Environment Agency/Joint Air Quality Unit

UK Urban NO_2 Network Annual Report 2020

September 2021

Move Forward with Confidence

BUREAU VERITAS

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Executive Summary

The UK Urban NO_2 Network (UUNN) is a nitrogen dioxide (NO_2) monitoring network that has been 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 the NO_2 monitoring data collected on the UUNN during 2020. The key statistics from the 2020 UUNN monitoring results are as follows:

- Monitoring was undertaken at 177 locations, inclusive of 25 existing AURN monitoring stations to provide co-location monitoring data for validating monitored NO_2 concentrations.
- An intercept correction factor of 2.494 was derived from the AURN co-location study.
- Across all 177 UUNN sites a data capture of 96.7% was achieved in 2020.
- 14 sites were removed from the compliance assessment due to low data capture, leaving 163 included within the compliance assessment.
- Following correction, annual mean NO_2 concentrations at five UUNN sites exceeded the 40µg/m^3 limit value in 2020.

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) 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 are 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 the provision of additional NO_2 monitoring data for inclusion within the national UK compliance assessment. Previously the national assessment of NO_2 has comprised of a 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 40µg/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.

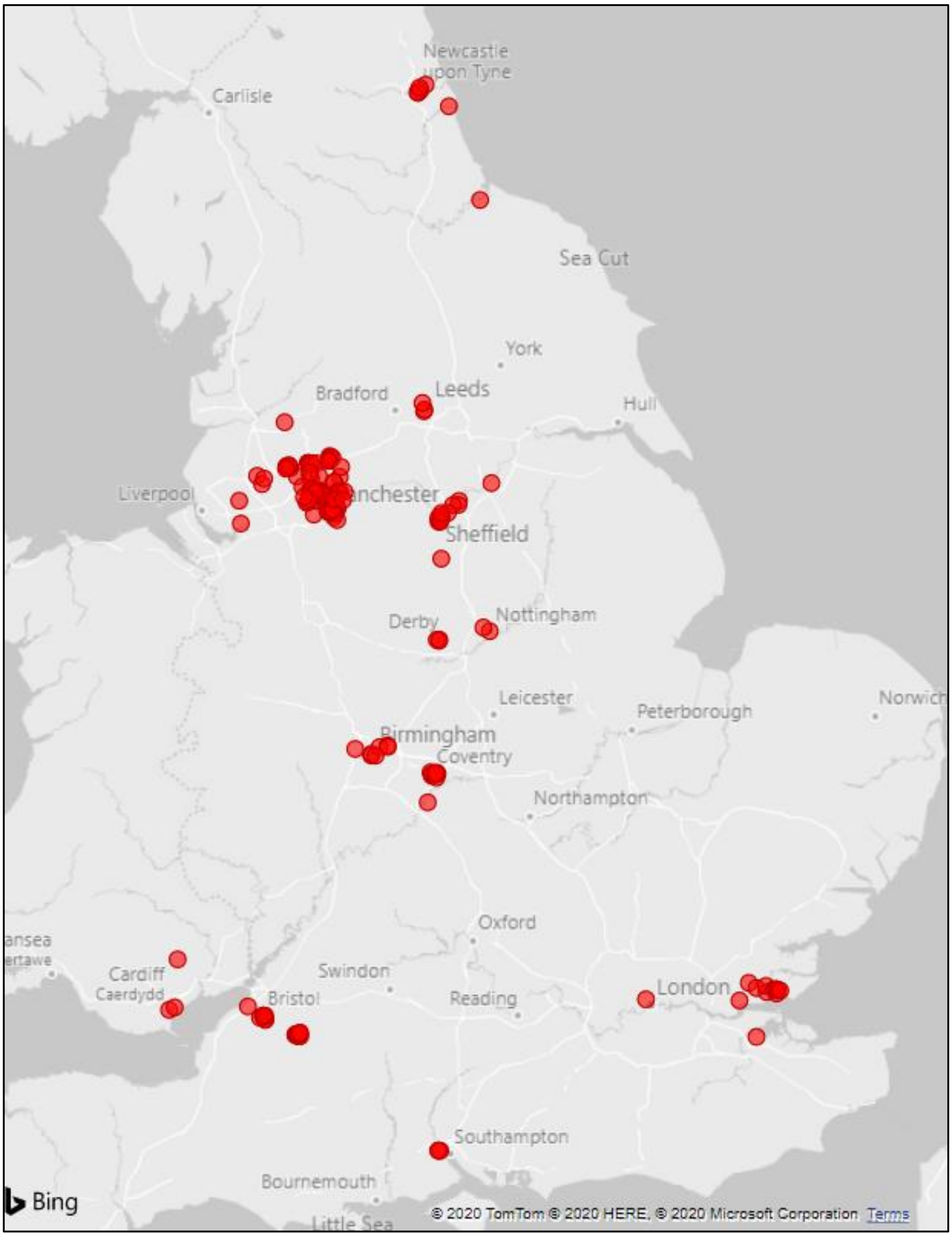
1.2 The Network

Monitoring locations for Phase 1 of the UUNN were established during a rigorous site selection exercise that was completed in late 2019. For each road link that met the criteria detailed in section 1.1, a site selection exercise was carried out to identify measurement locations that met the siting requirements 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. Of the road links shortlisted for a UUNN measurement, siting was not possible on almost 25%, either due to health and safety or access constraints, or because it wasn't possible to identify a suitable location that met the Schedule 1 siting criteria.

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 also 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 2020 UUNN monitoring calendar is provided in Appendix B.

Following site selection and site establishment, monitoring was undertaken at 177 locations during 2020. This includes 25 AURN monitoring sites to provide co-location monitoring data for validating monitored NO_2 concentrations. Figure 1.1 provides an overview of the Phase 1 UUNN monitoring locations.

Figure 1.1: Overview of UUNN Monitoring Locations



2 Uncertainty Calculations for Co-located AURN sites

As detailed in Section 1.2, monitoring has been undertaken at 25 existing AURN monitoring stations to provide data for validating all UUNN monitored NO_2 concentrations. At these 25 sites the UUNN diffusion tubes are co-located with reference method chemiluminescent analysers. Data from these 25 sites allows for the calculation of correction factors and uncertainties that can be applied to all sites in the UUNN.

Correction factors and the overall uncertainty have both been calculated in line with the Guide to Demonstration of Equivalence (GDE)[5]. Annual averages of the 25 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.

Co-location sites have only been included in the calculations when the data capture of the reference method (AURN continuous analysers) is greater than 85%. While only UUNN sites with greater than 85% data capture were used to report compliance, several sites were included in the calculation of the correction factors despite having only nine months of data (approximately 75%). The inclusion of these sites led to a greater range of concentrations and therefore much higher confidence in the correction factor calculated. Two sites had fewer than nine months' data capture and were removed from the calculation.

In line with the GDE[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 and Figure 2.2. The slope is 1.001 and is equivalent to 1 within the error. The slope therefore does not need to be corrected. The intercept is 2.494 and is statistically significantly different from zero based on two standard deviations. All annual mean concentrations were therefore corrected by subtracting 2.494µg/m^3.

The expanded uncertainty of the annual mean concentrations after applying the bias correction, is 8.82%. 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. The expanded uncertainty of 8.82% is also within the 15% uncertainty requirement for fixed measurements, although UUNN measurements have not been reported as fixed measurements for the 2020 assessment.

A point of note is that 2020 can be described as an unusual year due to the impacts of the COVID-19 pandemic. It has been documented that pandemic restrictions resulted in decreased road traffic, resulting in decreased emissions. This will have impacted NO_2 concentration data collected in 2020 and therefore influenced the

[5] European Commission Equivalence Working Group. *Guide to the Demonstration of Equivalence of Ambient Air Monitoring Methods*, 2010, https://ec.europa.eu/environment/air/quality/legislation/pdf/equivalence.pdf

[6] *Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe,* Annex 1, https://www.legislation.gov.uk/eudr/2008/50/annex/I

calculation of expanded uncertainty. It is therefore possible that the expanded uncertainty for 2020 may change in future years.

Figure 2.1: Scatter plot with Equivalence Calculations for annual averages of 2020 data: DT data before correction

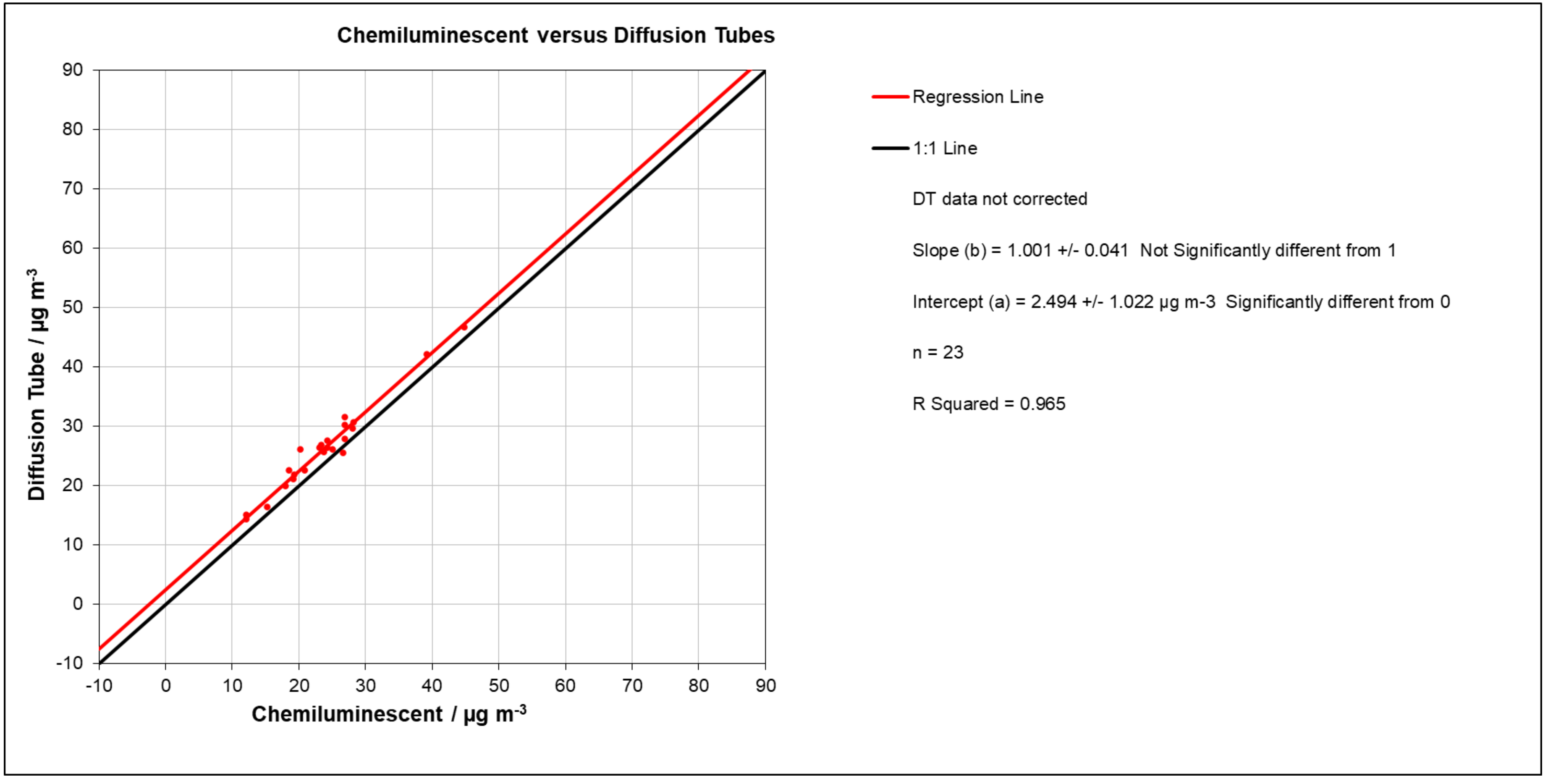
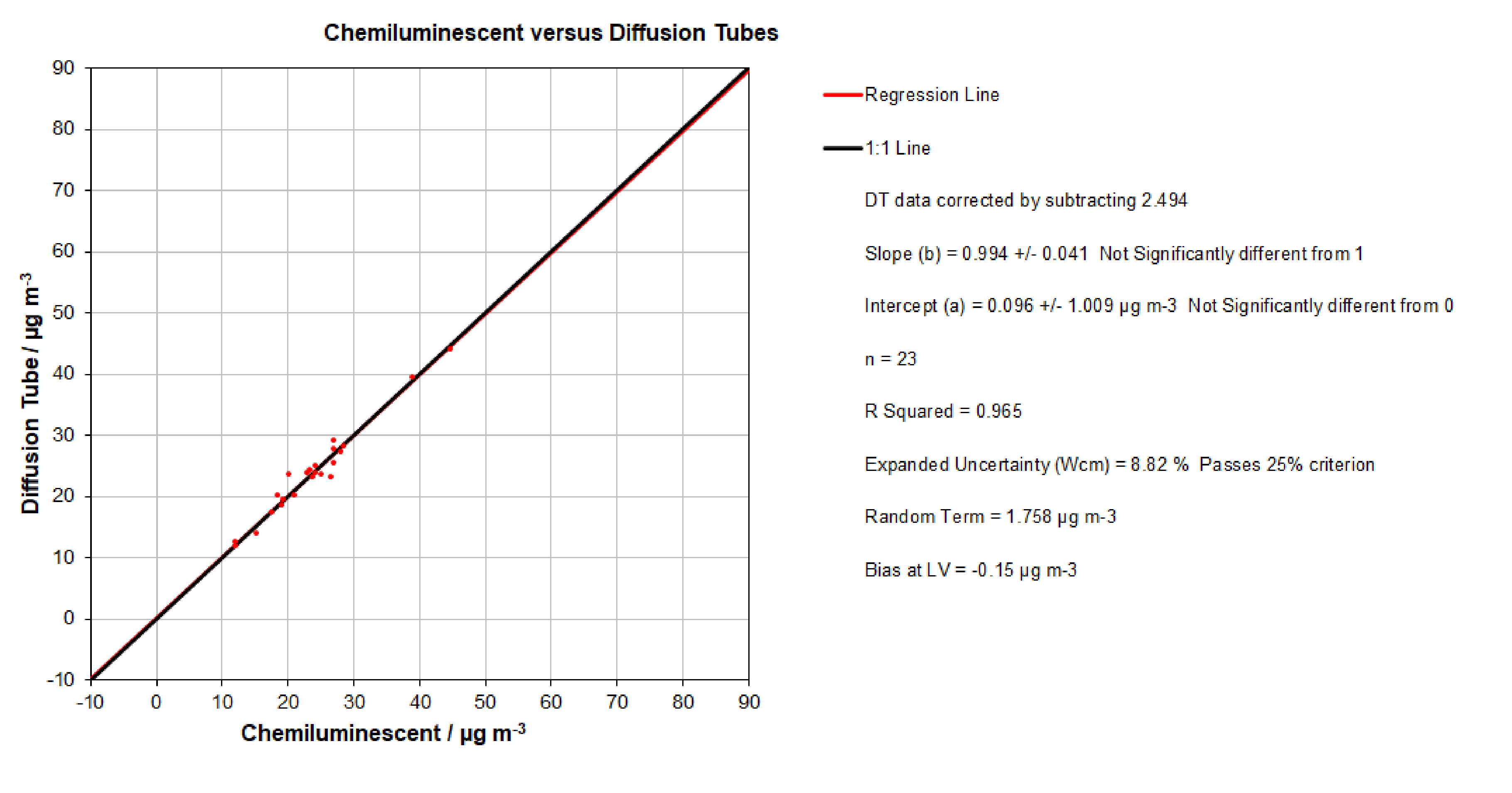


Figure 2.2: Scatter plot with Equivalence Calculations for annual averages of 2020 data: DT data Corrected



3 Network Performance and Corrected Data

The following section provides an overview of both the data capture achieved across the UUNN within 2020, and the NO_2 concentrations for the UUNN sites that met specific data capture requirements within 2020. All concentration data presented within this section has been intercept corrected by subtracting 2.494µg/m^3 as detailed in Section 2.

3.1 2020 Data Capture

Data capture within the UUNN has been assessed through the implementation of 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 177 sites operational within the UUNN in 2020 there were 14 Red Flag sites; 4 of which were AURN co-location sites. Therefore, there are 163 UUNN sites that met the data capture requirements. The Red Flag sites are not included in the compliance assessment.

In addition to the 14 Red Flag sites there were 16 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 within 2020 was the diffusion tubes being removed, either stolen or vandalised, during an exposure period. After being deployed in accordance with the monitoring calendar a number of diffusion tubes each month were found to be missing on the subsequent changeover date. In addition to tubes being removed the following reasons were apparent for reduced data capture:

- Access restrictions / roadworks at monitoring locations.
- Health and safety access considerations.
- Local Site Operator (LSO) error.

Table 3.1: Yellow and Red Flagged Sites

Yellow Flag Sites	Red Flag Site
UUNN_BATH_001	UUNN_BRIS_001 / UUNN_UKA00631
UUNN_BATH_003	UUNN_BRIS_006
UUNN_BOLT_001	UUNN_BURY_004
UUNN_BOLT_003	UUNN_GATE_001
UUNN_CARD_001	UUNN_NEWF_001

UUNN_CAST_001	UUNN_OLDH_002
UUNN_MANC_005	UUNN_SALF_007
UUNN_MANC_012	UUNN_SHEF_003
UUNN_SALF_011	UUNN_SOUT_002
UUNN_SHEF_005	UUNN_STOC_004
UUNN_SOOS_001	UUNN_TAME_008
UUNN_STOC_009	UUNN_UKA00596
UUNN_BATH_010 / UUNN_UKA00660	UUNN_UKA00564
UUNN_UKA00626	UUNN_UKA00601
UUNN_UKA00622	
UUNN_UKA00525	

3.2 Annual Mean Concentrations

Following the removal of the Red Flag sites, out of the 163 UUNN sites that met the data capture requirement there are five UUNN sites that exceeded the NO_2 annual mean limit value of 40µg/m^3. The UUNN sites that exceeded the annual mean limit value in 2020 are presented in Appendix C.

A full list of 2020 annual mean NO_2 monitoring results is presented through the UK-Air resource[7].

3.3 Monthly Mean Concentrations

Table 3.2 provides the average NO_2 concentration across the UUNN during 2020. It can be observed that the UUNN average NO_2 concentration is below 40µg/m^3

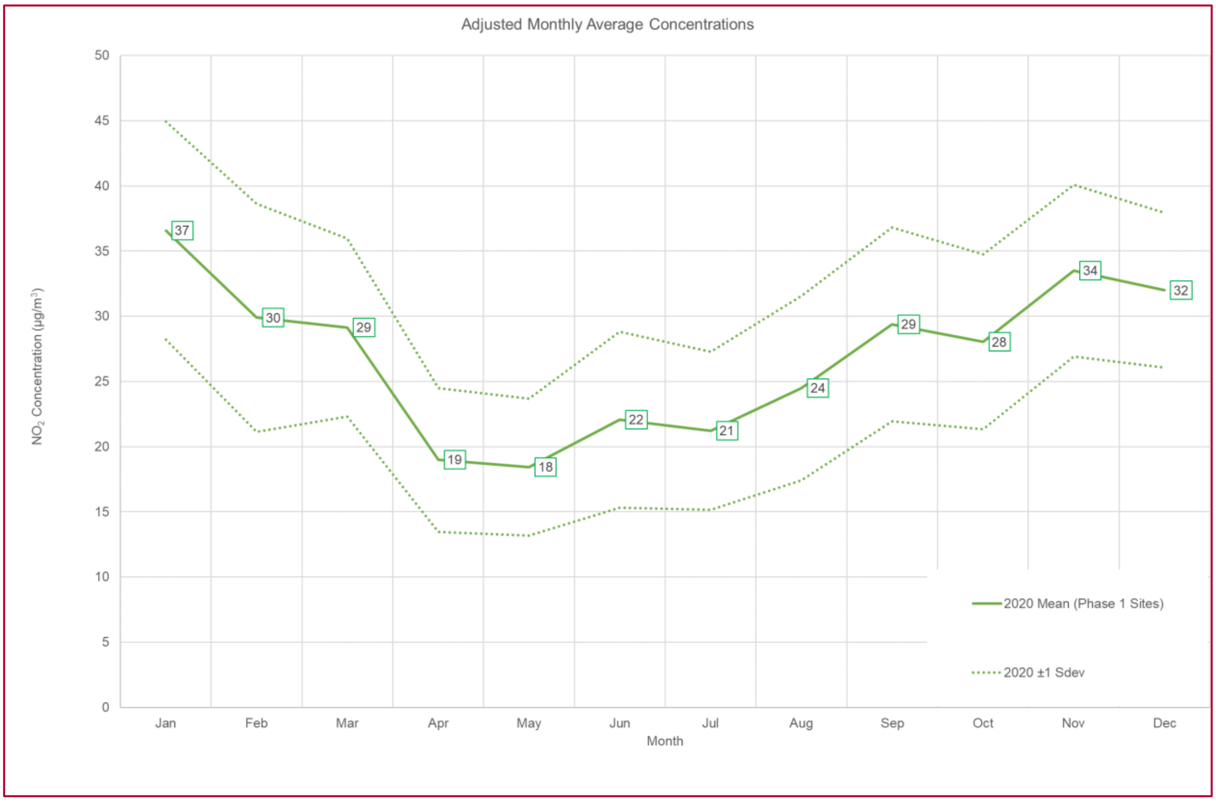
Table 3.2: Average NO_2 Concentration across all UUNN sites (2020)

	Month (2020)												Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Average NO_2 Concentration (µg/m^3)	37	30	29	19	18	22	21	24	29	28	34	32	27
Minimum NO_2 Concentration (µg/m^3)	16	14	16	9	7	10	9	11	14	14	17	16	-
Maximum NO_2 Concentration (µg/m^3)	72	63	57	50	43	55	40	55	61	53	58	50	-

Figure 3.1 displays the trend in average UUNN monthly NO_2 concentration throughout 2020. In addition to the monthly mean NO_2 concentration the concentration of one standard deviation above and below the annual mean has been plotted. This presents the area between which 68% of UUNN concentrations fall within. Although some seasonal variation in the average NO_2 concentration is expected, the drop of around 10µg/m^3 observed between March and April 2020 is considered to be at least in part due to reduced road traffic flows as a consequence of the COVID-19 pandemic and associated restrictions.

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

Figure 3.1: Average NO_2 Concentration across UUNN sites (2020)



4 Network Response to COVID-19 Pandemic

As detailed in previous sections, the COVID-19 pandemic has had an impact upon the reported 2020 annual mean NO_2 concentrations. In addition, the pandemic has impacted the day-to-day functioning of the UUNN, and the network has had to adapt to remain resilient in the face of many challenges caused by the COVID-19 pandemic in 2020.

A number of additional processes have been introduced to minimise any potential disruptions, and to ensure the safety of the LSOs. In addition, several ad-hoc research studies have been completed to ensure that where any changes have been made, the potential resulting effects have been researched and addressed.

5 Summary

The UK Urban NO_2 Network (UUNN) is an air quality monitoring network that monitors concentrations of nitrogen dioxide (NO_2). It has been designed and implemented to provide additional evidence for the national compliance assessment for NO_2, which previously comprised of the Automatic Urban and Rural Network (AURN), and a national air quality model; the Pollution Climate Mapping (PCM) model.

The implementation of the UUNN has been 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 2020 UUNN monitoring results are as follows:

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- An intercept correction factor of 2.494 was derived from the AURN co-location study.
- Across all 177 UUNN sites a data capture of 96.7% was achieved in 2020.
- 14 sites were removed from the compliance assessment due to low data capture, leaving 163 sites providing data for the 2020 compliance assessment.
- Following intercept correction annual mean NO_2 concentrations at five UUNN sites exceeded the 40µg/m^3 limit value in 2020.
- The Phase 2 expansion of the UUNN was successfully implemented in January 2021, increasing the number of UUNN sites by 123. Following the implementation of Phase 2 the total number of UUNN stands at 300, inclusive of 38 AURN co-location study sites.

Appendices

Appendix A: Overview of UUNN Diffusion Tubes

Overview

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) uppermost, and the open end 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)[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 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

[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

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 back into the vial.

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

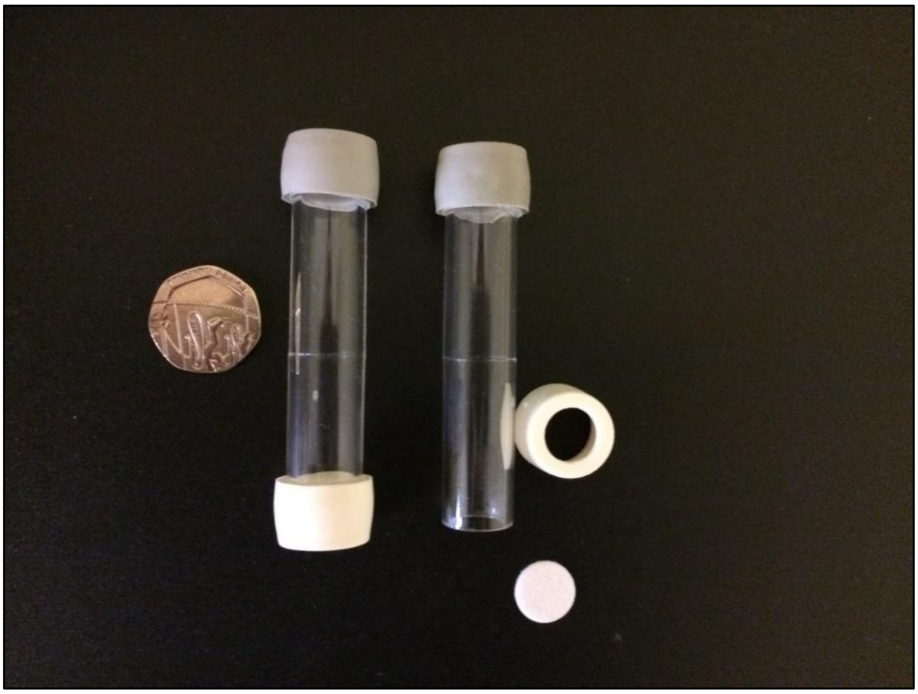

Figure A.2: Example UUNN Monitoring Location

Appendix B: 2020 UUNN Monitoring Calendar

Table B.1: 2020 UUNN Timetable for Tube Changes

Year	Month	Target Date (Acceptable Date)
2020	January	**02-Jan** (03-Jan)
	February	(30-Jan) **31-Jan**
	March	**02-Mar** (03-Mar)
	April	**01-Apr** (02-Apr)
	May	**30-Apr** (01-May)
	June	**01-Jun** (02-Jun)
	July	**01-Jul** (02-Jul)
	August	**31-Jul** (03-Aug)
	September	**01-Sep** (02-Sep)
	October	**01-Oct** (02-Oct)
	November	**02-Nov** (03-Nov)
	December	**01-Dec** (02-Dec)
2021	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	Road	Local Authority	2020 Annual Mean NO_2 Concentration
Sites in Exceedance of 40µg/m^3 Limit Value			
UUNN_BIRM_003	A4400	Birmingham	52
UUNN_BRIS_009	A4044	Bristol	44
UUNN_MANC_005	A34 (Oxford Rd)	Manchester	45
UUNN_MANC_013	A665 (ring road)	Manchester	41
UUNN_UKA00315	Marylebone Road	London (co-location site)	42