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Analysis of the relationship between annual mean nitrogen dioxide concentration and exceedences of the 1-hour mean AQS Objective.

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Executive summary

In the Local Air Quality Management Technical Guidance LAQM TG (03), issued in 2003, it was recommended that a Detailed Assessment should be carried out for potential exceedences of the 1-hour NO_2 objective if the annual mean was above 40 $\mu g\ m^{-3}$. A subsequent analysis of data from the UK's Automatic Urban and Rural Monitoring Network (AURN) led to advice being posed as a Frequently Asked Question (FAQ) on the Review and Assessment Helpdesk website that *"it would be appropriate to base the decision of a likely exceedence of the 1-hour nitrogen dioxide objective on an exceedence of 60* $\mu g\ m^{-3}$ *as an annual mean"*. This advice was based on an analysis of data for the period 1980 to 2001. Defra and the Devolved Administrations are currently updating the Technical Guidance, to be issued as LAQM TG (08), and it was considered appropriate to revisit the evidence for the current advice.

This report presents updated analysis of this relationship in the light of:

- Several more years of ratified AURN data now being available.
- Data from other non-AURN monitoring networks.
- A number of severe NO_2 pollution episodes recorded across south-east England in 2007.
- The findings of the AQEG report on primary NO_2 which showed an increase in direct emissions of this pollutant (i.e. NO_2 emitted directly from source, rather than formed in the atmosphere by oxidation of emitted NO).

From the analysis we conclude that:

- It is predominantly the south east of England where an exceedence of the hourly mean nitrogen dioxide objective (i.e more than 18 hourly averaged concentrations $> 200\ \mu g\ m^{-3}$) is likely whilst reporting an annual mean NO_2 of less than 60 $\mu g\ m^{-3}$.

- Episodic conditions, particularly experienced during consecutive cold and still winter days (such as in November and December 2007), can have a significant and unpredictable effect on exceedences of the hourly NO_2 objective at lower annual mean concentrations. Since 2007 was the first year in many that such conditions were reported, it is impossible to say at this stage whether this was just an unusual event driven by exceptional meteorology, or whether the increasing proportion of primary NO_2 emitted directly into the atmosphere will result in an increased frequency of such events in the future.

- Local topographical effects and exceptionally localised pollution (for example a nearby diesel generator) may also be able to produce an hourly nitrogen dioxide objective exceedence with an annual mean NO_2 of less than 60 $\mu g\ m^{-3}$. However, these situations can be more easily understood and addressed at a local level.

- Analysis shows that statistically, on the basis of the dataset available here, the chance of measuring an hourly nitrogen dioxide objective exceedence whilst reporting an annual mean NO_2 of less than 60 $\mu g\ m^{-3}$ is relatively low (around 5%).

- By removing a relatively small number of hourly objective nitrogen dioxide exceedences for south-east England in 2007 from the analysis, it has been shown that the advice previously given to local authorities generally still holds widely across the UK.

The following recommendations are made based on the conclusions of the analysis:

- Local authorities should continue to use the threshold of 60 $\mu g\ m^{-3}$ NO_2 as the trigger for considering a likely exceedence of the hourly mean nitrogen dioxide objective.

- This analysis should be updated on an annual basis in order to confirm that the unusual events of 2007 do not become commonplace in the future.

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1 Introduction

The Air Quality Strategy contains objectives for ambient concentrations of the pollutant nitrogen dioxide (NO_2) as follows:

- 200 μg m^{-3} as an hourly mean, not to be exceeded more than 18 times per calendar year.
- 40 μg m^{-3} as an annual mean, for protection of human health.

Of the two objectives, the annual mean objective of 40 μg m^{-3} is the more stringent. A monitoring station which records an annual mean of 40 μg m^{-3} or less is unlikely to also record more than 18 hourly means greater than 200 μg m^{-3} (i.e. an exceedence of the hourly objective) in the same year.

It is therefore useful to understand the relationship between the annual mean and the number of exceedences of the 1-hour objective, to establish whether the annual mean can be used to predict the likelihood of exceeding the hourly mean objective. Such a relationship is useful, as it allows many Local Authorities who are monitoring annual mean NO_2 concentration using low-cost indicative techniques such as diffusion tubes (which require an exposure period of days or weeks) to rule out the possibility of an exceedence of the hourly mean objective without recourse to expensive automatic analysers capable of producing hourly mean NO_2 data.

Previous research carried out on behalf of Defra and the Devolved Administrations identified a relationship between the annual mean and the 1-hour objective, such that exceedences of the latter were considered unlikely where the annual mean was below 60 μg m^{-3} (www.uwe.ac.uk/aqm/review/hourlyno2report.pdf). This was based on an analysis of data from the Automatic Urban and Rural Network (AURN) for the period 1980 to 2001.

The purpose of this report is to present updated analysis of this relationship in the light of:

- The current updating of Technical Guidance LAQM.TG(03), to be published as LAQM.TG(08)
- Recent ratified AURN data.
- Data from other non-AURN monitoring networks.
- A number of high NO_2 pollution episodes recorded across south-east England in 2007.
- The findings of the AQEG report on primary NO_2, which showed an increase in direct emissions of this pollutant.

The data are analysed and discussed and then conclusions drawn on the future validity of the relationship.

2 Analysis of Data

The relationship between the annual mean and the number of hourly exceedences (i.e. 1-hour means greater than 200 μg m^{-3}) in the calendar year has been re-assessed using automatic air quality monitoring data from years 2003 to 2007, obtained from the monitoring networks listed in Table 1 below.

Table 1: network sites used in the analysis.

Network	Network description	No. of sites (approx.)
AURN	Defra and Devolved Administrations national network.	100
Calibration Club	Local air quality management sites located across the whole of the UK.	100
London Air Quality Network (LAQN)	Sites in the London area, approximately 10 sites are shared with the AURN.	100
Kent & Medway Air Quality Monitoring Network	A collection of sites in Kent, south east England.	30

Please note one rural contract site, which had been part of an amalgamation of contract sites into the Calibration Club network for the purpose of this analysis, was necessarily discluded from the analysed dataset due to a significant effect observed on the statistics as a result of a persistent and localised structure maintenance-related source.

Figure 1 presents the results of the initial analysis. The threshold of 18 exceedences of the 1-hour mean limit value of 200 μg m^{-3} is shown by the solid black horizontal line, and the previously used annual mean threshold of 60 μg m^{-3} is shown by a vertical dotted blue line. There are a small number of points in the top left hand area, i.e. cases where there are more than 18 exceedences of the hourly limit value despite the annual mean being < 60 μg m^{-3} . Figure 1 illustrates the following:

- The majority of points in the top left quadrant are for 2007 data (indicated by red points).The winter episodes in 2007 are likely to have contributed significantly to the number of sites exceeding the hourly NO_2 objective whilst also reporting an annual mean of less than 60 μg m^{-3}.
- There were four urban sites exceeding the hourly objective in 2007 in the London network, three of these occurred with an annual mean of less than 60 μg m^{-3}.
- Dartford St Clements Roadside, in the Kent network, has repeatedly exceeded the hourly objective over many years with an annual mean of just below 60 μg m^{-3}.
- In years other than 2007, the majority of sites exceeding the hourly objective where the annual mean was below 60 μg m^{-3}, were kerbside and roadside sites, and predominantly located within south-east England.
- The envelope of the data plotted suggested that 60 or more exceedences (ie more than 3 times the objective) are possible for sites with an annual mean of 60 μg m^{-3}.

It therefore would appear that, while this updated study shows more cases where sites exceeded the hourly NO_2 objective whilst also reporting an annual mean of less than 60 μg m^{-3}, these appear to be associated with exceptional conditions or unusual sites. In view of these findings the investigation was extended to look at ways of excluding exceptional sites and episodes.

Figure 2 shows the same analysis with all data for 2007 removed. This was intended to remove any effects due to the winter pollution episodes of 2007. This shows that between 2003 and 2006 there were only three sites which reported annual mean NO_2 of less than 60 $\mu g\ m^{-3}$ but still exceeded the hourly objective; Aberdeen Market Street roadside site in 2006, London Brent 3 in 2004 and Dartford St Clements Roadside in 2005. Additionally London Hillingdon 1 was on the threshold of exceeding the hourly objective in 2003 with an annual mean of around 50 $\mu g\ m^{-3}$.

Figure 3 shows the same analysis with all roadside and kerbside sites removed (i.e. showing urban non-roadside and rural sites only). This shows only four points in the top left hand quarter, all of which are London sites. Apart from the four London urban background sites exceeding the hourly objective in 2007, there have been a number of other London sites with annual mean NO_2 of 40 – 50 $\mu g\ m^{-3}$ where the hourly NO_2 objective has been close to being exceeded.

Figure 4 shows the same analysis for all years and all sites (as in Figure 1), but with the removal of all hourly measurements corresponding to the November and December 2007 episodes for sites in the south east of England which had been in or near the critical region of the plot. Where hourly measurements were removed the corresponding statistics were recalculated. This shows that once the effects of the episodes in 2007 have been removed from the statistics only five sites remained which reported an annual mean NO_2 of less than 60 $\mu g\ m^{-3}$ but still exceeded the hourly objective. All were within the annual mean NO_2 range of 55 – 59 $\mu g\ m^{-3}$.

Figure 5 is the original analysis for all years with the removal of any site in south east England where the annual mean NO_2 was below 60 $\mu g\ m^{-3}$ and the number of exceedences of the hourly limit value was either close to or above 18. This shows that with the removal of sites in south east England for all years, only one site (Aberdeen Market Street roadside site) remains with an annual mean NO_2 of less than 60 $\mu g\ m^{-3}$ but still exceeded the hourly objective.

Finally Figure 6 quantifies the probability of measuring an hourly objective exceedence for various bands of the annual mean of NO_2. Please note the statistics produced are based on the data obtained from 160 or more automatic monitoring sites over the past five years. The figure indicates that there is more than twice as much chance of measuring an hourly objective exceedence with an annual mean in the band 60 – 69 $\mu g\ m^{-3}$ than in the band below. The probability of measuring an hourly objective exceedence with an annual mean of between 50 – 59 $\mu g\ m^{-3}$ is around 5% based on the limitations of the dataset available. Above the existing threshold of 60 $\mu g\ m^{-3}$ the probability increases to around 12%. Lower bands show only a 1% probability or less.

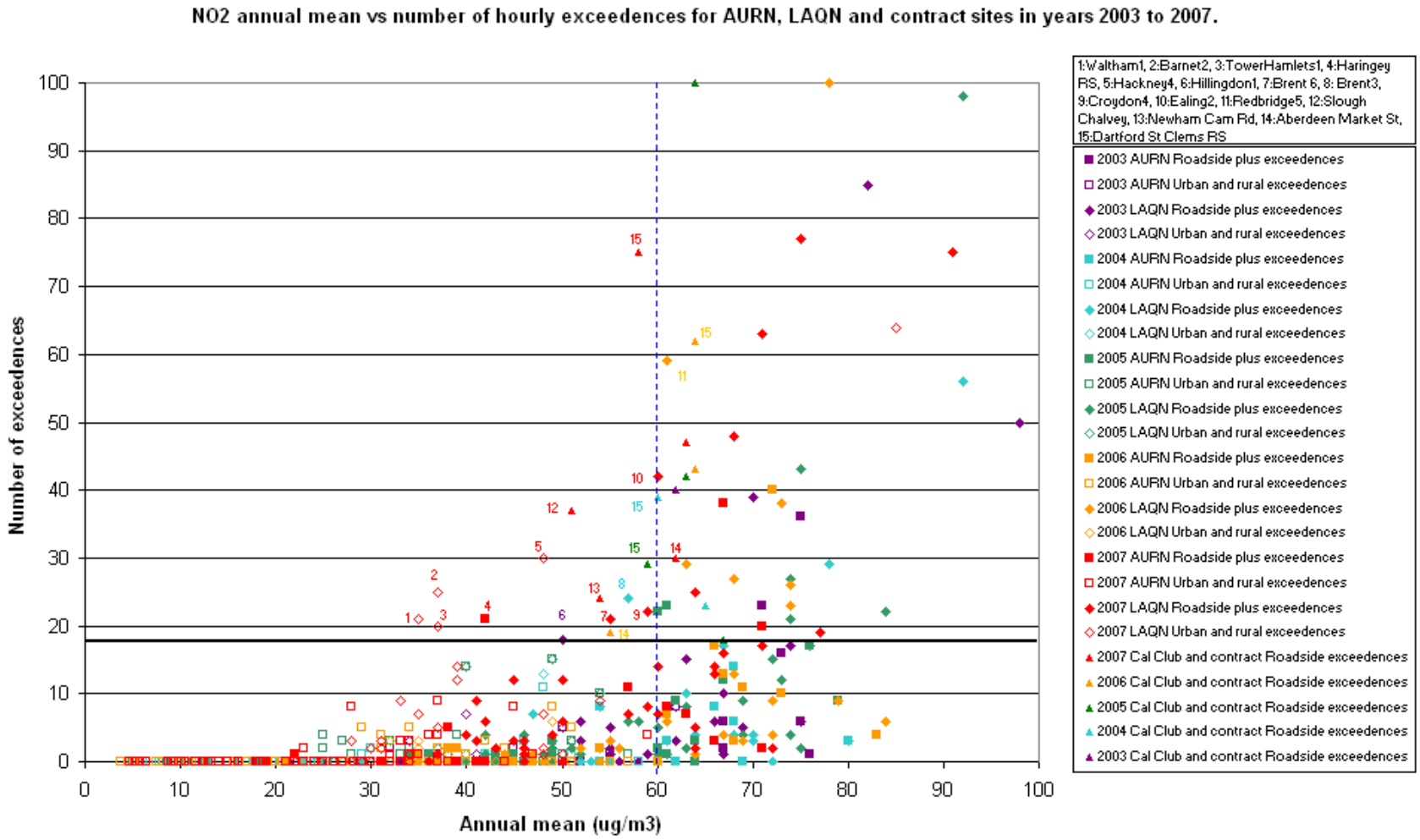

Figure 1: The relationship between the NO_2 annual mean and the number of exceedences of the hourly objective for sites in four networks.

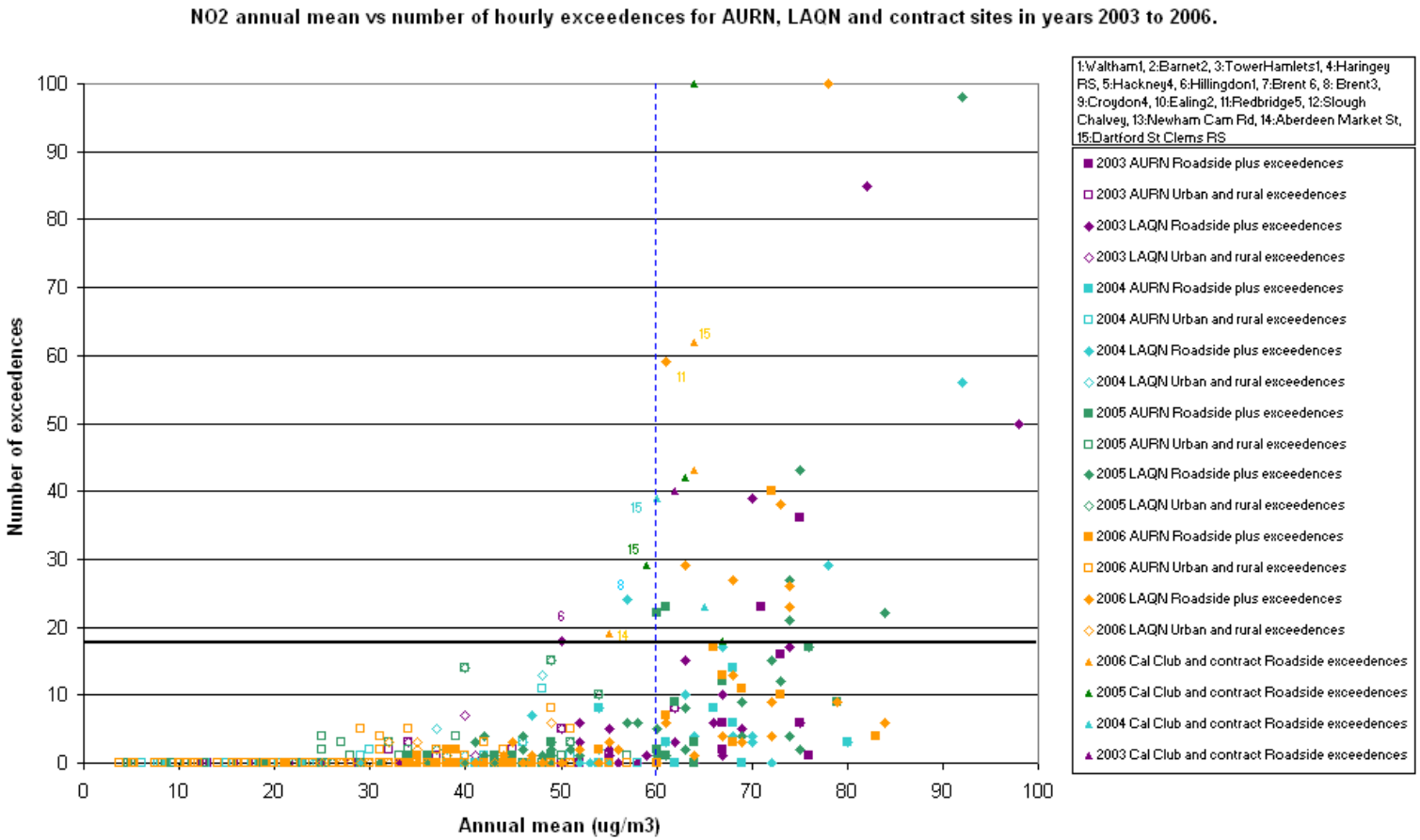

Figure 2: The relationship between the NO_2 annual mean and the number of exceedences of the hourly objective for sites in four networks without including statistics for 2007.

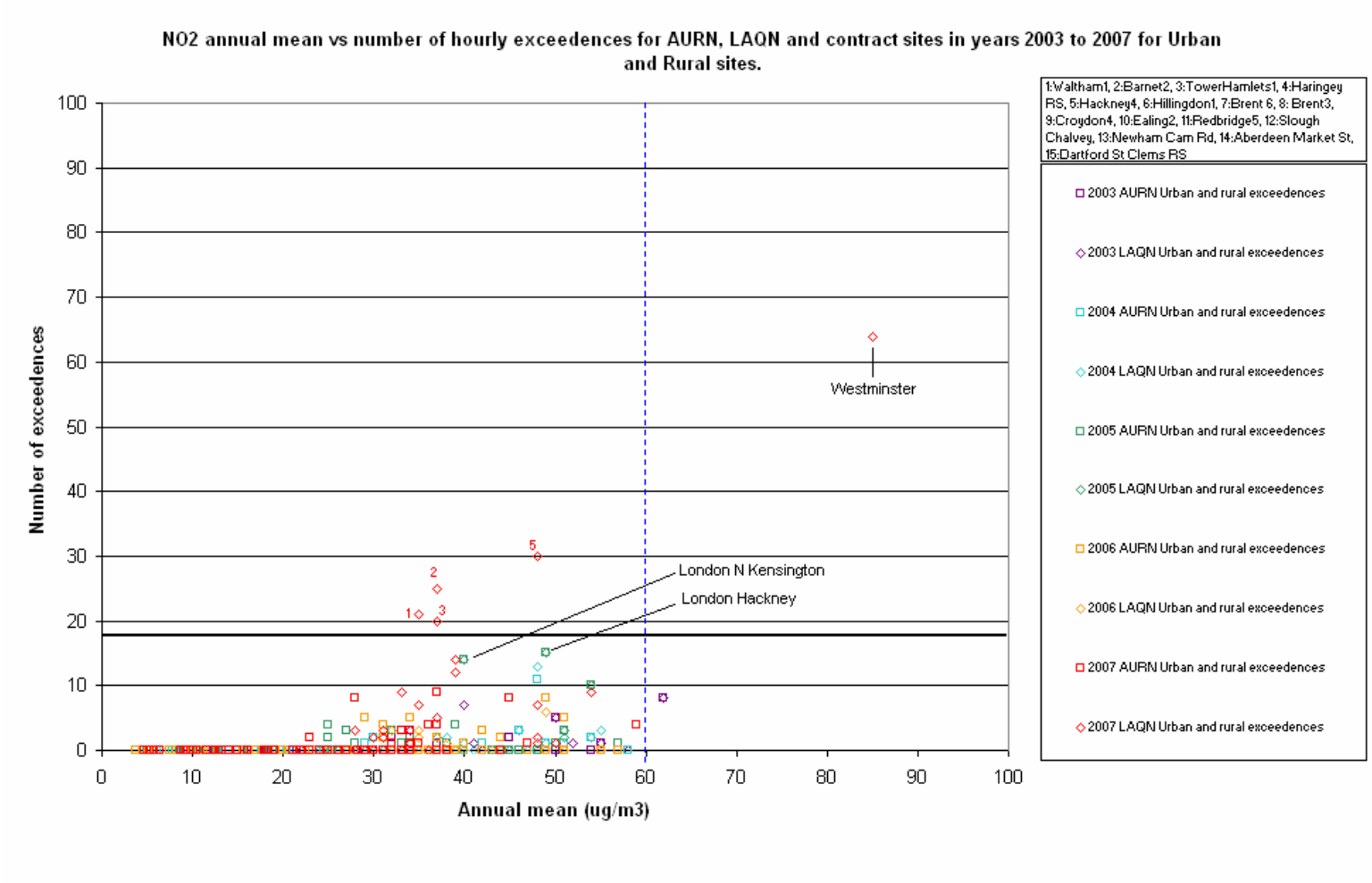

Figure 3: The relationship between the NO_2 annual mean and the number of exceedences of the hourly objective for sites in four networks for urban non-roadside and rural sites only.

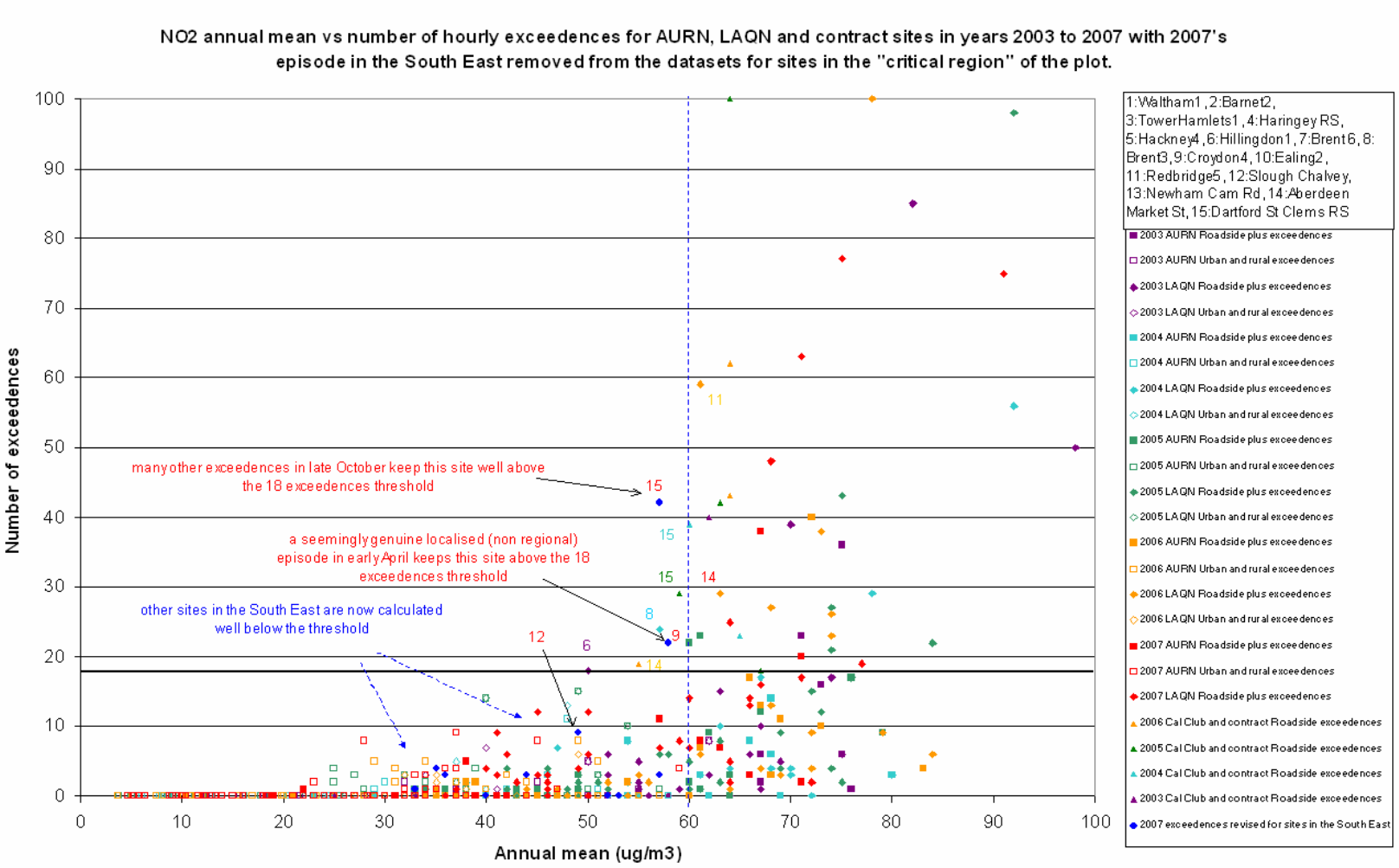

Figure 4: The relationship between the NO_2 annual mean and the number of exceedences of the hourly objective for sites in four networks after removal of 2007's episode concentrations for sites in the South East.

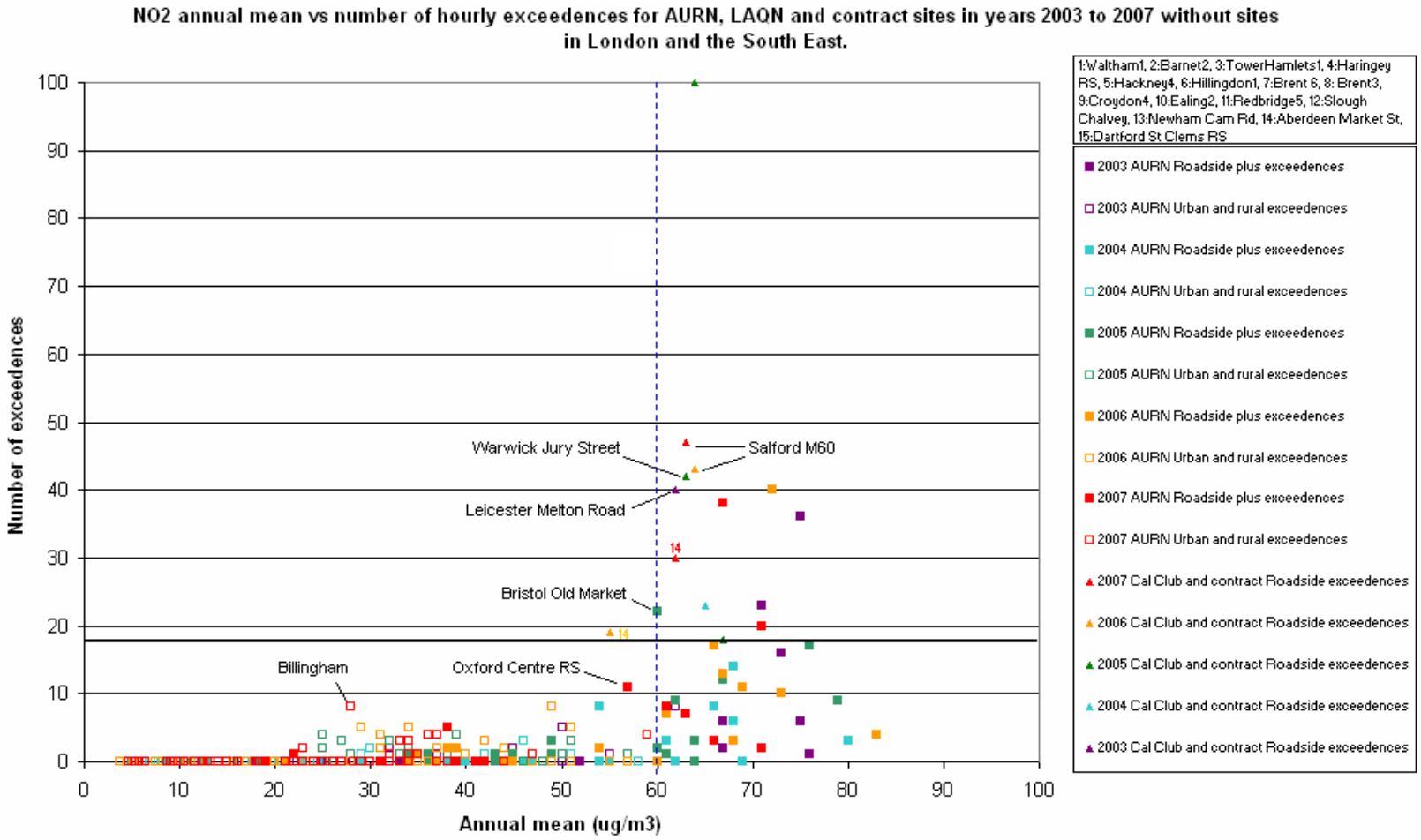

Figure 5: The relationship between the NO_2 annual mean and the number of exceedences of the hourly objective for sites in two networks after removal of all data for sites in the South East.

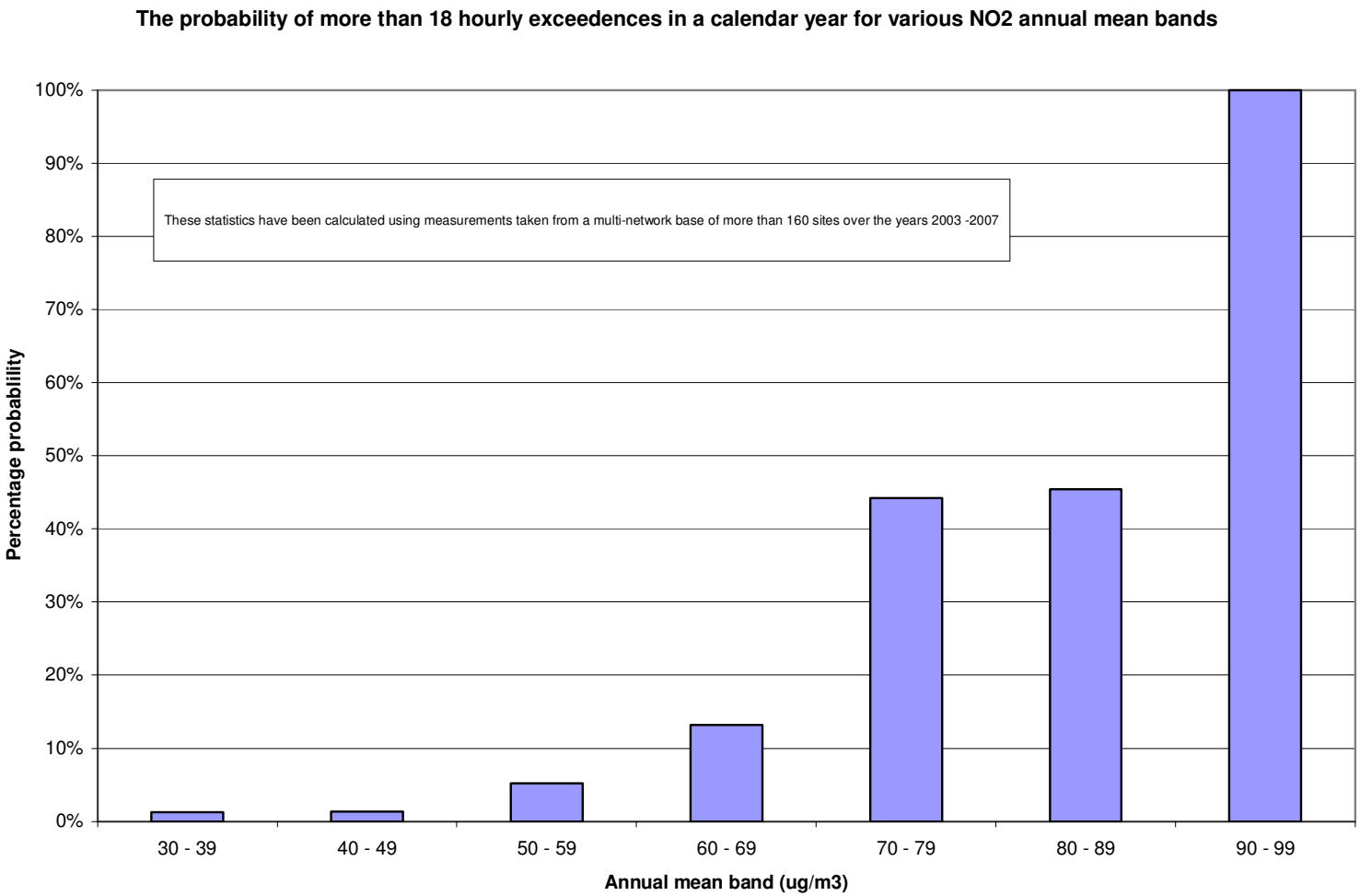

Figure 6: The probability of measuring an hourly objective exceedence for various bands of NO_2 annual mean.

3 Conclusions and Recommendations

Analysis of the relationship between the annual mean NO_2 concentration and the number of hourly means greater than 200 $\mu g\ m^{-3}$ in the same calendar year has been carried out, based on data from around two hundred UK automatic air quality monitoring sites sites over the past five years.

This has identified a relatively small number cases where there were more than 18 exceedences of the hourly limit value in a year (i.e. exceedence of the hourly mean objective), despite the annual mean being < 60 $\mu g\ m^{-3}$. However, a large proportion of these appear to have been attributable to episodic conditions occurring in 2007, or associated with unusual sites.

The analysis has shown that it is predominantly the south east of England where an exceedence of the hourly mean nitrogen dioxide objective may occur whilst reporting an annual mean NO_2 of less than 60 $\mu g\ m^{-3}$.

Episodic conditions, particularly experienced during consecutive cold and still winter days (such as in November and December 2007), can have a significant and unpredictable effect on exceedences of the hourly NO_2 objective at lower annual mean concentrations. Since 2007 was the first year in many that such conditions were reported, it is impossible to say at this stage whether this was just an unusual event driven by exceptional meteorology, or whether the increasing proportion of primary NO_2 emitted directly into the atmosphere will result in an increased frequency of such events in the future.

Local topographical effects and exceptionally localised pollution (for example a nearby diesel generator) may also be able to produce an hourly nitrogen dioxide objective exceedence with an annual mean NO_2 of less than 60 $\mu g\ m^{-3}$. However, these situations can be more easily understood and addressed at a local level.

Analysis shows that statistically, on the basis of the dataset available here, the chance of measuring an hourly nitrogen dioxide objective exceedence whilst reporting an annual mean NO_2 of less than 60 $\mu g\ m^{-3}$ is very low.

By removing the relatively small number of hourly objective nitrogen dioxide exceedences for south-east England in 2007 from the analysis, it has been shown that the advice previously given to local authorities generally still holds widely across the UK.

It is therefore recommended that local authorities continue to use the threshold of 60 $\mu g\ m^{-3}$ NO_2 as the guideline for considering a likely exceedence of the hourly mean nitrogen dioxide objective. It is also recommended that this analysis is updated on an annual basis in order to confirm that the unusual events of 2007 do not become commonplace in the future.

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