Greater Manchester's Outline Business Case to tackle Nitrogen Dioxide Exceedances at the Roadside

Nitrogen Dioxide Diffusion Tube Monitoring Report - 2018

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1 Introduction

1.1 Background

Jacobs was commissioned by Transport for Greater Manchester (TfGM) to commence a baseline air quality monitoring survey to inform proposed clean air plan measures in January 2018 as part of the Greater Manchester Clean Air Plan (GM CAP). These locations were based on the roads predicted to be in exceedance in 2021 in the "UK Plan for Tackling Roadside Nitrogen Dioxide Concentrations" (Defra, 2017).

Diffusion tubes were placed at roadside locations around Greater Manchester to determine the concentrations of nitrogen dioxide (NO_2) across the extent of the GM CAP study area. The diffusion tubes were replaced monthly throughout the survey with supply and analysis by Staffordshire Scientific Services.

This report presents the results of the NO_2 diffusion tube monitoring programme for the GM CAP for 2018.

1.2 Study area

The study area includes the key links identified by Defra, in seven of the Greater Manchester districts; Manchester (MAN), Salford (SAL), Stockport (STP), Bury (BUR), Bolton (BLT), Tameside (TAM) and Trafford (TRF).

1.3 Purpose of the report

The purpose of this report is to:

- set out the methodology for the monitoring survey;
- present the results of the NO_2 diffusion tube monitoring; and
- identify any locations where the average annual mean exceeds the current standard of 40 $\mu g/m^3$ for annual mean NO_2.

2 Background Information

2.1 Topic Definition

Air quality is a description of the concentrations of specific pollutants in ambient air, taking account of the effects of pollution on human health and ecosystems.

The main pollutants of concern around the study area are those emitted by vehicle traffic, primarily NO_2. NO_2 is a colourless, odourless gas that has been shown to have adverse health effects, including causing respiratory irritation to people with pre-existing conditions, such as asthma. It is formed principally from the oxidation of nitric oxide (NO) through the action of near-surface ozone in the atmosphere. Combustion in air (e.g. in vehicle engines) predominantly forms NO in addition to smaller amounts of NO_2 from the reactions of atmospheric nitrogen and oxygen, with the mixture of NO_2 and NO collectively termed as nitrogen oxides (NO_x). NO_x is emitted from internal combustion engines, as well as other forms of combustion, and also has some natural sources, including lightning.

2.2 Legislative and Planning Context

The key regulations and policies relevant to air quality in the study area are detailed in Table 2.1.

Table 2.1 Key air quality legislation and policies

Legislation	Description
The European Union Directive 2008/50/EC Ambient Air Quality and Cleaner Air for Europe	These European Directives form the basis for UK air quality legislation. Although published in 2007, the Air Quality Strategy is consistent with The Air Quality Standards Regulations (England) 2010. The UK government is responsible to the European Commission (EC) for ensuring that it complies with the provisions of the EU Directives. The UK currently is in breach of the limit values for nitrogen dioxide (NO_2) and PM_{10} (particulate matter with an aerodynamic diameter of less than 10 microns).

Legislation	Description
The Air Quality Standards Regulations 2010.	Transposes the air quality limit values set out in the European Union (EU) ambient air quality directive 2008/50/EC (European Commission, 2008) to UK law. The UK Government is responsible to the European Commission (EC) for ensuring that it complies with the provisions of EU Directives. On the UK Government's behalf, the Department for Transport and Defra have Public Service Agreements relating to EU limit values. The responsibilities of local authorities with respect to meeting air quality standards are not the same as the responsibilities of the UK Government to the EC. Local authorities do have statutory duties for LAQM but are not obliged to ensure AQOs are met, but worked towards.
The Air Quality (England) (Amendment) 2000/2002 Regulations.	Legislates for the AQOs for pollutants set out in the 2000 Air Quality Strategy, which was revised in 2007. (Department for Environment, Food and Rural Affairs (Defra, 2007). AQOs exist for a variety of pollutants including NO_2, NO_x, PM_{10} and $PM_{2.5}$. These are established for both the protection of human health and the protection of vegetation and ecosystems.
Environment Act 1995, Part IV.	Introduced a system of local air quality management (LAQM) in the UK. This requires local authorities to review and assess air quality within their boundaries regularly and systematically against Air Quality Objectives (AQOs), appraise development and transport plans against these assessments and make plans to meet the AQOs where these are exceeded.

NO_2 concentrations are subject to the UK Air Quality Objectives (AQOs) and EU limit values outlined in Table 2.2. To determine compliance with the 1-hour mean AQO, research undertaken on behalf of Department of Environment, Food and Rural Affairs (Defra, 2018) identified that road traffic emission related exceedances of the NO_2 1-hour mean AQO are unlikely to occur where the annual mean is below 60 µg/m^3.

Table 2.2 Air Quality Objectives / EU Limit Value for nitrogen dioxide

Pollutant	Period/Statistic	AQO / EU Limit value ($\mu g/m^3$)
NO_2 (for human health)	Annual mean	40
	1-hour mean, not to be exceeded more than 18 times per year (equivalent to the 99.79th percentile of 1-hour means)	200

The government considers the concentration-based standards at integer values, and therefore exceedance of the annual mean 40 $\mu g/m^3$ standard occurs when >40.4 $\mu g/m^3$ because data should be reported to 1 decimal place and therefore would round to 41 ug/m^3 as an integer.

3 Methodology

3.1 Diffusion Tubes

The use of diffusion tubes is a simple way to measure air quality and gives an indication of average pollution concentrations over a time period ranging from one to five weeks. They are a type of passive sampler, whereby the air flow is controlled by natural diffusion and does not involve the pumping of any air. The tubes are 71mm long with an internal diameter of 11mm and contain two stainless steel gauzes at one end. These contain an absorbent (triethanolamine) that traps the nitrogen dioxide and converts it to nitrite, which is then analysed in an accredited laboratory. The other end of the tube is left open to the atmosphere, facing downward to prevent any rain or dust entering the tube. To ensure that the tubes do not collect any pollutant after leaving their site location they are sealed before their journey to the laboratory.

The low cost of the tubes enables sampling at a number of points within an area of interest. This is useful in highlighting 'hotspots' of high concentrations where more detailed studies may be required.

NO_2 diffusion tubes are an indicative monitoring technique and may exhibit biases relative to continuous analysers, with positive bias being more common than negative (Defra, 2008). Bias adjustments are therefore applied to the tubes as described in Section 3.4 of this report. Factors that can cause under- and over-estimation of diffusion tube NO_2 concentrations include:

- the tube location;
- meteorology; i.e. wind turbulence at the open end of the tube;
- blocking of UV light by the tube material;
- interference from peroxyacetyl nitrate (PAN); and
- handling during laboratory analysis.

The diffusion tubes were supplied by Staffordshire Scientific Services and prepared using 20% triethanolamine (TEA) in water. Technical Guidance Note LAQM.TG(16) issued by the Defra (2018) requires diffusion tubes results to be adjusted for bias against a continuous monitoring chemiluminescence analyser.

3.2 Monitoring locations

A total of 64 diffusion tubes were set up over the 58 monitoring locations. A description of the site locations is provided in Appendix B.

In addition to the 64 diffusion tubes installed, travel blanks and office blanks were used to identify possible contamination of diffusion tubes while in transit or whilst in storage. For every monitoring period a travel blank travelled with all of the other diffusion tubes, which was not exposed. The travel blanks were taken to the site when the tubes were installed, but returned to the office storage for the duration of the exposure period. The travel blanks were taken to the site again when the tubes were collected after exposure. The office blanks remain in storage at all times and do not travel to the site. Both the travel and office blanks were sent to the Staffordshire Scientific Services laboratory for analysis along with the exposed tubes. The results of travel and office blanks were used to identify any contamination issues.

3.3 Monitoring timescales

The diffusion tubes were set up and changed monthly for a period of 12 months. The tubes were changed over a period of two days at the start of each monthly exposure period, hence there is an overlap of one day between each period. The start and end dates for each monthly exposure period are shown in Table 3.1. At the end of the 12 month period, a time-weighted average concentration (i.e. period weighted mean concentration) has been calculated to account for variability in the number of exposure days over each monthly period.

Table 3.1 Start and end dates for monthly monitoring periods

Month	Start date	End date	Number of days
January	9th January 2018 [a,b]	9th February 2018	31
February	8th February 2018	9th March 2018	29
March	8th March 2018	11th April 2018	34
April	10th April 2018	9th May 2018	29
May	8th May 2018	12th June 2018	35
June	11th June 2018	6th July 2018	25
July	5th July 2018	10th August 2018	36

Month	Start date	End date	Number of days
August	9th August 2018	14th September 2018	36
September	13th September 2018	16th October 2018	33
October	15th October 2018	16th November 2018	32
November	15th November 2018	15th December 2018	30
December	14th December 2018	16th January 2019	33

a. Diffusion tubes located at monitoring zones TRF1(4,5), MAN1, STP1, STP2, STK5 were installed on 12 January 2018.
b. Diffusion tubes located at monitoring zones TRF1(1,2,3), TRF2, SAL1, MAN4, MAN2, MAN 3 were installed on 17 January 2018.

3.4 Bias adjustment

In accordance with LAQM.TG(16), there is a choice of applying either a national bias adjustment factor or a local bias adjustment, calculated by co-locating tubes with local continuous monitoring sites. The national bias adjustment factor is calculated using the LAQM National Diffusion Tube Bias Adjustment Factor Spreadsheet (Mar, 2019). Bias factors are collated in a national database from a number of co-location studies, allowing the bias at a range of site locations with consistent analysis methods (laboratory and analysis technique) to be considered. This study applies the year 2018 national bias adjustment factor of 0.88 to the raw monitored diffusion tube concentrations.

Diffusion tubes were also co-located at the Trafford A56 (TRF2), Stockport Hazel Grove (STK5) and Bury Radcliffe (BUR1) continuous monitoring sites to determine a local bias adjustment. Continuous monitoring site concentrations were downloaded from the Air Quality England (2019) website. At each of the three sites, the NO_2 concentrations from the continuous analysers were compared with the raw mean tube concentrations from the three diffusion tubes over the monitoring period. A summary of the results is given in Table 3.2. Based on the ratio of the continuous analyser concentrations to the diffusion tube concentrations, a local bias adjustment factor was calculated to be 0.83. This was therefore consistent with the national bias adjustment factor that was applied herein, the use of which is a conservative approach.

Table 3.2 Comparison of NO_2 concentrations for the continuous analysers and co-located diffusion tubes (µg/m^3) and data capture (%).

Site	Monitoring technique	Monitoring period average (µg/m^3) – mean followed by individual tubes	Data capture (%) – mean followed by individual tubes
Trafford A56 (TRF2 a, b, c)[1]	Co-location diffusion tubes (Dm)	35.0 (a: 36.0, b: 36.4, c: 35.6)	100 (a: 100, b: 100, c: 100)
	Continuous monitoring (Cm)*	26.7	100
Stockport Hazel Grove (STK5 a, b, c)[2]	Co-location diffusion tubes (Dm)	28.7 (a: 28.8, b: 29.4, c: 29.7)	100 (a: 100, b: 100, c: 100)
	Continuous monitoring (Cm)*	24.9	79
Bury Radcliffe (BUR1 a, b, c)[3]	Co-location diffusion tubes (Dm)	28.3 (a: 29.0, b: 28.1, c: 28.4)	78 (a: 83, b: 83, c: 68)
	Continuous monitoring (Cm)*	25.5	99

*Ratification of continuous monitoring data: TRF2 is ratified up to 30th September 2018. STK5 and BUR1 are ratified up to 31st December 2018. Data is provisional thereafter.

3.5 Study limitations

Diffusion tubes with data capture of 75% and above are considered to give a reliable representation of NO_2 concentrations over the 12 month period. Monthly tube collections at the Manchester (tubes MAN 1-4 and 4-2) and Salford-1 (tubes SAL 1-2, 1-3, 1-4 and 1-5) sites have been hampered by roadworks since October. As a result of the roadworks and associated pavement closures, several tubes were removed and access to other tube locations was restricted during certain site visits. The data capture at these tube locations was therefore below 75% over the 12 month monitoring period and NO_2 concentrations at these locations.

[1] Web source: http://www.airqualityengland.co.uk/site/data.php?site_id=TRF2

[2] Web source: http://www.airqualityengland.co.uk/site/latest?site_id=STK5

[3] Web source: http://www.airqualityengland.co.uk/site/latest?site_id=BUR1

As the diffusion tubes are accessible to the public and to outdoor conditions there is always a possibility that they can become misplaced (e.g. stolen, vandalised etc) between monthly site visits. This has resulted in reduced data capture at several sites. However, the data capture remained acceptable (75% and above) for all tube locations except for tubes at Manchester (tubes MAN 1-4, 4-2 and 4-3), Salford (tubes SAL 1-2, 1-3, 1-4 and 1-5), and Stockport (STP 2-2 and 2-1). Sites with data capture of 75% or above are considered representative of the annual mean concentration based on guidance in LAQM.TG(16).

4 Monitoring Results

All tubes were provided and analysed by the same laboratory and NO_2 concentrations calculated for each tube based on individual exposure times. No data was provided for missing tubes and any low readings were checked with the laboratory for justification. The full raw and bias adjusted results are presented in Appendix C, respectively.

The bias adjusted annual mean NO_2 concentrations for 2018 at all sites with data capture greater than 75% are presented in Table 4.1, excluding sites co-located at the continuous monitoring stations. The average NO_2 concentrations are shown in bold and underlined where concentrations exceed annual mean NO_2 concentrations of 40.4 µg/m^3. Concentrations are also underlined where concentrations exceed 35 µg/m^3, which is the concentration used to define the Greater Manchester Air Quality Management Area (i.e. where locations should be considered at risk of exceeding the annual mean of 40 µg/m^3).

Of the 46 monitored tube locations presented in Table 4.1, 29 locations measured NO_2 concentrations exceeding 40.4 µg/m^3. This included 14 tubes over the central Manchester regions (two tubes at MAN 1, five at MAN 2, four at MAN 3 and three at MAN 4) and 4 tubes in Stockport (four tubes at STP 1 and two tubes at STP 2). Concentrations over 40.4 µg/m^3 were also recorded for four locations at Tameside (TAM 1), two locations in Bury (BUR 1-1 and BUR 1-2) and one tube in both Bolton and Trafford (BLT 1-1 and TRF 1-3). In addition, 13 tubes recorded concentrations of greater than 35 µg/m^3 so are considered at risk of exceeding the annual mean standard. NO_2 concentrations above 60 µg/m^3 were recorded at three sites (MAN 2-4, MAN 2-5 and STP 1-4) indicating the possibility of the 1-hour mean standard being exceeded.

Table 4.1: Bias-adjusted annual mean NO_2 results.

Site	Annual mean bias adjusted NO_2 concentration (µg/m^3)	Data capture (%)
BLT 1-1	**53.5**	92
BLT 1-2	31.2	100
BLT 1-3	35.1	100
BLT 1-4	38.5	92

Site	Annual mean bias adjusted NO_2 concentration (µg/m^3)	Data capture (%)
BLT 1-5	38.6	100
BUR 1-1	**43.5**	75
BUR 1-2	**47.8**	100
BUR 1-3	37.1	92
BUR 1-4	38.5	92
BUR 1-5	38.6	100
MAN 1-1	34.6	100
MAN 1-2	34.9	100
MAN 1-3	**49.6**	100
MAN 1-5	**42.7**	92
MAN 2-1	**49.6**	100
MAN 2-2	**41.3**	100
MAN 2-3	**48.0**	100
MAN 2-4	**62.8**	92
MAN 2-5	**70.5**	92
MAN 3-1	**41.3**	83
MAN 3-2	37.1	92
MAN 3-3	**40.7**	92

Site	Annual mean bias adjusted NO_2 concentration (µg/m^3)	Data capture (%)
MAN 3-4	**50.1**	92
MAN 3-5	**45.3**	100
MAN 4-1	**49.0**	75
MAN 4-4	**46.6**	75
MAN 4-5	**59.1**	75
SAL 1-1	**47.4**	92
STP 1-1	**45.1**	100
STP 1-2	**51.1**	100
STP 1-3	38.7	100
STP 1-4	**62.0**	92
STP 1-5	**54.7**	92
STP 2-3	38.5	100
STP 2-4	**54.5**	100
STP 2-5	**43.5**	83
TAM 1-1	39.0	83
TAM 1-2	**51.8**	92
TAM 1-3	**46.6**	83
TAM 1-4	**55.6**	100

Site	Annual mean bias adjusted NO_2 concentration ($\mu g/m^3$)	Data capture (%)
TAM 1-5	**41.6**	75
TRF 1-1	39.0	83
TRF 1-2	38.8	100
TRF 1-3	**47.4**	100
TRF 1-4	34.8	100
TRF 1-5	38.7	92

5 Discussion

This monitoring survey indicates that annual mean NO_2 concentrations are likely to be in exceedance of 40 $\mu g/m^3$ at 29 locations around Greater Manchester (shown in bold in Table 4.1), with a further 13 locations considered to be at risk of exceeding 40.4 $\mu g/m^3$.

An annual mean benchmark of 60 $\mu g/m^3$ is utilised for indicating the potential exceedance of the short term 1- hour mean standard (200 $\mu g/m^3$), as discussed in section 2.2. The 1-hour mean NO_2 standard has the potential to have been exceeded at three sites (MAN 2-4, MAN 2-5 and STP 1-4), where the annual mean NO_2 concentrations exceeded 60 $\mu g\ m^3$.

6 Conclusions

A 12 month diffusion tube survey at 58 selected monitoring locations around Greater Manchester has been undertaken on behalf of Transport for Greater Manchester to inform the proposed Clean Air Plan study. The monitoring survey provides measurements of annual average NO_2 concentrations over several local authorities including central Manchester, Salford, Stockport, Bury, Bolton, Tameside and Trafford**.**

The results indicate that NO_2 concentrations are likely to be in exceedance of the annual mean 40 µg/m^3 at 29 locations around Greater Manchester, with a further 13 locations considered to be at risk of exceeding annual mean concentrations of 40 µg/m^3.

Additionally, exceedances of the one-hour mean standard were possible at at three sites (MAN 2-4, MAN 2-5 and STP 1-4) based on observed annual mean concentrations above 60 µg m^3.

7 References

Air Quality England (2019) Local Authority Summary [Online]. [Accessed February 2019]. Available from: http://www.airqualityengland.co.uk

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Defra (2018). Local Air Quality Management. Technical Guidance LAQM.TG(16). April 2018

Defra (2019) LAQM National Diffusion Tube Bias Adjustment Factor Spreadsheet (03/19) [online]. [Accessed June 2019]. Available from: https://laqm.defra.gov.uk/bias-adjustment-factors/national-bias.html

Environment Act 1995, HMSO

European Commission (2008) European Union (EU) Directive 2008/50/EC on ambient air quality and cleaner air for Europe (CAFÉ), 21st May, 2008

Appendix A. Abbreviations

AQO	Air Quality Objective
AQ	Air Quality
AQMA	Air Quality Management Area
AURN	Automatic Urban and Rural Network
Defra	Department of Environment Food and Rural Affairs
LAQM	Local Air Quality Management
LAQM.TG(16)	Local Air Quality Management Technical Guidance 2016
NO_2	Nitrogen Dioxide
NO	Nitrogen Monoxide
NO_x	Oxides of Nitrogen (NO_2 + NO)
TEA	Triethanolamine
EU	European Union
EC	European Commission

Appendix B. Diffusion Tube Locations

Table B.1 Diffusion Tube Locations

Site name	Road section	Location		Distance from nearest kerb (m)	Diffusion tube height (m)
		X	Y		
BUR1 (a,b,c)	A665	378204	407480	4.5	1.56
BLT 1-1	A666	373078	407332	On railing, elevated above roadside (no data)	1.7
BLT 1-2	A666	372414	408758	Long distance from kerbside- (no data)	1.87
BLT 1-3	A666	372899	407651	1.96	2.32
BLT 1-4	A666	372422	408629	2.3	1.8
BLT 1-5	A666	372631	408264	3	1.2
BUR 1-1	A58	379355	410630	2.5	2.05
BUR 1-2	A58	379851	410974	0.86	1.91
BUR 1-3	A58	379918	410926	1.3	2.23
BUR 1-4	A58	379822	410944	0.75	2.1
BUR 1-5	A58	379549	410802	1.96	2.32
MAN 1-1	A5103	382637	391216	1.1	2.45
MAN 1-2	A5103	382726	391364	3	2.45
MAN 1-3	A5103	382854	391602	2	2.15
MAN 1-4	A5103	382971	391822	2.6	2.42
MAN 1-5	A5103	382793	391431	2.15	2.15
MAN 2-1	A57 (M)	383370	397133	2.5	2.25
MAN 2-2	A57 (M)	383637	397097	7.3	2.5
MAN 2-3	A57 (M)	383855	397070	1.4	2.33
MAN 2-4	A57 (M)	383273	397147	1.75	1.2
MAN 2-5	A57 (M)	383357	397166	1.8	1.3
MAN 3-1	A635	385291	397454	7.3	2.35
MAN 3-2	A635	385352	397461	7.3	2.55
MAN 3-3	A635	385400	397487	1.32	2.4
MAN 3-4	A635	385271	397427	1.38	2.4
MAN 3-5	A635	385119	397457	0.95	2.05
MAN 4-1	A57 (M)	382842	397408	0.52	2
MAN 4-2	A57 (M)	382756	397571	0.65	2.28

Site name	Road section	Location		Distance from nearest kerb (m)	Diffusion tube height (m)
		X	Y		
MAN 4-3	A57 (M)	382770	397613	0.55	2.35
MAN 4-4	A57 (M)	382884	397414	0.2	2.3
MAN 4-5	A57 (M)	382828	397501	2.3	2.42
SAL 1-1	A57	382407	397762	2.55	2.36
SAL 1-2	A57	382571	397719	1.45	2.3
SAL 1-3	A57	382321	397758	2.03	2.3
SAL 1-4	A57	382592	397688	2.5	2.15
SAL 1-5	A57	382397	397738	2.45	2.3
STK5 (a,b,c)	A6	391482	387638	5.2	2.59
STP 1-1	A34	385324	387412	2.8	2.4
STP 1-2	A34	385247	387620	2.85	2.45
STP 1-3	A34	385118	387954	2	2.15
STP 1-4	A34	385081	388171	7.3	2.46
STP 1-5	A34	385380	387258	2.25	2.06
STP 2-1	A34	385016	388520	0.6	2.35
STP 2-2	A34	385048	388888	2.24	3.26
STP 2-3	A34	385052	388779	0.6	2.37
STP 2-4	A34	385043	388635	1.78	2.34
STP 2-5	A34	385078	389157	On bridge over motorway (no data)	***
TAM 1-1	A635	392768	398502	2.95	2.42
TAM 1-2	A635	393040	398602	2.5	1.97
TAM 1-3	A635	392586	398405	3.25	2.26
TAM 1-4	A635	393000	398603	1.43	1.97
TAM 1-5	A635	392541	398419	2.0	2.2
TRF 1-1	A56	379268	393579	1.7	1.2
TRF 1-2	A56	379352	393804	2.0	1.2
TRF 1-3	A56	379209	393467	1.7	2.0
TRF 1-4	A56	379313	393769	3.54	2.14
TRF 1-5	A56	379239	393597	7.3	1.92
TRF2 (a,b,c)	A56	379414	394016	7.3	2.47

a,b,c indicates triplicate diffusion tubes

Appendix C. Annual mean NO_2 concentration calculations

Table C.1: 12 month mean NO_2 concentration calculations

Site name	Period weighted mean (raw data) ($\mu g/m^3$)	Bias adjustment factor	Data capture (%)	National bias-adjusted 2018 annual mean concentration ($\mu g/m^3$)
BLT 1-1	60.8	0.88	92	53.5
BLT 1-2	35.4	0.88	100	31.2
BLT 1-3	39.9	0.88	100	35.1
BLT 1-4	43.7	0.88	92	38.5
BLT 1-5	43.9	0.88	100	38.6
BUR 1-1	49.4	0.88	75	43.5
BUR 1-2	54.3	0.88	100	47.8
BUR 1-3	42.2	0.88	92	37.1
BUR 1-4	43.7	0.88	92	38.5
BUR 1-5	43.9	0.88	100	38.6
MAN 1-1	39.3	0.88	100	34.6
MAN 1-2	39.6	0.88	100	34.9
MAN 1-3	56.3	0.88	100	49.6
MAN 1-4	49.4	0.88	67	43.5
MAN 1-5	48.5	0.88	92	42.7
MAN 2-1	56.3	0.88	100	49.6
MAN 2-2	47.0	0.88	100	41.3
MAN 2-3	54.6	0.88	100	48.0
MAN 2-4	71.4	0.88	92	62.8
MAN 2-5	80.1	0.88	92	70.5
MAN 3-1	47.0	0.88	83	41.3
MAN 3-2	42.2	0.88	92	37.1
MAN 3-3	46.2	0.88	92	40.7
MAN 3-4	57.0	0.88	92	50.1
MAN 3-5	51.5	0.88	100	45.3
MAN 4-1	55.7	0.88	75	49.0
MAN 4-2	68.5	0.88	67	60.3
MAN 4-3	69.0	0.88	50	60.7
MAN 4-4	52.9	0.88	75	46.6
MAN 4-5	67.2	0.88	75	59.1
SAL 1-1	53.8	0.88	92	47.4
SAL 1-2	56.0	0.88	67	49.3
SAL 1-3	63.2	0.88	58	55.7
SAL 1-4	54.8	0.88	67	48.2
SAL 1-5	60.3	0.88	33	53.0
STP 1-1	51.3	0.88	100	45.1
STP 1-2	58.0	0.88	100	51.1
STP 1-3	44.0	0.88	100	38.7
STP 1-4	70.4	0.88	92	62.0
STP 1-5	62.2	0.88	92	54.7
STP 2-1	58.2	0.88	67	51.2
STP 2-2	74.8	0.88	67	65.8
STP 2-3	43.8	0.88	100	38.5

Site name	Period weighted mean (raw data) (µg/m^3)	Bias adjustment factor	Data capture (%)	National bias-adjusted 2018 annual mean concentration (µg/m^3)
STP 2-4	62.0	0.88	100	54.5
STP 2-5	49.5	0.88	83	43.5
TAM 1-1	44.3	0.88	83	39.0
TAM 1-2	58.9	0.88	92	51.8
TAM 1-3	53.0	0.88	83	46.6
TAM 1-4	63.1	0.88	100	55.6
TAM 1-5	47.3	0.88	75	41.6
TRF 1-1	44.3	0.88	83	39.0
TRF 1-2	44.1	0.88	100	38.8
TRF 1-3	53.9	0.88	100	47.4
TRF 1-4	39.5	0.88	100	34.8
TRF 1-5	44.0	0.88	92	38.7
BUR1 (a)	29.0	0.88	83	25.5
BUR1 (b)	28.1	0.88	83	24.7
BUR1 (c)	28.4	0.88	67	25.0
TRF 2 (a)	36.0	0.88	100	31.7
TRF 2 (b)	36.4	0.88	100	32.1
TRF 2 (c)	35.6	0.88	100	31.3
STK5 (a)	28.8	0.88	100	25.4
STK5 (b)	29.4	0.88	100	25.9
STK5 (c)	29.7	0.88	100	26.2

“-“ indicates tube was inaccessible, missing or erroneous

Table C2. Raw monthly mean NO_2 concentrations (ug/m^3)

Site	Monthly monitoring period											
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**	**P12**
BLT 1-1	68.4	70.6	65.7	63.2	-	70.8	60.1	56.1	53.1	59.3	43.8	58.0
BLT 1-2	48.2	40.5	35.0	32.2	25.7	24.4	33.1	29.0	27.3	43.7	40.1	45.9
BLT 1-3	54.5	46.4	39.8	43.4	21.6	30.2	33.6	35.2	38.3	42.2	43.5	50.5
BLT 1-4	-	49.7	45.7	-	44.6	37.6	37.6	35.5	43.4	49.6	41.2	60.7
BLT 1-5	68.2	66.9	67.6	65.0	-	56.0	47.7	42.2	49.3	53.8	59.3	53.1
BUR 1-1	54.1	-	37.6	58.2	59.7	-	-	48.8	54.2	34.8	46.2	51.0
BUR 1-2	65.2	55.6	52.6	56.0	48.6	52.2	52.6	44.2	53.0	57.4	43.4	70.5
BUR 1-3	44.9	44.8	43.7	-	33.1	31.9	31.5	-	33.6	43.4	44.9	50.8
BUR 1-4	50.8	46.5	42.9	39.1	41.3	42.7	39.5	31.3	36.0	42.3	48.6	48.7
BUR 1-5	65.6	59.7	51.6	35.4	39.1	42.8	28.6	31.2	42.7	39.9	61.6	61.2
BUR1 (a)	-	40.2	29.2	27.0	-	25.2	23.6	23.3	25.6	26.4	30.8	38.2
BUR1 (b)	-	37.0	30.1	26.1	25.6	24.7	22.7	20.7	20.0	-	36.2	38.1
BUR1 (c)	-	36.1	-	24.5	25.1	-	24.4	20.4	21.0	-	39.6	36.4
MAN 1-1	45.6	48.1	37.6	39.0	32.2	31.7	28.4	27.9	36.6	42.3	50.9	50.9
MAN 1-2	22.2	48.4	42.3	44.2	42.3	36.2	32.2	32.6	39.8	39.7	46.8	48.6
MAN 1-3	62.3	53.5	48.7	59.5	62.4	52.8	52.6	38.7	55.5	61.4	58.3	70.1
MAN 1-4	57.6	53.7	47.1	55.1	50.1	-	-	45.9	44.6	41.3	-	-
MAN 1-5	58.3	44.9	45.5	50.6	37.4	45.3	51.9	-	47.3	44.2	47.9	60.5
MAN 2-1	61.6	64.5	51.4	56.7	65.8	60.3	54.0	49.9	45.7	51.1	53.9	61.0
MAN 2-2	55.0	51.2	48.4	45.9	47.9	51.5	43.6	39.4	40.2	42.4	48.0	50.0
MAN 2-3	83.2	49.4	49.9	52.5	47.6	52.0	51.9	48.9	50.3	56.4	51.9	61.0
MAN 2-4	65.5	73.5	65.0	66.9	81.6	84.6	72.6	66.5	70.0	61.7	-	77.5
MAN 2-5	93.1	83.0	75.2	89.4	99.2	-	79.1	65.4	74.2	66.5	70.7	85.6
MAN 3-1	66.8	47.2	39.4	48.1	39.2	-	-	37.9	46.3	46.6	49.1	49.2
MAN 3-2	55.6	47.2	41.2	43.4	41.7	39.6	26.3	35.8	40.8	42.8	49.8	-
MAN 3-3	59.8	52.5	46.7	49.6	42.2	42.7	37.7	37.0	37.0	-	49.3	53.7
MAN 3-4	57.1	53.7	48.5	50.2	58.9	60.1	56.1	44.7	48.3	-	98.5	50.5
MAN 3-5	67.0	59.7	45.2	50.8	42.7	44.2	46.9	45.1	48.9	51.9	52.8	62.7
MAN 4-1	64.9	64.8	54.1	50.5	63.3	58.7	52.1	46.8	46.3	-	-	-
MAN 4-2	-	-	-	-	-	-	-	-	-	-	-	-
MAN 4-3	-	-	-	-	-	-	-	-	-	-	-	-
MAN 4-4	68.5	49.3	48.1	50.7	47.4	54.7	57.0	49.4	51.4	-	-	-
MAN 4-5	94.6	63.9	56.7	82.1	55.9	61.8	64.6	61.6	63.5	-	-	-
SAL 1-1	-	-	-	-	-	-	-	-	-	-	-	-
SAL 1-2	64.0	55.7	52.1	53.2	52.3	57.7	-	50.5	-	-	-	62.6
SAL 1-3	-	-	-	-	-	-	-	-	-	-	-	-
SAL 1-4	-	-	-	-	-	-	-	-	-	-	-	-
SAL 1-5	70.7	-	-	-	-	57.2	64.8	48.3	-	-	-	-
STK5 (a)	32.5	32.7	34.6	26.7	29.9	24.0	28.1	21.3	23.6	24.5	32.5	35.7
STK5 (b)	32.8	31.5	34.8	28.1	32.0	23.6	27.6	19.6	24.8	29.0	36.1	32.9
STK5 (c)	32.7	35.6	32.6	27.7	30.0	24.3	28.5	21.7	24.3	29.1	34.0	36.1
STP 1-1	-	-	-	-	-	-	-	-	-	-	-	-
STP 1-2	71.2	55.4	45.6	63.4	50.7	58.6	62.5	51.3	54.4	60.3	58.2	64.7
STP 1-3	44.6	39.8	30.9	34.0	41.9	33.4	35.3	29.0	-	-	-	49.5
STP 1-4	-	-	-	-	-	-	-	-	-	-	-	-
STP 1-5	66.7	58.7	38.1	66.7	67.0	70.5	69.0	54.3	-	60.8	66.6	65.3
STP 2-1	65.7	-	56.1	64.3	62.9	61.3	56.4	49.5	-	-	-	-
STP 2-2	-	39.0	36.8	32.7	34.1	-	-	35.2	37.2	42.7	40.9	-
STP 2-3	55.9	41.4	38.8	47.2	30.0	41.5	44.8	37.7	47.3	45.9	43.7	51.3
STP 2-4	72.6	50.4	53.4	66.6	59.2	61.1	65.5	55.7	62.7	63.0	59.1	74.3
STP 2-5	54.8	50.1	48.6	52.8	45.7	50.0	48	41.1	-	-	49.8	53.7
TAM 1-1	57.0	45.9	40.0	39.9	38.2	38.9	41.7	-	-	41.9	42.9	56.4
TAM 1-2	60.5	56.8	50.7	57.3	-	59.0	60.6	57.7	59.1	58.8	54.1	73.3
TAM 1-3	59.1	56.5	47.2	48.0	50.2	53.9	54.4	-	-	51.9	47.5	61.3
TAM 1-4	77.5	58.3	54.7	62.1	62.5	66.2	68.5	54.3	59.1	65.2	58.3	70.9
TAM 1-5	59.1	-	37.8	47.3	38.0	-	49.8	38.7	-	48.7	45.0	61.4
TRF 1-1	63.7	39.9	37.8	49.4	40.9	42.1	42.6	42.8	-	37.5	46.3	-
TRF 1-2	59.7	42.7	34.2	43.2	38.9	42.8	46.7	43.2	47.4	40.6	36.1	54.1
TRF 1-3	67.4	53.6	48.6	56.3	48.2	50.0	52.9	49.8	55.2	57.8	46.1	61.0
TRF 1-4	45.1	41.1	41.7	42.0	35.1	34.5	28.7	28.4	41.0	41.3	48.1	47.3
TRF 1-5	52.6	45.3	44.5	46.5	-	38.5	33.4	35.3	40.5	49.8	50.9	47.0

Site	Monthly monitoring period											
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**	**P12**
TRF 2 (a)	45.4	36.0	32.4	38.6	31.0	29.6	33.3	30.8	34.8	34.9	39.8	45.4
TRF 2 (b)	45.8	37.1	32.4	37.7	29.3	30.1	34.0	30.2	31.2	40.2	40.6	48.6
TRF 2 (c)	48.9	40.3	33.9	36.1	31.9	28.3	30.3	30.2	30.6	35.5	37.8	43.1

“-“ indicates tube was inaccessible, missing or erroneous