Environment Agency / Joint Air Quality Unit

UK Urban NO_2 Network Operational Annual Report 2023

September 2024

Table of Contents

List of Tables

List of Figures

Executive Summary

The UK Urban NO_2 Network (UUNN) is a nitrogen dioxide (NO_2) monitoring network that was developed to provide additional monitoring data for the national compliance assessment for NO_2. Data from the UUNN supplements the other data used in the assessment, from the Automatic Urban and Rural Network (AURN) and Pollution Climate Mapping (PCM) model.

Monitoring is completed using Palmes-type diffusion tubes, a monitoring method widely used for the measurement of NO_2 across the UK. The diffusion tubes used in the UUNN, as detailed within Appendix A, are modified to improve data quality. The tubes are deployed in triplicate at each monitoring location to reduce the level of uncertainty and therefore increase the level of accuracy associated with each monitored concentration.

This report summarises activities undertaken, and data collected on the UUNN during 2023. The key statistics from the 2023 UUNN monitoring results are as follows:

- Monitoring was successfully undertaken at 296 locations during 2023. 257 of these are at roadside sites unique to the UUNN, with one located at the Manchester Air Quality Supersite located within the University of Manchester's Fallowfield campus, and 38 are located at existing AURN roadside monitoring stations (also known as 'co-locations');
- Across all 296 UUNN sites a data capture of 95.3% was achieved in 2023;
- 28 sites (26 unique UUNN and two co-located AURN) were removed from the compliance assessment due to being 'Red Flagged' as they had more than one monitoring period of missing results from a single tube[1];
- The expanded uncertainty of the annual mean concentrations was found to be 12.6% which is well within the required 25% uncertainty level required for indicative monitoring;
- UUNN data were ratified and adjusted based upon data recorded at sites co-located with AURN monitors. This led to the slope and intercept correction factors of 0.990 and 2.355 respectively, derived from the AURN co-location study;
- Following slope and intercept correction and removal of Red Flag sites (except those where the 'objective estimation method'[1] was applied), 12 UUNN sites (listed in Table C.1 in Appendix C) exceeded the annual mean limit value for nitrogen dioxide (40µg/m^3), as required under the Air Quality Standards Regulations 2010;
- A further 21 UUNN sites were within 10% of the limit value in 2023.

[1] Three sites that were Red Flagged have been included in the compliance assessment under objective estimation as described in Section 3.2.

1 Introduction

1.1 Aims of the UUNN

The primary aim of the UUNN is to provide additional local NO_2 monitoring data for inclusion within the national UK compliance assessment. Prior to 2020 the national assessment of NO_2 comprised the UK-wide automatic monitoring network; the Automatic Urban and Rural Network (AURN), and national scale modelling; the Pollution Climate Mapping (PCM) model.

UUNN locations were selected specifically to target areas where local monitoring had indicated a potential exceedance of the annual mean NO_2 limit value, and where concentrations predicted by the PCM model and by local modelling (completed by a relevant local authority) were not in good agreement.

1.2 The Network

The UUNN has been established since January 2020 and over the last few years has developed in different phases, responding to the evidence needs of the national compliance assessment.

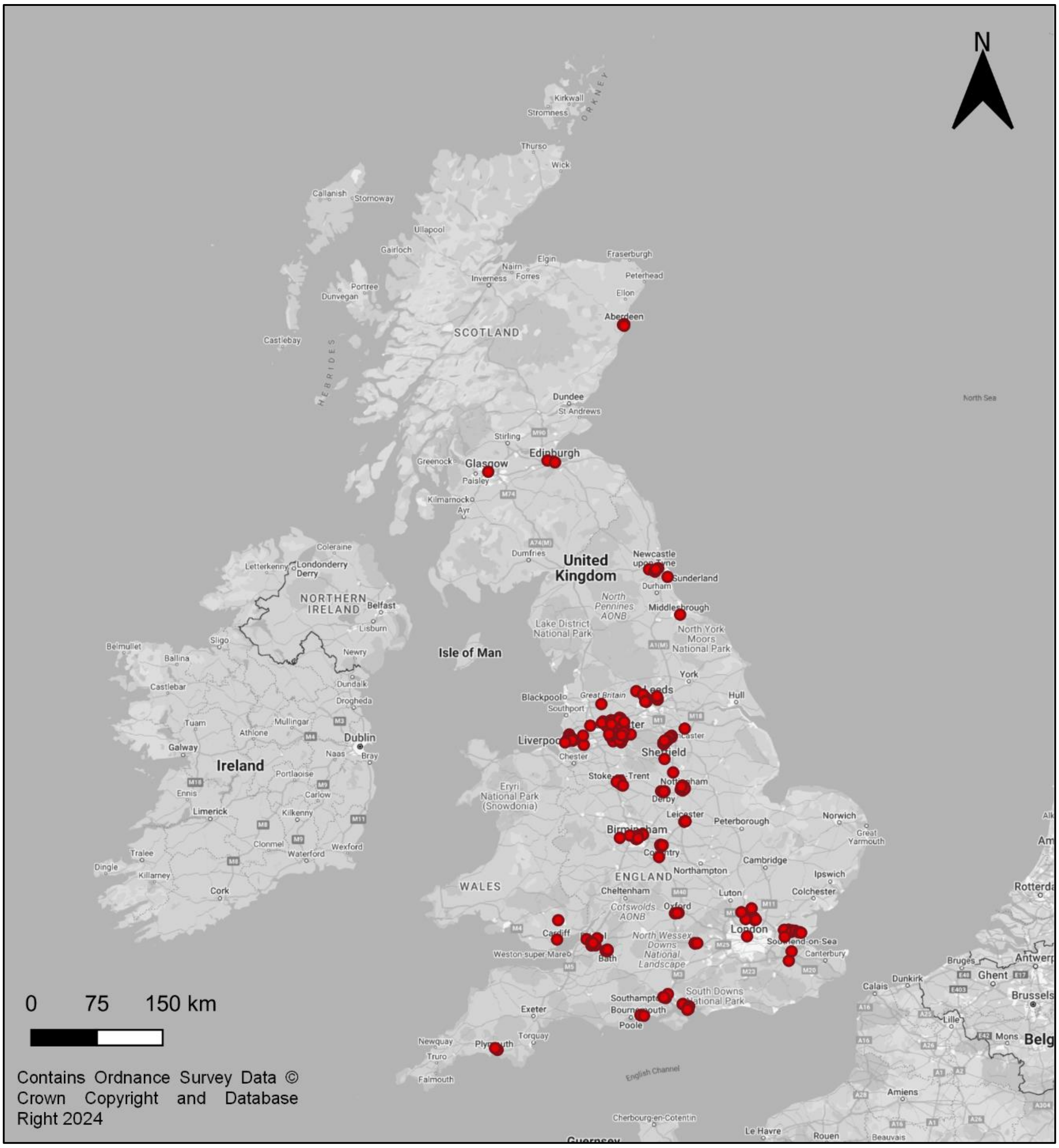
In 2022 the network reported data at 290 sites. At the end of 2022 a small number of sites were removed or deployed for monitoring in 2023. This report therefore describes data for 296 sites that were live in 2023. 257 of the monitoring locations are at roadside sites, 38 are located at existing AURN roadside monitoring stations to provide co-located monitoring data for validating monitored NO_2 concentrations and one site is the Manchester Air Quality Supersite.

Figure 1.1 provides a map of the UUNN monitoring locations that were operational throughout 2023.

Monitoring is completed using Palmes-type diffusion tubes, a monitoring method widely used for the measurement of NO_2 across the UK. The diffusion tubes used in the UUNN are modified to improve data quality, as detailed in Appendix A. UUNN diffusion tubes are sited in line with the UK's Air Quality Standards Regulations (2010)[2], deployed in triplicate at each monitoring location to reduce the level of uncertainty, and therefore increase the level of accuracy associated with each monitored concentration. UUNN diffusion tubes differ from those used to monitor for the UK Local Air Quality Management (LAQM) regime in terms of siting criteria, and also in the use of the additional wind cap, which is used in the UUNN to reduce the effects of turbulence on monitored concentrations. Diffusion tubes collect data on a monthly basis; each set of diffusion tubes is changed every 4-5 weeks adhering to a specific UUNN monitoring calendar. The monthly diffusion tube changeovers are undertaken by a cohort of Local Site Operators (LSOs). The 2023 UUNN monitoring calendar is provided in Appendix B.

[2] Air Quality Standards Regulations (2010): https://www.legislation.gov.uk/uksi/2010/1001/contents

Figure 1.1: UUNN Monitoring Locations



2 Data Adjustment and Uncertainty

Monitoring has been undertaken at 38 existing AURN monitoring stations to provide data for validating all UUNN monitored NO_2 concentrations (co-located sites). At these 38 sites the UUNN diffusion tubes are co-located with reference method chemiluminescent analysers. Data from these 38 sites allows for the calculation of correction factors and uncertainties that can be applied for all sites in the UUNN.

Correction factors and the overall uncertainty have both been calculated in line with the Guide to Demonstration of Equivalence 2010 (GDE 2010)[3]. Annual averages of the 38 co-location sites have been used to plot an x/y scatter graph with the reference method on the x-axis and the average of the three co-located diffusion tubes on the y-axis.

In order that potential problems in the co-location data are not used to make calculations that could propagate to create errors for other UUNN sites, data have only been processed where the data capture of the reference method is greater than 75%, recognising the balance between data capture and number of sites included in the derivation of correction factors.

In line with GDE 2010[3], the line of best fit has been calculated using orthogonal regression, allowing the intercept to be non-zero. The results of this analysis are given in Figure 2.1. The resultant slope is 0.990 and the intercept is 2.355.

The intercept value is statistically significantly different from zero based on two standard deviations. Subsequently, it is necessary to subtract 2.355 µg/m^3 from all of the monthly diffusion tube data for 2023.

Regarding the resultant slope factor of 0.990, this remains close to 1 (which is the ideal value), however, the level of bias[4] at the limit value (40 µg/m^3), must also be considered. Without slope correction applied, the level of bias at the limit value is 1.95 µg/m^3. It is considered that this level of bias is too high and, therefore, the slope correction has been applied, resulting in a small residual bias at the limit value of <0.01µg/m^3.

The annual average concentrations, after slope and intercept correction (subtracting 2.355 µg/m^3 (intercept) and dividing by 0.990 (slope)), are shown in Figure 2.2.

The expanded uncertainty of the annual mean concentrations after applying the correction, is 12.6%. This is well within the 25% uncertainty level[3] required for supplementary measurements such as diffusion tubes to be used to determine compliance with the annual mean NO_2 limit value.

[3] Guide to Demonstration of Equivalence 2010

[4] Bias represents the overall tendency of the diffusion tubes to under or over-read relative to the reference chemiluminescent analyser.

Figure 2.1: Scatter plot with Equivalence Calculations for annual averages of 2023 data: data before correction

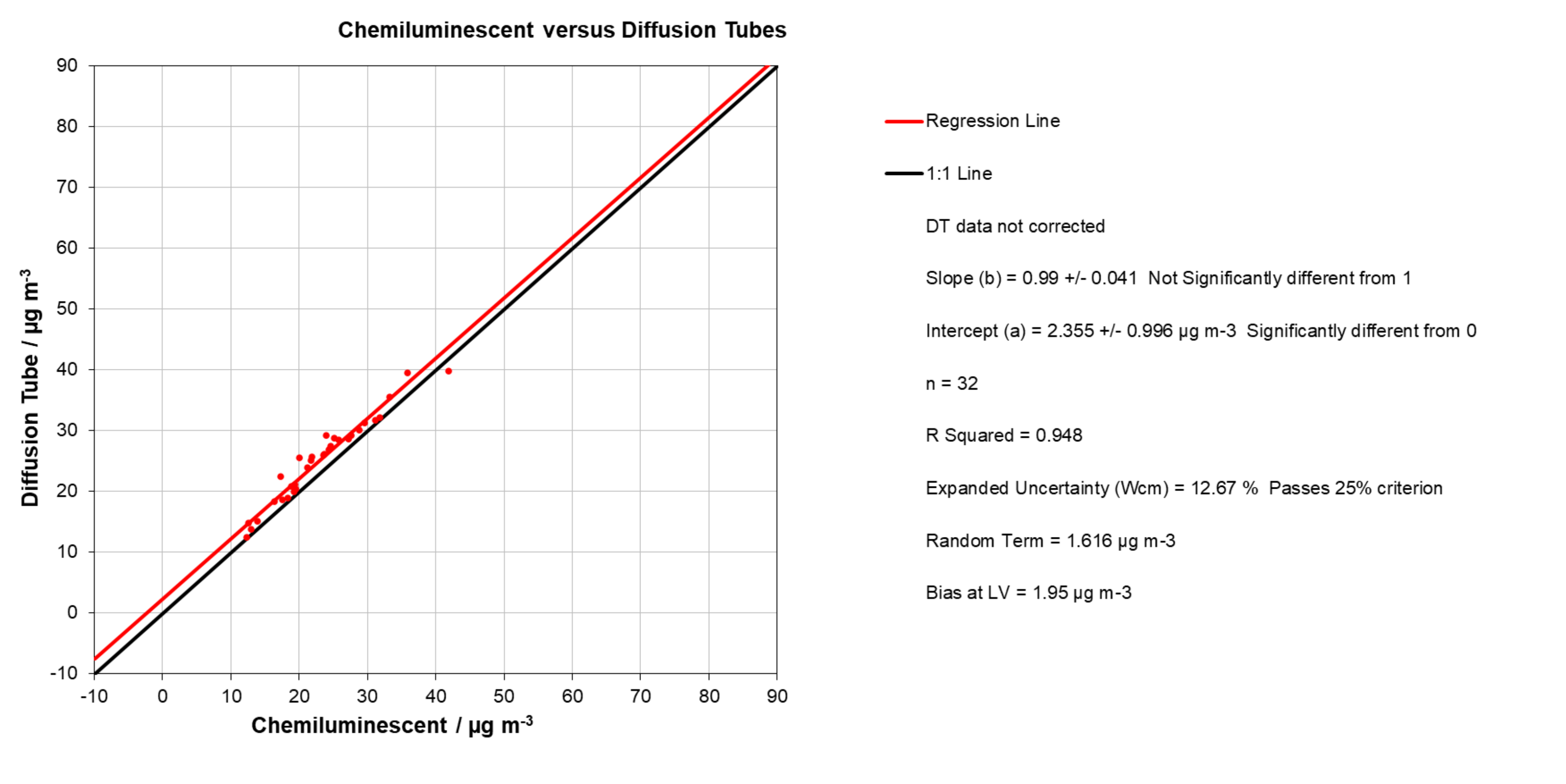
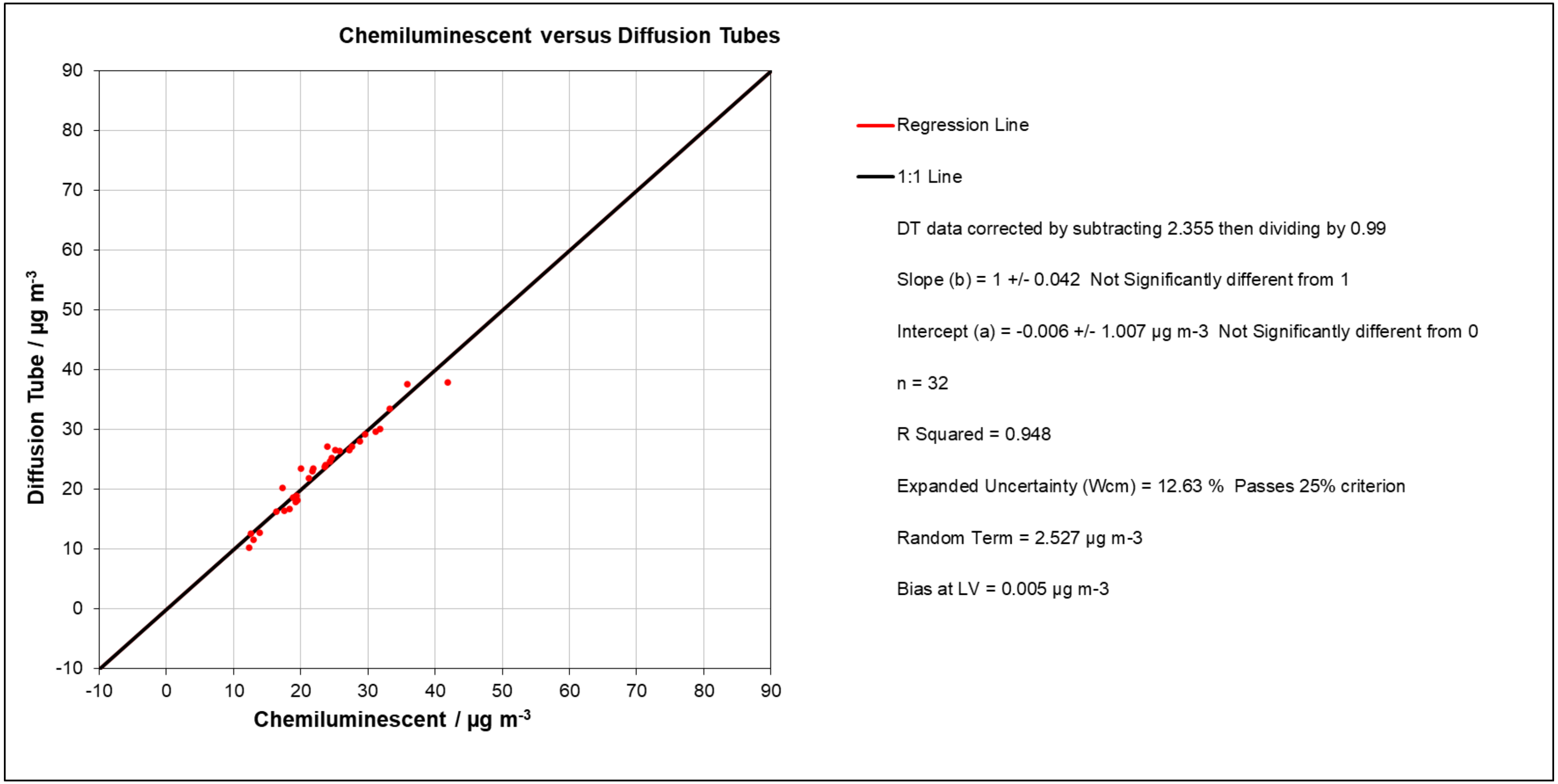


Figure 2.2: Scatter plot with Equivalence Calculations for annual averages of 2023 data: data corrected



3 Network Performance and Corrected Data

The following section provides an overview of both the data capture achieved across the UUNN within 2023, and the NO_2 concentration data for the UUNN sites that met specific data capture requirements within 2023. All concentration data presented within this section have been slope and intercept corrected as detailed in Section 2.

3.1 2023 Data Capture

Data capture within the UUNN has been assessed through a two-tiered 'flag' assessment.

- A site is issued a Yellow Flag if data cannot be provided for a one month period, or when a monthly measurement is based upon a single diffusion tube measurement at a site for one month within an annual reporting cycle.

- A site is issued a Red Flag if it fails to provide any data for a second month within an annual reporting cycle or provides data from only a single tube for a second month.

Of the 296 sites operational within the UUNN in 2023 (excluding the Manchester Air Quality Supersite which is not used in the compliance assessment) there were 31 Red Flag sites; 29 UUNN sites and two co-location sites at AURN analysers. These Red Flag sites do not meet the data capture requirements for compliance reporting. Three sites that were Red Flagged have been included in the compliance assessment under objective estimation, as described in Section 3.2. The remaining 28 sites (26 UUNN and 2 co-located AURN) are not included in the compliance assessment.

The total number of UUNN sites used in the compliance assessment is therefore 268; a combination of 232 UUNN sites and 36 co-location sites at AURN analysers. In addition to the Red Flagged sites, there were 65 sites that met the criteria for a Yellow Flag. The Yellow Flag and Red Flag sites are listed in Table 3.1.

The cause for the majority of data loss was tubes being removed during an exposure period, either being stolen or vandalised. After being deployed in accordance with the monitoring calendar a number were found to be missing on the subsequent changeover date. In addition to tubes being removed, site access restrictions / roadworks taking place at monitoring locations also resulted in lower data capture, as well as elevated co-variance of monitored concentrations (between tubes and/or compared to AURN data).

Table 3.1: Red Flagged Sites

Red Flag Site				
UUNN_BASI_008	UUNN_CVTR_007	UUNN_LIVE_019	UUNN_MIDD_002	UUNN_SOUT_002
UUNN_BATH_009	UUNN_CVTR_009*	UUNN_LIVE_021	UUNN_NEWF_001	UUNN_STOC_003
UUNN_BOLT_001	UUNN_DERB_005	UUNN_MANC_005	UUNN_PORT_002*	UUNN_STOK_012
UUNN_BRAD_005	UUNN_EDIN_003	UUNN_MANC_015	UUNN_READ_001	UUNN_TAME_005
UUNN_BRAD_007	UUNN_GATE_001	UUNN_MANC_021	UUNN_SALF_015	UUNN_UKA00553
UUNN_BRIS_009*	UUNN_LEIC_002	UUNN_MANC_025	UUNN_SHEF_005	UUNN_UKA00651
UUNN_BURY_003				

Note: *Red Flagged sites included in the compliance assessment under objective estimation

Table 3.2: Yellow Flagged Sites

Yellow Flag Sites				
UUNN_BASI_005	UUNN_CVTR_008U	UUNN_MANC_029	UUNN_SHEF_009	UUNN_UKA00525
UUNN_BATH_001	UUNN_DERB_002	UUNN_NEWC_002	UUNN_SHEF_012	UUNN_UKA00564
UUNN_BATH_002	UUNN_FARE_001	UUNN_NEWC_004	UUNN_SHEF_015	UUNN_UKA00579
UUNN_BATH_004	UUNN_FARE_002	UUNN_OLDH_001	UUNN_SOOS_006	UUNN_UKA00595
UUNN_BATH_006	UUNN_LIVE_015	UUNN_PORT_003	UUNN_STOC_002	UUNN_UKA00598
UUNN_BATH_007	UUNN_LIVE_016	UUNN_PORT_004	UUNN_STOK_005	UUNN_UKA00601
UUNN_BOLT_009	UUNN_MANC_031	UUNN_PORT_005	UUNN_STOK_006	UUNN_UKA00603
UUNN_BROX_005	UUNN_MANC_004	UUNN_PORT_007	UUNN_STOK_011	UUNN_UKA00622
UUNN_BURY_008	UUNN_MANC_010	UUNN_PORT_009	UUNN_STOK_015	UUNN_UKA00627
UUNN_CVTR_001	UUNN_MANC_013	UUNN_READ_003	UUNN_TAME_001	UUNN_UKA00630
UUNN_CVTR_002	UUNN_MANC_018	UUNN_ROCH_003	UUNN_TAME_008	UUNN_UKA00631
UUNN_CVTR_003	UUNN_MANC_022	UUNN_SHEF_003	UUNN_TRAF_003	UUNN_UKA00634
UUNN_CVTR_004	UUNN_MANC_024	UUNN_SHEF_006	UUNN_TRAF_004	UUNN_UKA00660

3.2 Annual Mean Concentrations

Following the removal of Red Flag sites, there were 12 UUNN sites that exceeded the 40µg/m^3 limit value in 2023. These 12 sites are presented in Table C.1 in Appendix C and include UUNN_BRIS_009 and UUNN_CVTR_009, which were added after an objective estimation method was applied.

For the 2023 reporting year, an objective estimation method has been applied in zones for which the maximum annual mean NO_2 concentration is determined by UUNN measurements with 9 or 10 months of data for the reporting year. This is to ensure that the best available evidence is used in the air quality assessment to determine the compliance status of these reporting zones. Sites UUNN_BRIS_009, UUNN_PORT_002 and UUNN_CVTR_009 have therefore been included in the 2023 compliance assessment.

The UUNN sites that exceeded the annual mean limit value, and those that are within 10% of the annual mean in 2023 are presented in Appendix C.

A full list of 2023 annual mean NO_2 monitoring results can be accessed using the UK-Air resource[5].

3.3 Monthly Mean Concentrations

Table 3.3 provides the average NO_2 concentration across the UUNN during 2023. It can be observed that the UUNN average NO_2 concentration is below the 40 µg/m^3 limit value for all monthly periods within 2023, when taking the average across all sites in the network.

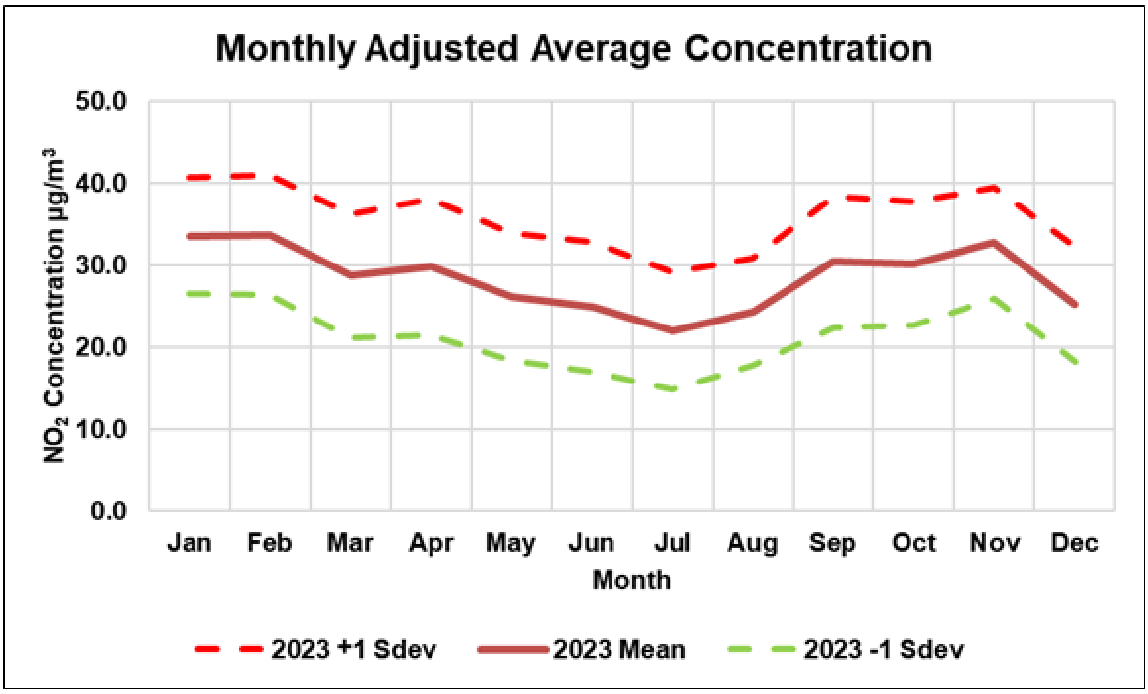
Table 3.3: Average NO_2 Concentration across all UUNN sites (2023)

	Month (2023)												Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Average NO_2 Concentration (µg/m^3)	33.6	33.7	28.7	29.8	26.2	24.9	22.1	24.3	30.4	30.2	32.7	25.3	28.5
Minimum NO_2 Concentration (µg/m^3)	14.1	13.7	10.0	11.2	7.0	5.9	4.3	6.0	9.5	10.3	13.4	6.7	n/a
Maximum NO_2 Concentration (µg/m^3)	57.9	60.3	57.9	58.7	53.3	54.7	44.4	44.7	58.4	62.4	61.4	54.7	n/a

[5] https://uk-air.defra.gov.uk/compliance-data

Figure 3.1 displays the trend in average UUNN monthly NO_2 concentration throughout 2023, demonstrating a small level of seasonal variation, where concentrations through the summer months are often lower than those in winter months.

Figure 3.1: Average NO_2 Concentration across UUNN sites (2023)



4 Summary

The UK Urban NO_2 Network (UUNN) is an air quality network that monitors concentrations of nitrogen dioxide (NO_2) at selected roadside locations. It has been designed and implemented to provide supplementary evidence for the national assessment for NO_2, alongside the Automatic Urban and Rural Network (AURN), and national air quality model; the Pollution Climate Mapping (PCM) model.

Monitoring is completed using Palmes-type diffusion tubes, a monitoring method widely used for the measurement of NO_2 across the UK. The diffusion tubes used in the UUNN are modified to improve accuracy and are deployed in triplicate at each monitoring location to reduce the level of uncertainty, and therefore increase the data quality, associated with each monitored concentration.

The key statistics from the 2023 UUNN monitoring results are as follows:

- Monitoring was successfully undertaken at 296 locations during 2023. 257 of these are at roadside sites unique to the UUNN, with one located at the Manchester Air Quality Supersite within the University of Manchester's Fallowfield campus. 38 are located at existing AURN roadside monitoring stations (also known as co-locations);

- Across all 296 UUNN sites a data capture of 95.3% was achieved in 2023;

- 28 sites (26 UUNN and 2 co-located AURN) were removed from the compliance assessment due to being 'Red Flagged' as they had more than one monitoring period of missing results from a single tube[6];

- The expanded uncertainty of the annual mean concentrations was found to be 12.6% which is within the required 25% uncertainty level required for Indicative measurements, and within the required 15% uncertainty level required for fixed measurements;

- A slope and intercept correction factor of 0.990 and 2.355 was derived from the AURN co-location study;

- Following slope and intercept correction and removal of Red Flag sites (except those where the objective estimation method was applied), 12 UUNN sites exceeded the 40µg/m^3 limit value in 2023;

- A further 21 UUNN sites were within 10% of the limit value in 2023.

[6] Three sites that were Red Flagged have been included in the compliance assessment under objective estimation as described in section 3.2.

Appendices

Appendix A:
Overview of UUNN Diffusion Tubes

Overview of Diffusion Tubes

Diffusion tubes consist of small transparent plastic tubes approximately 7.1 cm long. They contain chemical reagent which absorbs nitrogen dioxide in the form of nitrite. The reagent in this case is triethanolamine (TEA), a solution of which is applied to fine stainless-steel mesh grids at one end of the tube, which is sealed with a coloured plastic cap (in this case, grey). The other end of the tube is also sealed with a removable white plastic cap.

When deploying a standard diffusion tube for monitoring, the white cap is removed, and the tube fixed to street furniture or another suitable structure. The tube is placed in a vertical position, with the coloured end cap (containing the absorbent reagent) pointing upwards, and the open end pointing downwards. It is left in place for 4/5 weeks, then re-sealed using the white cap and returned to the laboratory for analysis. It is then possible to calculate the average ambient concentration of NO_2 at the monitoring site over the tube exposure period, from the amount of nitrite ion remaining in the tube following exposure.

Because of their susceptibility to exposure-related sources of bias, the user must apply an 'adjustment factor' before comparing the annual mean NO_2 concentration with applicable limit values or objectives. The 'adjustment factor' is based on the results of a co-location study in which diffusion tubes are used alongside a reference chemiluminescent analyser.

Diffusion tubes rely on having a column of still, unmixed air, of a known length, inside the tube. Wind turbulence around the open end of the tube can cause the air in the bottom few millimetres of the tube to be mixed with the surrounding air. This shortens the diffusive path length (the effective length of tube), resulting in over-estimation of the ambient NO_2 concentration (positive bias).

Diffusion Tubes Used in the UUNN

The tubes deployed on the UUNN have a modification in comparison to standard diffusion tubes in the form of a wind protection cap. This is intended to reduce potential positive bias resulting from the effects of wind turbulence and thereby improve the accuracy of the diffusion tube measurements. This wind protection cap (white) consists of a small disk of porous polyethylene filter material which is fitted over the lower end of the tube. Gases, such as nitrogen dioxide, can pass through the material and travel up the tube by molecular diffusion as would happen with an open tube, but the polyethylene filter prevents wind turbulence in what would otherwise be the open end of the tube. Martin et al (2014)[7] tested various types of wind protection cap: the type which provided the best results in their trials has been adopted for use on the UUNN (this is referred to as 'type III' within the Martin et al (2014)[7] paper).

The absorbent compound, TEA, is coated onto a fine stainless steel mesh and mounted in the grey end cap (which is at the top when the tube is in use). The other end of the tube (which is at the bottom when the tube is in use) contains the porous polyethylene filter (for wind protection) mounted in the white cap. The tubes are supplied with the wind caps fitted with each tube supplied in a plastic screw-topped vial. They are stored within the vials until deployment, and upon collection they are sealed by removing the wind protection cap and replacing it with a solid end cap, and then sealing back into the vial.

[7] Martin, N.A. et al (2014), *Measurement of nitrogen dioxide diffusive sampling rates for Palmes diffusion tubes using a controlled atmospheric test facility (CATFAC)*, Atmospheric Environment 94 (2014), pp 529 – 537

Figure A.1: Diffusion Tube with Wind-Protection Cap

Tube on right shows separated components

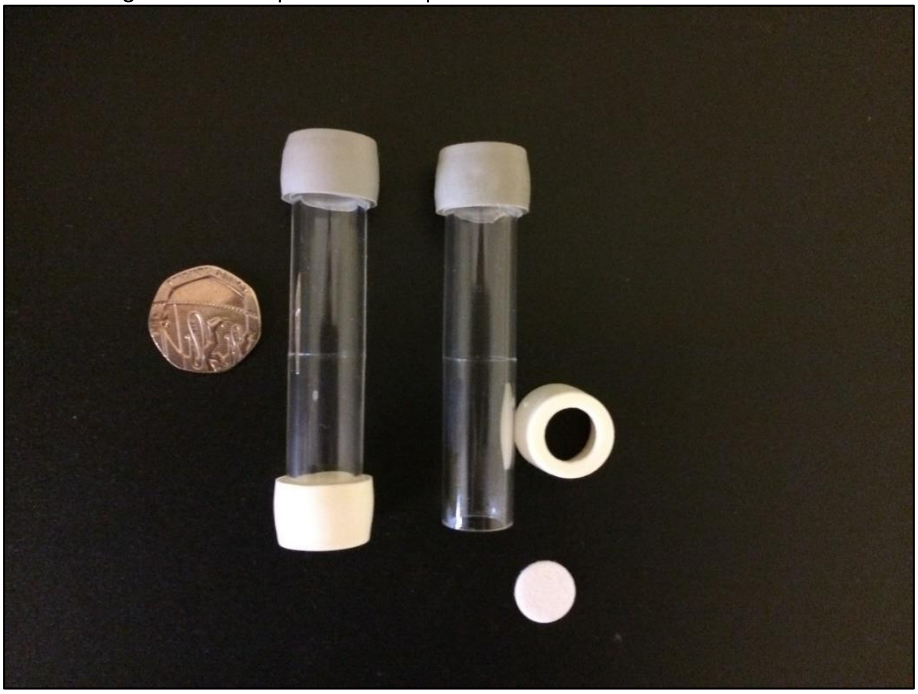


Figure A.2: Example UUNN Monitoring Location

Appendix B:
2023 UUNN Monitoring Calendar

Table B.1: 2023 UUNN Timetable for Tube Changes

Year	Month	Target Date (Acceptable Date)
2023	January	**03-Jan** (04-Jan) *
	February	**01-Feb** (02-Feb) *
	March	**01-Mar** (02-Mar) *
	April	**03-Apr** (04-Apr) *
	May	**02-May** (03-May) *
	June	**01-Jun** (02-Jun) *
	July	**03-Jul** (04-Jul) *
	August	**01-Aug** (02-Aug) *
	September	**04-Sep** (05-Sep) *
	October	**02-Oct** (03-Oct) *
	November	**01-Nov** (02-Nov) *
	December	**04-Dec** (05-Dec) *
2024	January	**02-Jan** (03-Jan) *

Notes:
* Where the Target Date falls on a Bank Holiday in Scotland, it is acceptable that tube changes for those sites in Scotland are undertaken on the date following the acceptable date also.

Appendix C: UUNN Exceedance Sites

Table C.1: UUNN Sites in Exceedance of the 40 µg/m³ Limit Value

Site ID	Local Authority	2023 Annual Mean NO_2 Concentration (µg/m³)
Sites in Exceedance of 40 µg/m³ Limit Value		
UUNN_MANC_029	Manchester	54.1
UUNN_BIRM_003	Birmingham	46.1
UUNN_CVTR_009	Coventry	45.9
UUNN_MANC_007	Manchester	45.2
UUNN_VOWH_001	Vale of White Horse*	45.1
UUNN_BRIS_009	Bristol	44.9
UUNN_MANC_027	Manchester	44.8
UUNN_LIVE_011	Liverpool	42.9
UUNN_MANC_014	Manchester	42.6
UUNN_MANC_013	Manchester	41.2
UUNN_NOTT_001	Nottingham	41.1
UUNN_BRAD_008	Bradford	41.0

Note: *Site located on National Highways Strategic Road Network (SRN)

Table C.2: UUNN Sites Within 10% of the 40 µg/m³ Limit Value

Site ID	Local Authority	2023 Annual Mean NO_2 Concentration (µg/m³)
Sites Within 10% of 40 µg/m³ Limit Value		
UUNN_LIVE_013	Liverpool	40.4
UUNN_SHEF_013	Sheffield	40.3
UUNN_MANC_028	Manchester	40.2
UUNN_BIRM_008	Birmingham	39.4
UUNN_BASI_002	Basildon	39.3
UUNN_BRIS_011	Bristol	38.3
UUNN_SHEF_003	Sheffield	38.3
UUNN_MANC_004	Manchester	37.8
UUNN_BURY_001	Bury	37.8
UUNN_UKA00315	London Marylebone Road	37.7
UUNN_LEED_007	Leeds	37.7
UUNN_UKA00610	Stoke on Trent	37.6
UUNN_LIVE_006	Liverpool	37.4
UUNN_SALF_012	Salford	37.4
UUNN_LEIC_003	Leicester	37.3
UUNN_NOTT_005	Nottingham	36.9
UUNN_MANC_016	Manchester	36.4
UUNN_NEWC_004	Newcastle	36.3
UUNN_BRAD_009	Bradford	36.3
UUNN_STOC_009	Stockport	36.3
UUNN_ABER_004	Aberdeen	36.1