	Calendar year mean	30 (16)
World Health Organisation ⁽⁶⁾ (Non-Mandatory Guidelines)	Health Guideline	1-hour mean	200
	Health Guideline	Annual mean	40

(1) Conversions between $\mu\text{g m}^{-3}$ and ppb are as used by the EC, i.e. 1ppb NO₂ = 1.91 $\mu\text{g m}^{-3}$ at 20°C and 1013 mB.

(2) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007, The Stationery Office, ID 5611194 07/07.

(3) Air Quality Regulations 2007 (SI 2007/64), Air Quality Standards (Wales) Regulations 2007 (Welsh SI 2007 717 (W63)), Air Quality Standards (Scotland) Regulations 2007 (SSI 2007 No. 182), Air Quality Standards (Northern Ireland) Regulations 2007 (Statutory Rule 2007 No. 265)

(4) Council Directive 85/203/EEC.

(5) Council Directive 2008/50/EC.

(6) WHO Guidelines for Air Quality WHO/SDE/OEH/00.02 (2000).

Benzene

Guideline Set By	Description	Criteria Based On	Value ⁽¹⁾ / $\mu\text{g m}^{-3}$ (ppb)
The Air Quality Strategy^(2,3) All UK England⁽⁴⁾ & Wales⁽⁵⁾ only: Scotland⁽⁶⁾ & Northern Ireland	Objective for Dec. 31 st 2003	Running annual mean	16.25 (5)
	Objective for Dec. 31 st 2010	Annual mean	5 (1.54)
	Objective for Dec. 31 st 2010	Running annual mean	3.25 (1.0)
ED Directive on Ambient Air Quality and Cleaner Air for Europe ⁽⁸⁾	Limit Value. To be achieved by Jan 1 st 2010	Annual calendar year mean	5 (1.5)

(1) Conversions between $\mu\text{g m}^{-3}$ and ppb are those used by the EC, i.e. 1ppb benzene = 3.25 $\mu\text{g m}^{-3}$ at 20°C and 1013 mB.

(2) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007, The Stationery Office, ID 5611194 07/07.

(3) Air Quality (England) Regulations 2000 (SI 2000/928), Air Quality (Scotland) Regulations 2000 (SSI 2000/97), Air Quality (Wales) Regulations 2000 (SI 2000/1940 (W138)).

(4) Air Quality (Amendment) (England) Regulations 2002 (SI 2002/3043)

(5) Air Quality (Amendment) (Wales) Regulations 2002 (SI 2002/3182 (W298))

(6) Air Quality (Amendment) (Scotland) Regulations 2002 (SI 2002/297)

(7) Council Directive 2008/50/EC.

Appendix 2

Calibration Procedures for Automatic Analyser

The analyser at Halkett Place is calibrated monthly by the Health Protection team. Standard gas calibration mixtures are used to check the instrument’s span, and chemically scrubbed air is used to check the instrument’s zero. All gas calibration standards used for routine analyser calibration are certified against traceable primary gas calibration standards at the Gas Standards Calibration Laboratory at AEA. The calibration laboratory operates within a specific and documented quality system and has UKAS accreditation for calibration of the gas standards used in this survey. The calibration form used is shown below.

Jersey Calibration Form

JERSEY
HALKETT PLACIDPERATOR: DATE: EPISODE? y/n
 TIME: GMT
 SAMPLE SYSTEM OK? y/n

Pre Calibration Checks

NOx

Analyser OK:
 Sample LED on:
 Cal LED on:
 Fault LED off:
 Serial Number:

Time:
 Range:
 Units:
 Stabil: ppb
 Sample Flow: cc/min
 Ozone Flow: cc/min
 PMT: mV
 Norm PMT: mV
 Azero: mV
 HVPS: V
 Rcell Temp: deg C
 Box Temp: deg C
 PMT Temp: deg C
 IZS Temp: deg C
 Moly Temp: deg C
 RCELL: inHg
 SAMP: inHg
 NOx Slope:
 NOx Offs: mV
 NO Slope:
 NO Offs: mV

Calibration

Zero

	1	2	3	(Average)
NO:	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
NO2:	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

Cal Cylinder

	1	2	3	(Average)
NO:	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
NO2:	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

Cyl no: Pressure: psi

Final Checks

Analyser OK: y/n
 Analyser sampling ambient: y/n
 Tubing connected to inlet: y/n

Cylinder turned off: y/n
 Filter changed: y/n
 Status flags off: y/n

Comments:

Calibration end time: GMT

Post Calibration Checks

NOx

Analyser OK:
 Sample LED on:
 Cal LED on:
 Fault LED off:
 Serial Number: 16126

Time:
 Range:
 Units:
 Stabil: ppb
 Sample Flow: cc/min
 Ozone Flow: cc/min
 PMT: mV
 Norm PMT: mV
 Azero: mV
 HVPS: V
 Rcell Temp: deg C
 Box Temp: deg C
 PMT Temp: deg C
 IZS Temp: deg C
 Moly Temp: deg C
 RCELL: inHg
 SAMP: inHg
 NOx Slope:
 NOx Offs: mV
 NO Slope:
 NO Offs: mV

An important aspect of QA/QC procedures is the 12-monthly intercalibration and audit check undertaken every 12 months. This audit has two principle functions, firstly to check the instrument and the site infrastructure, and secondly to recalibrate the transfer gas standards routinely used on-site, using standards recently checked in the calibration laboratory. AEA’s audit calibration procedures are UKAS accredited to ISO 17025.

In line with current operational procedures within the Defra Automatic Urban and Rural Network (AURN), full intercalibration audits take place at the end of winter and summer. At these visits, the essential functional parameters of the monitors, such as noise, linearity and, for the NO_x monitor, the efficiency of the NO₂ to NO converter are fully tested. In addition, the on-site transfer calibration standards are checked and re-calibrated if necessary, the air intake sampling system is cleaned and checked and all other aspects of site infrastructure are checked.

Appendix 3

Nitrogen Dioxide Diffusion Tubes: Bias

Adjustment Factor

The precision and accuracy of the diffusion tubes in this study were quantified by exposing them in triplicate alongside the automatic NO_x analyser at Halkett Place.

The percentage by which the diffusion tubes over-or under-estimate with respect to the automatic chemiluminescent analyser (defined within the European Community as the reference method for NO₂) is calculated as follows:

Percentage bias $B = 100 \times (D-C)/C$

- where D = the average NO₂ concentration as measured using diffusion tubes and C is the average NO₂ concentration as measured using the automatic analyser.

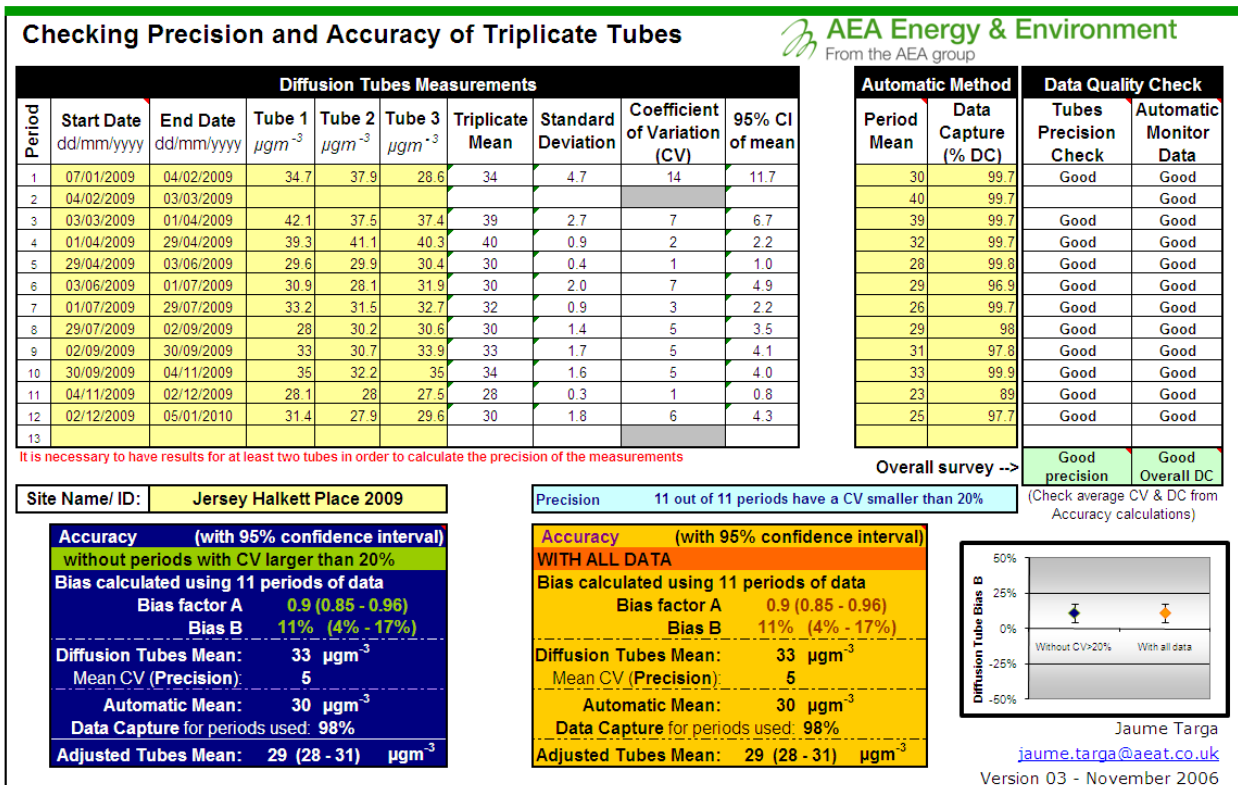
The diffusion tube annual mean concentrations measured at the other (non-co-located) sites can be adjusted for the diffusion tube over/under-read, by application of a bias adjustment factor, calculated as follows:

Bias adjustment factor = C/D (where D and C are the annual mean NO₂ concentrations as measured using diffusion tubes and the automatic analyser respectively, as above).

These calculations were carried out using a spreadsheet tool developed by AEA: see Figure A3.1 below. This spreadsheet shows the diffusion tube concentrations to 1 decimal place as reported by the analyst – but given the uncertainty on diffusion tube measurements it is only considered valid to report to the nearest integer in the report.

(Note – the annual mean calculated by the spreadsheet for the automatic monitor is shown as 30 $\mu\text{g m}^{-3}$ rather than 31 $\mu\text{g m}^{-3}$: this is because the spreadsheet shows the mean of the 12 monthly means, rather than the mean of the complete hourly dataset. This makes a negligible difference to the bias adjustment factor).

Figure A3.1 Precision and Bias Spreadsheet, showing Halkett Place dataset.



Appendix 4

BTEX Diffusion Tubes: Monthly Dataset and Annual Means 1997-2009

Table A4.1 Monthly mean Hydrocarbon Concentrations, $\mu\text{g m}^{-3}$ – Beresford Street

Start Date	benzene	toluene	ethyl benzene	m,p -xylene	o-xylene
7-Jan-09	2.7	8.0	1.7	5.4	2.0
4-Feb-09	2.4	8.5	1.8	6.0	2.4
3-Mar-09	1.6	6.7	1.5	4.5	1.6
1-Apr-09	2.2	8.1	1.8	5.6	2.1
29-Apr-09	1.1	5.5	1.2	4.2	1.8
3-Jun-09	1.1	5.6	1.2	4.3	1.5
1-Jul-09	1.2	6.1	1.3	4.0	1.6
29-Jul-09	1.2	5.3	1.3	4.8	1.8
2-Sep-09	1.7	6.9	1.6	6.1	2.1
30-Sep-09	1.6	7.4	1.6	5.9	2.2
4-Nov-09	2.3	7.1	1.6	5.4	2.2
2-Dec-09	2.6	8.1	1.6	5.8	2.3
Average	1.8	6.9	1.5	5.2	2.0

Table A4.2 Monthly mean Hydrocarbon Concentrations, $\mu\text{g m}^{-3}$ – Le Bas Centre

Start Date	benzene	toluene	ethyl benzene	m,p -xylene	o-xylene
7-Jan-09	2.5	7.6	3.1	5.2	2.2
4-Feb-09	2.1	7.0	1.5	4.9	2.0
3-Mar-09	1.5	5.2	1.2	3.5	1.2
1-Apr-09	1.4	5.8	1.3	4.3	1.5
29-Apr-09	1.0	3.7	1.0	3.1	1.1
3-Jun-09	0.8	3.6	0.9	2.9	1.0
1-Jul-09	1.2	7.2	1.8	4.1	1.6
29-Jul-09	0.8	4.4	1.0	3.5	1.3
2-Sep-09	1.2	4.6	1.1	3.4	1.3
30-Sep-09	1.0	5.3	1.1	4.0	1.5
4-Nov-09	1.1	4.8	1.3	3.9	1.5
2-Dec-09	1.9	5.9	1.2	4.3	1.8
Average	1.4	5.4	1.4	3.9	1.5

Table A4.3 Monthly mean Hydrocarbon Concentrations, $\mu\text{g m}^{-3}$ – Springfield Garage

Start Date	benzene	toluene	ethyl benzene	m,p -xylene	o-xylene
7-Jan-09	8.4	55.0	9.3	33.1	12.5
4-Feb-09	5.9	29.1	4.6	15.9	5.9
3-Mar-09	4.5	23.4	3.9	12.6	4.6
1-Apr-09	5.2	29.6	4.7	16.6	5.7
29-Apr-09	3.5	22.3	3.8	13.5	4.9
3-Jun-09	Site closed				
1-Jul-09					
29-Jul-09					
2-Sep-09					
30-Sep-09					
4-Nov-09					
2-Dec-09					
Average	5.5	31.9	5.3	18.4	6.7

Table A4.4 Monthly mean Hydrocarbon Concentrations, $\mu\text{g m}^{-3}$ – Faux Bie

Start Date	benzene	toluene	ethyl benzene	m,p -xylene	o-xylene
7-Jan-09					
4-Feb-09					
3-Mar-09					
1-Apr-09					
29-Apr-09					
3-Jun-09	0.9	4.9	1.0	3.1	1.0
1-Jul-09	1.1	6.1	1.2	3.2	1.3
29-Jul-09	1.1	7.2	1.4	4.6	1.7
2-Sep-09	1.3	4.4	1.1	3.3	1.2
30-Sep-09	1.2	5.9	1.1	3.5	1.3
4-Nov-09	1.4	5.0	1.2	3.0	1.2
2-Dec-09	1.8	5.2	0.9	3.3	1.3
Average	1.3	5.5	1.1	3.4	1.3

Table A4.5 Monthly mean Hydrocarbon Concentrations, $\mu\text{g m}^{-3}$ – Clos St Andre

Start Date	benzene	toluene	ethyl benzene	m,p -xylene	o-xylene
7-Jan-09	1.1	1.8	0.5	1.2	0.5
4-Feb-09	1.0	2.4	0.6	1.9	0.7
3-Mar-09	0.8	1.6	0.5	1.2	0.4
1-Apr-09	0.9	2.3	0.6	1.5	0.6
29-Apr-09	0.5	1.3	0.6	1.3	0.6
3-Jun-09	0.5	1.4	0.5	1.2	0.3
1-Jul-09	0.8	1.4	0.6	1.0	0.5
29-Jul-09	0.4	1.5	0.4	1.3	0.5
2-Sep-09	0.6	1.7	0.6	1.7	0.6
30-Sep-09	0.4	2.1	0.5	1.5	0.6
4-Nov-09	0.9	1.4	0.5	0.9	0.4
2-Dec-09	1.2	2.0	0.4	1.5	0.8
Average	0.8	1.7	0.5	1.4	0.5

Table A4.6 Monthly mean Hydrocarbon Concentrations, $\mu\text{g m}^{-3}$ – Handsford Lane

Start Date	benzene	toluene	ethyl benzene	m,p -xylene	o-xylene
7-Jan-09	1.9	5.6	2.4	8.6	2.7
4-Feb-09	1.5	4.3	2.0	7.1	2.3
3-Mar-09	1.1	3.9	1.9	6.8	2.1
1-Apr-09	1.1	5.5	1.9	7.0	2.2
29-Apr-09	0.4	5.0	1.6	6.8	2.0
3-Jun-09	0.9	4.9	2.2	10.4	2.5
1-Jul-09	0.6	4.4	1.6	7.4	2.0
29-Jul-09	0.8	4.4	1.8	8.7	2.0
2-Sep-09	1.2	6.5	2.4	11.0	3.2
30-Sep-09	0.7	5.4	2.3	10.9	3.2
4-Nov-09	1.2	4.4	2.2	10.0	2.4
2-Dec-09	1.7	4.1	1.7	7.1	2.6
Average	1.1	4.9	2.0	8.5	2.4

Table A4.7 Monthly mean Hydrocarbon Concentrations, $\mu\text{g m}^{-3}$ – Airport

Start Date	benzene	toluene	ethyl benzene	m,p -xylene	o-xylene
7-Jan-09	1.3	1.3	0.6	1.5	0.4
4-Feb-09	0.8	1.0	0.3	0.8	0.4
3-Mar-09	0.9	3.0	0.5	1.0	0.2
1-Apr-09	0.5	1.2	0.3	0.8	0.2
29-Apr-09	0.3	2.4	0.4	1.3	0.5
3-Jun-09	0.5	2.8	0.4	0.7	0.2
1-Jul-09	0.3	0.9	0.4	0.6	0.3
29-Jul-09	0.5	0.7	0.4	0.6	0.3
2-Sep-09	0.5	3.9	0.3	0.3	0.1
30-Sep-09	0.4	4.4	2.0	2.2	0.9
4-Nov-09	0.4	1.2	0.5	0.6	0.2
2-Dec-09	0.8	1.3	0.2	0.6	0.4
Average	0.6	2.0	0.5	0.9	0.4

Table A4.8 Comparison of Hydrocarbon Concentrations, Jersey, 1997 - 2009.

	benzene, $\mu\text{g m}^{-3}$	toluene, $\mu\text{g m}^{-3}$	ethylbenzene $\mu\text{g m}^{-3}$	m+p xylene, $\mu\text{g m}^{-3}$	o-xylene, $\mu\text{g m}^{-3}$
Beresford Street					
1997	10.4	20.7	5.3	11.9	5.3
1998	8.1	18.8	4.0	10.2	4.4
1999	5.9	13.8	2.7	7.5	3.5
2000	2.9	14.2	3.5	10.2	4.0
2001	3.3	14.9	3.5	9.7	3.5
2002	2.6	13.0	2.7	8.0	3.1
2003	2.0	11.5	2.2	6.6	2.2
2004	1.9	9.8	5.1	5.5	2.0
2005	1.7	8.9	1.8	5.3	1.9
2006	2.2	7.4	1.3	4.6	1.6
2007	1.7	10.4	1.7	4.4	1.8
2008	1.6	6.1	1.4	4.3	1.6
2009	1.8	6.9	1.5	5.2	2.0
Le Bas Centre					
1997	9.1	17.2	5.3	9.7	4.4
1998	7.5	16.1	3.1	8.4	4.0
1999	3.6	11.1	2.2	5.7	2.7
2000	2.9	12.6	3.1	8.4	3.1
2001	2.6	13.4	2.7	7.5	3.1
2002	2.0	8.0	1.8	5.7	2.2
2003	1.3	8.0	1.8	4.9	1.8
2004	1.3	6.6	3.3	3.9	1.4
2005	1.3	5.3	1.1	3.4	1.2
2006	1.5	4.4	0.8	2.8	1.0
2007	1.5	6.5	1.3	3.2	1.3
2008	1.4	5.6	1.4	3.7	1.4
2009	1.4	5.4	1.4	3.9	1.5
Handsford Lane					
2004	1.0	16.1	7.3	8.5	2.0
2005	1.0	3.7	2.1	7.1	2.2
2006	1.2	4.8	1.3	5.1	1.6
2007	1.1	6.7	2.2	6.4	2.2
2008	1.0	4.0	2.2	7.6	2.2
2009	1.1	4.9	2.0	8.5	2.4

Table A4.8 continued Comparison of Hydrocarbon Concentrations, -continued : Jersey, 1997 - 2009.

	benzene, $\mu\text{g m}^{-3}$	toluene, $\mu\text{g m}^{-3}$	ethylbenzene $\mu\text{g m}^{-3}$	m+p xylene, $\mu\text{g m}^{-3}$	o-xylene, $\mu\text{g m}^{-3}$
Springfield Garage					
1997	25.0	47.9	8.4	19.0	8.4
1998	25.0	47.1	6.6	19.0	7.5
1999	14.6	41.7	5.7	16.8	6.6
2000	5.2	35.2	8.0	22.1	8.8
2001	6.8	42.9	8.0	23.0	8.4
2002	5.5	36.8	6.2	19.0	7.1
2003	4.9	34.1	5.7	15.9	5.7
2004	4.7	30.9	13.5	14.5	5.2
2005	3.3	22.8	3.6	11.2	4.0
2006	3.9	21.7	2.6	10.2	3.7
2007	4.3	29.5	4.0	11.9	4.4
2008	4.2	21.7	3.5	11.4	4.4
2009 ^a	5.5	31.9	5.3	18.4	6.7
Faux Bie					
2009 ^b	1.3	5.5	1.1	3.4	1.3
Clos St Andre					
2000	1.0	3.4	0.9	2.7	0.9
2001	1.3	4.6	1.3	2.7	1.3
2002	1.0	2.7	0.9	2.2	0.9
2003	1.0	4.2	0.9	1.8	0.4
2004	0.7	2.2	1.2	1.2	0.4
2005	0.7	2.2	0.5	1.3	0.5
2006	1.0	2.0	0.4	1.2	0.4
2007	0.8	2.9	0.8	1.8	1.2
2008	0.8	2.1	1.0	1.5	0.5
2009	0.8	1.7	0.5	1.4	0.5
Airport					
2002	1.0	2.7	0.9	2.2	0.9
2003	1.0	3.1	0.4	0.9	0.4
2004	0.6	1.1	1.1	0.6	0.3
2005	0.6	1.6	0.2	0.6	0.2
2006	1.0	1.4	0.5	0.9	0.3
2007	0.8	3.4	0.5	1.0	0.4
2008	0.6	1.7	0.3	0.8	0.3
	0.6	2.0	0.5	0.9	0.4

Footnotes:

- a) 2009 mean for Springfield Garage was based January – May 2009.
b) 2009 mean for Faux Bie based on July – December only.

AEA group
551.11 Harwell Business Centre
Didcot
Oxfordshire
OX11 0QJ

