UK URBAN NO_2 NETWORK OPERATIONAL ANNUAL REPORT 2024

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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 2024. The key statistics from the 2024 UUNN monitoring results are as follows:

- Monitoring was successfully undertaken at 300 locations during 2024. 261 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 300 UUNN sites a data capture of 96.3% was achieved in 2024;
- 28 sites (24 UUNN sites and four co-location sites at AURN analysers) were removed from the compliance assessment due to being 'Red Flagged';
- 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 1.064 and 0.503 µg/m^3 respectively, derived from the AURN co-location study;
- Following slope and intercept correction and removal of Red Flag sites 8 UUNN sites (listed in Table C.1 in Appendix C) exceeded the annual mean limit value for nitrogen dioxide (40 µg/m^3), as required under the Air Quality Standards Regulations 2010;
- A further 11 UUNN sites were within 10% of the limit value in 2024.

1. INTRODUCTION

1.1 AIMS OF UUNN

The primary aim of the UUNN is to supplement the current national assessment for air quality (which is comprised of the Automatic Urban and Rural Network (AURN) and Pollution Climate Mapping (PCM) approaches) to provide additional local NO_2 monitoring data for the national UK compliance report.

UUNN monitoring is sited on major roads where concentrations predicted by the PCM model and by local modelling (completed by a relevant local authority) were not in good agreement. UUNN monitoring has also been sited on road links where local authority monitoring has identified a potential exceedance that is not yet captured in the national assessment.

1.2 THE NETWORK

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

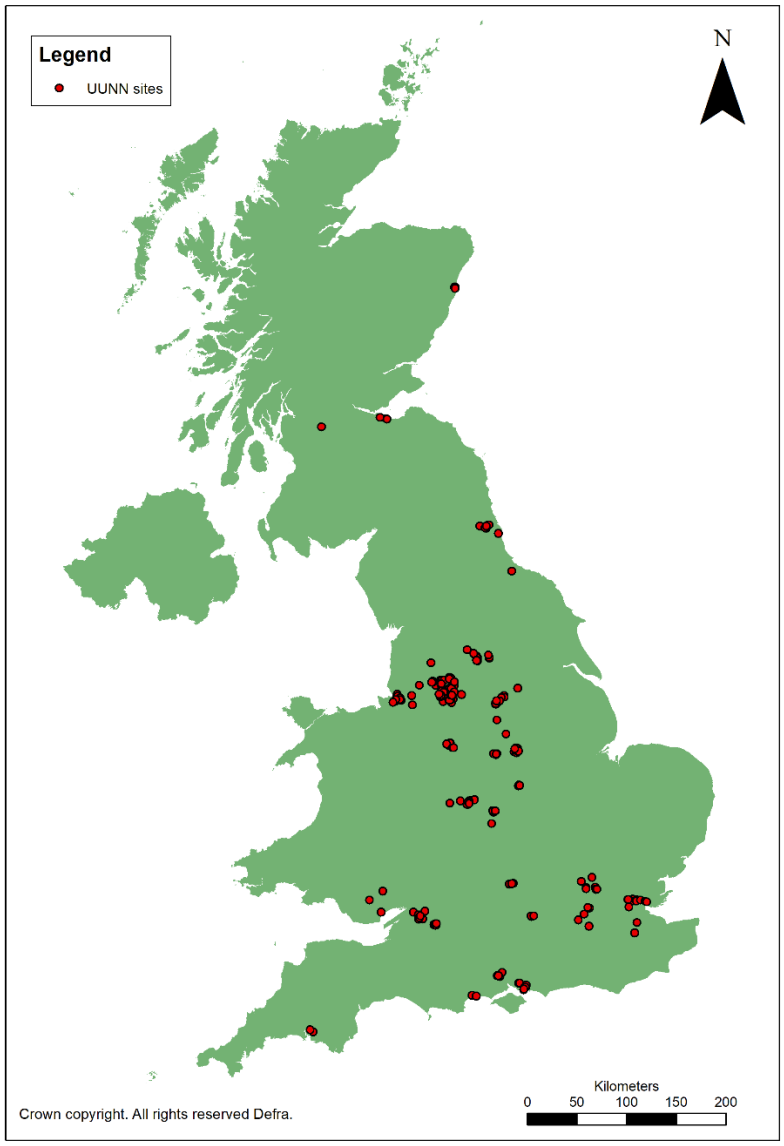
In 2023 the network reported data at 296 sites. At the end of 2023 a small number of sites were removed or deployed for monitoring in 2024. This report therefore describes data for 300 sites that were live in 2024. 261 of the monitoring locations are at roadside sites, 38 are located at existing AURN 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 2024.

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)[1], 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 2024 UUNN monitoring calendar is provided in Appendix B.

[1] 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)[2]. 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 85%, recognising the balance between data capture and number of sites included in the derivation of correction factors.

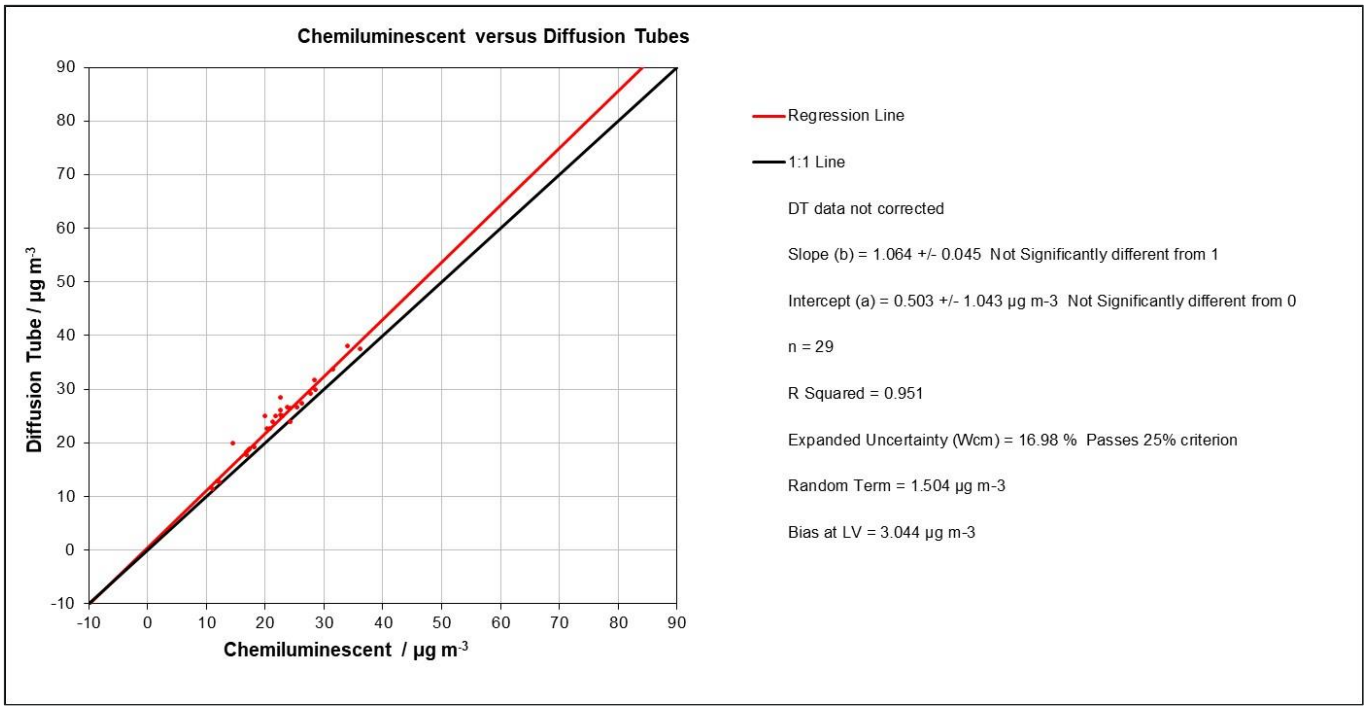
In line with GDE 2010, the line of best fit has been calculated using orthogonal regression, allowing the intercept to be non-zero. The results of this analysis are given in Figure 2.1. The resultant slope is 1.064 and the intercept is 0.503.

Regarding the resultant slope factor of 1.064, this remains close to 1 (which is the ideal value), however, the level of bias[3] 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 3.04 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 <0.01 µg/m^3.

The annual average concentrations, after slope and intercept correction (subtracting 0.503 µg/m^3 (intercept) and dividing by 1.064 (slope)), are shown in Figure 2.2.

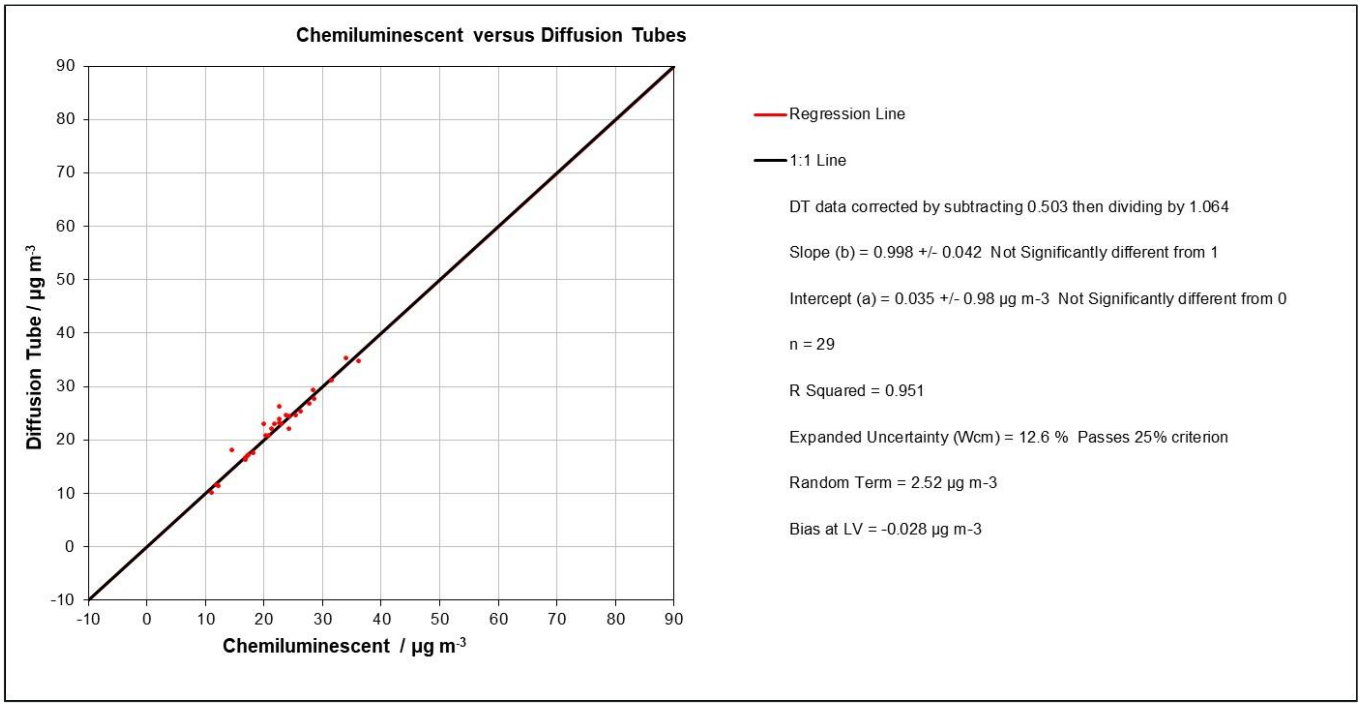
The expanded uncertainty of the annual mean concentrations after applying the correction, is 12.6%. This is well within the 25% uncertainty level required for supplementary measurements such as diffusion tubes to be used to determine compliance with the annual mean NO_2 limit value.

Figure 2.1: Scatter plot for the annual averages of 2024 data without correction



[2] Guide to Demonstration of Equivalence 2010 https://environment.ec.europa.eu/topics/air/air-quality/assessment_en
[3] Bias represents the overall tendency of the diffusion tubes to under or over-read relative to the reference chemiluminescent analyser.

Figure 2.2: Scatter plot for the annual averages of 2024 data with slope and intercept correction



3. NETWORK PERFORMANCE AND CORRECTED DATA

The following section provides an overview of both the data capture achieved across the UUNN within 2024, and the NO_2 concentration data for the UUNN sites that met specific data capture requirements within 2024. All concentration data presented within this section have been slope and intercept corrected as detailed in Section 2.

3.1 2024 DATA CAPTURE

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

- A Yellow flag is issued to a UUNN site if:
  - No valid data is returned for one month in a calendar year; or
  - Valid data returned for only a single tube for two months in a calendar year; or
  - No valid data is returned for one month plus valid data returned for only a single tube for one month in a calendar year.
- A Red Flag is issued for a UUNN site if:
  - No valid data is returned for two or more months in a calendar year; or
  - Valid data returned from only a single tube for three or more months in a calendar year; or
  - No valid data is returned for one month and valid data returned from only a single tube for two or more months in a calendar year.

Of the 300 sites operational within the UUNN in 2024 (excluding the Manchester Air Quality Supersite which is not used in the compliance assessment[4]) there were 28 Red Flag sites; 24 UUNN sites and four co-location sites at AURN analysers. These Red Flag sites do not meet the data capture requirements for compliance reporting and are not included in the compliance assessment.

The total number of UUNN sites used in the compliance assessment is therefore 271; a combination of 237 UUNN sites and 34 co-location sites at AURN analysers. In addition to the Red Flagged sites, there were 40 sites that met the criteria for a Yellow Flag. The Yellow Flag and Red Flag sites are listed in Tables 3.1 and 3.2 respectively.

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.

Table 3.1: Red Flagged Sites

Red Flag Site				
UUNN_BIRM_014	UUNN_BURY_003	UUNN_MAID_002	UUNN_RHCY_001	UUNN_UKA00258
UUNN_BIRM_017	UUNN_BURY_004	UUNN_MANC_011	UUNN_ROTH_001	UUNN_UKA00598
UUNN_BRAD_007	UUNN_GATE_001	UUNN_MANC_032	UUNN_ROTH_002	UUNN_UKA00603
UUNN_BRAD_009	UUNN_GATE_002	UUNN_NEWC_002	UUNN_SOUT_002	UUNN_UKA00612
UUNN_BRIS_006	UUNN_GLON_004	UUNN_NEWF_001	UUNN_STOC_003	
UUNN_BROX_003	UUNN_LEED_008	UUNN_READ_001	UUNN_STOK_012	

[4] The site is not used in the compliance assessment because it is a background, rather than roadside, site.

Table 3.2: Yellow Flagged Sites

Yellow Flag Site				
UUNN_BOLS_001	UUNN_CVTR_009	UUNN_MANC_024	UUNN_SHEF_001	UUNN_STOK_005
UUNN_BRAD_003	UUNN_DERB_002	UUNN_NEWC_004	UUNN_SHEF_002	UUNN_VOWH_001
UUNN_BRIS_013	UUNN_GLON_003	UUNN_OXFO_001	UUNN_SHEF_003	UUNN_WIGA_001
UUNN_BROX_001	UUNN_LEIC_002	UUNN_RCHF_001	UUNN_SHEF_007	UUNN_UKA00525
UUNN_BROX_004	UUNN_LIVE_016	UUNN_ROTH_003	UUNN_SHEF_011	UUNN_UKA00553
UUNN_BROX_005	UUNN_LIVE_021	UUNN_SALF_010	UUNN_SHEF_014	UUNN_UKA00579
UUNN_BROX_006	UUNN_MANC_005	UUNN_SALF_013	UUNN_SHEF_015	UUNN_UKA00622
UUNN_CAST_001	UUNN_MANC_021	UUNN_SALF_015	UUNN_SHEF_016	UUNN_UKA00631

3.2 ANNUAL MEAN CONCENTRATIONS

Following the removal of Red Flag sites, there were 8 UUNN sites that exceeded the 40 µg/m^3 limit value in 2024. These 8 sites are presented in Table C.1 in Appendix C.

The UUNN sites that exceeded the annual mean limit value, and those that are within 10% of the annual mean in 2024 are presented in Appendix C. A full list of 2024 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 2024. 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 2024, when taking the average across all sites in the network.

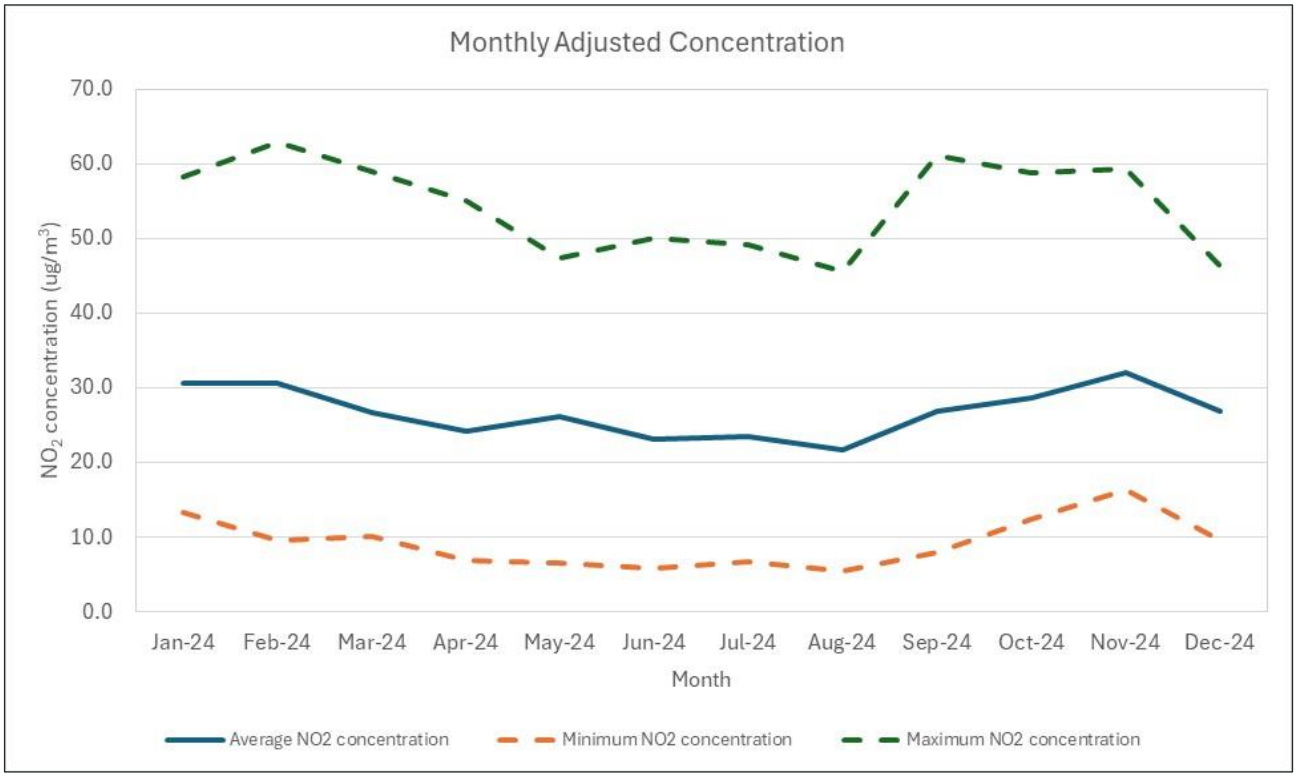
Table 3.3: Average NO_2 Concentration across all UUNN sites (2024)

	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Average NO_2 concentration (ug/m^3)	30.6	30.7	26.7	24.3	26.2	23.1	23.6	21.7	27.0	28.7	32.0	26.8	26.7
Minimum NO_2 concentration (ug/m^3)	13.3	9.7	10.2	7.0	6.6	5.8	6.7	5.5	7.9	12.4	16.4	9.6	N/A
Maximum NO_2 concentration (ug/m^3)	58.3	62.9	59.0	55.1	47.5	50.0	49.2	45.6	61.1	58.8	59.3	46.3	N/A

Figure 3.1 displays the trend in average UUNN monthly NO_2 concentration throughout 2024, demonstrating a small level of seasonal variation, where concentrations through the summer months are often lower than those in winter months.

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

Figure 3.1: Average NO_2 Concentration across UUNN sites (2024)



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 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 2024 UUNN monitoring results are as follows:

- Monitoring was successfully undertaken at 300 locations during 2024. 261 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 300 UUNN sites a data capture of 96.3% was achieved in 2024;
- 28 sites (24 UUNN sites and four co-location sites at AURN analysers) were removed from the compliance assessment due to being 'Red Flagged';
- 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 1.064 and 0.503 µg/m^3 respectively, derived from the AURN co-location study;
- Following slope and intercept correction and removal of Red Flag sites 8 UUNN sites (listed in Table C.1 in Appendix C) exceeded the annual mean limit value for nitrogen dioxide (40 µg/m^3), as required under the Air Quality Standards Regulations 2010;
- A further 11 UUNN sites were within 10% of the limit value in 2024.

5. APPENDICES

5.1 APPENDIX A: OVERVIEW OF UUNN DIFFUSION TUBES

5.1.1 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).

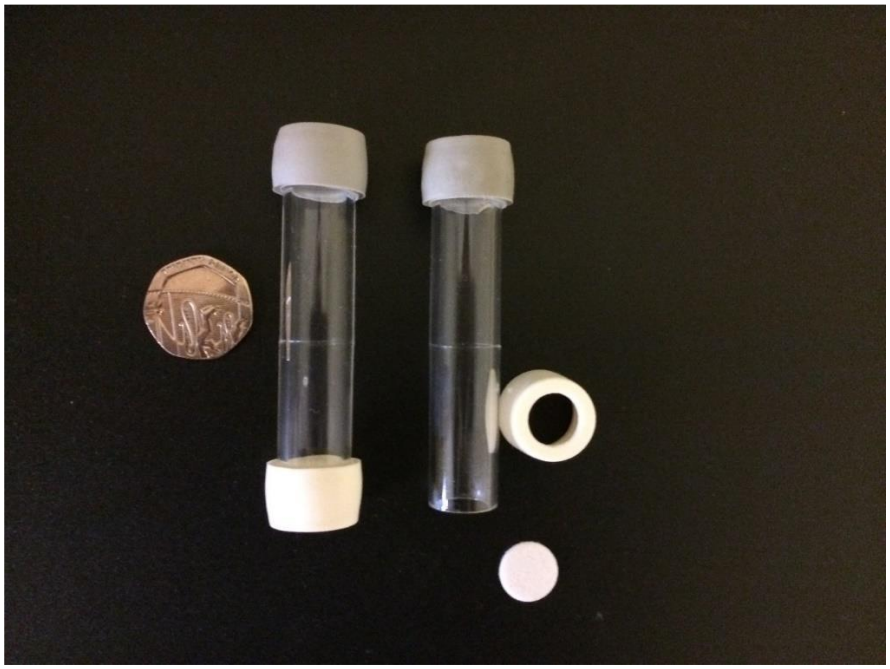
5.1.2 Diffusion Tubes Used in the UUNN

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)[6] 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) 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.

[6] 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



The tube on the right shows the separated components. The wind cap is the white cap on the base of the tube on the left and is shown separated into its components next to the tube on the right.

Figure A.2: Example UUNN Monitoring Location

5.2 APPENDIX B: 2024 UUNN MONITORING CALENDAR

Table B.1: 2024 UUNN Timetable for Tube Changes

Year	Month	Target Date (Acceptable Date)
2024	January	02-Jan (03-Jan)
	February	01-Feb (02-Feb)
	March	04-Mar (05-Mar)
	April	02-Apr (03-Apr)
	May	01-May (02-May)
	June	03-Jun (04-Jun)
	July	01-Jul (02-Jul)
	August	01-Aug (02-Aug)
	September	02-Sep (03-Sep)
	October	01-Oct (02-Oct)
	November	04-Nov (05-Nov)
	December	02-Dec (03-Dec)
2025	January	06-Jan (07-Jan)

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.

5.3 APPENDIX C: UUNN EXCEEDANCE SITES

Table C.1: UUNN Sites in Exceedance of the 40 µg/m^3 Limit Value

Site ID	Local Authority	2024 Annual Mean NO_2 Concentration (µg/m^3)
UUNN_BIRM_003	Birmingham	41.9
UUNN_BRIS_009	Bristol	44.6
UUNN_BRIS_018	Bristol	42.2
UUNN_CVTR_009	Coventry	41.2
UUNN_LIVE_024	Liverpool	43.1
UUNN_MANC_005	Manchester	54.7
UUNN_MANC_007	Manchester	43.8
UUNN_MANC_029	Manchester	49.6

Table C.2: UUNN Sites Within 10% of the 40 µg/m^3 Limit Value

Site ID	Local Authority	2024 Annual Mean NO_2 Concentration (µg/m^3)
UUNN_BIRM_008	Birmingham	36.1
UUNN_BRAD_008	Bradford	39.3
UUNN_LIVE_006	Liverpool	36.0
UUNN_LIVE_011	Liverpool	39.1
UUNN_LIVE_013	Liverpool	40.2
UUNN_MANC_013	Manchester	39.5
UUNN_MANC_014	Manchester	39.9
UUNN_MANC_027	Manchester	39.2
UUNN_MANC_028	Manchester	38.0
UUNN_SHEF_013	Sheffield	37.0
UUNN_VOWH_001	Vale of White Horse	39.9

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