Environment Agency/Joint Air Quality Unit

UK Urban NO_2 Network Operational Annual Report 2022

September 2023

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 2022. The key statistics from the 2022 UUNN monitoring results are as follows:

- Monitoring was successfully undertaken at 290 locations during 2022. 252 of these are at roadside sites unique to the UUNN, and 38 are located at existing AURN roadside monitoring stations;
- Across all 290 UUNN sites a data capture of 93% was achieved in 2022;
- 24 sites (22 UUNN and 2 AURN) were removed from the compliance assessment due to being 'Red Flagged' as they had more than one monitoring period of missing results;
- The expanded uncertainty of the annual mean concentrations was found to be 9.11% which is well within the required 25% uncertainty level required for indicative monitoring;
- An intercept correction factor of 1.777 was derived from the AURN co-location study. The slope was found to be 1.001 meaning slope correction was not required;
- Following intercept correction, 16 UUNN sites exceeded the 40µg/m^3 limit value in 2022.

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 a number of phases; Phase 1 in January 2020, Phase 2 in January 2021 and Phase 2a in January 2022.

Further adjustments to the network occurred in January 2023 (Phase 3). As this report focuses on network activities in 2022, full details of Phase 3 adjustments will be provided in the 2023 annual report rather than this document.

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. Prior to 2020 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. More recently UUNN monitors have also been sited on road links where local monitoring by a relevant local authority has identified a potential exceedance that is not yet captured in the national assessment.

1.2 The Network

The monitoring locations for Phases 1, 2 and 2a 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

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[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)

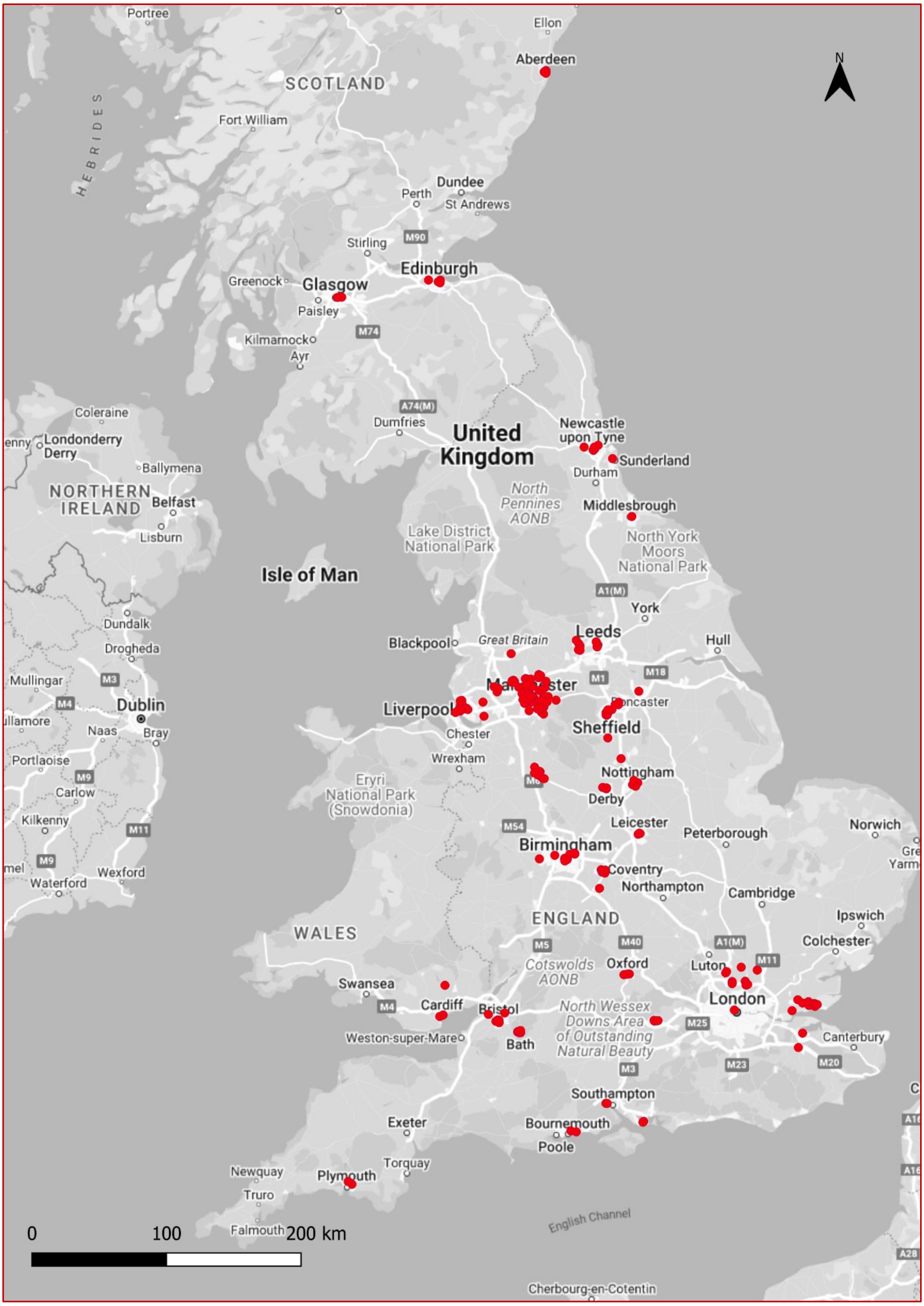
[3] Department for Environment, Food and Rural Affairs (Defra) and Department for Transport (DfT), *UK plan for tackling roadside nitrogen dioxide concentrations,* 2017, https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017

points for the measurement of pollutants (including NO_2) in ambient air. As detailed above further adjustments to the network occurred in January 2023 (Phase 3).

In 2021 the network reported data at 292 sites. At the end of 2021 a small number of sites were removed or deployed (Phase 2a) for monitoring in 2022. This report therefore describes data for 290 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.

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 2022 UUNN monitoring calendar is provided in Appendix B.

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. 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 1.001 and the intercept is 1.777. As the slope is 1.001 it is equivalent to 1 within the error. The slope therefore does not need to be corrected.

The intercept value is statistically significantly different from zero based on two standard deviations. All concentrations were therefore corrected by subtracting 1.777µg/m^3.

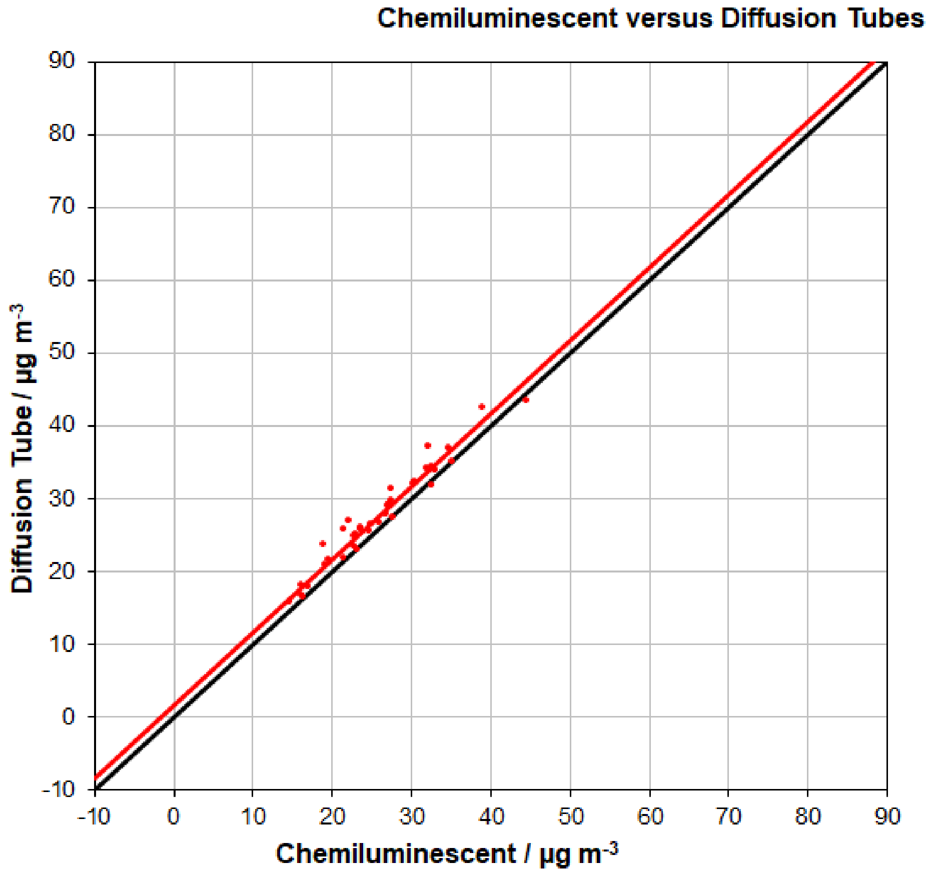
The results after intercept correction are shown in Figure 2.2.

The expanded uncertainty of the annual mean concentrations after applying the correction, is 9.11%. 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.(as transposed into UK law by means of the Air Quality Standards Regulations)

Figure 2.1: Scatter plot with Equivalence Calculations for annual averages of 2022 data: data before correction



Regression Line

1:1 Line

DT data not corrected

Slope (b) = 1.001 +/- 0.037 Not Significantly different from 1

Intercept (a) = 1.777 +/- 0.983 µg m-3 Not Significantly different from 0

n = 37

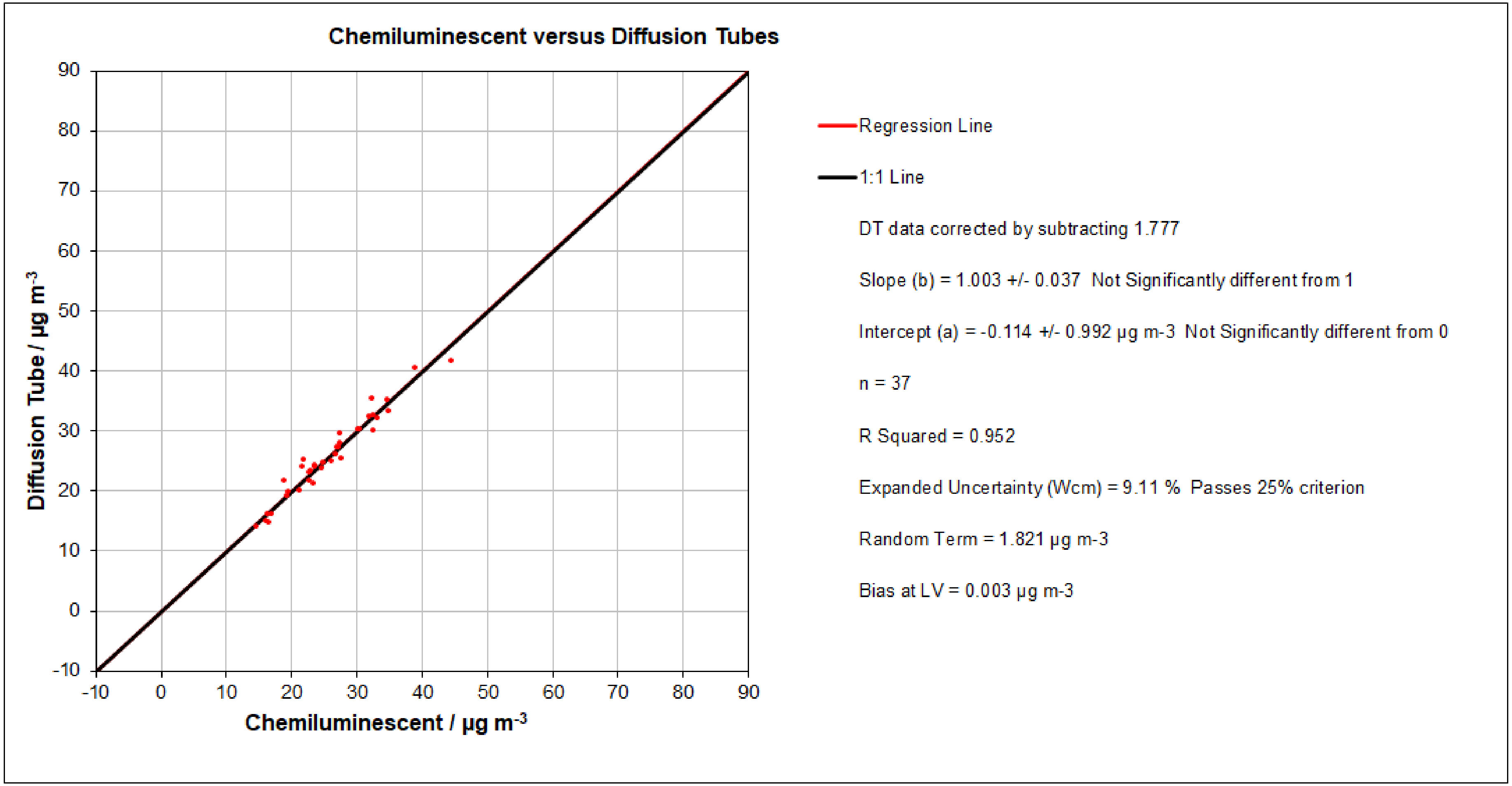
R Squared = 0.953

Expanded Uncertainty (Wcm) = 11.84 % Passes 25% criterion

Random Term = 1.515 µg m-3

Bias at LV = 1.821 µg m-3

Figure 2.2: Scatter plot with Equivalence Calculations for annual averages of 2022 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 2022, and the NO_2 concentration data for the UUNN sites that met specific data capture requirements within 2022. All concentration data presented within this section have been intercept corrected as detailed in Section 2.

3.1 2022 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 290 sites operational within the UUNN in 2022 there were 24 Red Flag sites; 22 UUNN sites and 2 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 266; a combination of 230 UUNN sites and 36 co-location sites at AURN analysers. In addition to the 24 Red Flag sites there were 39 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

Red Flag Site				
UUNN_BOLT_006	UUNN_EDIN_003	UUNN_MANC_017	UUNN_SHEF_006	UUNN_STOK_017
UUNN_BRIS_006	UUNN_GATE_001	UUNN_NEWC_002	UUNN_SHEF_009	UUNN_TAME_005
UUNN_BURY_003	UUNN_LEIC_002	UUNN_NEWF_001	UUNN_SHEF_012	UUNN_UKA00622
UUNN_CARD_001	UUNN_LIVE_006	UUNN_SHEF_003	UUNN_SOUT_002	UUNN_UKA00629
UUNN_EDIN_002	UUNN_MANC_015	UUNN_SHEF_005	UUNN_STOC_003	
Yellow Flag Sites				
UUNN_BATH_001	UUNN_CAST_001	UUNN_MANC_006	UUNN_SHEF_004	UUNN_VOWH_001
UUNN_BATH_003	UUNN_EDIN_004	UUNN_MANC_021	UUNN_SHEF_010	UUNN_WIGA_002
UUNN_BATH_006	UUNN_LEED_008	UUNN_OXFO_001	UUNN_SHEF_011	UUNN_UKA00258
UUNN_BRAD_001	UUNN_LIVE_002	UUNN_PORT_001	UUNN_SHEF_013	UUNN_UKA00529
UUNN_BRIS_003	UUNN_LIVE_013	UUNN_PORT_002	UUNN_SHEF_014	UUNN_UKA00612
UUNN_BRIS_009	UUNN_LIVE_021	UUNN_ROCH_003	UUNN_STOC_006	UUNN_UKA00613
UUNN_BROX_001	UUNN_MAID_001	UUNN_SALF_010	UUNN_STOC_008	UUNN_UKA00651
UUNN_BURY_004	UUNN_MANC_031	UUNN_SGLO_001	UUNN_TAME_001	

3.2 Annual Mean Concentrations

Following the removal of any Red Flag sites, there were 16 UUNN sites that exceeded the 40µg/m^3 limit value in 2022. The UUNN sites that exceeded the annual mean limit value in 2022 are presented in Appendix C.

A full list of 2022 annual mean NO_2 monitoring results can be accessed using the UK-Air resource[7].

3.3 Monthly Mean Concentrations

Table 3.2 provides the average NO_2 concentration across the UUNN during 2022. It can be observed that the UUNN average NO_2 concentration is below the 40µg/m^3 limit value for all monthly periods within 2022, when taking the average across all sites in the network.

Table 3.2: Average NO_2 Concentration across all UUNN sites (2022)

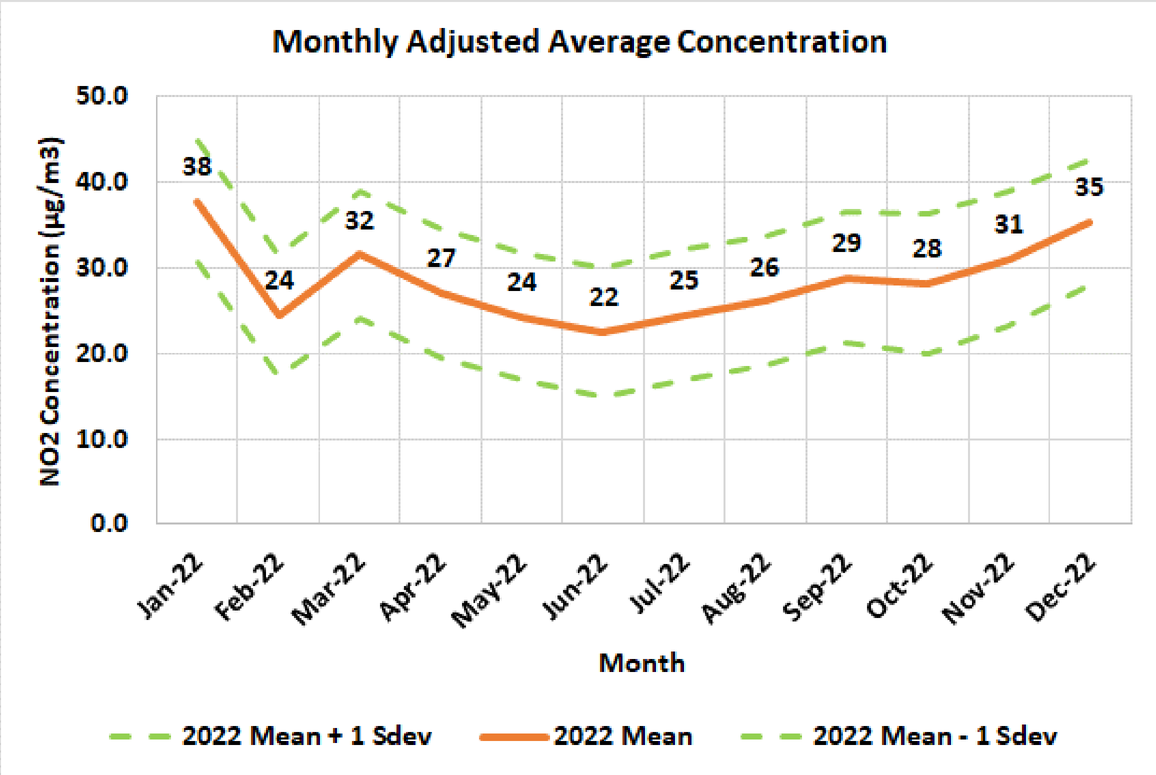
	Month (2022)												Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Average NO_2 Concentration (µg/m^3)	38	24	32	27	24	22	25	26	29	28	31	35	28
Minimum NO_2 Concentration (µg/m^3)	18	9	16	11	7	5	7	9	11	10	12	20	-
Maximum NO_2 Concentration (µg/m^3)	58	51	59	58	51	53	55	55	60	60	60	62	-

Figure 3.1 displays the trend in average UUNN monthly NO_2 concentration throughout 2022, demonstrating a small level of seasonal variation, where

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

concentrations through the summer months are often lower than those in winter months.

Figure 3.1: Average NO_2 Concentration across UUNN sites (2022)



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 Phases 1, 2 and 2a. 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.

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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)[8] 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)[8] paper).

[8] 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)

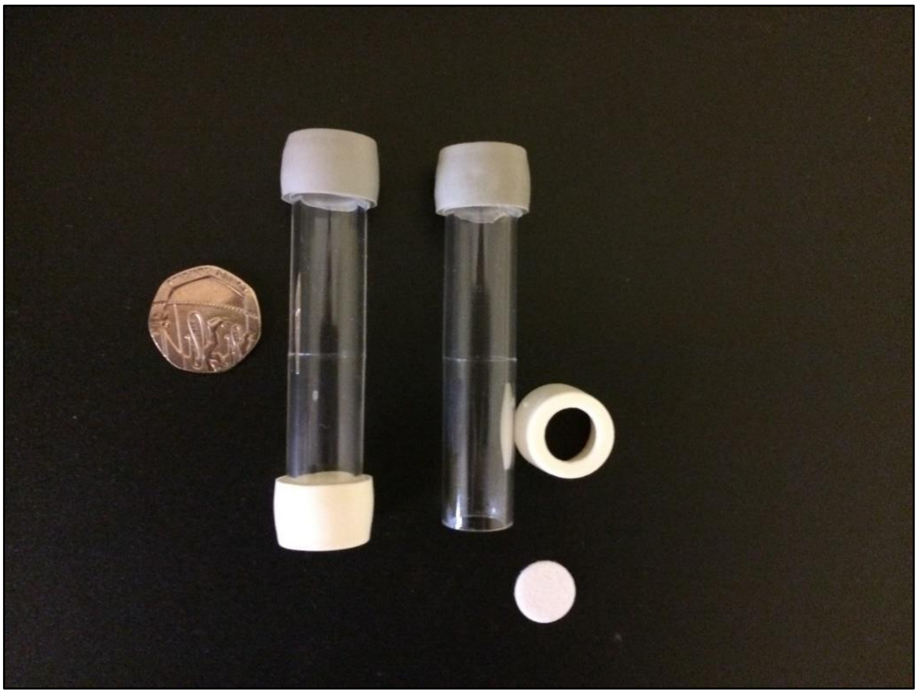

Figure A.2: Example UUNN Monitoring Location

Appendix B:
2022 UUNN Monitoring Calendar

Table B.1: 2022 UUNN Timetable for Tube Changes

Year	Month	Target Date (Acceptable Date)
2022	January	**04-Jan** (05-Jan) *
	February	**01-Feb** (02-Feb)
	March	**01-Mar** (02-Mar)
	April	**31-Mar** (01-Apr)
	May	**03-May** (04-May)
	June	**06-Jun** (07-Jun)
	July	**04-Jul** (05-Jul)
	August	**01-Aug** (02-Aug) *
	September	**01-Sep** (02-Sep)
	October	**29-Sep** (30-Sep)
	November	**01-Nov** (02-Nov)
	December	**01-Dec** (02-Dec)
2023	January	**03-Jan** (04-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 40µg/m³ Limit Value

Site ID	Local Authority	2022 Annual Mean NO_2 Concentration (µg/m³)
Sites in Exceedance of 40µg/m³ Limit Value		
UUNN_MANC_005	Manchester	54.2
UUNN_MANC_029	Manchester	54.1
UUNN_BRIS_009	Bristol	49.1
UUNN_VOWH_001	Vale of White Horse	48.0
UUNN_BIRM_003	Birmingham	46.6
UUNN_MANC_007	Manchester	45.0
UUNN_MANC_013	Manchester	44.7
UUNN_MANC_027	Manchester	43.7
UUNN_SHEF_013	Sheffield	43.3
UUNN_LIVE_011	Liverpool	43.1
UUNN_NOTT_001	Nottingham	42.6
UUNN_MANC_028	Manchester	42.3
UUNN_UKA00315	London Marylebone Road	41.7
UUNN_LEED_007	Leeds	40.8
UUNN_MANC_014	Manchester	40.7
UUNN_MANC_004	Manchester	40.6