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Update on Implementation of the Daily Air Quality Index

Information for Data Providers and Publishers

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Title	Update on Implementation of the Daily Air Quality Index
Authors	Defra – Emily Connolly King's College, London - Gary Fuller and Timothy Baker Ricardo-AEA - Paul Willis

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Any enquiries regarding this document/publication should be sent to us at:

Emily Connolly, Department for Environment, Food and Rural Affairs
Area 5E Ergon House, 17 Smith Square, London, SW1P 3JR

or email aqevidence@defra.gsi.gov.uk

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Update on the implementation of Daily Air Quality Index

Overview

The Committee on the Medical Effects of Air Pollutants (COMEAP) published its Review of the UK Air Quality Index in June 2011[i]. Following these recommendations, Defra and the Devolved Administrations implemented a new index; the Daily Air Quality Index (DAQI), from 1st January 2012 as described in a Defra communication of 1st December 2011[ii].

This document is an update to these communications that defined the index. The aims of this document are:

1) To clarify the way in which the index should be calculated.

2) To detail minor changes to the index to bring it fully into line with EU Limit Value concentrations.

3) To draw together lessons from the way in which the index has been used by data providers and to provide recommendations for all users of the index.

Clarifying the Daily Air Quality Index

The DAQI informs people about short-term levels of outdoor air pollution and their potential health effects. It has a ten point scale; divided into four bands – low, moderate, high and very high.

Previous communications from Defra[iii] described the following attributes of the DAQI:

1) Updated health advice.

2) Changes to the index bands for particulate matter (PM_{10}), nitrogen dioxide (NO_2), and ozone (O_3).

3) Inclusion of fine particulate matter ($PM_{2.5}$) in the index.

4) Removal of carbon monoxide (CO) from the index.

5) Changes to the presentation of the index, to be a 10-point scale with four bands of low, moderate, high and very high.

6) Introduction of a concept of trigger values to allow for the prediction of episodes of elevated air pollution in real time as they emerge.

7) Links to the long-term health effects of air pollution to be provided with the index.

The following information is intended to clarify the way in which the index should be calculated.

Data rounding and averaging

The DAQI is defined in terms of integer pollutant concentrations averaged as 15 minute, hourly, 8-hour and daily mean concentrations. Calculating these averages, rounding, and the point at which rounding occurs, is critical in the comparison of concentrations to the index definitions:

1) All ppb to µg/m³ conversion factors should be to 4 decimal places.

2) When calculating an hourly, 8-hour or daily mean concentration it is necessary to ensure that data capture of at least 75% is achieved [iv] i.e.:

    - 3 x 15 minute mean concentrations are required to calculate an hourly mean
    - 6 hourly mean concentrations are required to calculate an 8-hour mean
    - 18 hourly mean concentrations are required to calculate a daily mean.

3) Rounding has to be the very last step of any calculation, i.e. immediately before comparing the result with the index and has to be done only once.

    Care has to be taken when rounding, since multiple rounding can alter a numeric value in some cases. For example, 50.486 µg/m³ is rounded to 50 µg/m³. Rounding this value in a first step to one decimal place gives 50.5 µg/m³ and rounding in a second step to and integer would yield 51 µg/m³.

    8-hour mean and daily mean concentrations for the index should be calculated from un-rounded hourly means.

4) All comparisons with the index should be undertaken with concentrations rounded to integers.

Particulate matter measurement methods

The DAQI builds upon the recommendations of the COMEAP review which also sought to align the index with the EU Limit Values. For this reason the Particulate Matter (PM) index values, and importantly the associated health advice, are based on EU reference or equivalent measurements.

It is widely accepted that different PM measurement methods may yield different results, largely due to their ability to measure semi-volatile PM. Given that elevated PM concentrations in the UK are often driven by semi-volatile PM, the divergence between measurement methods can be greatest during moderate, high or very high air pollution [v] [vi].

The use of non-reference equivalent PM measurements (eg. TEOM *1.3 or uncorrected beta attenuation) to calculate the index may therefore lead to misleading health information being provided to the public. For this reason only EU reference or equivalent measurements should be used as inputs for the index calculation. Similarly models used for air pollution forecasts should be designed to replicate EU reference equivalent concentrations.

Retrospective index calculations

The DAQI can be used to summarise air pollution and to allow comparisons over long time periods. For instance trends in the number of days with moderate, high or very high air pollution can be used to judge changes in the frequency of air pollution episodes. However care needs to be taken in interpreting these outputs since the DAQI is primarily designed to provide health information on short-term variations in air quality and not longer-term exposure.

The COMEAP report recommends the use of triggers to complement the index and to allow for the prediction of episodes of elevated air pollution as they emerge. However, all retrospective analysis of DAQI bands should be based on the measured concentrations and averaging times in Table 1 and the trigger method should not be used for retrospective analysis of DAQI values.

Changes to the index

The Commission Implementing Decision 2011/850/EU for the Air Quality Directive sets out common rules for the reciprocal exchange of information and reporting on ambient air quality [vii]. These rules are being piloted by a core group of EU countries, including the UK, before coming into force in 2014. Through this process Defra have identified a number of minor changes which need to be made to the DAQI to ensure it is consistent with the EU Directive reporting, a key intention of the COMEAP review.

Changes to the index and banding concentrations

Exceedence of EU Limit Value concentrations has been defined to occur when concentrations (following integer rounding) are above the Limit Value concentration. For example, exceedence of the PM_{10} daily mean of 50 µg/m^3 has been defined to occur when concentrations are in excess of this level. Therefore a daily mean of 50 µg/m^3 should fall in the low, not moderate, band to ensure that days of moderate or above is more directly comparable with the number of exceedences of the daily mean Limit Value. Applying this rule to the DAQI has resulted in the following changes:

- The minimum concentration for the moderate band has increased by one µg/m^3 to ensure that the low/moderate division is compatible with the Limit Values for PM_{10}, SO_2 and NO_2 and that the ratio of $PM_{2.5}$ to PM_{10} is maintained though the index.

- The minimum concentration for the high and very high bands has been increased by one µg/m^3 consistent with changes to the moderate band.

- The divisions between index values have been adjusted so that they are more evenly distributed within each band.

The revised DAQI is shown in Table 1 and replaces that launched in January 2012. Historic index values should be recalculated to the point when the DAQI was first implemented.

Table 1: The revised Daily Air Quality Index.

Band	Index	Ozone	Nitrogen Dioxide	Sulphur Dioxide	$PM_{2.5}$ Particles (EU Reference Equivalent)	PM_{10} Particles (EU Reference Equivalent)
		Running 8 hourly mean	hourly mean	15 minute mean	24 hour mean	24 hour mean
		µgm^{-3}	µgm^{-3}	µgm^{-3}	µgm^{-3}	µgm^{-3}
Low	1	0-33	0-67	0-88	0-11	0-16
	2	34-66	68-134	89-177	12-23	17-33
	3	67-100	135-200	178-266	24-35	34-50
Moderate	4	101-120	201-267	267-354	36-41	51-58
	5	121-140	268-334	355-443	42-47	59-66
	6	141-160	335-400	444-532	48-53	67-75
High	7	161-187	401-467	533-710	54-58	76-83
	8	188-213	468-534	711-887	59-64	84-91
	9	214-240	535-600	888-1064	65-70	92-100
Very High	10	241 or more	601 or more	1065 or more	71 or more	101 or more

Changes to the trigger concentrations.

The averaging times of one day for PM_{10} and $PM_{2.5}$ and 8-hours for O_3 mean it is not possible to provide public information about an unexpected pollution episode from measurement data until it is well established. To address this, COMEAP recommended the use of trigger values to complement the DAQI. These triggers were derived by COMEAP to provide information to the public to warn of exposure as it is taking place at moderate, high or very high levels. This method has similarities to the way in which the previous UK Air Quality Index defined moderate concentrations of O_3 on the basis of both hourly and 8-hourly mean concentrations.

Trigger concentrations are hourly pollution measurements that indicate a period of moderate, high or very high air pollution may be taking place or is likely to happen soon. These triggers are intended for use by organisations that operate real-time public information services.

The triggers are based on two consecutive hourly mean concentrations. The first hourly mean has to be greater than or equal to a threshold. To avoid false triggers from short-term measurement spikes, the trigger has to be confirmed by a second hourly mean. It is clearly desirable to be able to predict pollution exposure before the accumulated 8-hour or daily mean concentration indicates that moderate, high or very high air pollution has

occurred. For this reason the triggers are biased towards detecting increasing concentrations, i.e. the second hourly mean concentration has to be greater or equal to the first.

Changes to the concentrations that define each index band clearly require a change to the predictive triggers. These have been recalculated using the same method as for the original COMEAP report. O_3 triggers were calculated from the same dataset used in the COMEAP analysis, namely measurements from monitoring sites in London and Southeast England from 2000 to 2008 (including AURN), a total of 4.7 million hourly measurements. The availability of EU reference measurements for PM_{10} and $PM_{2.5}$ has increased since the time of the COMEAP analysis and hence this revision of the triggers has been undertaken on an extended dataset of EU reference equivalent PM_{10} and $PM_{2.5}$ concentrations from the AURN and from London and neighbouring networks from 2004 to 2011. Approximately 385,000 site days of PM_{10} concentrations were modelled for each possible trigger for each band and approximately 73,000 site days were modelled in the same way for $PM_{2.5}$.

The revised trigger concentrations for each index band are shown in Table 2 along with their Gilbert Skill Score, an indicator of predictive capability[viii].

Table 2: Revised trigger concentrations for PM_{10}, PM2.5 and O3. GSS=Gilbert Skill Score

Pollutant	Band	Trigger (ug m^{-3})	GSS
Particulate Matter, PM_{10}	Moderate or above	68	0.533
	High or above	107	0.348
	Very high or above	177	0.188
Particulate Matter, $PM_{2.5}$	Moderate or above	50	0.591
	High or above	74	0.422
	Very high or above	101	0.260
Ozone,O_3	Moderate or above	105	0.791
	High or above	170	0.726
	Very high or above	Not determined	n/a

2012 Implementation

The DAQI has been implemented across the air quality information systems operated by Defra and the Devolved Administrations and by others including the London and other air quality networks operated by King's College London, local authority monitoring programmes undertaken by Ricardo AEA and a number of authorities including Bristol City Council.

The DAQI allows information on air pollution exposure to be provided at a range of temporal scales:

Retrospective analysis: the DAQI can be used to summarise the frequency of air pollution episodes in a way which is consistent with Air Quality Objectives and EU Limits.

Near-real time pollution exposure: This has formed the foundation for many public information systems in the past. Real-time measurements can provide detailed information on the magnitude and spatial extent of air pollution episodes, and can detect pollution episodes that have not been adequately forecast.

However, the retrospective nature of the health information used to underpin the DAQI means that instantaneous pollution concentrations reflected in a running average might not identify a pollution episode sufficiently early to allow information to be communicated in a timely fashion, and so appropriate precautions to be taken. This provides challenges for tools that were used to display the pre-2012 UK air quality index.

Supplementing near real time data with triggers was recommended by COMEAP to maximise the utility of near real-time air pollution measurements and to provide an early warning system for episodes. In the absence of an air pollution episode when the triggers are not activated and insufficient measurements are available to calculate a valid daily mean for PM_{10} or $PM_{2.5}$ (6pm or later), there remains the question of which data to display to keep the public informed about "current" or "recent" concentrations and their exposure.

One approach is to use the 24 hours running mean data for PM so that information on what has recently been measured is available at all times. This has the advantage of being able to inform the public about recent pollutant exposure regardless of whether an episode is occurring and when the COMEAP recommended triggers have not been activated. This should enable susceptible members of the public to understand and manage their symptoms at all times.

However, it should be noted that running mean statistics should not be used for retrospective analysis of DAQI values as it is likely, for example, to overestimate the daily mean PM index values which are recommended to be reported by COMEAP. Data providers should make it clear which statistics are being used for public information and how they are calculated.

Forecasts:

Forecasts should be made using the new DAQI averaging times. The trigger methodology offers new opportunities to supplement forecasts undertaken using deterministic modelling tools.

UK-AIR

Defra implemented the Daily Air Quality Index on UK-AIR[ix] in January 2012. Simultaneously communicating retrospective exposure to inform the public of what has happened alongside what is expected to happen in the next 24 hours is a presentational challenge and something Defra is continually seeking to improve.

The four time-based scenarios are used as described below.

- **Retrospective concentrations** – measurement data including daily (midnight to midnight) DAQI averages for PM. Provides information about historical exposure and allows analysis of trends in the frequency of pollution episodes.

- **Recent concentrations** – near real time data including the 24 hour running mean to inform about the previous 24 hours exposure for PM, and higher resolution averaging times for other pollutants. Enables continuous provision of information.

- **Today's (calendar day) predicted concentrations** – triggers from measured data can be used to forewarn about episodes. This is a new way of using near real time measurement data to provide health relevant pollution information in the short term. Whilst Defra are not publishing trigger values explicitly on UK-AIR, Defra's forecasting team have recently adopted the triggers as an input to the production of the daily forecasts. Where triggers are activated and have not been forecast, updates are made to the UK-AIR forecast to alert the public to the changing situation. Analysis has shown that around 5% of forecasts during 2012 would have been improved through incorporation of the triggers. In particular where measured concentrations were elevated, the forecasts were most significantly improved; around 50% of the high or worse measured days were better predicted by incorporating triggers.

- **Tomorrow and future predicted concentrations** – modelled air pollution forecasts including DAQI midnight to midnight data for PM. To inform about potential future exposure and allow early interventions to reduce exposure. Air pollution forecasts are provided daily on UK-AIR, via email, Twitter and other dissemination channels, and use the DAQI averaging periods. Recent changes to the UK-AIR website include greater clarification on the applicability of the forecast for today – to capture the changing situation, tomorrow (midnight to midnight forecasts for the following day) and the longer term outlook. Day of the week is now specified to support this increased clarity, for example, "Forecast for Wednesday" in line with the DAQI.

Implementation by others

New opportunities to provide air pollution information to the public are being opened up by smart phone applications, mobile phone push notifications and social media. An excessively prescriptive definition of the use of the DAQI may slow the uptake and use of the index and unnecessarily constrain creativity in conveying air pollution information to the public. However, by using the index information providers are taking a shared responsibility to ensure its continued credibility. Care has to be taken when using the index to ensure that it is calculated consistently between information providers and that misleading health advice is not given through incorrect reporting. This applies equally to those displaying exposure information based on measurements and those displaying forecasts. Core parts of the index should not be changed or altered. These include:

- The concentrations that determine the 1 to 10 index values and the bands; low, moderate, high and very high.
- The method of calculating the index values which needs to be done using the appropriate measurement methods and averaging periods.
- The associated health advice for each band.

Where these methods are not followed the information provider should not purport to be using the Daily Air Quality Index.

Annex A: Model performance of each trigger and their respective Gilbert Skill Scores (GSS)

PM_{10} trigger moderate or above at 51 µg m^{-3} GSS=0.533		Event observed	
		Yes	No
Event modelled	Yes	14,165	8,556
	No	3,842	358,504

PM_{10} trigger high or above at 76 µg m^{-3} GSS=0.348		Event observed	
		Yes	No
Event modelled	Yes	1,552	2,135
	No	769	380,611

PM_{10} trigger very high or above at 101 µg m^{-3} GSS=0.188		Event observed	
		Yes	No
Event modelled	Yes	135	355
	No	193	384,384

$PM_{2.5}$ trigger moderate or above at 36 µg m^{-3} GSS=0.591		Event observed	
		Yes	No
Event modelled	Yes	2,523	1162
	No	579	68,759

$PM_{2.5}$ trigger high or above at 54 µg m^{-3} GSS=0.442		Event observed	
		Yes	No
Event modelled	Yes	419	379
	No	151	72,074

$PM_{2.5}$ trigger very high or above at 71 µg m^{-3} GSS=0.260		Event observed	
		Yes	No
Event modelled	Yes	65	160
	No	25	72,773

O_3 trigger moderate or above at 101 µg m^{-3} GSS=0.791		Event observed	
		Yes	No
Event modelled	Yes	32,927	2,358
	No	6,359	4,305,744

O_3 trigger high or above at 161 µg m^{-3} GSS=0.726		Event observed	
		Yes	No
Event modelled	Yes	1,500	168
	No	398	4,345,322

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