Department for Environment Food & Rural Affairs

Department for Transport

Methodology review of the NO_2 Compliance Assessment:

Evidence for using high quality measurements over PCM modelled concentrations

Date: September 2022

Foreword

The Air Quality Expert Group (AQEG) is an expert committee of the Department for Environment, Food and Rural Affairs (Defra) and considers current knowledge on air pollution and provides advice on such matters as the concentrations, trends, sources and characteristics of air pollutants in the UK.

In 2019 Defra requested advice from AQEG on the question of how best to use evidence provided by measurements and models in reporting compliance with the NO_2 annual mean limit value. Various options were explored, and a sub-group of AQEG members was formed to help steer and input into the work to identify the most suitable approach.

The analysis in this report was presented to the subgroup in various stages over the last three years, allowing the subgroup to review and advise on the work as it progressed. A range of possible solutions have been explored of varying complexity, ranging from a simple comparison of measurement and model uncertainty, to exploring data fusion or assimilation options that combine measured and modelled concentrations.

The analysis and proposed approach outlined here were presented to the subgroup in 2021 and was judged to be a practical approach based on robust evidence. The sub-group suggested continuing to investigate more sophisticated approaches such as data fusion or assimilation techniques in the longer-term, noting that these would be more complex to implement and could be potentially less transparent to end-users including members of the public. When presented to the full Air Quality Expert Group, there was consensus that the approach set out in this paper is a proportionate and reasonable evidence-based approach that makes good use of the available evidence to provide a national assessment of NO_2 concentrations, and for the purpose of reporting compliance with the annual mean limit value.

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Executive Summary

The UK's Air Quality Standards Regulations[1] require reporting of ambient air quality data on an annual basis. The UK uses three sources of evidence to assess compliance with the annual mean NO_2 limit value: measurements from the Automatic Urban and Rural Network (AURN)[2], modelled values from the Pollution Climate Mapping (PCM) model[3], and diffusion tube measurements from the UK Urban NO_2 Network (UUNN)[4].

This report presents the results of analysis undertaken to determine whether a measured or a modelled concentration should be used to determine the compliance status of a road link[5] when both are available. To do this we have assessed which of these provides the best available evidence, by comparing the ability of the PCM model and measurements to predict representative concentrations along a road link, as required by the legislation.

We found that the expanded uncertainty in the PCM model is significantly greater than the expanded uncertainty in the UUNN and AURN measurements. We therefore conclude that high-quality measurements such as those from the UUNN and AURN provide the best available estimate of representative concentrations and should be used to report compliance for all road links where available. Measurements from the AURN have lower uncertainty than the UUNN and therefore in locations where AURN and UUNN measurements are both available, measurements from the AURN should be used to report compliance over the UUNN.

To complement this statistical analysis, we carried out a detailed review of road links where the PCM modelled concentrations and measured concentrations disagreed in 2020, to provide some insight into why the PCM model is underperforming in some locations. This assessment provides further qualitative evidence to support an approach of using measurements, where available, to determine compliance status over PCM modelled values. We intend to continue to explore the factors which lead to underperformance and use them to identify potential further improvements to the model. By reviewing the uncertainty of the PCM model as future improvements are implemented, we can track the success of model improvements, and use this to assess how the model should be included in the compliance assessment in the future.

[1] https://www.legislation.gov.uk/uksi/2010/1001/pdfs/uksi_20101001_en.pdf

[2] https://uk-air.defra.gov.uk/networks/network-info?view=aurn

[3] https://uk-air.defra.gov.uk/research/air-quality-modelling?view=modelling

[4] https://uk-air.defra.gov.uk/networks/network-info?view=UUNN

[5] A road link is a section of road between two major junctions.

1. Introduction

The UK's Air Quality Standards Regulations (AQSR) require reporting of ambient air quality data on an annual basis. They include detailed provisions on the monitoring and reporting of air quality, including the location and number of sampling points, the measurement methods to be used, data quality objectives and siting criteria each monitoring station must meet.

Currently, the UK is compliant with ambient air quality limit values set by the AQSR for most pollutants. The annual mean limit value for nitrogen dioxide (NO_2) concentrations is the only statutory air quality limit value that the UK is currently failing to meet[6]. This report focusses on how evidence is used to assess compliance with this limit value.

The UK has three sources of evidence used to assess compliance with the annual mean NO_2 limit value set under the AQSR. These are measurements from the AURN, modelled values from the PCM model, and diffusion tube measurements from the UUNN. The measurement networks include both roadside and background sites, with roadside sites targeting major urban roads also modelled by the PCM model. This means that many road links are modelled by the PCM model as well as having a roadside measurement site. This report presents the evidence base used to determine whether a measured or a modelled concentration should be used to report the compliance status of a road link when both are available.

The previous approach taken on these links was to report all measured and modelled values, but to always use the highest concentration to determine compliance, whether measured or modelled. This is a conservative approach in which we always reported an exceedance if any of the data indicates one, but it has the disadvantage of not considering the quality of the data available. This is particularly important in areas where local authorities have put local measures in place to reduce NO_2 concentrations, as the effects of localised measures can be difficult to capture in a national scale model such as the PCM model. Under this previous approach we would report non-compliance in the event of a modelled exceedance in a location, even if measurements indicated compliance and the model had not fully captured the effects of local measures.

While high quality measurements are generally considered a better assessment of NO_2 concentrations than models due to having lower uncertainty, experts in Defra's independent Air Quality Expert Group (AQEG) had previously raised concerns with simply always using a measurement over a model to report compliance due to the issue of *representativeness*. As specified by the AQSR (and previously the Ambient Air Quality Directive (AQD)[7]), for roadside NO_2 assessments we are required to report a concentration that is representative of at least a 100m stretch of road in order to avoid very small 'micro-environments'. Since for the UK assessment we report a single concentration for each road link that is at least 100m in length, our approach has been to report a concentration that is as representative as possible of the road link as a whole.

[6] https://uk-air.defra.gov.uk/library/annualreport/assets/documents/annualreport/air_pollution_uk_2020_Compliance_Assessment_Summary_Issue1.pdf

[7] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:02008L0050-20150918&from=EN#tocId46

The issue raised by AQEG was that, while high quality measured concentrations will give a better estimate of NO_2 in the local area, they are not necessarily more representative of a road link overall. The AURN and UUNN networks are sited according to the guidelines set out in the AQSR, which are designed to avoid sampling micro-environments and to be as representative as possible of the road they are assessing. However, the PCM model, in theory, could still be more representative of the full road link as it uses average characteristics along a road link, such as average traffic numbers, and therefore does not predict small scale variations in concentrations along a road.

A review of the evidence conducted by the UK Centre for Ecology and Hydrology (UK CEH) concluded that, while there were no studies explicitly comparing the relative suitability of models and measurements for compliance reporting:

> *"For points in space, measurements are implicitly given greater weight than models. For lines, areas and volumes in space, models are implicitly given greater weight than measurements."*

The review also found that:

> *"Where a measurement and a model are being assessed for compliance purposes, a data hierarchy framework within which a calculated uncertainty and a calculated representativeness is carried out with both sets of data may allow the hierarchy for policy use to be assessed."*

The approach outlined here seeks to address this issue by providing a calculated uncertainty in the PCM model and a calculated value of measurement representativeness. This allows us to build an evidence base to evaluate whether modelled concentrations from the PCM model or measurements from the UUNN and AURN provide a better estimate of a representative roadside NO_2 concentration, and therefore provide better evidence for determining compliance.

The advantage of this approach is that it considers all available evidence together to develop an approach to apply over all road links where we have a measurement and modelled value. The evidence base we have developed consists of:

- Statistical analysis of the uncertainty in the modelled and measured datasets (in 2018 and 2020), accounting for the variation along a road link.
- Comparison of UUNN and PCM modelled concentrations in 2020, including qualitative assessment of road links where UUNN and PCM modelled values disagree.

Together this evidence indicates that high quality measurements such as those in the AURN and UUNN networks currently provide a better estimate of representative concentrations along a road link than the PCM modelled values, even accounting for the variation along a road link. We therefore conclude that the measurements from the AURN and UUNN, where available, should be used to determine compliance with the annual mean NO_2 limit value in preference over PCM modelled values.

2. Statistical comparison of model and measurement uncertainty

2.1. Representative dataset

To evaluate whether NO_2 concentrations from measurements or the PCM model are more representative, we have compared the ability of each to predict a representative value.

In previous discussions with the AQEG subgroup it was agreed that the most representative value for a particular road link would be the average of all concentrations along that link. The AURN and UUNN measurement networks feeding into the national compliance assessment all only measure NO_2 at a single point along a road link. As a proxy, the most representative concentrations we had available were therefore the average of multiple diffusion tube measurements along a road link, deployed by local authorities for detailed assessment of NO_2 under Local Air Quality Management (LAQM). We found 336 links with at least 3 diffusion tube measurements along the link.

We screened the diffusion tube dataset to remove as many as possible that were not compliant with the AQSR siting requirements or on road links modelled by the PCM model. A full detailed assessment of every measurement location was not practical or proportionate, but measurements were removed that were:

- Within 25m of a major junction
- Less than 1.5 or greater than 4m above the ground
- Further than 10m from the kerb
- Achieved less than 90% data capture
- Were within 0.5m of the nearest building or obstruction
- On rural road links

We are confident that this screening removed the vast majority of non-AQSR compliant measurements, but as an additional check a very detailed examination took place on a randomly selected subset of 16 links. The results are not included here but analysis on the measurements that met the AQSR requirements in this detailed assessment gave results that are entirely consistent with the findings presented in this paper.

After screening we had a dataset of 58 links with at least 3 diffusion tube measurements on each, and 29 links with at least 4 measurements on each. These links have a wide geographical distribution, a range of street canyon sizes and a mixture of measurements on both windward and leeward sites, which allows us to be confident that inferences made from this dataset can be applied to other measurement networks. The averages of the measurements on each road link, referred to in the remainder of this report as the “link means”, provides us with a dataset of representative concentrations for each road link, and the standard deviation of the measurements around the average gives us an estimate of how much concentrations vary along a road link.

2.2. Measurement expanded uncertainty

To assess the uncertainty in the measurements we have calculated an expanded uncertainty, following the general methodology set out in the Guide to Uncertainty in Measurements (GUM)[8]. This accounts for both the uncertainty in the measurement itself and the uncertainty since concentrations vary along a road link, and we do not know where in this range of concentrations our measurement lies. This therefore provides the uncertainty of a randomly selected measurement around the average value on that road link.

We have two measurement networks feeding into the national compliance assessment: the AURN network of continuous analysers and the UUNN network of diffusion tubes. The uncertainty in short-term measurements from the AURN tends to be between 9 and 15%, however the uncertainty in the annual average concentrations used to assess compliance will be considerably lower and will be closer to the uncertainty in the calibration standards used, typically around 4 or 5%. Since the UUNN has higher measurement uncertainty than the AURN network, we have done this analysis for the UUNN. If the UUNN measurements provide higher quality data than the PCM model, the AURN will by extension also provide higher quality data.

The expanded uncertainty for UUNN measurements has two components:

- Standard uncertainty in the measurement itself which was found to be 4.4% or 1.76µgm^{-3} in 2020 (8.8% at 95% confidence).[9]
- Uncertainty due to variation along a road link: this was calculated as the standard deviation of the difference between the individual diffusion tube measurements in the LAQM dataset and their corresponding link means. We used the measurements from the 29 links with at least 4 diffusion tubes present which met AQSR siting criteria, which gave a standard deviation of 4.6µgm^{-3}.

The details of each component are given in Table 1 below. The expanded uncertainty is calculated by combining the two components in quadrature (expanded standard deviation) and then multiplying by a factor *k* to obtain the appropriate confidence interval.

Source of Uncertainty	Type	Distribution	Degrees of freedom	Standard uncertainty (µgm^{-3})
Measurement	A	Normal	21	1.76
Variation along a road link	A	Normal	126	4.6
Expanded uncertainty k=2 (95% confidence)				9.85

Table 1: Uncertainty budget for UUNN measurements

The AQSR specifies that uncertainties should be applicable in the region of the appropriate limit value, in this case 40µgm^{-3}. The expanded uncertainty in 2020 at the limit value is approximately

$$U = 100 \times \frac{9.85}{40} = 25\%$$

[8] Guide to the Expression of Uncertainty in Measurement, https://www.bipm.org/en/committees/jc/jcgm/publications

[9] UK Urban NO_2 Network Annual Report, https://uk-air.defra.gov.uk/library/reports?report_id=1057

The UUNN aims to achieve a measurement uncertainty of below 20%, which corresponds to an expanded uncertainty of 31%. Given that the uncertainty in both 2020 and 2021 was under 15%, it is unlikely that the UUNN uncertainty will increase above 20%.

2.3. PCM model uncertainty using Bland-Altman

We have assessed the uncertainty in the PCM model using the Bland-Altman method, using the link means as our "gold standard" reference method. The Bland-Altman method was previously discussed and approved as a suitable method of evaluating uncertainty by the AQEG subgroup.

The PCM models concentrations at 4m from the kerb. We therefore adjusted each measured diffusion tube concentration from our diffusion tube dataset to be at 4m from the kerb using the LAQM distance adjustment tool[10] before calculating the link means. This provides a fair comparison between PCM modelled values and measurements and reduces the PCM model uncertainty compared to when no adjustment is made.

The Bland-Altman method looks at the distribution of the percentage difference, *x*, between the candidate method, here the PCM model, and the reference method, here the diffusion tube link means. The method was applied by following these steps:

1. The percentage difference between modelled and measured concentrations was calculated for each site : $x = 100 \times \frac{Measured\ NO_2 - Modelled\ NO_2}{Measured\ NO_2}$
2. x was plotted for each site against measured concentrations creating a Bland-Altman plot (see Figure 1)
3. The mean of the percentage differences across all sites was calculated and is equivalent to bias: $\bar{x}$
4. The standard deviation of the percentage differences across all sites was calculated: σ
5. An upper limit of agreement (2 standard deviations where k = coverage factor) was determined by:

$$ULA = \bar{x} + k \times \sigma$$

6. A lower limit of agreement (2 standard deviations) was determined by:

$$LLA = \bar{x} - k \times \sigma$$

7. Any outliers (outside the ULA and LLA) were removed for the calculation of the uncertainty and steps 3 – 6 were repeated.

[10] https://laqm.defra.gov.uk/air-quality/air-quality-assessment/no2-falloff/

8. The percentage uncertainty was calculated[11] by:

$$U_{95}(\%) = \bar{x} + (k \times \sigma)$$

Several improvements to the PCM model were implemented for the 2020 assessment, to use updated evidence and/or improved methodologies for modelling traffic speed, meteorology and primary NO_2 emissions (fNO_2). We have therefore calculated the uncertainty for both the original 2018 PCM modelling[12] and alternative 2018 PCM modelling with these improvements included, which was run as a scoping study to test and quality assure the improvements prior to implementing them in the 2020 assessment.

The original 2018 PCM model uncertainty was found to be 37%, and the uncertainty in the 2018 PCM model with improvements was 31%. Since these improvements will be included in future compliance assessments, we used the uncertainty in the improved PCM model for our comparisons here.

We do not expect the PCM model uncertainty to change substantially if no further improvements to the model have been made. While this assessment has been done on the 2018 PCM model results, it should therefore also apply to the 2020 PCM modelling. In fact, due to additional uncertainties in the effects of the Covid-19 pandemic, it is likely that the model uncertainty will be slightly higher in 2020 and 2021. Further PCM model improvements are currently under development, and we plan to recalculate the model uncertainty when new improvements are implemented.

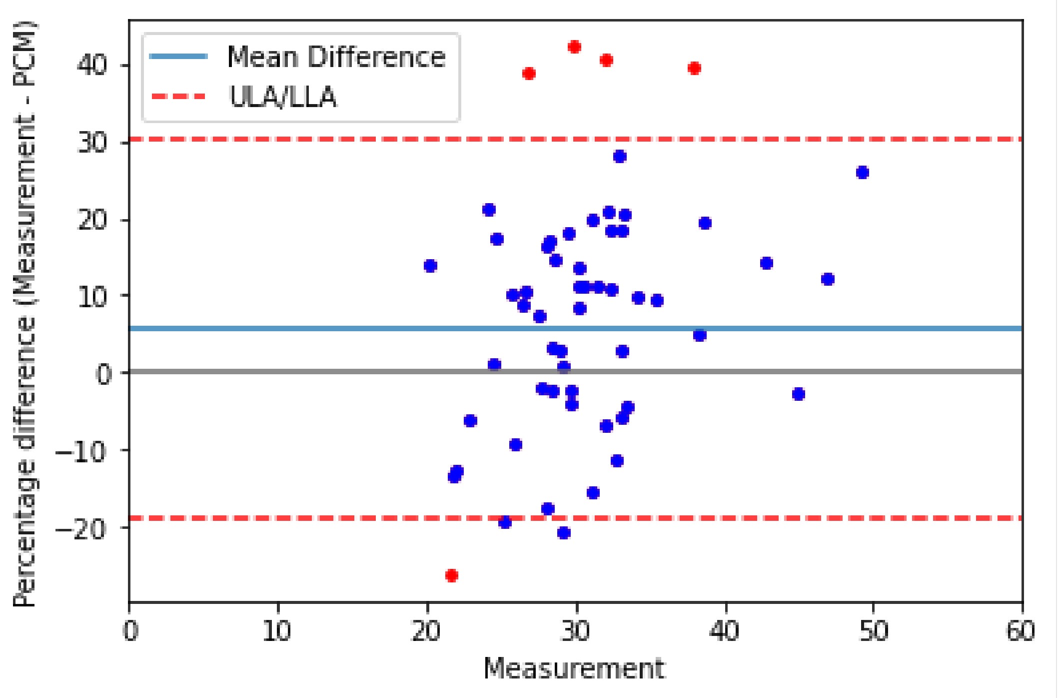

Figure 1: Bland-Altman plot showing the distribution of difference between PCM modelled NO_2 values and link means. Outlier points outside the ULA and LLA are shown in red.

As an additional check, we calculated the uncertainty in the PCM model using:

[11] Following the methodology in https://www.researchgate.net/publication/226769646_Should_non-significant_bias_be_included_in_the_uncertainty_budget

[12] Available to view and download here https://uk-air.defra.gov.uk/data/gis-mapping/.

- The AURN as the reference method
- Local authority continuous analysers which are known to meet AQSR siting requirements as the reference method.

The resulting uncertainty values are included in Annex 1. While some variation was found between different datasets, none indicated an uncertainty below 30%, and both gave higher uncertainties compared to the assessment using link means. This is expected as the link means should be less susceptible to small-scale variation along a road link and should therefore agree give better agreement with the PCM model.

It is important to note that the Bland-Altman method of calculating uncertainty was chosen as it provides a simple, intuitive, and well documented way of assessing model performance, based on difference from measurements. However, it does not provide a full assessment of the suitability of the PCM model for use in compliance reporting. Details on how to carry out such an assessment have been set out by the Forum for Air Quality Modelling in Europe (FAIRMODE)[13] and are beyond the scope of this report.

3. Comparison of 2020 measurements and PCM modelled concentrations

To provide some wider context we have also carried out a road link level comparison of the 2020 annual mean NO_2 concentrations from the UUNN and PCM model, to gain some insight into why the PCM model and measurements sometimes disagree. From this assessment we have identified a range of potential reasons for discrepancies and have looked in detail at some of the individual road links where the disagreements were largest. In most cases, on road links with a 2020 UUNN measurement and a PCM modelled concentration, the UUNN concentration was higher than the PCM modelled concentration (see Figure 2 for a histogram of the differences). In 2020, only 61 out of the 201 links with measurements had modelled concentrations greater than the measured concentrations. This suggests that for the most part the PCM model tends to underestimate NO_2 concentrations in these locations compared to UUNN measurements (although it should be noted that UUNN diffusion tubes were deliberately sited on road links where local assessments suggested the PCM model was not accurately representing local NO_2 levels, so this should not be considered representative of PCM model performance more widely).

[13] Guidance document on modelling quality objectives and benchmarking, S. Janssen, 2018, https://fairmode.jrc.ec.europa.eu/document/fairmode/WG1/Guidance_MQO_Bench_vs2.2.pdf

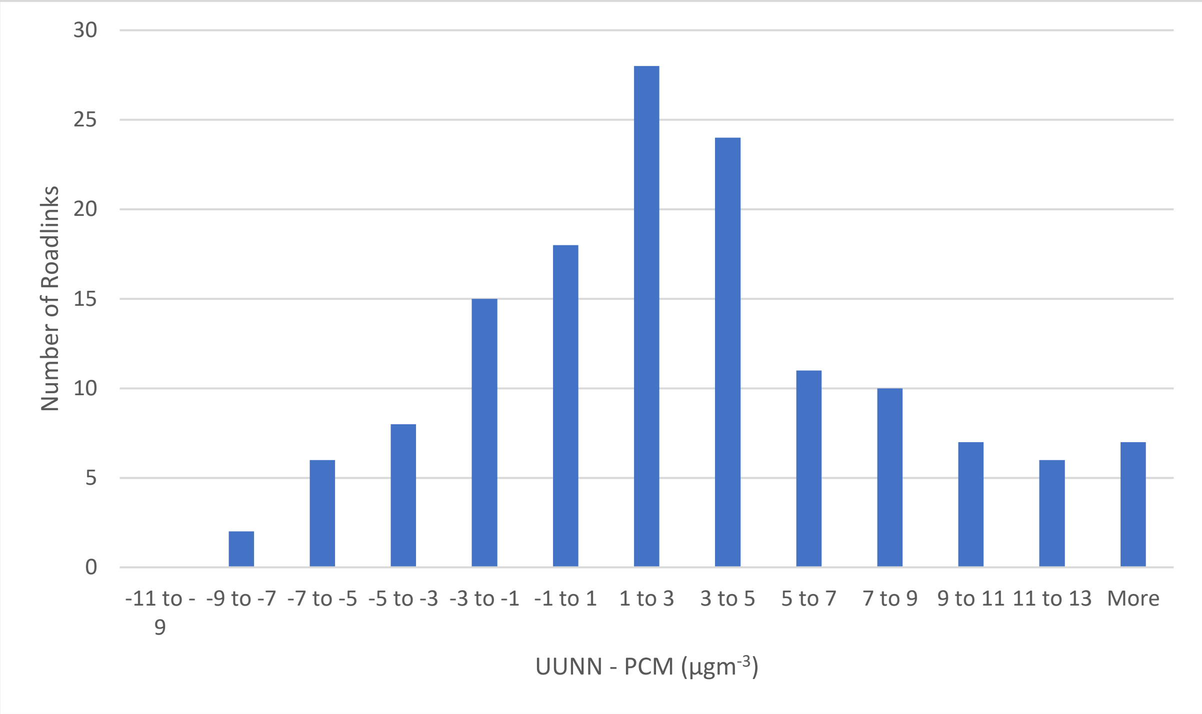

Figure 2: Histogram of difference between UUNN measurements and PCM modelled concentrations in 2020

We found a number of possible reasons for the disagreement between UUNN and PCM modelled values, including:

1. Street canyons: the PCM model currently does not explicitly model street topography. This may lead to the model underestimating concentrations on road links surrounded by high buildings, known as street canyons, as this can slow the dispersion of pollutants. The model has also been observed to overestimate concentrations on road links where there is no canyon at all. This may be because the PCM model is calibrated using measurements from the AURN, of which some sites are in canyons. When calibrated, all road links in the PCM model may therefore effectively be given a small canyon effect.
2. Elevated roads: the PCM model doesn't explicitly model elevation, and on elevated roads concentrations may disperse more rapidly, resulting in the measurement being lower than the modelled concentration.
3. Road links with another road link close by: the PCM models road links in isolation so the emissions from nearby roads will not be accounted for in the roadside increment. Other roads will be included in the background contribution but will be spread across a 1kmx1km grid.
4. Road links with nearby large emissions sources such as stations or railways: these sources are only accounted for in the background emissions which are at 1km resolution – concentrations for road links very close to stations or over railways may therefore be underestimated.

This provides an insight into why the PCM model is likely to be underperforming in some cases, and further supports an approach of using measurements to determine compliance status over PCM modelled values. Details of some specific examples are included in Annex 2.

4. Compliance reporting

The expanded uncertainty in the UUNN measurements, accounting for the variation along a road link is 25%. This is lower than the uncertainty of 31% for the PCM model. This difference is statistically significant, with a p-value of 0.05. According to the probability scale recommended in EFSA's *Guidance on uncertainty analysis in scientific assessments*[14], this means that it is "very likely to extremely likely" that the measurement uncertainty is lower than the PCM model uncertainty. **This demonstrates that the UUNN (and by extension AURN) measurement networks provide better estimates of representative NO_2 concentrations than the PCM model and should therefore be used where available to report compliance, in line with the interpretation above.**

Based on this evidence we have moved from the previous approach of using the highest concentration on a road link to determine compliance, to using the best available evidence to determine compliance. This means that a measurement will be used to report compliance on all road links where we have a measurement available from the UUNN or AURN, in preference to the PCM model. Where UUNN measurements are co-located with AURN monitors for validation purposes, AURN measurements will be used in preference to UUNN measurements. While this is less conservative than the previous approach, the evidence presented here demonstrates that this will improve the accuracy of the compliance assessment by prioritising the best available evidence. In particular, this will reduce the risk associated with reporting modelled concentrations where the PCM model is not effectively capturing local characteristics such as street canyons or elevation, and/or the effects of local measures deployed by local authorities.

This change in approach means there may be situations where a road link is reported as compliant with the annual mean NO_2 limit value according to the measured concentration, even though the modelled concentration is above the limit value. We do not expect these specific cases to be common and as an extra precaution we will conduct additional case by case qualitative assessments for any road links which fit these criteria to ensure that we are confident that the measurement is providing the best available evidence.

We intend to continue to identify and implement improvements to the PCM model and will monitor the uncertainty of the model as these improvements are implemented. In this way, if a point is reached where the PCM model uncertainty becomes comparable to that of the measurements, we will re-assess how the model and measurements are used in reporting compliance.

5. Summary and next steps

We have compared the ability of the PCM model and the UUNN and AURN measurement networks to predict a representative concentration along a road link. We found that the UUNN and AURN have lower uncertainty than the PCM model, even accounting for variation along a road link. We have therefore updated our approach to reporting compliance to use measured NO_2 concentrations from the AURN and UUNN to determine the compliance status of a road link, in all cases where available.

[14] https://efsa.onlinelibrary.wiley.com/doi/full/10.2903/j.efsa.2018.5123

We are confident from looking at specific locations where the PCM model and UUNN disagreed in 2020, that in cases where there is a substantial disagreement this is due to the PCM model not capturing the specific geography or characteristics of the road link, and not due to the measurement being in an un-representative location.

We plan to continue to investigate opportunities to improve the PCM model, to implement analysis to further understand it's strengths and weaknesses, and to monitor changes in PCM model performance as new improvements are included. In this way we can both monitor and quantify improvements to the model and can use this information to inform our approach to reporting compliance.

Annex 1

PCM model uncertainty was calculated using link means as well as measurements from the AURN, local authority continuous analysers, and the UUNN. The resulting uncertainty values are included in Table 2. All measurements were first corrected to be at 4m from the kerb to ensure a fair comparison to the PCM model.

All uncertainties were calculated using the Bland-Altman method and include a bias component $\bar{x}$ (the mean difference between PCM modelled values and measurements), and a random variation component (the standard deviation in the difference between PCM model and measurements). The random variation was expanded to cover a 95% confidence interval using a coverage factor k, dependant on the number of degrees of freedom. We have calculated the expanded uncertainty as the bias + the random variation, as outlined in Moroto et al. 2002[15]

Measurement (all adjusted to be at 4m from kerb)	Number of sites	Bias, $\bar{x}$ (positive = PCM underestimating) (%)	Coverage factor *k*(df)	Random variation: $k \times \sigma$ (%)	Uncertainty: $\bar{x} + k \times \sigma$ (%)
2018 PCM					
Link Means	57	7.5	2.00	29	**36.5**
AURN	59	-0.5	2.00	42	**42.5**
AQD compliant local authority continuous analysers	26	-4	2.06	47.5	**51.5**
2018 PCM with improvements					
Link Means	57	6.2	2.00	25	**30.6**
AURN	59	-4	2.00	35	**39**
AQD compliant local authority continuous analysers	26	-6	2.06	43	**49**
2020 PCM with improvements					
AURN	59	1.3	2.00	38	**39.3**
UUNN	144	7.5	1.98	28	**35.5**

Table 2: PCM uncertainty

[15] Maroto et al. 2002, https://www.researchgate.net/publication/226769646_Should_non-significant_bias_be_included_in_the_uncertainty_budget

Annex 2

Below are some specific examples of situations where the PCM model disagreed with measurements in 2020. This provides some insight into why the PCM model is likely to be underperforming in some specific locations and further supports an approach of using measurements to determine compliance status over PCM modelled values.

1. **Road links in close proximity**: the PCM model currently does not explicitly account for cases where there is second road link nearby and therefore represents an additional source of local road transport emissions. This results in the PCM model underestimating roadside NO_2 concentrations for these roads. The A4400 in Birmingham, shown in Figure 3 is an example of this. We estimate that there are around 7 examples of this across road links with UUNN sites, to varying degrees.

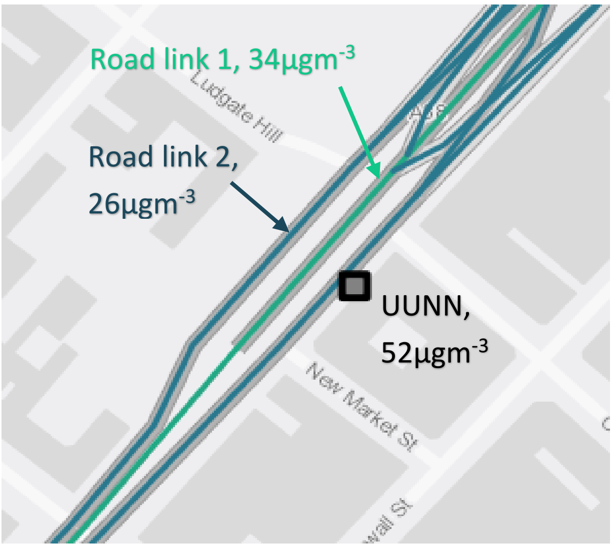

Figure 3: Birmingham example of road links in close proximity. "Road link 1" and "Road link 2" are two road links which are modelled by the PCM model in isolation. In reality, the concentrations both in 2020 and 2021 measured by the UUNN are significantly higher, as concentrations from both roads are contributing to the total.

2. **Railway lines:** while emissions from rail transport are included in the PCM model background emissions, the resolution of the background means situations where a road link is very close to a station or near a busy railway line with many diesel trains, the emissions may not be accurately captured. This leads to an underestimation in the PCM modelled roadside NO_2 concentration. See Figure 4 for an example.

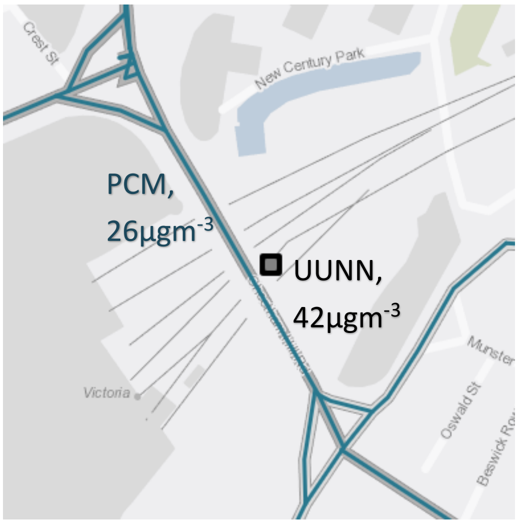

Figure 4: Road link next to busy railway line where the measured concentration is significantly higher than the modelled concentration.

3. **Road links over a bridge or causeway:** The increased airflow on roads in very open landscape or on bridges can lead to lower concentrations. The PCM model in these situations tends to overestimate concentrations. The road link in New Forest shown in Figure 5 is an example of this. The UUNN site on this road link did not have sufficient data capture to be used in the 2020 compliance assessment, but all months where data was collected, including winter months where concentrations are expected to be at their highest, showed NO_2 concentrations significantly lower than the PCM modelled concentration.

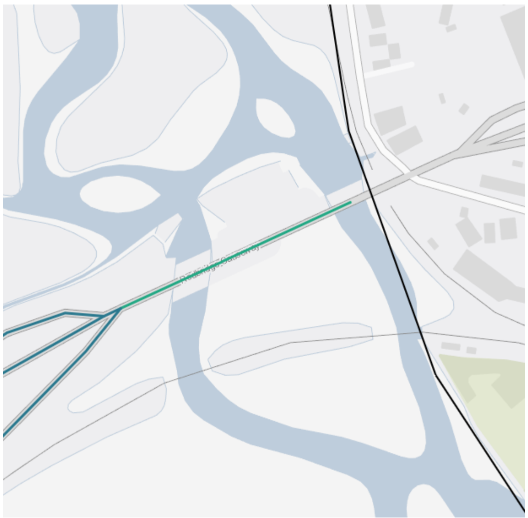

Figure 5: Road link on a bridge in New Forest