

Diffusion Tube and Continuous Monitoring Summary

Camborne, Pool and Redruth Area

1st November 2008 – 30th April 2009

Prepared for Cornwall Council by;

The Air Quality Unit
Room E15, Opie Building
Cornwall College
Trevenson Road
Camborne
TR15 3RD



Report on the monitoring of nitrogen dioxide in Camborne, Pool and Redruth area

1st November 2008 – 30th of April 2009

Air Quality Unit, Cornwall College, TR15 3RD (agu@cornwall.ac.uk)

Commissioned by Chris Selby, Environmental Protection Manager, Cornwall Council, Camborne.

1.0 Introduction

Nitrogen dioxide (NO₂) concentrations have been continuously monitored since 16th of March 2006 in Wesley Street, Camborne and the 11th of April 2006 in Penryn Street, Redruth. The current continuous monitoring programme is a continuation of ongoing NO₂ diffusion tube surveys that indicated high concentrations of traffic-related NO₂ at these sites. In December 2005, in response to exceedences of the National Air Quality Strategy (NAQS) objectives, Kerrier District Council (KDC) declared an Air Quality Management Area (AQMA) which encompassed the Camborne, Pool and Redruth area (CPR). The extent of the AQMA boundary matches that of the CPR regeneration area; this is to ensure that future redevelopments do not compound the existing air quality situation. A diffusion tube monitoring programme was initiated to continue monitoring NO₂ in previously identified hotspots and to gather baseline data around predevelopment sites.

1.1. Nitrogen dioxide

NO₂ is not only a health damaging pollutant but also a good proxy measure for other traffic-related pollutants. The UK Government's National Air Quality Strategy (NAQS) objectives for NO₂ are shown in Table 1. As stated in the LAQM.TG (09) the NAQS annual mean objective applies to 'air at locations which are situated outside of buildings or other natural or man-made structures, above or below ground, and where members of the public are regularly present'. The NAQS 1-hour mean objective is more specific and only applies to those locations 'where members of the public are regularly present for an hour or more, in locations close to heavily trafficked roads.' LAQM.TG(09) states that if an annual mean concentration exceeds 60 µg m⁻³ then it is likely that the NAQS 1-hour mean objective would have been exceeded.

NETCEN gives estimated background concentrations of NO₂ in the CPR of 9.2 µg m⁻³ (<http://www.airquality.co.uk/archive/laqm/laqm.php>).

Table 1. NAQS objectives for NO₂

Nitrogen dioxide (NO ₂)	Measured as	Concentration
	Annual mean	40 µg m ⁻³
	1-hour mean (18 annual exceedences)	200 µg m ⁻³

2.0 Monitoring Locations

2.1 Wesley Street

An Airpointer (Air Monitors) is positioned on Wesley Street, Camborne and is collocated with triplicate NO₂ diffusion tubes for comparison. The monitor is mounted on a lamp post against the façade of a residential house adjacent to the roadside (Figure 1 and Plate 1). Wesley Street is a busy route through Camborne, particularly in the morning and evening rush hour; this is compounded by a bus stop which causes traffic hold-up, a pedestrian crossing and a road junction. Residential properties line one side of the street approximately two metres from the road opposite which is a car park serving Tesco's superstore and petrol station.

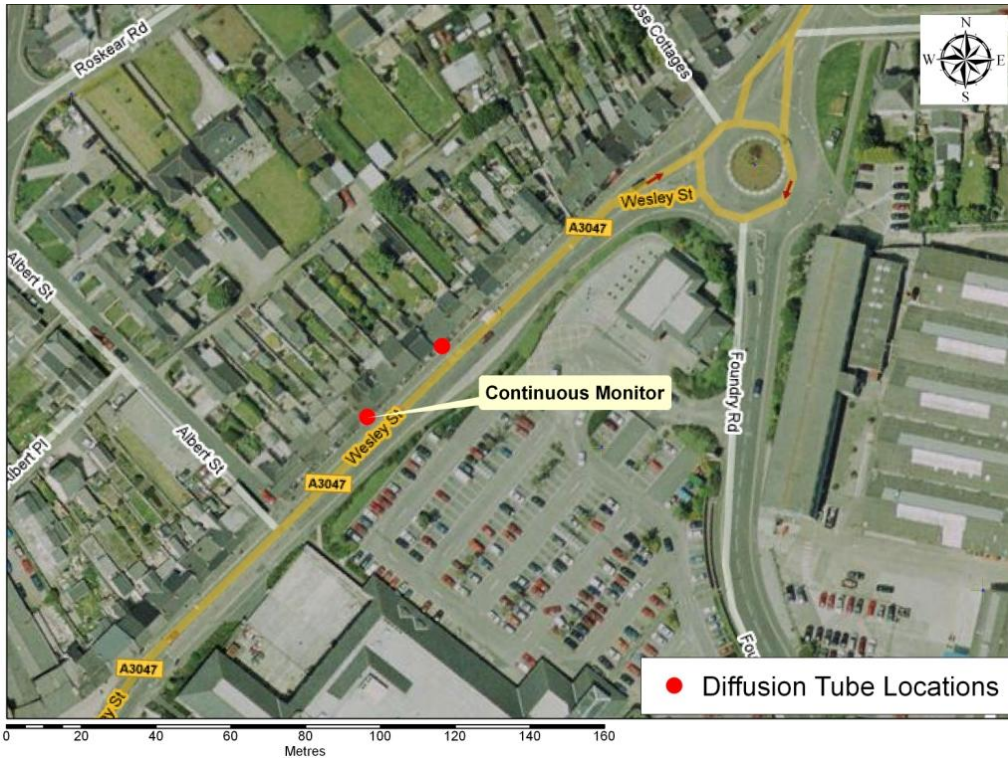


Figure 1. The location of the continuous monitor and diffusion tubes in Wesley Street.



Plate 1. The Airpointer mounted on a lamp post in Wesley Street, Camborne

2.2 Penryn Street

Penryn Street transects Redruth town centre and forms part of the eastern town centre access, diverging from the A393, a primary route between Redruth and Falmouth. Traffic lights are located at either end of Penryn Street and regulate heavy traffic flow during the morning and evening rush

hours. Penryn Street is lined by tall properties, including residential properties, shops and pubs, creating a 'canyon effect' compounding the poor air quality.

A Signal continuous chemiluminescent nitrogen oxides (NO_x) analyser is positioned in St Rumon's Gardens adjacent to Penryn Street (Plate 2). The monitor inlet head is positioned in a window space in the wall around the gardens on Penryn Street (Plate 3) and is approximately 2 m from the roadside, the inlet head is partially sheltered by the aperture in the wall. Triplicate diffusion tubes have been collocated with the inlet head since November 2007, and also at site 27 since November 2008 to evaluate the drop off of traffic-related pollution from the roadside to the monitor. The location of the tubes in comparison the monitor is illustrated in Appendix I.



Plate 2. The Signal continuous NO_x monitor viewed from inside St Rumon's Gardens.



Plate 3. The inlet head for the monitor situated in a recess viewed from Penryn Street.

2.3 Diffusion tube monitoring sites

Pollution hotspots in the CPR area have been identified in previous diffusion tube surveys (<http://www.caqf.org.uk>) and are a focus of this study. The number of diffusion tube monitoring sites in the CPR survey was reduced in November 2008, the sites which were exceeding or close to exceeding continued to be monitored. In this report the CPR district has been divided into three geographical areas to reflect the location of NO_2 diffusion tube monitoring in the CPR regeneration area.

- **Wesley Street and Tuckingmill** (Figure 4). Site numbers 6 and 7 are situated in Wesley Street, Camborne, previously identified as a pollution hotspot, and monitored as part of a long-term programme. Site 6 has triplicate diffusion tubes collocated with a continuous NO_2

monitor (Plate 1). Site 62 is situated in Tuckingmill, this was adjacent to a bus stop until August 2008 when the bus stop was relocated approximately 10m up the hill towards Camborne town centre.

- **Redruth Town Centre** (Figure 5), site numbers 25 – 28 and 61). Congestion and resulting poor air quality in Redruth Town Centre can be attributed to factors such as canyon street topography and traffic management systems combined with high traffic flow. Site 61 is collocated with a continuous NO_x monitor in St Rumon's Gardens, Penryn St.
- **Trefusis Junction** (Figure 6), site numbers 36, 43). Trefusis Junction is located on the B3300, a primary route between Redruth town centre and the A393. The junction has many attributes which exacerbate pollutant concentrations, such as queuing traffic, inclines, traffic lights and street canyons.

3.0 Equipment

3.1 Continuous monitor

Both the Airpointer (Wesley Street, Plate 1) and the Signal 'Street Nitrogen Oxides box' (Penryn Street, Plate 2) continuously monitor ambient concentrations of nitrogen oxides (NO_x) and are a DEFRA approved method for monitoring NO₂. Both monitors utilise the chemiluminescent method for determining NO₂ concentrations, this is an EU reference method specified in the First Air Quality Daughter Directive. Due to its relatively small size, the Airpointer can be mounted on street furniture at the epicentre of a pollution hotspot.

As the inlet head of the Signal monitor in Penryn Street is not located directly at the roadside three diffusion tubes have been collocated with the inlet head with a further three tubes at the roadside (approximately 30 metres from the inlet head). It is intended that the difference between the results for the two sets of diffusion tubes will give formula for assessing the drop-off in concentrations from the roadside to the Signal inlet.

3.2 Diffusion tubes

Diffusion tubes are an inexpensive method of monitoring ambient NO₂ concentrations and provide long-term averages. Diffusion tubes have been used extensively in the CPR area and have provided valuable data regarding the extent of air pollution concentrations in the locality.

Tubes are supplied by Gradko International with a preparation method of 20% TEA (triethanolamine) in water. Tubes are exposed for monthly periods and are deployed at the beginning of each month. QA/QC analysis undertaken by the Workplace Analysis Scheme for Proficiency (WASP 2008) programme for NO₂ diffusion tube analysis (operated by the Health and Safety Laboratory) reported that tubes supplied by Gradko International (Type I, 20% triethanolamine (TEA) in water) demonstrated "good" performance (http://www.laqmsupport.org.uk/Summary_of_Laboratory_Performance_in_WASP_R100-I04.pdf).

3.2.1 Diffusion tube bias adjustment

Triplicate tubes have been collocated with the continuous monitor in Wesley Street, Camborne and Penryn Street, Redruth since November 2007. Using AEA's Diffusion Tube Precision, Accuracy and Bias spreadsheet these collocated programmes will provide a local bias adjustment factor which can be applied to individual tubes in the surrounding area. The spreadsheet is available to download from www.airquality.co.uk/laqm/tools/AEA_DifTPAB_v03.xls. A local bias adjustment factor of 0.72 was derived for Wesley Street, this has been applied to tubes at Sites 6 and 7 in Wesley Street (Appendix 2). Due to the poor data capture in Penryn Street, resulting from laptop problems, a local factor cannot be calculated for this site for 2008 (Appendix 3). The National bias adjustment

factor has been updated from 0.89 to 0.90 for 2008 and 2009 and has been applied to the 2008 and 2009 diffusion tube results unless otherwise stated.

(<http://www.uwe.ac.uk/aqm/review/diffusiontube050509.xls>).

3.3 Traffic monitoring

Traffic volume, type and mean speed are continuously recorded in Wesley Street in Camborne using a Cornwall Council Automated Traffic Counter. This data provides a valuable tool for determining the relationship between air quality and traffic patterns. A comparison of traffic and NO₂ levels at Wesley Street in Camborne is displayed in Figures 11-13.

4.0 Results

4.1 Wesley Street

4.1.1 6-month continuous monitoring summary (1st November 2008 – 30th April 2009)

Data from the period 1st November 2008 to 30th April 2009 is summarised in Table 2. The 6-month mean NO₂ concentration was 37.0 µg m⁻³, which does not exceed the NAQS annual mean objective of 40 µg m⁻³. The maximum one hour mean concentration was 241.2 µg m⁻³, which occurred on the 2nd of April 2009 and a further exceedence occurred on the 20th of April 2009. Hourly means exceeded the annual objective level of 40 µg m⁻³ for a total of 31.3 % of the monitoring period.

Table 2. Summary of continuous monitoring data for the period 01/11/2008 – 30/04/2009.

Start date	No. of days	Annual Mean	200µg 1hr	
01/11/2008	181		37.0	Exceedences
End date	Data Capture	Max		241.2
30/04/2009	86.2%	Percentile		169.4

4.1.2 12-month continuous monitoring summary (1st May 2008 – 30th April 2009)

A summary of the data from the last 12 months (1st May 2008 – 30th April 2009) is illustrated in Table 3. The mean NO₂ concentration over this period was 38.3 µg m⁻³, therefore not exceeding the NAQS annual objective. There were two exceedences of the one hour mean, which occurred on the 2nd and 20th of April 2009. Hourly means exceeded the objective level of 40 µg g m⁻³ for a total of 35.6 % of the monitoring period.

Table 3. Summary of continuous monitoring data for the period 01/05/2008 – 30/04/2009.

Start date	No. of days	Annual Mean	200µg 1hr	
01/05/2008	365		38.3	Exceedences
End date	Data Capture	Max		241.2
30/04/2009	91.9%	Percentile		161.6

4.1.3 A comparison of continuous monitoring and collocated diffusion tubes

Triplicate diffusion tubes are collocated at the continuous monitor's inlet head; this allows a comparative study of the two methods, gives a degree of confidence to diffusion tube data collected in the CPR monitoring programme and, with nine months' worth of valid data, will allow a local bias adjustment to be calculated. The difference over the six-month period (01/11/2008 – 30/04/2009) between the continuous monitor and the triplicate diffusion tubes was 9.9 µg m⁻³ (20.7%) and the difference over the 12-month period ending 30/04/2009 was 11.1 µg m⁻³ (22.4%) (Table 4). A paired t-test shows no significant difference between the two monitoring methods (P-Value = 0.071) and can be seen in Figure 2.

Table 4. A comparison of continuous and diffusion tube data over the diffusion tube exposure period.

	Continuous Monitor	Collocated Diffusion Tubes
6-month mean	37.9 µg m ⁻³	47.7 µg m ⁻³
12-month mean	38.5 µg m ⁻³	49.6 µg m ⁻³

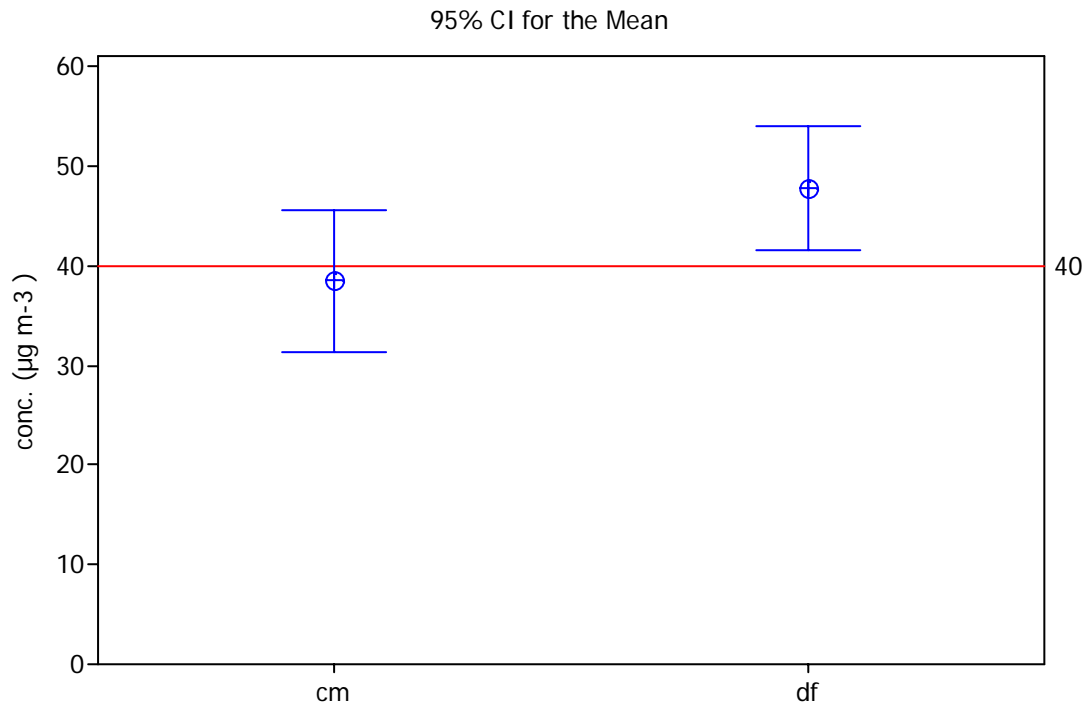


Figure 2. An interval plot of annual means for the Wesley Street continuous monitor and collocated diffusion tubes (01/11/2008 – 30/04/2009).

4.2 Penryn Street

4.2.1 6-month continuous monitoring summary (1st November 2008 – 30th April 2009)

The 6-month mean NO₂ concentration was 37.8 µg m⁻³, this did not exceed the NAQS objective of 40 µg m⁻³ (Table 5). There were no exceedences of one hour mean and the hourly means exceeded the 40 µg m⁻³ for 27.6% of the monitoring period. Data capture was 66.6% due to problems with the laptop. As the data capture is below 90 %, it is likely that episodes may have been missed and therefore a percentile was calculated which refers to exceedences of the hourly mean. The percentile for this period did not exceed 200 µg m⁻³, and therefore it was unlikely that the annual objective was surpassed.

Table 5. Summary of continuous monitoring data for the period 01/11/2008 – 30/04/2009.

Start date	No. of days	Annual Mean	200µg 1hr	
01/11/2008	181	37.8	Exceedences	0
End date	Data Capture		Max	132.52
30/04/2009	66.6%		Percentile	119.33

4.2.2 12-month continuous monitoring summary (1st May 2008 – 30th April 2009)

Table 6 is a summary of the data recorded over the last 12 months. The annual NO₂ concentration was 32.6 µg m⁻³, which does not exceed the NAQS annual objective of 40 µg m⁻³. There were also no exceedences of the hourly mean with only 22.1% of the monitoring period exceeding 40 µg m⁻³. The data capture for the 12-month period was 66.9% due to problems with the laptop and the power supply. The percentile did not exceed 200 µg m⁻³ therefore it was unlikely that the annual mean was exceeded.

Table 6. Summary of continuous monitoring data for the period 01/05/2008 – 30/04/2009.

Start date	No. of days	Annual Mean	200µg 1hr	
01/05/2008	365	32.6	Exceedences	0
End date	Data Capture		Max	132.52
30/04/2009	66.9%		Percentile	109.44

4.2.3 A comparison of continuous monitoring and collocated diffusion tube

At the continuous monitor's inlet head, triplicate diffusion tubes are collocated, which allows a comparative study of the two methods and gives a degree of confidence to diffusion tube data collected in the CPR monitoring programme. Nine months' worth of valid data is required to calculate a local bias adjustment. Over the last 6 months (01/11/2008 – 30/04/2009), the disparity between the continuous monitor and the triplicate diffusion tubes was 4.6 µg m⁻³ (≈10.7%) and 4.6 µg m⁻³ (≈11.7%) over the last 12 months (Table 7). A paired *t*-test show that there is a statistical difference between the two monitoring methods over the monitoring period (*P* = 0.000) although this cannot be seen in Figure 3.

Table 7. A comparison of continuous and diffusion tube data over the exposure period for the diffusion tubes.

	Continuous Monitor	Collocated Diffusion Tube
6-month mean	38.4 µg m ⁻³	43.0 µg m ⁻³
12-month mean	33.2 µg m ⁻³	37.6 µg m ⁻³

4.2.4 A summary of the drop-off in diffusion tube concentrations from the roadside

The location of the collocated tubes with the monitor and the roadside tubes (Site 27) is illustrated in Appendix I. Site 27 is 30 metres from the inlet head. The difference over the 6-month period

(01/11/2008 – 30/04/2009) between the triplicate diffusion tubes and Site 27 is $11.9 \mu\text{g m}^{-3}$ ($\approx 22\%$) and the difference over the 12-month period ending 30/04/2009 is $13.1 \mu\text{g m}^{-3}$ ($\approx 26\%$) (Table 8).

Table 8. A comparison data for the diffusion tubes collocated with the Signal monitor and the triplicate diffusion tubes at Site 27.

	Collocated Diffusion Tube	Diffusion Tube at Site 27
6-month mean	$43.0 \mu\text{g m}^{-3}$	$54.9 \mu\text{g m}^{-3}$
12-month mean	$37.6 \mu\text{g m}^{-3}$	$50.7 \mu\text{g m}^{-3}$

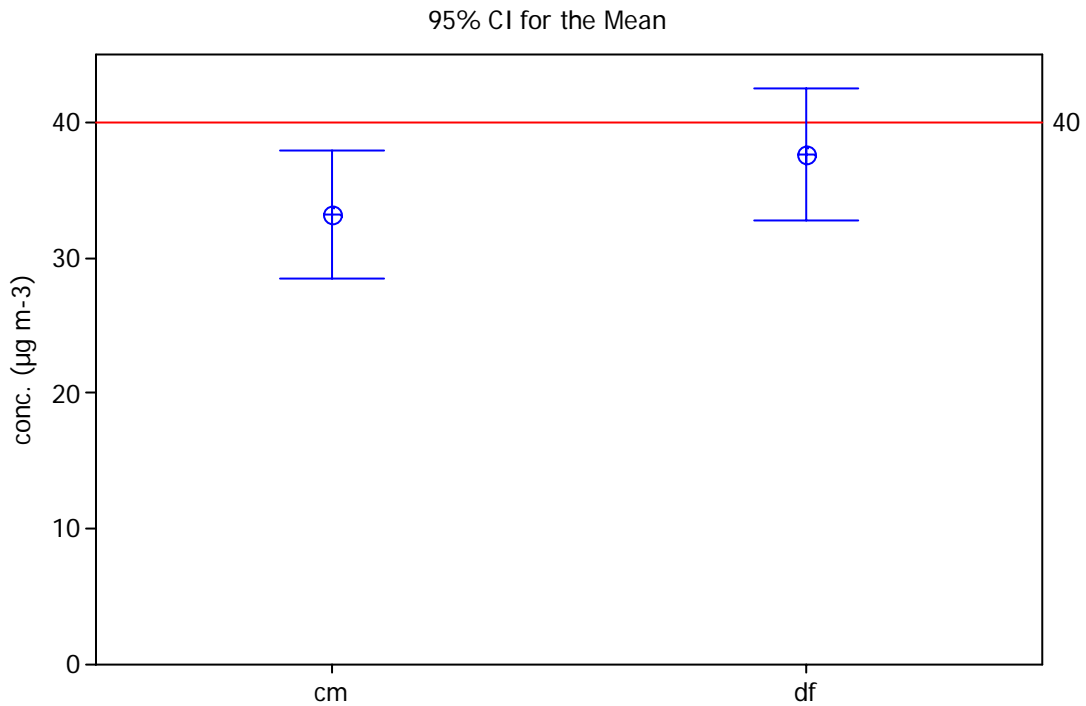


Figure 3. An interval plot of annual means for the Penryn Street continuous monitor and collocated diffusion tubes (01/11/2008 – 30/04/2009).

4.3 Diffusion tube monitoring

The following figures illustrate the locations of the diffusion tubes within the CPR area and also the annual NO₂ concentration. The diffusion tube concentrations were calculated using the national bias adjustment factor (0.9) as only a local factor has been derived for tubes in Wesley Street.

Exceedences of the annual NO₂ concentration were observed at the Site 6 and Site 7 in Wesley Street (Figure 4), Site 25, 26, 27 and 28 in Penryn Street (Figure 5) and at Site 43 in Trefusis Junction in Redruth (Figure 6). The highest concentration was observed at Site 7 of 58.8 µg m⁻³, which is adjacent to the bus stop in Wesley Street. Additional graphs and tables of diffusion tube data for this survey are available in Appendix 5 and 6.

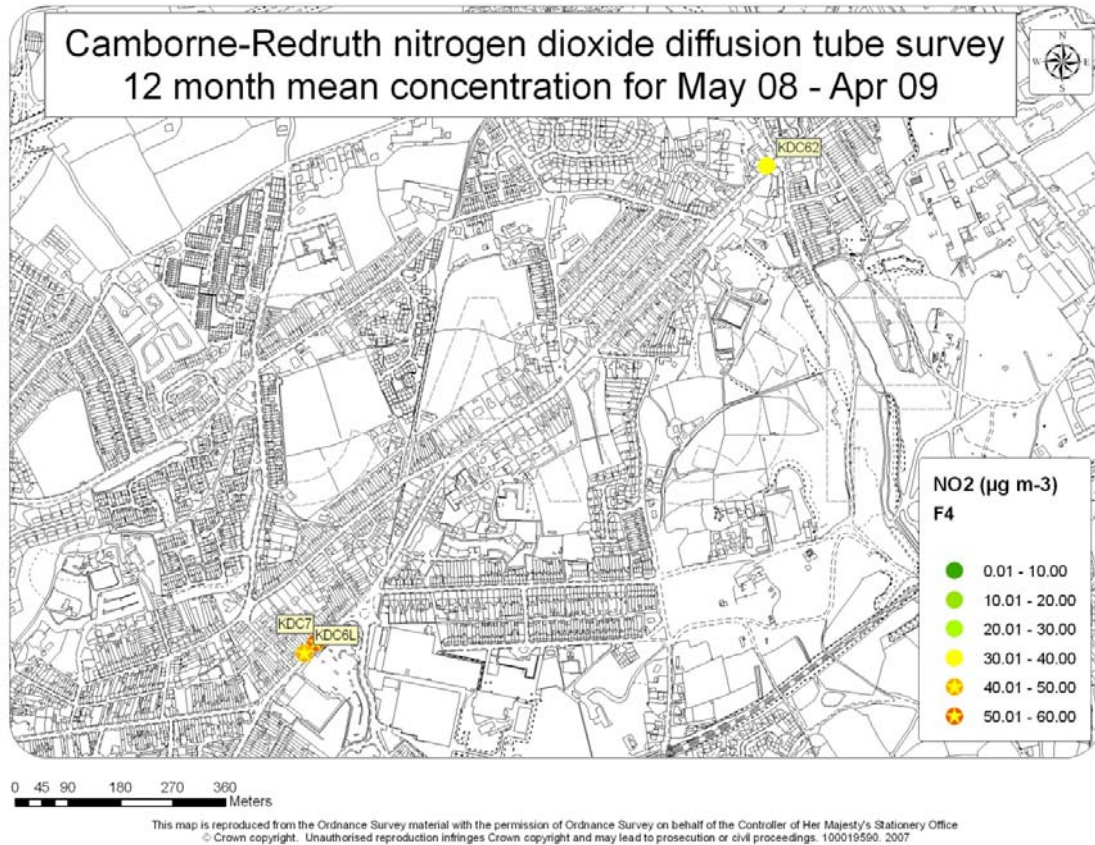


Figure 4. Diffusion tube locations and annual mean concentrations for Wesley Street and Tuckingmill (May 2008 – April 2009).

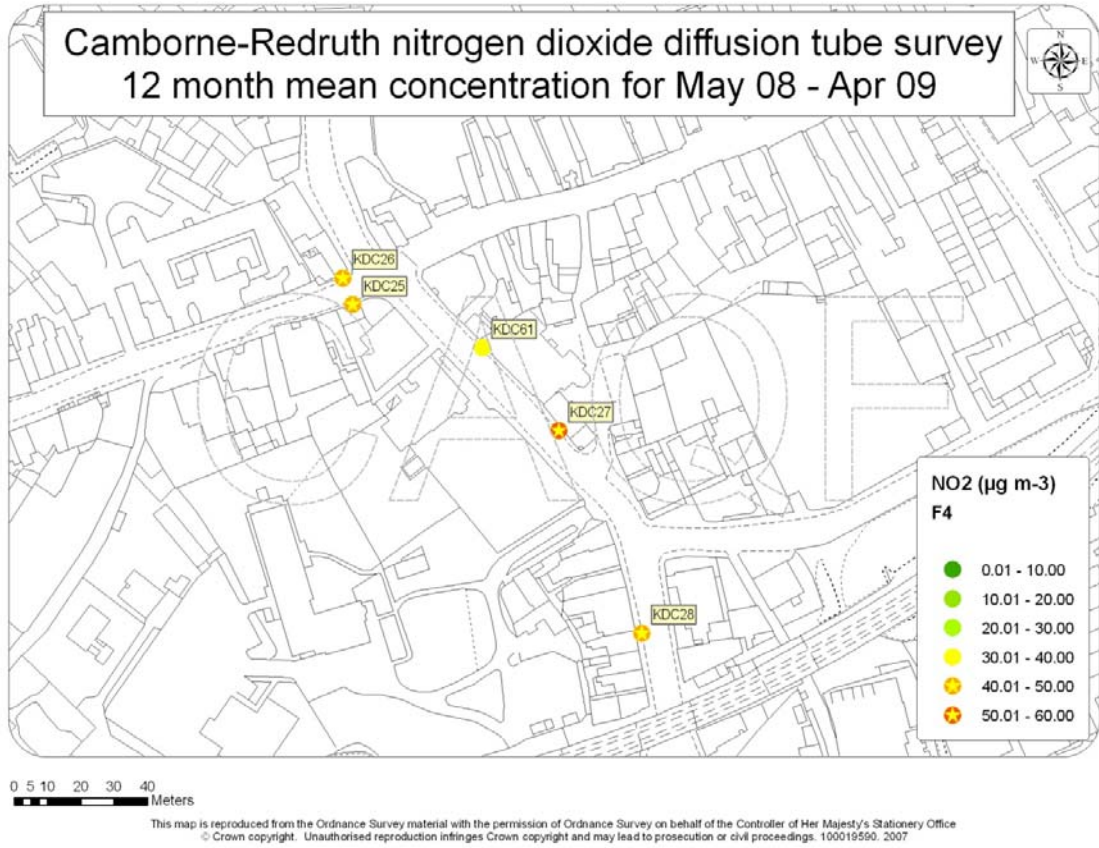


Figure 5. Diffusion tube locations and annual mean concentrations for Redruth town centre (May 2008 – April 2009).

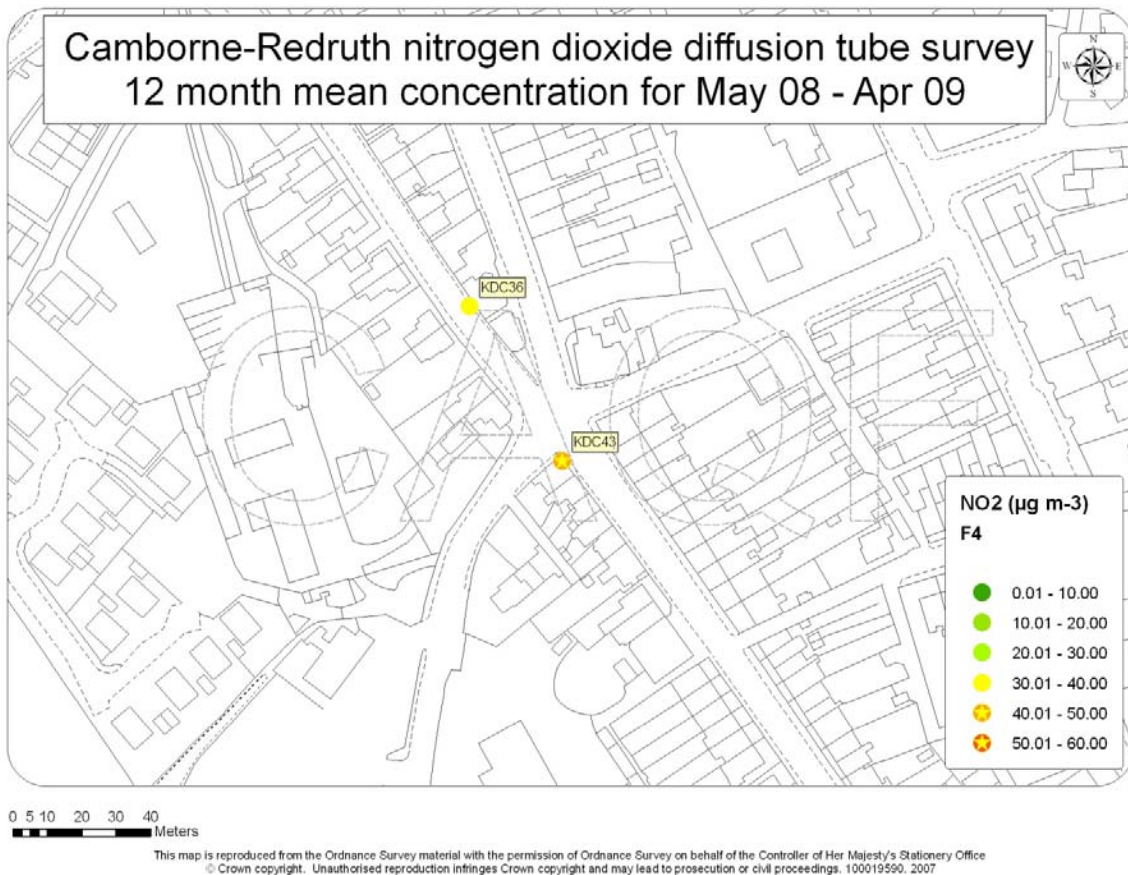


Figure 6. Diffusion tube locations and annual mean concentrations for Trefusis Junction (May 2008 – April 2009).

Table 9 illustrates the large disparity between the local and national bias adjustment factors, highlighting the need for a local factor in Penryn Street to apply to be able to apply it to the tubes in that locality.

Table 9. Mean NO₂ concentration for the last 12 months for the diffusion tubes in Wesley Street, calculated using the national bias adjustment factor and the local factor for Wesley Street (Appendix 2).

Site	National	Local
KDC6	47.74	38.19
KDC7	58.78	47.02

5.0 Discussion

5.1 Exceedences

In Wesley Street, the mean NO₂ concentration for the 6-month monitoring period (01/11/2008 – 30/04/2009) was 37.0 µg m⁻³; below the NAQS annual NO₂ objective value of 40 µg m⁻³. The mean NO₂ concentration for the 12-month period ending 30/04/2009 was 38.3 µg m⁻³; this also falls below the NAQS annual objective. Two exceedences of the 1-hour mean objective occurred on 02/04/2009 and 20/04/2009, both these exceedences occurred at 09.00 at either side of the April school holiday.

The mean NO₂ concentration for the monitoring period 01/11/2008 – 30/04/09 in Penryn Street, was 37.8 µg m⁻³, which was below the NAQS annual objective. The NO₂ concentration for the 12-month monitoring period ending the 30/04/09 was 32.6 µg m⁻³. No exceedences of either the annual or 1-hour objective were observed in Penryn Street.

Diffusion tubes at Site 6 and 7 in Wesley Street, Sites 25-27 in Penryn Street and Site 43 at Trefusis Junction exceeded the annual NO₂ objective:

5.2 Data Capture

Data capture over the 6-month monitoring period (01/11/2008 – 30/04/2009) at the continuous monitor in Wesley Street, Camborne was 86.2%. This is below the Defra data capture objective of 90%. This was due to problems with the molybdenum converter, which has now been replaced (Figure 7). The 12-month data capture value (01/05/2008 – 30/04/2009) was 91.9%.

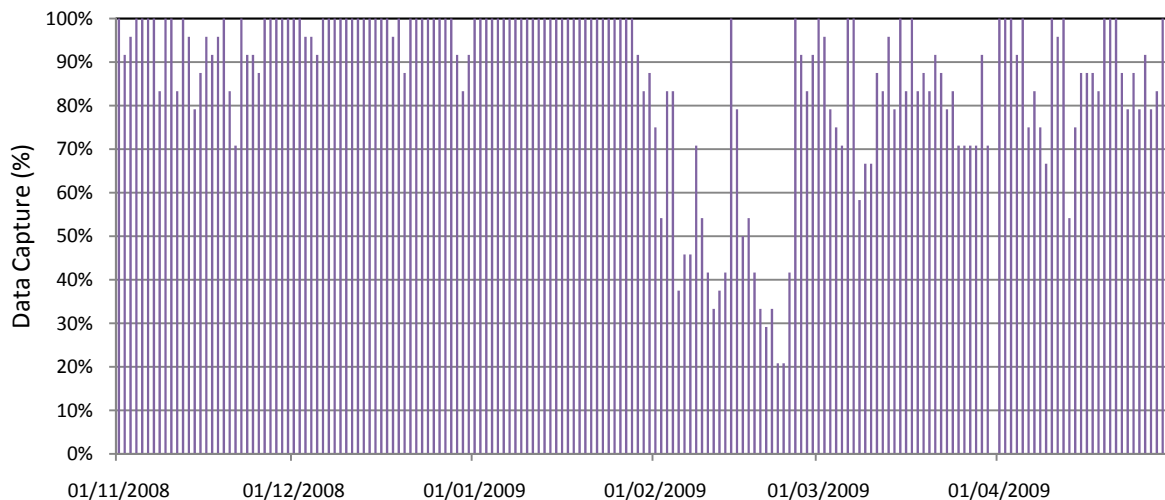


Figure 7. Data capture for the monitor in Wesley Street, the 6-month period ending 30/04/2009.

The data capture over the last 6 months for the continuous monitor in Penryn Street was 66.6% (Figure 8). This value is below the Defra data capture objective of 90%. Low data capture resulted from problems associated with the laptop. Data capture for the last 12 months was 66.9%, therefore due to poor data capture a local bias adjustment factor could not be calculated for Penryn Street for 2008.

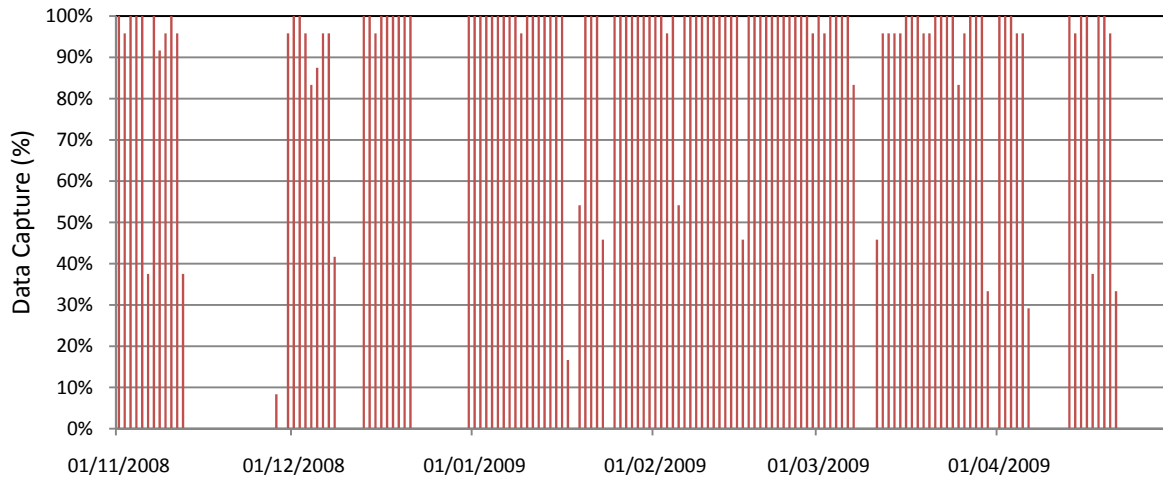


Figure 8. Data capture for the monitor in Wesley Street, the 6-month period ending 30/04/2009.

5.3 Diurnal Patterns

The mean NO₂ concentration recorded on Weekdays, Saturdays and Sundays on Penryn Street (Figure 9) for the period 01/11/2008 – 30/04/2009 was 40.55 µg m⁻³, 34.64 µg m⁻³ and 30.31 µg m⁻³ respectively. On Wesley Street (Figure 10) for the same period, concentrations were 38.53 µg m⁻³, 35.28 µg m⁻³ and 26.76 µg m⁻³ respectively. Figures 9 and 10 plot the weekday, Saturday and Sunday diurnal NO₂ concentration patterns as a 15-minute mean at Penryn Street and Wesley Street.

The diurnal NO₂ concentration pattern recorded in both Penryn Street and Wesley Street display typical traffic-related pollution scenario; that is NO₂ concentrations increase in the morning, maintaining a sustained high concentration throughout the day and decrease in the evening. The weekday diurnal maximum concentration occurs in the morning coinciding with school and commuter traffic. Weekend concentrations peak later than those observed during the weekdays with Saturday concentrations generally higher than those recorded on Sundays with exceptions in the early hours of the Sunday mornings. An automatic traffic counter on Wesley Street allows comparison between traffic levels and NO₂ concentrations. Comparisons of diurnal NO₂ and traffic concentrations for Weekdays, Saturdays and Sundays traffic at Wesley Street are available in Figures 11-13.

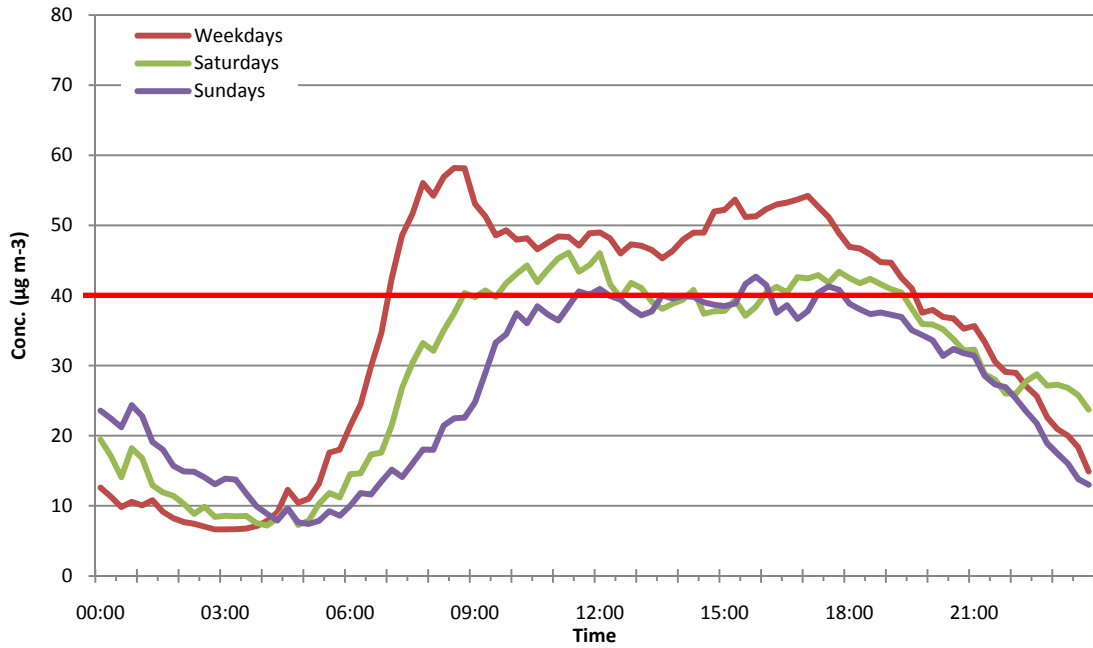


Figure 9. Diurnal patterns recorded in Penryn Street for the 12-month period ending 30/04/2009. The horizontal red line indicates the NAQS annual mean objective.

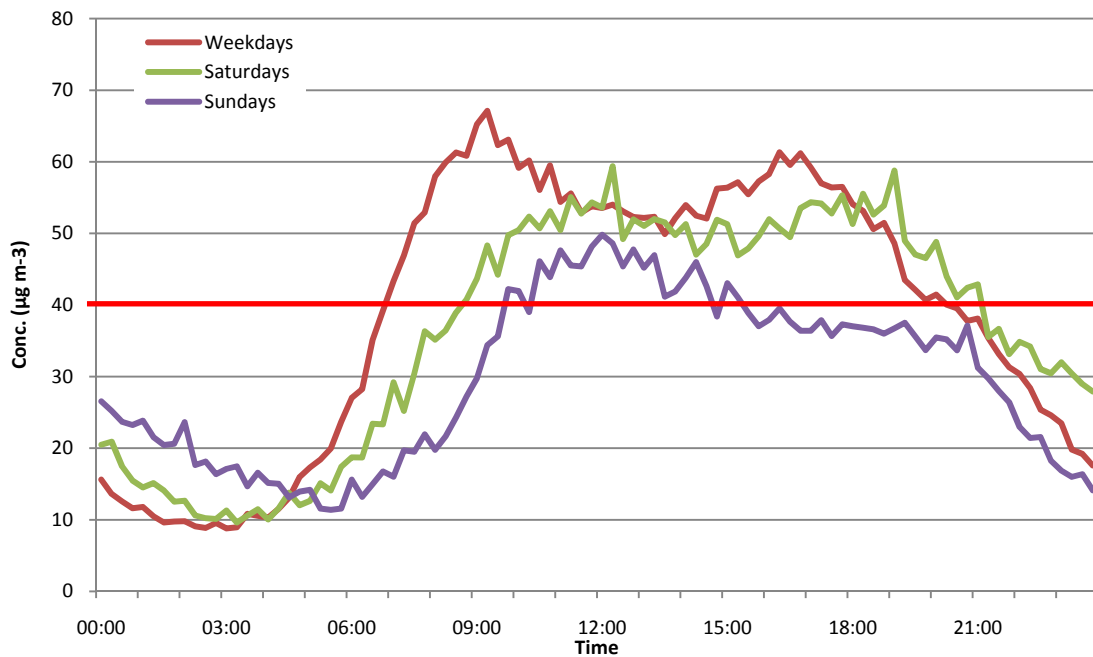


Figure 10. Diurnal patterns recorded in Wesley Street for the 12-month period ending 30/04/2009. The horizontal red line indicates the NAQS annual mean objective.

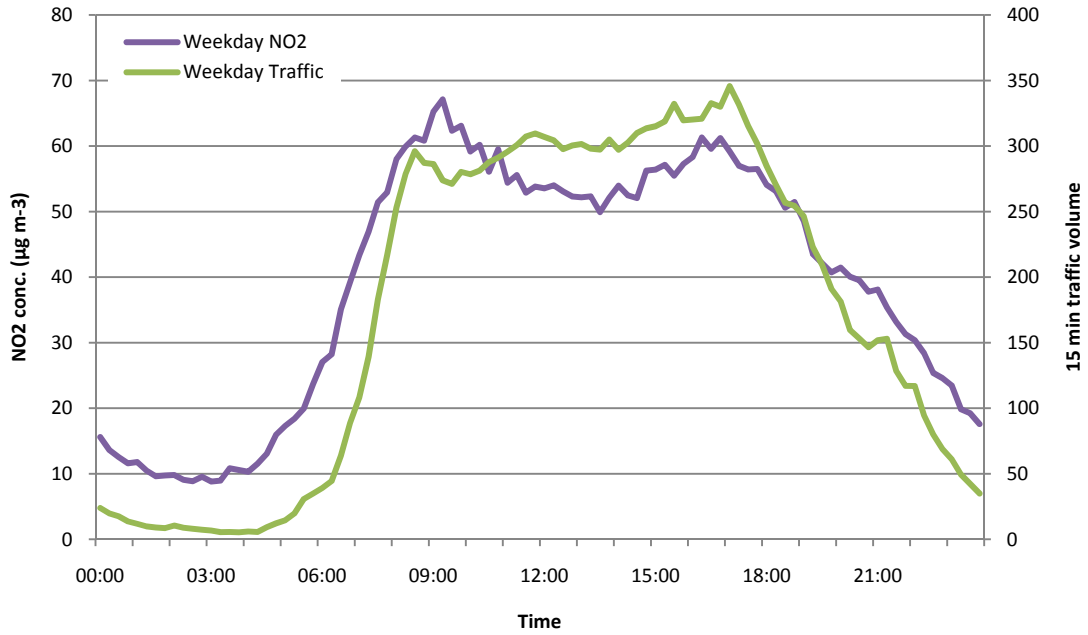


Figure 11. A comparison of weekday diurnal NO₂ and traffic concentrations recorded in Wesley Street for the 12-month period ending 30/04/2009.

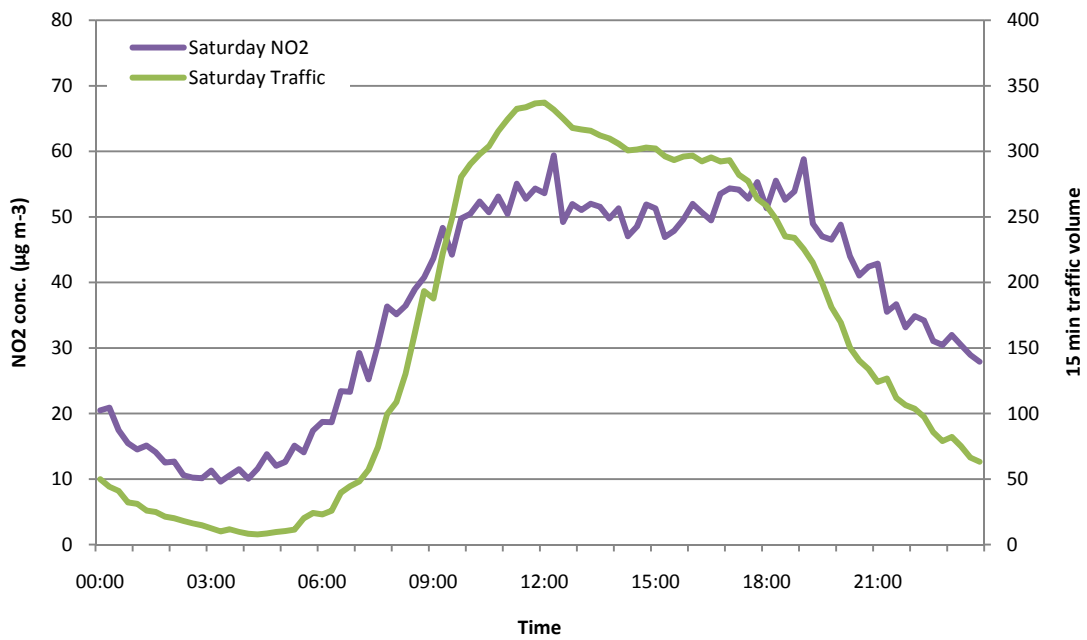


Figure 12. A comparison of Saturday diurnal NO₂ and traffic concentrations recorded in Wesley Street for the 12-month period ending 30/04/2009.

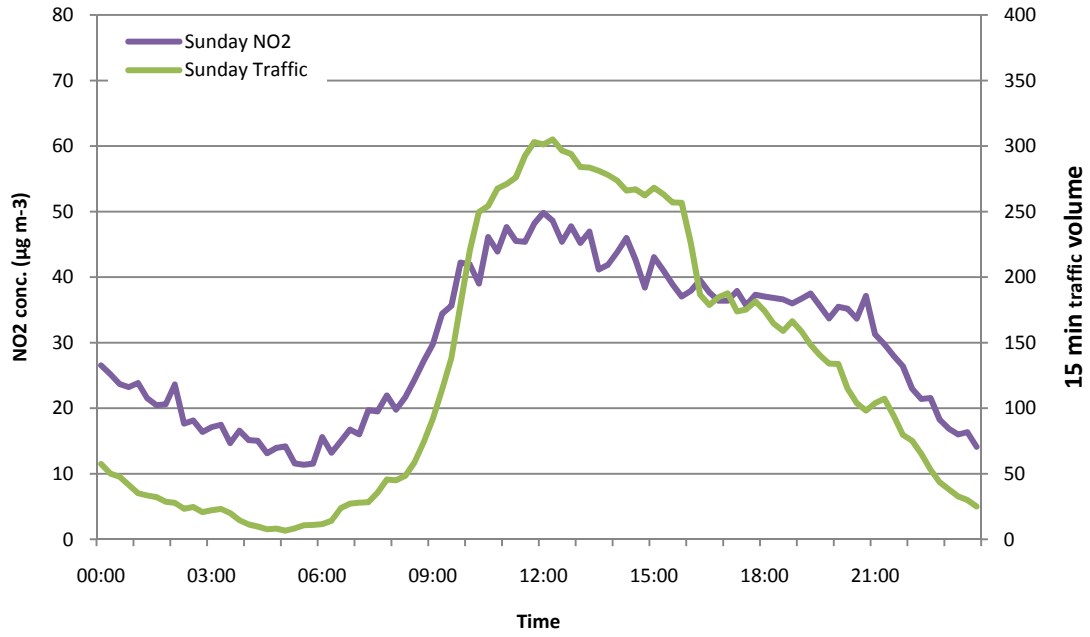


Figure 13. A comparison of Sunday diurnal NO₂ and traffic concentrations recorded in Wesley Street for the 12-month period ending 30/04/2009.

6.0 Conclusion

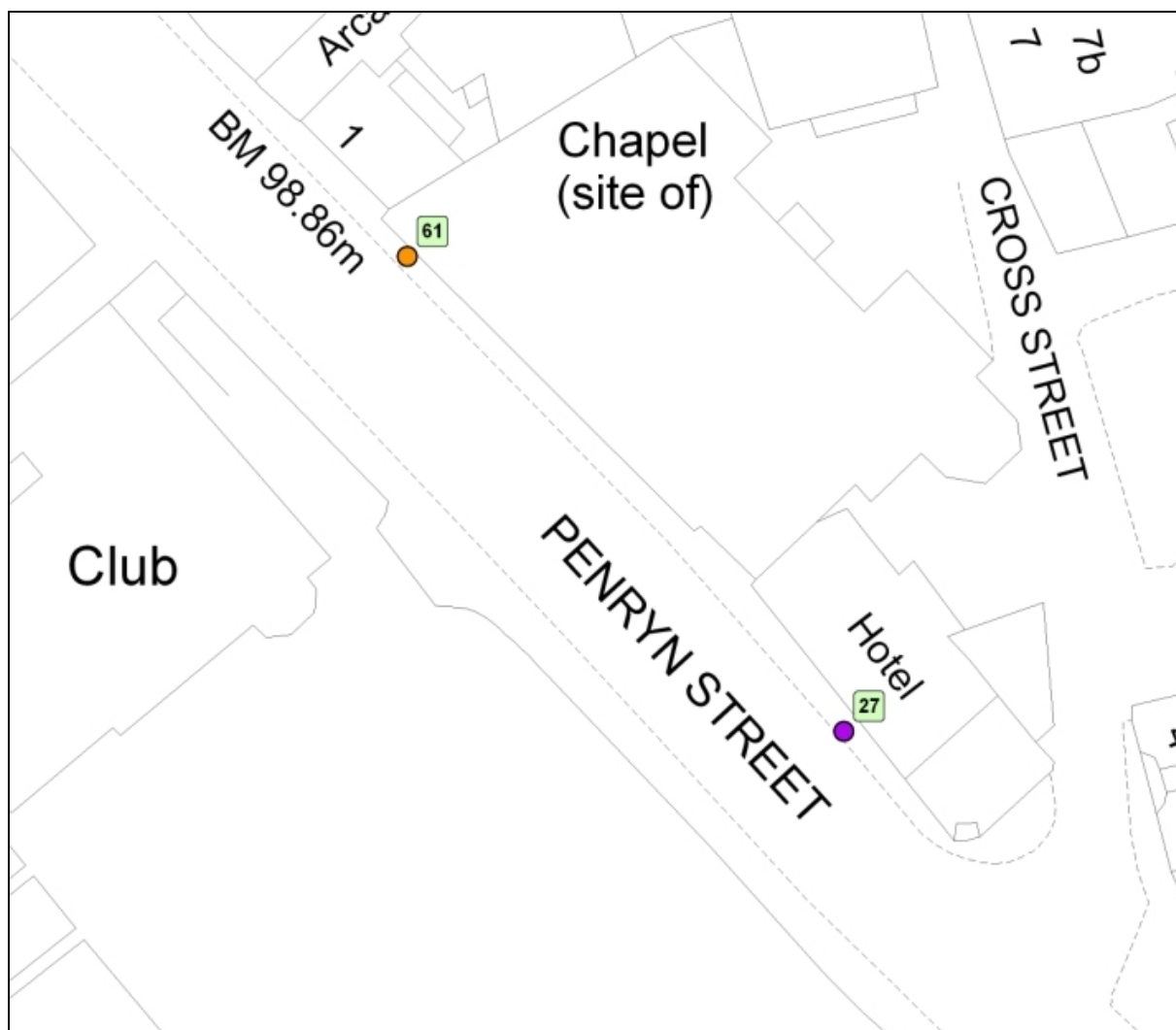
- The mean NO₂ concentration recorded in Penryn Street for November 1st 2008 – April 30th 2009 by the continuous monitor was 37.8 µg m⁻³; this resulted in no exceedences of the NAQS objectives for the annual mean. However, there is a 12-13 µg m⁻³ drop-off in the diffusion tube concentrations from the roadside (KDC27) to the monitor (KDC 6).
- The mean NO₂ concentration recorded in Wesley Street for November 1st 2008 – April 30th 2009 by the continuous monitor was 37.0 µg m³; two exceedences of the 1-hour mean were recorded in April 2009.
- The Penryn Street monitor recorded a data capture value of 66.6% between November 1st 2008 and April 30th 2009, falling below Defra's objective of 90%. The 99.8th percentile has been calculated for this 6-month period and indicates no exceedance of the NAQS objectives for the annual mean (119.33 µg m⁻³).
- The Wesley Street monitor recorded a data capture value of 86.2% between November 1st 2008 and April 30th 2009. This also falls below Defra's objective of 90% with the 99.8th percentile being calculated for this 6-month period again indicating no possible exceedance of the NAQS objective for the annual mean during the monitoring period (161.57 µg m⁻³).
- There was a statistically significant difference in recorded NO₂ concentration between the continuous monitor and collocated diffusion tube methods at the Penryn Street site, but not the Wesley Street site.
- The diurnal NO₂ concentration pattern displays a typical traffic-related pollution scenario.

Confidentiality

All sampling results from the monitoring sites in the CPR area will be the property of Cornwall Council, and will be subject to strict confidentiality and not disclosed any third party without prior formal permission from Cornwall Council.

Disclaimer

Cornwall College cannot accept any responsibility for the use to which the information is put nor for decisions, inferences or conclusions that are made on the basis on the information provided. No responsibility is taken for the accuracy of the sampling unless this is done under our own supervision.



Appendix I. Position of the diffusion tubes in Penryn Street, Redruth. Tube number 61 also marks the position of the continuous monitor inlet head.

Appendix 2. Collocation data applied to the Diffusion Tube Precision, Accuracy and Bias spreadsheet for Wesley Street.

Checking Precision and Accuracy of Triplicate Tubes

From the AEA group

Diffusion Tubes Measurements									
Period	Start Date dd/mm/yyyy	End Date dd/mm/yyyy	Tube 1 $\mu\text{g m}^{-3}$	Tube 2 $\mu\text{g m}^{-3}$	Tube 3 $\mu\text{g m}^{-3}$	Triplicate Mean	Standard Deviation	Coefficient of Variation	95% CI of mean
1	08/10/2008	28/10/2008							
2	28/10/2008	07/03/2008	52.53	55.90	52.04	53	2.1	4	5.2
3	07/03/2008	01/04/2008	50.43	42.10	55.10	49	6.6	13	16.4
4	01/04/2008	07/05/2008	53.38	59.25	60.59	58	3.8	7	9.5
5	07/05/2008	02/06/2008		56.13	58.61	57	1.8	3	16.8
6	02/06/2008	01/07/2008	60.23	64.34	61.15	62	2.2	3	5.4
7	01/07/2008	07/08/2008	50.75	52.29	47.86	50	2.2	4	5.6
8	07/08/2008	05/09/2008	39.25	49.90	45.45	45	5.4	12	13.3
9	05/09/2008	07/10/2008	39.41	42.63	32.53	38	5.2	14	12.8
10	07/10/2008	11/11/2008	61.57	53.50	63.08	59	5.2	9	12.8
11	11/11/2008	12/12/2008	61.39	61.86	62.34	62	0.5	1	1.2
12	12/12/2008	09/10/2009	57.87	60.84	60.86	60	1.7	3	4.3
13									

It is necessary to have results for at least two tubes in order to calculate the precision of the measurements

Site Name/ ID:	Wesley Street
Accuracy (with 95% confidence interval) without periods with CV larger than 20%	
Bias calculated using 11 periods of data	
Bias factor A	0.72 (0.64 - 0.83)
Bias B	39% (20% - 57%)
Diffusion Tubes Mean:	54 $\mu\text{g m}^{-3}$
Mean CV (Precision):	7
Automatic Mean:	39 $\mu\text{g m}^{-3}$
Data Capture for periods used:	95%
Adjusted Tubes Mean:	39 (35 - 45) $\mu\text{g m}^{-3}$

Precision	11 out of 11 periods have a CV smaller than 20%
Accuracy (with 95% confidence interval) WITH ALL DATA	
Bias calculated using 11 periods of data	
Bias factor A	0.72 (0.64 - 0.83)
Bias B	39% (20% - 57%)
Diffusion Tubes Mean:	54 $\mu\text{g m}^{-3}$
Mean CV (Precision):	7
Automatic Mean:	39 $\mu\text{g m}^{-3}$
Data Capture for periods used:	95%
Adjusted Tubes Mean:	39 (35 - 45) $\mu\text{g m}^{-3}$

Automatic Method	Data Quality Check
Period Mean	Tubes Precision Check
34.24	97.51
33.64	93.89
32.50	99.33
52.54	74.83
42.30	96.16
37.58	98.71
32.92	97.97
25.77	93.39
40.84	97.80
55.14	98.81
38.70	95.14
36.64	98.22

Overall survey --> **Good precision** **Good Overall**

(Check average CV & DC from Accuracy calculations)

Jaume Targa
jaume.targa@aeat.co.uk
Version 03 - November 2006

Appendix 3. Collocation data applied to the Diffusion Tube Precision, Accuracy and Bias spreadsheet for Penryn Street.

Checking Precision and Accuracy of Triplicate Tubes

From the AEA group

Diffusion Tubes Measurements									
Period	Start Date dd/mm/yyyy	End Date dd/mm/yyyy	Tube 1 $\mu\text{g m}^{-3}$	Tube 2 $\mu\text{g m}^{-3}$	Tube 3 $\mu\text{g m}^{-3}$	Triplicate Mean	Standard Deviation	Coefficient of Variation (CV)	95% CI of mean
1	08/10/2008	28/10/2008	42.76	42.53		43	0.2	0	1.5
2	28/10/2008	07/03/2008	42.13	55.51	53.29	50	7.2	14	17.8
3	07/03/2008	01/04/2008	40.14	39.70	41.79	41	1.1	3	2.7
4	01/04/2008	07/05/2008	46.71	47.95	37.72	44	5.6	13	13.9
5	07/05/2008	02/06/2008	31.91	41.98	39.76	38	5.3	14	13.1
6	02/06/2008	01/07/2008	42.55	45.47	46.74	45	2.1	5	5.3
7	01/07/2008	07/08/2008	32.64	37.89	36.32	36	2.7	8	6.7
8	07/08/2008	05/09/2008	34.89	34.04	32.20	34	1.4	4	3.4
9	05/09/2008	07/10/2008	26.86	29.40	28.10	28	1.3	5	3.2
10	07/10/2008	11/11/2008	36.28	35.00	34.34	35	1.0	3	2.5
11	11/11/2008	12/12/2008	51.96	55.78	55.58	54	2.2	4	5.3
12	12/12/2008	09/10/2009	46.09	44.51	42.64	44	1.7	4	4.3
13									

It is necessary to have results for at least two tubes in order to calculate the precision of the measurements

Site Name/ ID:	Penryn Street
Accuracy (with 95% confidence interval) without periods with CV larger than 20%	
Bias calculated using 6 periods of data	
Bias factor A	0.75 (0.69 - 0.83)
Bias B	33% (20% - 46%)
Diffusion Tubes Mean:	42 $\mu\text{g m}^{-3}$
Mean CV (Precision):	7
Automatic Mean:	32 $\mu\text{g m}^{-3}$
Data Capture for periods used:	89%
Adjusted Tubes Mean:	31 (29 - 35) $\mu\text{g m}^{-3}$

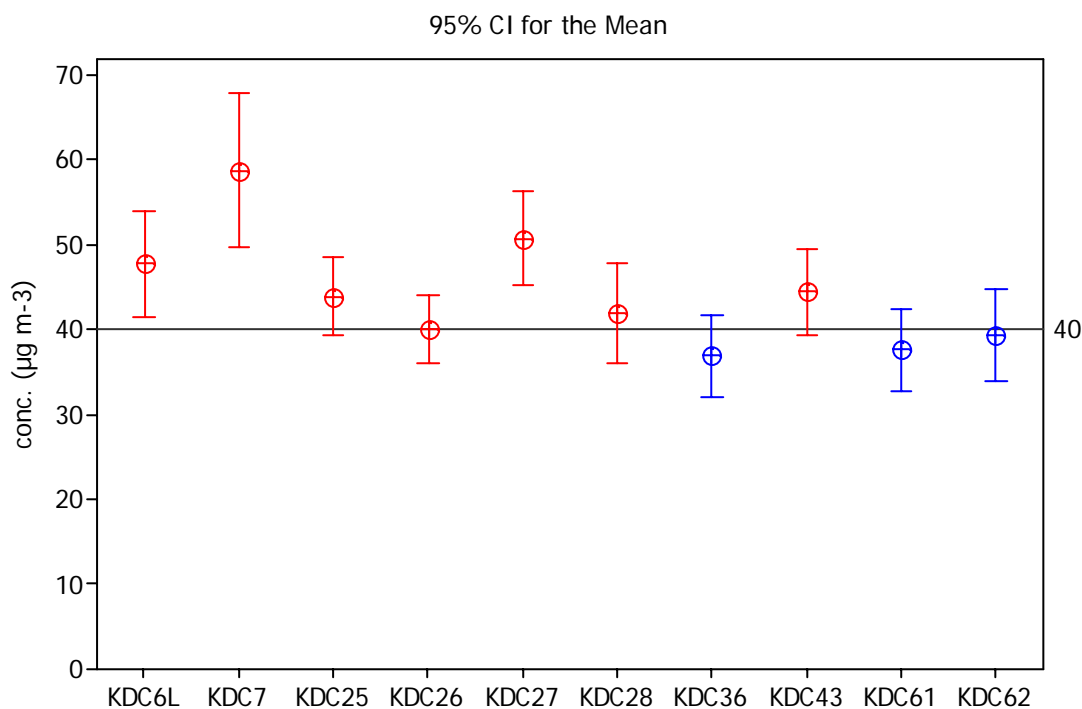
Precision	12 out of 12 periods have a CV smaller than 20%
Accuracy (with 95% confidence interval) WITH ALL DATA	
Bias calculated using 6 periods of data	
Bias factor A	0.75 (0.69 - 0.83)
Bias B	33% (20% - 46%)
Diffusion Tubes Mean:	42 $\mu\text{g m}^{-3}$
Mean CV (Precision):	7
Automatic Mean:	32 $\mu\text{g m}^{-3}$
Data Capture for periods used:	89%
Adjusted Tubes Mean:	31 (29 - 35) $\mu\text{g m}^{-3}$

Automatic Method	Data Quality Check
Period Mean	Tubes Precision Check
35.12	83.78
32.07	97.43
31.15	87.50
37.87	71.00
30.48	95.84
35.60	78.94
25.11	90.18
24.43	48.35
22.11	63.08
30.22	34.52
39.54	28.48
38.46	65.93

Overall survey --> **Good precision** **Poor Overall DC**

(Check average CV & DC from Accuracy calculations)

Jaume Targa
jaume.targa@aeat.co.uk
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Appendix 4. An interval plot of diffusion tube data for the period 01/05/2008 – 30/04/2009.

Appendix 5. Monthly recorded diffusion tube concentrations for the period 01/05/2008 – 30/04/2009. Gaps in the data indicate lost tubes.

Tube no	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09
KDC6L	46.71	56.34	45.77	40.83	34.75	54.04	56.29	54.47	52.52	61.38	27.13	49.04
KDC7	47.74	62.80	64.23	63.04	42.66	55.51	78.45	61.19	59.78	85.53	32.06	60.18
KDC25	51.68	39.85	42.36	45.07	27.52	41.66	44.04	55.78	44.47	42.08	46.12	52.21
KDC26	43.52	45.01	41.82	35.93	24.97	39.64	46.45	43.68	42.45	33.46	45.42	44.18
KDC27	64.02	49.18	42.56	45.83	33.79	46.81	53.50	53.19	48.85	62.79	61.73	53.22
KDC28	41.13	36.49	40.86	31.43	26.27	30.72	49.58	45.99	50.90	56.49	49.73	48.86
KDC36	51.21	29.25	29.87	24.14	41.02	35.15	40.45	46.82	33.42	41.50	39.65	36.04
KDC43	52.73	42.83		40.55	33.93	41.18	39.32	46.06	55.77	53.94	42.96	
KDC61	34.47	40.88	32.41	30.68	25.59	32.04	49.54	40.42	36.69	52.10	39.55	42.28
KDC62	36.63	36.82	40.57	35.96	20.74	49.91	46.06	44.59		49.90	36.16	41.09