Environment Agency/Joint Air Quality Unit

UK Urban NO_2 Network Operational Annual Report 2021

August 2022

Move Forward with Confidence

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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 established assessment, comprised of data 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 2021. The key statistics from the 2021 UUNN monitoring results are as follows:

- Monitoring was successfully undertaken at 292 locations during 2021. 254 of these are at roadside sites unique to the UUNN, and 38 are located at existing AURN roadside monitoring stations.
- A slope correction factor of 1.014 and an intercept correction factor of 2.568 were derived from the AURN co-location study.
- The expanded uncertainty of the annual mean concentrations was found to be 11.94%.
- Across all 292 UUNN sites a data capture of 97% was achieved in 2021.
- 15 sites (11 UUNN and 4 co-located with AURN), were removed from the compliance assessment due to being ‘Red Flagged’ due to having more than one monitoring period of one or no diffusion tube results. One site has been removed from the network due to ongoing data capture issues.
- Following intercept correction 12 UUNN sites exceeded the 40µg/m^3 limit value in 2021.

1 Introduction

The UK Urban NO_2 Network (UUNN) is an air quality monitoring network that monitors concentrations of nitrogen dioxide (NO_2). The programme of work is led by the Department for Environment, Food and Rural Affairs (Defra) and the Environment Agency (EA). The aim of the network is to increase the extent of NO_2 measurement data available for assessing national compliance against the annual mean limit value set out in the Air Quality Standards Regulations (2010)[1].

UUNN monitoring locations were initially focused in areas where Local Authorities are working with the Joint Air Quality Unit (JAQU)[2] or the Devolved Administrations to reduce NO_2 concentrations in line with the UK plan for tackling roadside NO_2 concentrations[3]. The network became operational in two phases; Phase 1 in January 2020 and Phase 2 in January 2021.

1.1 Aims of UUNN

The primary aim of the UUNN is to provide additional local NO_2 monitoring data for inclusion within the national UK compliance assessment. Previously the national assessment of NO_2 has 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 monitors were sited specifically to target areas where modelling had indicated an 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.

The two requirements to identify specific road links[4] for UUNN measurements within these areas are as follows:

- Where the PCM model and/or modelling completed by a relevant local authority had predicted an exceedance of the NO_2 annual mean limit value of $40\mu g/m^3$ in 2020 and/or 2021.
- Where the difference between the PCM model and modelling completed by a relevant local authority is larger than 20%.

[1] UK Government, *UK Air Quality Standards Regulations 2010*, 2010, https://www.legislation.gov.uk/uksi/2010/1001/contents/made

[2] The Joint Air Quality Unit is a joint unit of the Department for Transport (DfT) and the Department for Environment, Food and Rural Affairs (Defra)

[3] Department for Environment, Food and Rural Affairs (Defra) and Department for Transport (DfT), *UK plan for tackling roadside nitrogen dioxide concentrations,* 2017, https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017

[4] A road link is a section of road between two major junctions that is greater than 100m in length. There are approximately 9,000 road links in the PCM model which correspond to major urban roads for which compliance with the limit value for NO_2 is assessed.

1.2 The Network

The monitoring locations for both Phase 1 and Phase 2 of the UUNN were established during rigorous site selection exercises. For each road link that met the criteria detailed in section 1.1, the site selection exercises identified measurement locations that met the required siting criteria set out in Schedule 1 of the Air Quality Standards Regulations and avoiding any local hotspots. Schedule 1 provides detailed siting criteria for assessment of ambient air quality and location of sampling points for the measurement of pollutants (including NO_2) in ambient air.

Following the completion of the scoping exercise for Phase 2 the number monitoring locations was 296. Four sites have subsequently been removed from the dataset due to poor data capture in the first nine months of 2021. This report therefore describes data from the remaining 292 sites. This includes 38 AURN monitoring sites to provide co-location monitoring data for validating monitored NO_2 concentrations. Figure 1.1 provides a map of the UUNN monitoring locations.

A detailed investigation was undertaken during Q4 2021 in order to determine whether there were any suitable alternative locations for the four sites that were removed from the 2021 dataset. For three of the sites, an alternative site was either identified or site access arrangements were agreed, and will therefore be reinstated within the network in 2022. However, there was no suitable alternative site at one location, and this site has therefore been removed from the network.

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 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. 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 2021 UUNN monitoring calendar is provided in Appendix B.

Figure 1.1: UUNN Monitoring Locations

2 Bias Adjustment and Uncertainty

As detailed in Section 1.2, monitoring has been undertaken at 38 existing AURN monitoring stations to provide data for validating all UUNN monitored NO_2 concentrations. 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)[5]. 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%, in line with published Guidance[6]. This threshold has been applied to both automatic analyser data and diffusion tube data.

In line with GDE 2010[5], 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 1.014 and the intercept is 2.568.

The intercept value is statistically significantly different from zero based on two standard deviations. All concentrations were therefore corrected by subtracting 2.568µg/m^3.

The slope is not significantly different from 1, but without correcting the slope the level of bias[7] at the limit value is approximately 0.5µg/m^3. It is decided that this level of bias was too high as it could lead to inaccuracies when determining compliance with the limit value. Therefore, a slope correction has also been applied, resulting in a considerably lower bias at the limit value of <0.01µg/m^3.

The results after slope and intercept correction are shown in Figure 2.2.

The expanded uncertainty of the annual mean concentrations after applying the bias correction, is 11.94%. This is an excellent result for a diffusion tube network and is well within the 25% uncertainty level[6] required for supplementary measurements such as diffusion tubes to be used to determine compliance with the annual mean NO_2 limit value.

[5] Guide to Demonstration of Equivalence 2010

[6] Guidance on the Commission Implementing Decision laying down rules for Directives 2004/107/EC and 2008/50/EC of the European Parliament and of the Council as regards the reciprocal exchange of information and reporting on ambient air (Decision 2011/850/EU). European Commission. DG ENV 2013.

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

Figure 2.1: Scatter plot with Equivalence Calculations for annual averages of 2021 data: data before correction

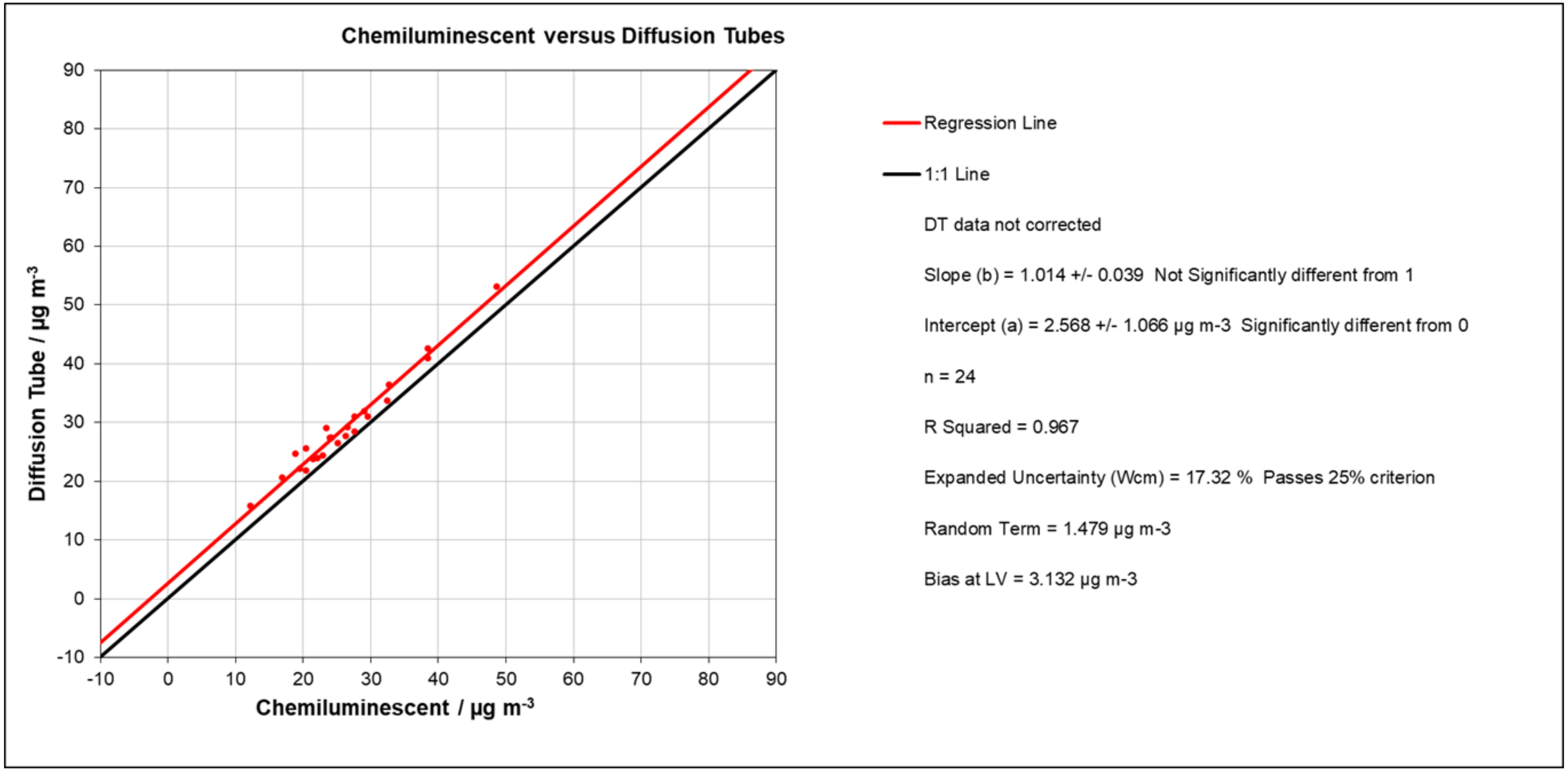
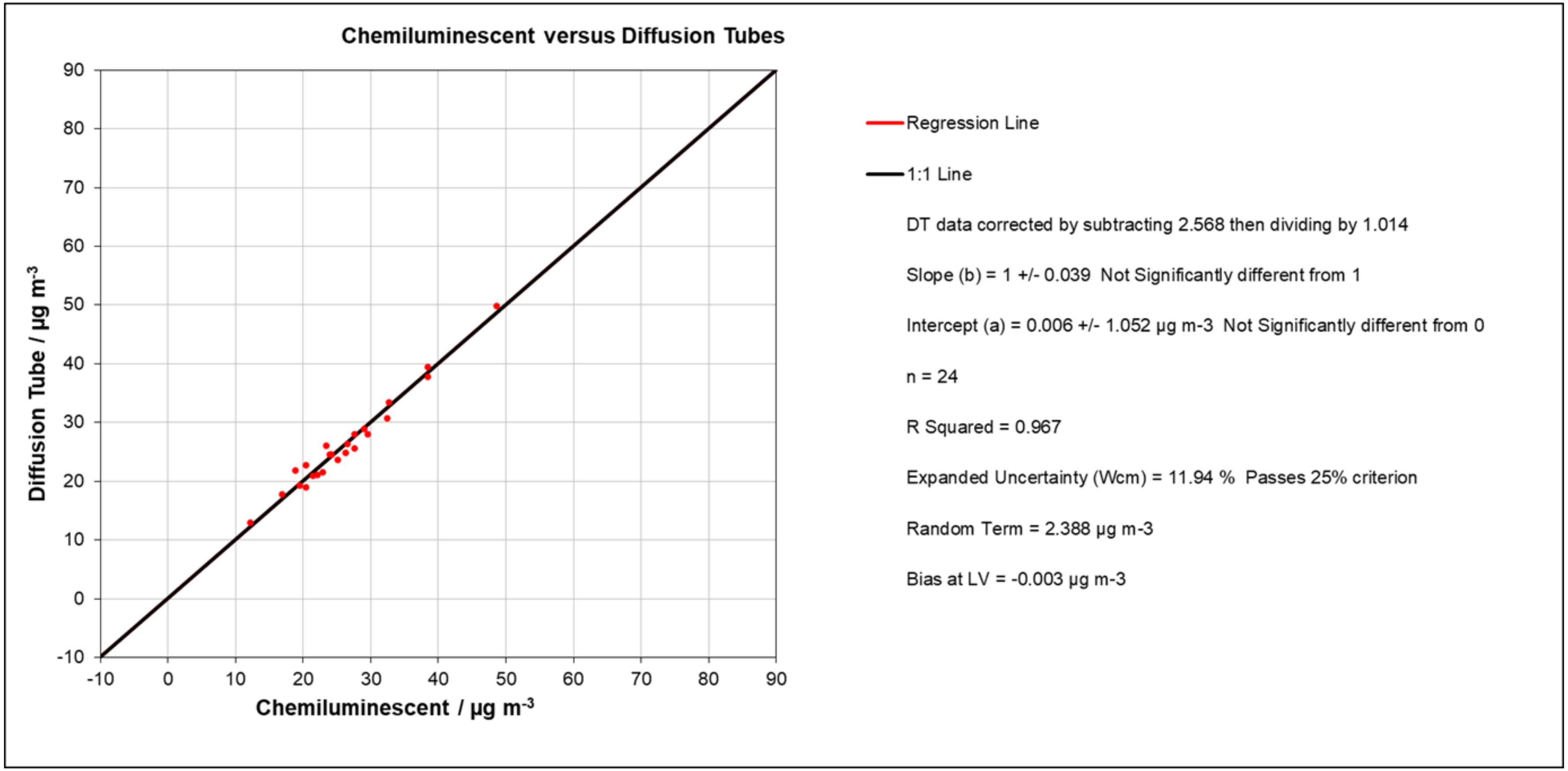


Figure 2.2: Scatter plot with Equivalence Calculations for annual averages of 2021 data: data corrected



3 Network Performance and Corrected Data

The following section provides an overview of both the data capture achieved across the UUNN within 2021, and the NO_2 concentration data for the UUNN sites that met specific data capture requirements within 2021. All concentration data presented within this section have been slope and intercept corrected as detailed in Section 2.

3.1 2021 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 for more than 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 292 sites operational within the UUNN in 2021 there were 15 Red Flag sites; 11 UUNN sites and 4 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 277; a combination of 243 UUNN sites and 34 co-location sites at AURN analysers. In addition to the 15 Red Flag sites there were 47 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.

Table 3.1: Yellow and Red Flagged Sites

Flag Assessment	Site Name		
Yellow Flag Sites	UUNN_ABER_001	UUNN_HERT_002	UUNN_SHEF_013
	UUNN_BATH_007	UUNN_HERT_003	UUNN_SOUT_002
	UUNN_BCPO_001	UUNN_LEIC_002	UUNN_TAME_003
	UUNN_BOLT_001	UUNN_LIVE_006	UUNN_WELW_001
	UUNN_BOLT_003	UUNN_LIVE_019	UUNN_WELW_002
	UUNN_BOLT_005	UUNN_LIVE_021	UUNN_UKA00596
	UUNN_BRAD_001	UUNN_MANC_026	UUNN_UKA00601
	UUNN_BRIS_004	UUNN_MIDD_002	UUNN_UKA00612
	UUNN_BRIS_006	UUNN_NEWF_001	UUNN_UKA00613

Flag Assessment	Site Name		
	UUNN_BURY_005	UUNN_PORT_001	UUNN_UKA00624
	UUNN_CARD_001	UUNN_READ_001	UUNN_UKA00626
	UUNN_CAST_002	UUNN_SALF_006	UUNN_UKA00629
	UUNN_EAST_001	UUNN_SALF_007	UUNN_UKA00631
	UUNN_EDIN_002	UUNN_SALF_010	UUNN_UKA00649
	UUNN_EHER_001	UUNN_SHEF_003	UUNN_UKA00660
	UUNN_HERT_001	UUNN_SHEF_005	
Red Flag Sites	UUNN_BOLT_003	UUNN_LIVE_006	UUNN_SOUT_002
	UUNN_BOLT_005	UUNN_LIVE_021	UUNN_UKA00601
	UUNN_BRIS_006	UUNN_MANC_026	UUNN_UKA00612
	UUNN_EAST_001	UUNN_NEWF_001	UUNN_UKA00626
	UUNN_HERT_003	UUNN_SALF_007	UUNN_UKA00631

3.2 Annual Mean Concentrations

Following the removal of any Red Flag sites, there were 12 UUNN sites that exceeded the 40µg/m^3 limit value in 2021. The UUNN sites that exceeded the annual mean limit value in 2021 are presented in Appendix C. It's worth noting that there were no Red Flag sites that monitored concentrations exceeding the limit value.

A full list of 2021 annual mean NO_2 monitoring results can be accessed using the UK-Air resource[8].

3.3 Monthly Mean Concentrations

Table 3.2 provides the average NO_2 concentration across the UUNN during 2021. It can be observed that the UUNN average NO_2 concentration is below the 40µg/m^3 limit value for all monthly periods within 2021, when taking the average across all sites in the network.

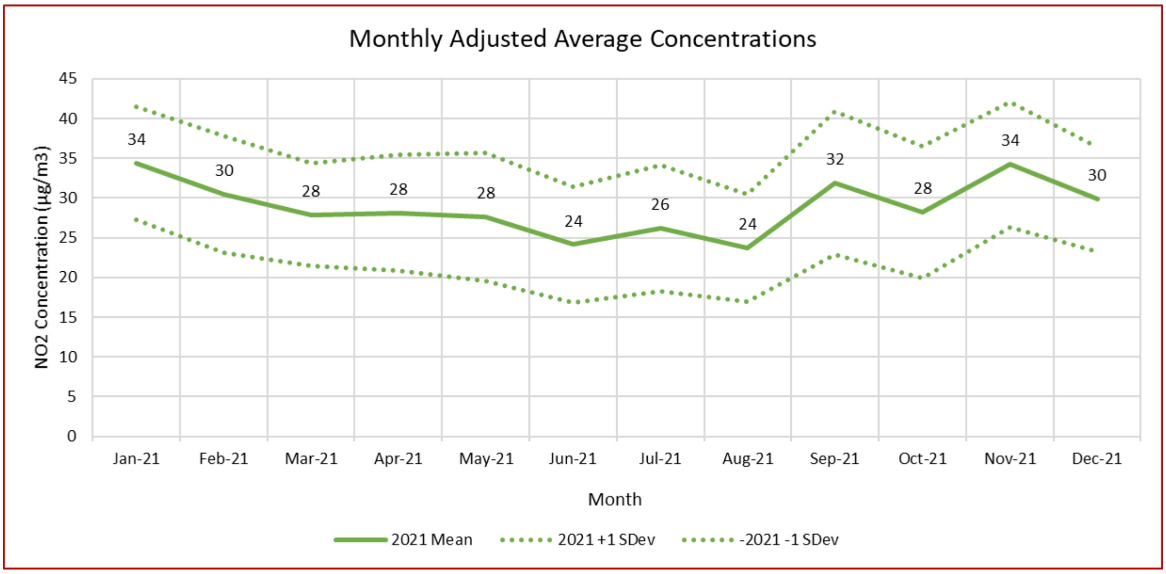
Table 3.2: Average NO_2 Concentration across all UUNN sites (2021)

	Month (2021)												Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Average NO_2 Concentration (µg/m^3)	34	30	28	28	28	24	26	24	32	28	34	30	29
Minimum NO_2 Concentration (µg/m^3)	17	11	12	12	10	7	9	9	12	10	15	13	-
Maximum NO_2 Concentration (µg/m^3)	59	67	55	54	60	50	56	46	65	64	57	51	-

Figure 3.1 displays the trend in average UUNN monthly NO_2 concentration throughout 2021, demonstrating a small level of seasonal variation, where concentrations through the summer months are often lower than those in winter months.

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

Figure 3.1: Average NO_2 Concentration across UUNN sites (2021)



4 Summary

The UK Urban NO_2 Network (UUNN) is an air quality network that monitors concentrations of nitrogen dioxide (NO_2). 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.

The implementation of the UUNN was completed across two phases; Phase 1 which became operational in January 2020, and Phase 2 which became operational in January 2021. 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 2021 UUNN monitoring results are as follows:

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- Following intercept correction 12 UUNN sites exceeded the 40µg/m^3 limit value in 2021.

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 a 'bias adjustment factor' before comparing the annual mean NO_2 concentration with applicable limit values or objectives. The 'bias 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)[9] 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)[9] paper).

[9] 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

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.

Figure A.1: Diffusion Tube with Wind-Protection Cap (tube on right shows separated components)

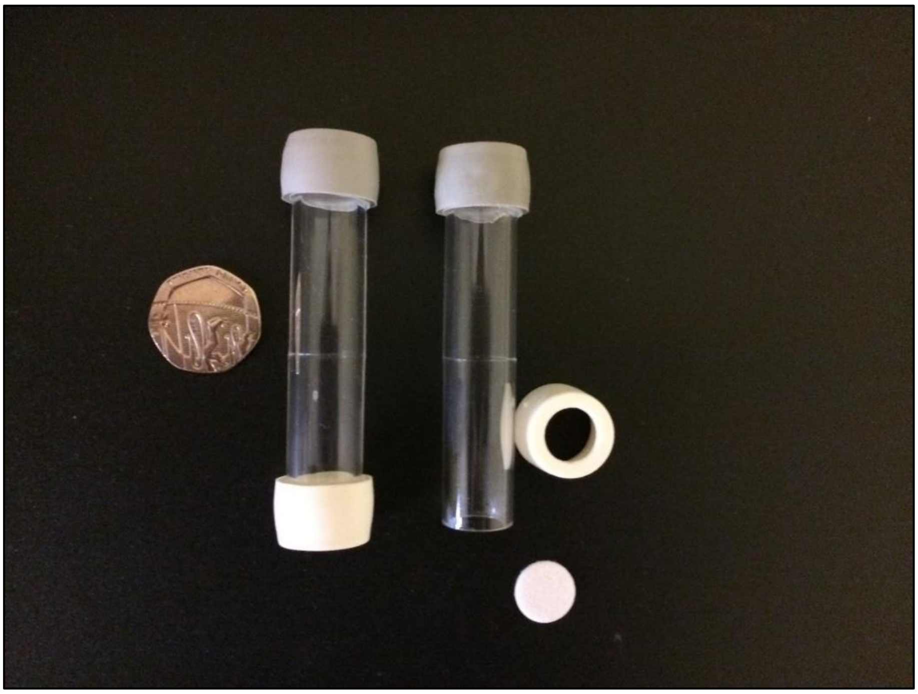

Figure A.2: Example UUNN Monitoring Location

Appendix B:
2021 UUNN Monitoring Calendar

Table B.1: 2021 UUNN Timetable for Tube Changes

Year	Month	Target Date (Acceptable Date)
2021	January	**04-Jan** (05-Jan)
	February	(01-Feb) **02-Feb**
	March	**01-Mar** (02-Mar)
	April	**01-Apr** (31-Mar)
	May	**04-May** (05-May)
	June	**01-Jun** (02-Jun)
	July	**01-Jul** (02-Jul)
	August	**02-Aug** (03-Aug)
	September	**01-Sep** (02-Sep)
	October	**30-Sep** (01-Oct)
	November	**01-Nov** (02-Nov)
	December	**01-Dec** (02-Dec)
2022	January	**04-Jan** (05-Jan)

Notes:
Changeovers should take place on the **Target Date.** Where this has not been possible the changeover should be done on the Acceptable Date.

Appendix C:
UUNN Exceedance Sites

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

Site ID	Local Authority	2021 Annual Mean NO_2 Concentration
Sites in Exceedance of 40µg/m^3 Limit Value		
UUNN_MANC_005	Manchester	51.5
UUNN_UKA00596	Caerphilly	49.8
UUNN_BIRM_003	Birmingham	49.4
UUNN_MANC_029	Manchester	48.5
UUNN_MANC_013	Manchester	45.4
UUNN_SHEF_013	Sheffield	44.9
UUNN_NOTT_001	Nottingham	44.5
UUNN_UKA00315	Westminster	44.0
UUNN_LIVE_011	Liverpool	43.2
UUNN_LEED_007	Leeds	43.1
UUNN_BRIS_009	Bristol City of	42.8
UUNN_MANC_007	Manchester	42.4