Deriving Background Concentrations of NOx and NO_2 for Use with 'CURED V2A'

September 2016

Experts in air quality
management & assessment

Prepared by: Dr Ben Marner and Kieran Laxen

Approved by: Prof. Duncan Laxen

1 Introduction

1.1 This note sets out the suggested approach to treating background concentrations of nitrogen dioxide (NO_2) and nitrogen oxides (NOx) when using the Calculator Using Realistic Emissions for Diesels (CURED) V2A. CURED V2A can be downloaded from http://www.aqconsultants.co.uk/Resources/AQC-Tools.aspx. The approach outlined in this note uses Defra's 2013-based maps of background concentrations, which can be downloaded from https://uk-air.defra.gov.uk/data/laqm-background-home and may also use local monitoring if suitable data are available.

1.2 The factors in this note have been updated from those in the note[1] which accompanied the previous iteration of CURED (V1A), but the overall approach has not changed. In a change to the previous format, this note begins by setting out the suggested approach (Section 2), and then goes on to provide an explanation of the scaling factors used (in Sections 3 and 4).

2 Suggested Approach

2.1 This approach assumes that you do not need to remove sectors from your background concentrations. If specific background sectors are also being removed, then the approach set out below will need to be adapted.

Step 1 – Uplift the Future-year Background NOx concentration[2]

2.2 Calculate:

$$\mathbf{A = B \times (C-D+1) + E}$$

Where: 'A' is the future-year background NOx concentration to use with CURED, 'B' is the summed concentration of all traffic sectors in Defra's background maps for your future year, 'C' is the future-year value from Table 1, 'D' is the base-year value from Table 1, and 'E' is the summed concentration of all non-traffic sectors in Defra's background maps for the future year.

2.3 To give an example for a nominal receptor[3], with a base year of 2015 and a future year of 2019:

- the sum of the road traffic components in 2019 (B) is 13.5 $\mu g/m^3$ of NOx and the sum of the non-road traffic components in 2019 (E) is 22.6 $\mu g/m^3$ of NOx; and
- the uplift value from Table 1 for 2019 (C) is 0.371, while for 2015 (D) it is 0.185.

The uplifted background NOx concentration in 2019 (A) is thus:

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1 Deriving Background Concentrations of NOx and NO2 - April 2016. Air Quality Consultants Ltd.

2 if no future-year modelling is being carried out, then this step can be missed.

3 Which happens to be within background grid square 411500, 290500 in Birmingham.

A = 13.5 x (0.371 - 0.185 + 1) + 22.6 = 38.6 μg/m^3

Step 2 – Calculate the Uplifted Future-year NO_2 concentration[2]

2.4 Background nitrogen dioxide concentrations should be calculated using V5 of Defra's background map sector removal tool[4] as follows:

i) enter the appropriate year (your future year), the grid co-ordinates and the future-year values for the mapped NOx road components. In the example shown in Figure 1, below, all of the values entered at "*Step 2*" of the sector removal tool are unedited from those in Defra's maps (i.e. they should not include any uplifts).

ii) Calculate 'F' as follows (using the nomenclature from Step 1):

F = B – (A – E)

(based on the example receptor from Step 1, this would be 13.5 – (38.6 – 22.6) = - 2.5)

iii) Enter value 'F' as the "*Sum of Road NOx to be removed*" at "*Step 3*" in the sector removal tool (see Figure 1). Value 'F' should be a negative number since NOx is being added rather than removed.

Step 1: Enter Year of Data	Step 2: Mapped Background Information (μg/m^3)						Step 3: NOx to be Removed (μg/m^3)	
2019	Mapped Background Grid Square Coordinates		Mapped Total NOx	Mapped NOx Road Traffic Sectors	Mapped NOx Non-Road Sectors	Mapped Total NO_2	Enter the Sum of Road NOx to be removed	Enter the Sum of Non-Road NOx to be removed
	X	Y	Total_NOx	Sum NOx Roads	Sum NOx Non-Roads	Total_NO_2		
	411500	290500	36.10	13.48	22.62	23.53	-2.50	

Figure 1: Example inputs to Defra's Sector Removal Tool

2.5 Figure 2 shows the results from Defra's sector removal tool for the nominal example receptor. The "*revised total NOx*" should match value 'A' (from Step 1). In this example, the uplifted NO_2 is 25.0 μg/m^3 (compared with the unadjusted NO_2 for 2019 of 23.5 μg/m^3). These output values should be taken to Step 3 of the calculation.

Revised NOx Totals (μg/m^3)			Revised NO_2 (μg/m^3)
Revised NOx Road Traffic Sectors	Revised NOx Non-Road Sectors	Revised Total NOx	Revised Total NO_2 after NOx removal
15.98	22.62	38.60	24.98

Figure 2: Example outputs from Defra's Sector Removal Tool

4 http://laqm.defra.gov.uk/documents/NO2-Adjustment-for-NOx-Sector-Removal-Tool-v5.0.xls

Additional Step for Inside the London Ultra-low Emission Zone (ULEZ)

2.6 Inside the ULEZ, the Step 1 calculation should be augmented to incorporate the 'ULEZ Scaling Factors' published by Defra [5,6]. Naming Defra's ULEZ Scaling Factor 'value G', the calculation for Step 1 would be written as:

A = B x (C-D+1) x (G) + E

Everything else would be applied as per outside the ULEZ.

2.7 To give an example for a nominal receptor within the ULEZ[7], with a base year of 2015 and a future year of 2020: Value 'B' is 23.0 $\mu g/m^3$, value 'E' is 29.4 $\mu g/m^3$, Value 'C' is 0.441, and Value 'D' is 0.185. Value 'G' is 0.4257. The future-year background NOx concentration ('A') is thus calculated as:

A = 23.0 x (0.441 - 0.185 + 1) x (0.4257) + 29.4 = 41.7 $\mu g/m^3$

2.8 Value 'F' is thus calculated as:

F = 23.0 – (41.7 – 29.4) = 10.7 (i.e. now a positive rather than a negative value)

2.9 The outputs from Defra's sector removal tool (which are the values to be taken to Step 3 of this calculation) are thus a total NOx concentration of 41.7 $\mu g/m^3$ and a total NO_2 concentration of 26.6 $\mu g/m^3$.

Step 3

When Using Defra's Maps and not Local Background Measurements

2.10 In order to calibrate the national maps against concurrent measurements, both the base-year and future-year total background concentration, of either[8] NOx or NO_2, should be multiplied by:

1+H

Where 'H' = the appropriate value given in Table 2. The value taken from Table 2 should be that for the base year, but should be applied to both the base and future years.

2.11 For example, if the predicted background NO_2 concentration for a 2015 base year is 39.8 $\mu g/m^3$ and the predicted background NO_2 concentration in a 2019 future year (following Steps

5 Page 19 of http://laqm.defra.gov.uk/documents/2013-based-background-maps-user-guide-v2.0.pdf (August 2016)

6 If Version 1.0 of Defra's note (http://laqm.defra.gov.uk/documents/2013-based-background-maps-user-guide-v1.0.pdf (July 2016) is used, then function 'G' should be replaced with '1-G' and the value of G in that document.

7 Which happens to be within background grid square 529500, 178500 in Westminster.

8 It is important not to double count the effect of any base-year calibration by applying a factor to NOx as part of Step 1 and then subsequently applying a factor to NO_2.

1 and 2) is 25.0 $\mu g/m^3$, then both of these values would be multiplied by 1.053, to give 41.9 $\mu g/m^3$ and 26.3 $\mu g/m^3$ for 2015 and 2019 respectively.

When Using Locally-measured Background Concentrations

2.12 Future-year concentrations should be calculated by multiplying the base-year measurement by:

future year concentration = base year measurement x I / J

Where 'I' is the uplifted future-year concentration of either NO_2 or NOx from Step 2 and 'J' is Defra's mapped value for the base year.

Note

2.13 For AQC's own modelling, Step 3 is routinely used for modelling carried out using emission factors from the EFT as well as with those from CURED.

Table 1: Typical Additional Emissions from CURED V2A Compared with EFT V7.0

Year	% Additional Emissions Expressed as a Fraction [a]
2013	0.173
2014	0.174
2015	0.185
2016	0.222
2017	0.265
2018	0.315
2019	0.371
2020	0.441
2021	0.499
2022	0.559
2023	0.622
2024	0.685
2025	0.746
2026	0.794
2027	0.836
2028	0.870
2029	0.898
2030	0.920

[a] for example 0.173 means that CURED V2A predicts, on average, 17.3% higher NOx emissions than EFT V7.0.

Table 2: Uplifts to be Applied to Total Background Concentrations

Base Year	% Concentration Uplifts Expressed as a Fraction [a,b]	
	NOx	NO_2
2014	0.094	0.053
2015	-0.009	0.004

[a] for example 0.094 means that the measured concentrations were, on average, 9.4% higher than the mapped concentrations.

[b] at the time that this note was produced, 2015 was the most recent full calendar year of available measurements and so uplift factors for subsequent years cannot be derived.

3 Derivation of Factors used in Table 1

3.1 The Department for Transport has published data for its traffic counters across the UK[9]. These are the traffic data used by Defra to produce its background maps. The 2-way flows reported for 2015 for the 20,000 link sections with more than 1,000 vehicles per day[10] have been input to EFT V7.0. Each road has been entered into the EFT several times to cover a range of years (from 2013 until 2030[11]) and a range of road types[12,13]. The average assumed speed was 50 kph on each link. The same procedure was then carried out using CURED V2A. The two sets of results were then compared to see how the calculated emissions differ.

3.2 Figure 3 shows the results. The whiskers show the range for each year (i.e. the minima and maxima) and show quite a large spread. The roads with the lowest proportions of heavy duty vehicles form the minima, while those dominated by heavy duty vehicles form the maxima. The apparent step-change in the maxima moving from 2026 to 2028 reflects a single road almost entirely made up of buses and relates to the assumed uptake of Euro VI buses in Inner London between these two years.

3.3 Despite the large range shown by the whiskers in Figure 3, the quartile ranges are very narrow, showing that the majority of roads had relatively uniform fleet compositions and thus uniform divergence in emissions when comparing CURED V2A with EFT V7.0.

3.4 Figure 4 shows the mean values from Figure 3. These are the numbers used in Table 1.

9 https://data.gov.uk/dataset/gb-road-traffic-counts

10 as an Annual Average Daily 2-way Flow

11 i.e. the 2015 flows were assumed each year. Not factoring in traffic growth will have only a minor effect on this analysis since the key traffic feature of interest is the vehicle fleet composition.

12 The road types used in the EFT were: Inner London; urban in England outside London, rural in England outside London, and rural in Scotland.

13 All roads were assumed to represent all geographical locations, regardless of the actual location of the traffic count point.

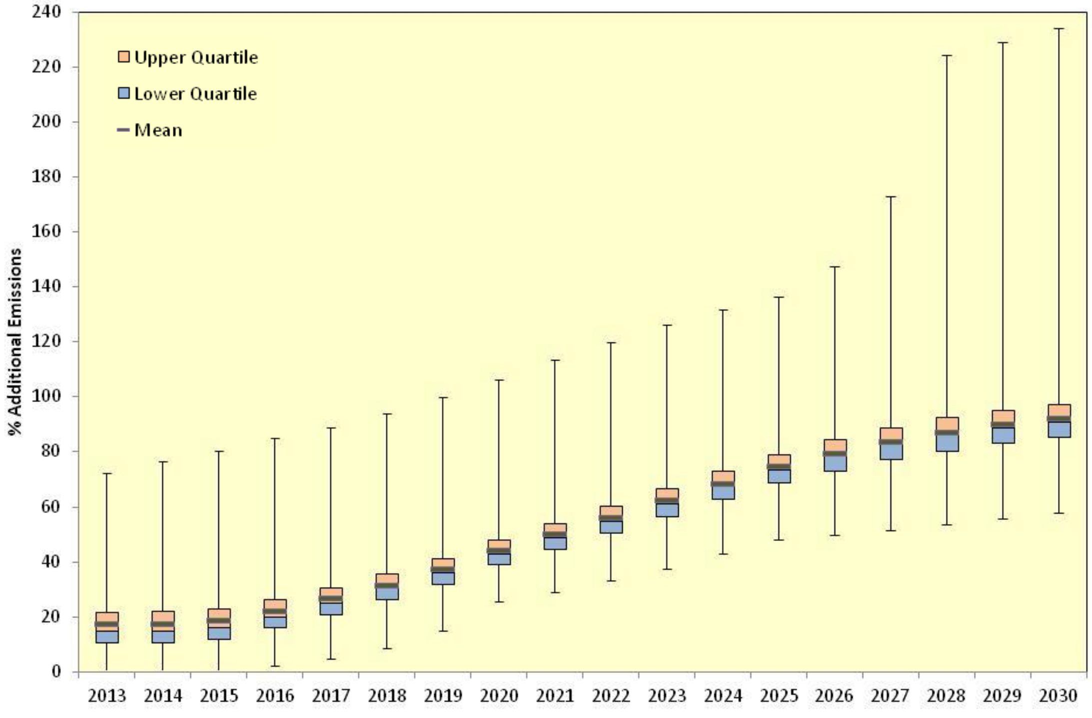

Figure 3: Additional NOx Emissions using CURED V2A Compared with EFT V7.0

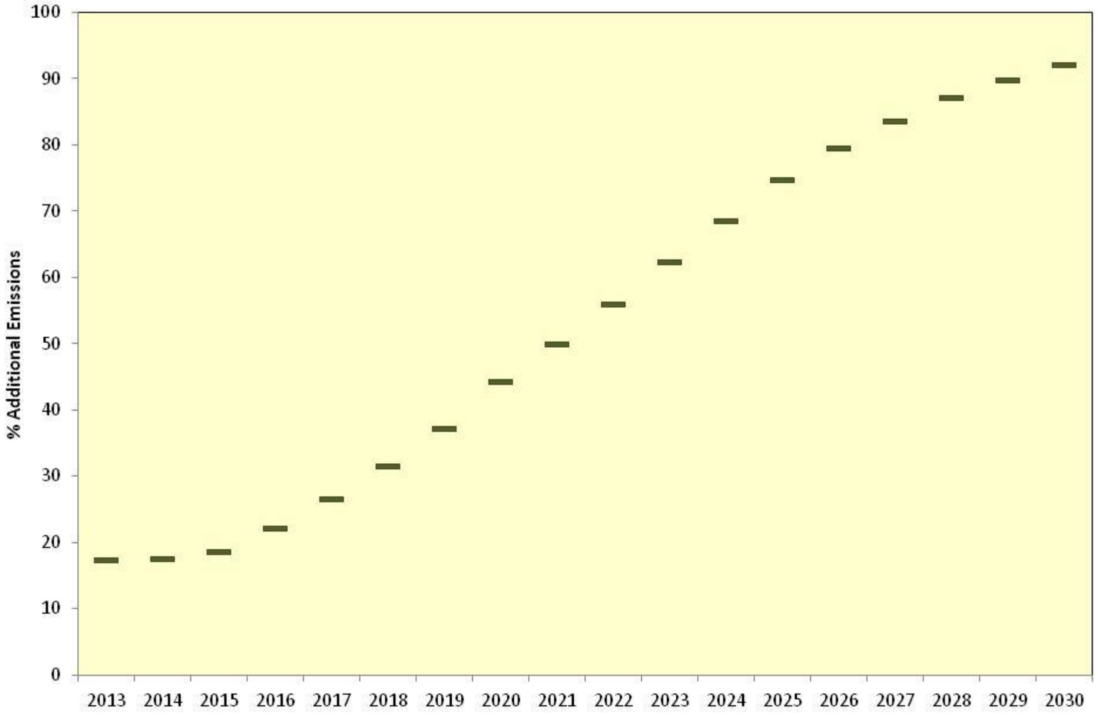

Figure 4: Mean Additional NOx Emissions using CURED V2A Compared with EFT V7.0

4 Derivation of Factors used in Table 2

4.1 Defra's 2013-based national background maps[14] cover the whole country on a 1x1 km grid and are published for each year from 2013 until 2030. The maps include the influence of emissions from a range of different sources; one of which is road traffic. The maps have been verified by Defra against measurements made at its Automatic Urban and Rural Network (AURN) sites during 2013 and so there can be reasonable confidence that the maps are representative of conditions during 2013. CURED predicts that Defra has over-predicted the rate at which concentrations have reduced since 2013. For this reason, it is necessary to re-calibrate the maps against more recent data.

2014 Base Year

4.2 For 2014, the mapped NO_2 values have been calibrated against concurrent (2014) measurements made at suitable[15] background AURN sites[16]. Based on the 52 sites with more than 75% data capture, the maps under predicted the measured background concentrations by 5.3% on average (Figure 5) (i.e. 1 / 0.9495 – 1 = 0.053). The value used in Table 2 for NO_2 for a 2014 base year is thus 0.053.

4.3 Figure 6 shows the same comparison for NOx. The value used in Table 2 for NOx for a 2014 base year is thus 0.094 (i.e. 1 / 0.9143 – 1 = 0.094).

2015 Base Year

4.4 For 2015, the mapped NO_2 values have been calibrated against the 61 background suitable AURN sites with more than 75% data capture (Figure 7). This shows that the maps under-predict the background concentrations by 0.4%, on average (i.e. 1/0.9964 – 1 = 0.004). The value used in Table 2 for NO_2 for a 2015 base year is thus 0.004.

4.5 Figure 8 shows the same comparison for NOx. For NOx, there is a marginal over-prediction in the maps. The value used in Table 2 for NOx for a 2015 base year is thus -0.009 (i.e. 1 / 1.0091 – 1) = -0.009.

14 http://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html

15 Sites such as London Hillingdon, which are not really representative of background conditions, have been removed from this analysis.

16 https://uk-air.defra.gov.uk/data/data_selector

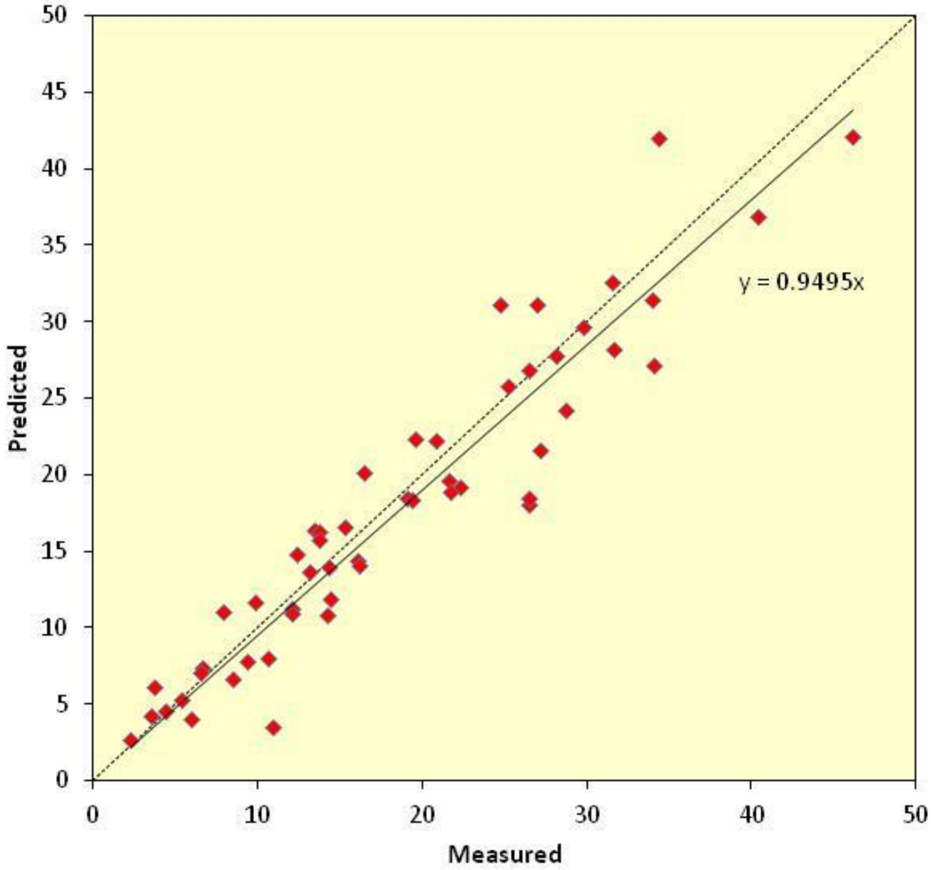

Figure 5: Predicted Mapped versus Measured NO_2 Concentrations at AURN Background Sites in 2014

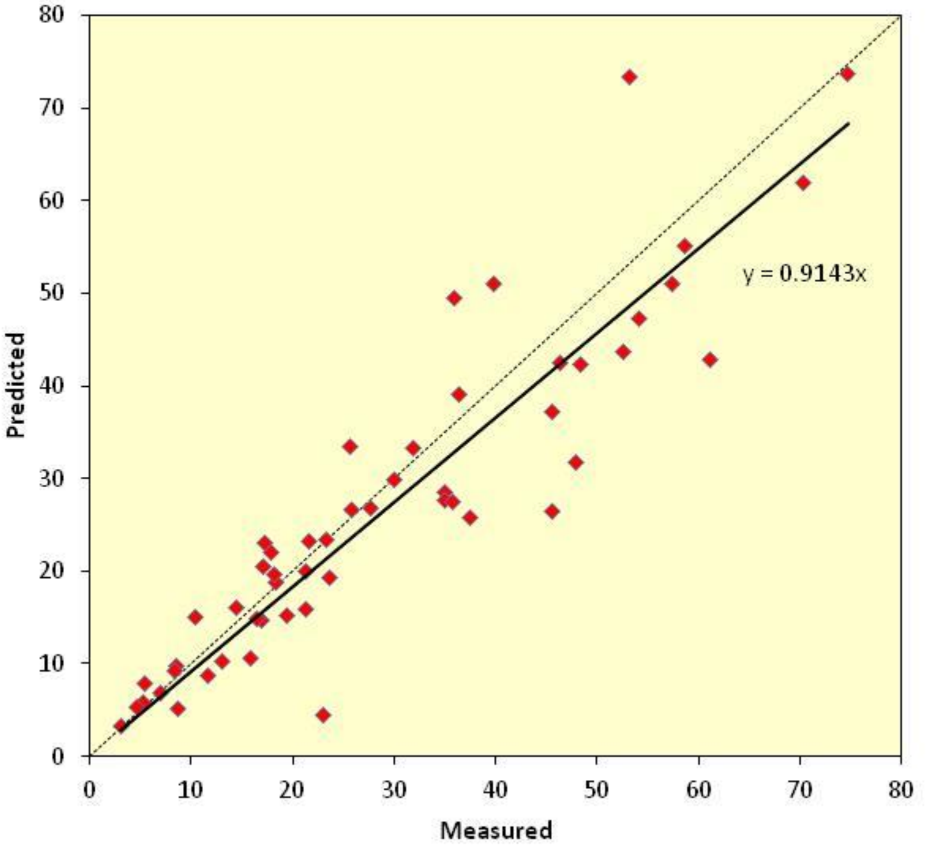

Figure 6: Predicted Mapped versus Measured NOx Concentrations at AURN Background Sites in 2014

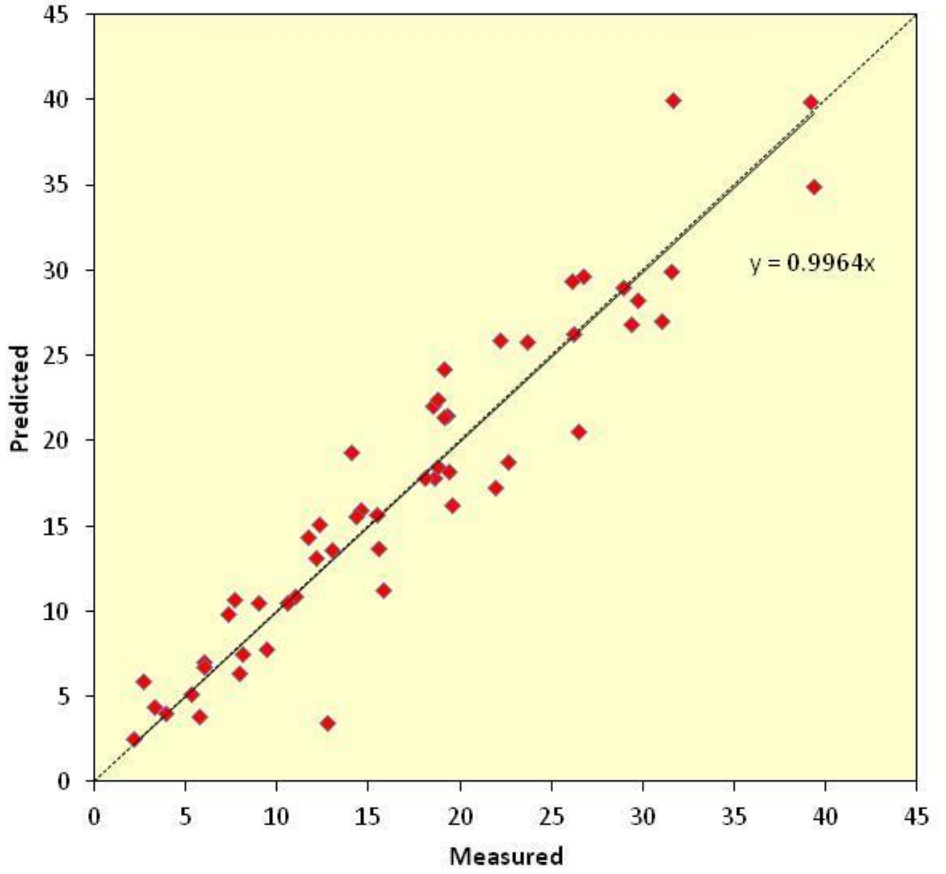

Figure 7: Predicted Mapped versus Measured NO_2 Concentrations at AURN Background Sites in 2015

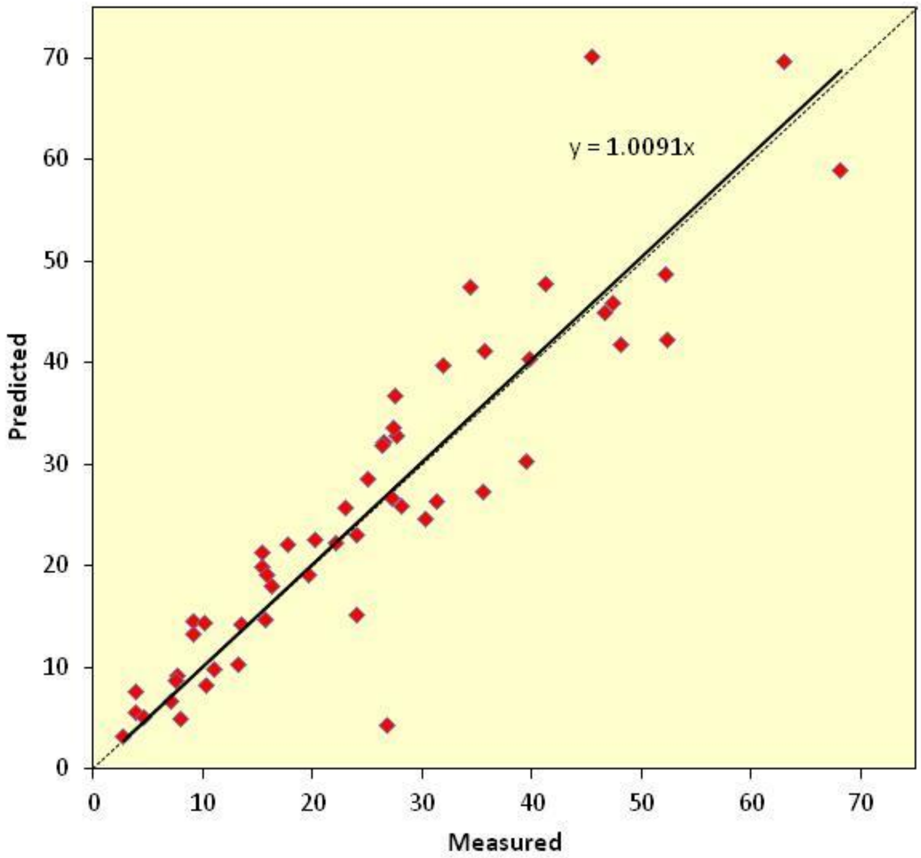

Figure 8: Predicted Mapped versus Measured NOx Concentrations at AURN Background Sites in 2015