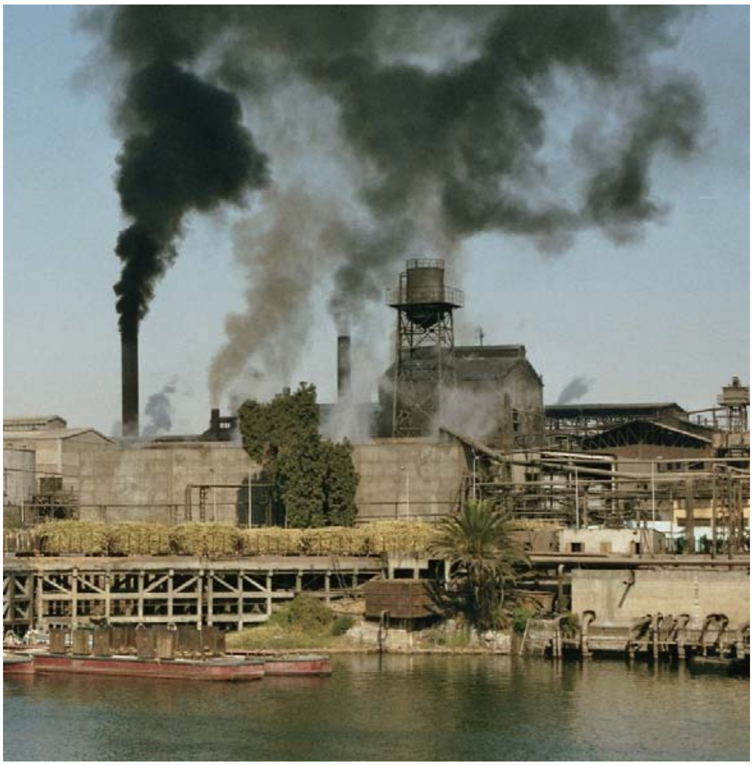
Air Quality and Air Quality Indices: a world apart ?



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Frank de Leeuw, Wim Mol

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Front page photo: a source of smog: black smoke emissions from a sugar refinery. (photograph by Frank de Leeuw).

Author affiliation:
FAAM de Leeuw and WJA Mol: Netherlands Environmental Assessment Agency (MNP) at National Institute for Public Health and the Environment (RIVM), Bilthoven, The Netherlands.

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Disclaimer:
This Technical paper has not been subjected to EEA member country review. It does not represent the formal views of the European Environment Agency.

ETC/ACC Technical paper 2005/5
European Topic Centre on Air and Climate Change
PO Box 303
3720 AH Bilthoven
The Netherlands
Phone +31 30 2743550
Fax +31 30 2744433
Email: etcacc@mnp.nl
Website: http://etc-acc.eionet.eu.int/

SUMMARY

The Air Quality Index (AQI) is a widely used concept to communicate with the public on air quality. A growing number of national and local environment agencies use the AQI for (near) real-time dissemination of air quality information. A survey of five different AQI operational in four countries showed a common concept behind the AQI but a strongly different practical implementation. Using actual concentration data from 10 stations over Europe, it is shown that, although there is a reasonable correlation between the five AQIs, both the classification of the air pollution situation as well as the determining pollutant is different in the various AQI.
The EEA is extending the current OzoneWeb towards a more full grown exchange platform of (near real-time) air pollution information. It has been suggested to present the information by means of an AQI. Doing this both at the European and at the local level by using different AQI approaches, this might result in conflicting or, at least, confusing messages to the public. Harmonisation of AQI will be needed.

CONTENTS

1. Introduction

The Air Quality Index (AQI) has become part of the information routinely provided to the public. The AQI makes it possible to describe the air quality in a simple, understandable way. The development of AQI goes back to the period when the first automatic monitors became available (see e.g. Shenfield, 1970). Disputes in the past illustrate the complexity of creating an accessible, understandable and uniformly acceptable AQI. In the last decade, the IT revolution and the growing access to internet revived the discussion on AQI, now focussing on the description of (near) on-line air quality.
The purpose of this paper is to identify the current situation in Europe with regard to the usage of air quality indices and to identify possible problems and/or obstacles that might be faced in extending the OzoneWeb[1] (and its future extensions with other components like SO_2, NO_2 and PM_{10}) to include air quality indices.
In many countries, air quality indices are part of the information communicated to the public. The indices summarise the air quality state consisting of a complex mixture of a wide range of pollutants into one figure (e.g. expressed as a coloured pictogram or as number) which is easily understandable by the public. The required concentration data to estimate the air quality index is generally confined to those pollutants for which concentration data is routinely (on-line) available from automatic monitors. As a reference for the index classes, health-related limit, target or guideline values are generally used; these are summarized in Chapter 2. In Chapter 3 we present an overview of a number of indices currently in use in Europe. Similarities and differences between the indices are discussed. This is further illustrated in Chapter 4 by applying the different approaches to AIRBASE data. A discussion on the possibilities to apply an index in the "In Your Neighbourhood" project is also given in Chapter 4.

This document covers the first deliverable in the sub-project "Proposal for improved EEA near real-time air quality (ozone) information system" within the Neighbourhood project. It also covers the activities in Subtask 1 in task 1.3.1.1 within the ETC/ACC 2005 Implementation plan (ETC/ACC, 2005).

[1] OzoneWeb is a web site (http://ozone.eionet.eu.int) developed by EEA which shows near real-time ozone concentrations over Europe.

2. Air Quality Standards

2.1. EU directive on NO_2, SO_2, PM_{10} and O_3

Table 1 presents an overview of limit and target values (set for the protection of human health) and of information and alert threshold values (set for information to the general public) as defined in the EU air quality framework directive and related daughter directives (EU, 1996; 1999; 2000; 2002). In addition to the health-protection limit and target values, values have been defined for the protection of ecosystems and vegetation.
In AIRBASE information on exceedances of limit and target values and related statistics is routinely available for all station submitting information under the Exchange of Information Decision (EU, 1997; 2001). Annually a summary of all information available in AIRBASE (meta-information on networks and stations, raw air quality data, statistical parameters) is prepared by the ETC/ACC, see Mol *et al.* (2005) for the most recent version.

Table 1. Overview of limit and target values and of information and alerts thresholds as defined in the first three daughter directives.

Compound	**Limit/target value**			**Target year**
PM_{10}	Annual average:	40 µg/m³		2005
	Daily average:	50 µg/m³	may be exceeded up to 35 days a year	2005
NO_2	Annual average	40 µg/m³		2010
	Hourly average:	200 µg/m³	may be exceeded up to 18 hours per year	2010
Ozone	Daily maximum 8-hourly running mean	120 µg/m³ (target value)	may be exceeded up to 25 days per year 1)	2010
SO_2	Daily average:	125 µg/m³	may be exceeded up to three days per year	2005
	Hourly average:	350 µg/m³	may be exceeded up to 24 hours per year	2005
CO	Daily maximum 8-hourly running mean	10 mg/m³		2005
Pb	Annual average:	0.5 µg/m³		2005 2)
Benzene	Annual average:	5 µg/m³		2010

Compound	**Information/Alert threshold**		
Ozone	Information: hourly average	180 µg/m3	
	Alert: hourly average	240 µg/m3	
SO_2	Alert: hourly average:	500 µg/m³	During three consecutive hours over at least 100 km2
NO_2	Alert: hourly average	400 µg/m³	During three consecutive hours over at least 100 km2

1) As an average over the three preceding years.
2) 2010 in the immediate vicinity of specific industrial sources, notified to EC before 19 July 2001.

2.2. WHO guidelines

The World Health Organisation (WHO) has prepared air quality guidelines (WHO, 1987, 2000). In relation to human health and current air quality, highest concern is on particulate matter (PM10, PM2.5) and ozone. Recent findings on the health impact of particulate matter and ozone are discussed in the reports of the WHO/CLRTAP Task Force on Health Aspects of Air Pollution (UNECE, 2003; 2004). The results can be summarized as:

Ozone: the principal metric for assessing the effects of ozone on mortality should be the daily maximum 8-hourly mean. Ozone effects should be assessed over the full year. Current evidence is insufficient to derive a level below which ozone has no effect on mortality. However, for several reasons it was recommended to define an exposure parameter as the sum of excess of daily maximum 8-means over a cut-off of 35 ppb calculated for all days in a year. This parameter is usual referred to as SOMO35.

PM: A causal relationship between PM exposure and mortality is assumed and the use of the annual mean of PM2.5 as an indicator for PM-related mortality is recommended.

On nitrogen dioxide (NO_2) a WHO working group did not find sufficient evidence to reconsider the current hourly and annual WHO-guidelines for NO_2. These guidelines are in line with the limit values set by the EU.

The recent WHO findings are not (yet) implemented in the air quality indices. For PM_{10} is must be concluded that with respect to health effects, the long term exposure is most important. The current indices are based on the short-term (daily) concentrations of PM_{10} and are more related to compliance with the PM_{10} limit value. A similar situation is the case for ozone.

3. Air Quality Indices

3.1. General concept

For different pollutants adverse effects on human health can be expected for a wide range of concentrations, e.g. in case of carbon monoxide concentrations of several mg/m^3 are of concern while for heavy metals of toxic compounds like benzo(a)pyrene (B(a)P), concentrations orders of magnitude smaller (of ng/m^3) are relevant. In communication with the general public providing information on the actual air quality is not meaningful to present concentration values unless the concentrations are related to the effect levels. Frequently this is done by converting the concentration into a dimensionless scale (between 1 to 10 or 1 to 100) which is also associated with an intuitive colour code (from green to red) and a linguistic description (e.g. from *very good* to *very poor*). Commonly the reference levels used in the conversion are based on health-protection related limit, target or guideline values set by the EU, at national or local level or by the WHO.
For describing the ambient pollutant mix, an overall air quality index (AQI) is constructed. In calculating such an overall AQI, firstly for each individual pollutant a sub-index is calculated. The overall index is set to the highest value of each of the pollutant considered. The AQI can be evaluated for a single station but also for a certain region, e.g. for an urban agglomeration. In this case, the regional or urban index might be based on the highest sub-index at any of the stations within the considered region or urban agglomeration (this approach is, for example, taken in the French ATMO-index) or it might be based on the highest sub-index calculated from the *averaged* concentrations at all stations (as is done, for example, in the Belgium index).

3.2. Some European examples

The strength of an air quality index is that it is able to translate a complex air quality state into a health-risk related concept and to communicate this in a simple, strongly visualised way to the public. At the European level, the weakness of the AQI is that the number of pollutants and concentration data used, the temporal resolution, the underlying reference data and the calculation procedures are highly variable in the indices defined in various parts of Europe; see the short descriptions on indices currently in use in a number of NW European countries provided in Annex 1.
In this paper we like to sketch the difference between the current approaches. For this intercomparison we have selected the indices in use in Belgium, France, Germany (Lower Saxony)[2] and the United Kingdom. A fifth index as proposed by the Citeair[3] project is included as well.

[2] In Germany, like in Austria, no common air quality index at the national level has been defined but a number of the Ländern has defined their own AQI. The German AQI discussed here is in use in Lower Saxony.
[3] The Citeair project is funded through the INTERREG IIIC programme and aims to foster the comparability of air quality data across European cities. For this, Citeair is developing a Common Air Quality Index. In this paper the definition of the index as presented during the Citeair workshop in March 2005, Rome is used which might be slightly different from the current definition.

The indices selected here do not form a complete list (for example, Helsinki, Finland has also introduced an air quality index, see http://www.ytv.fi/ENG/airquality/ def_index.htm; another pollution index is proposed for Naples, see Murena, 2004) but the given examples illustrate the different approaches[4]. More extended surveys of the application of indices in Europe and elsewhere are presented by Garcia and Colosio (2002) and by US-EPA (2002).

An overview of the characteristics of the selected indices is presented in Table 2. The upper class boundaries for the five indices are given in Figure 1.

[4] All indicators mentioned here are based on the maximum value of sub-indices calculated for the individual pollutants. One example (http://www.eurad.uni-koeln.de/index.html?/allgemeines/ links.html) calculates a cumulative index based on the modelled daily mean concentrations of 6 pollutants. In an atmospheric dispersion model daily data are but in the real world the are not available for every day in a year. When based on monitoring data, an additive index is very sensitive for missing values. An additive index has similar drawbacks as the index based on the most polluting component (see below): there is no direct relation of the index value with the pollution mix and/or with health impacts. This additive approach will not be further discussed here.

Table 2. Overview of Air Quality indices in use in Belgium, France, Germany and the United Kingdom and proposed by Citeair (see Annex 1 for further details).

	Air Quality Index						
	Belgium	France	Germany	UK	Citeair	UK	Citeair
# numerical levels, (scale)	10 (1-10)	10 (1-10)	6 (1-6)	10 (1-10)	5 (0- >100)[6]	10 (1-10)	5 (0->100)[6]
# colours	10	3	6	4	5	4	5
# verbal classes[1]	10	6	6	4	5	4	5
Update frequency	daily	daily	daily	daily	daily	hourly	hourly
Pollutant included in Air Quality Index:							
component	PM_{10}	PM_{10}	PM_{10}	PM_{10}[7]	PM_{10}	PM_{10}	PM_{10}[7]
averaging time	24h mean	24h mean	24h mean	daily max of 24h running means	daily max of 1h means[2]	24h running mean	1h mean
component	O_3	O_3	O_3	O_3	O_3	O_3	O_3
averaging time	daily max of 8h running means	daily max of 1h means	daily max of 1h means	daily max of 1h means or of 8h running means[3]	daily max of 1h means	1h mean or 8h running mean[3]	1h mean
component	NO_2	NO_2	NO_2	NO_2	NO_2	NO_2	NO_2
averaging time	daily max of 1h means	daily max of 1h means	daily max of 1h means	daily max of 1h means	daily max of 1h means	1h mean	1h mean
component	SO_2	SO_2	SO_2	SO_2	SO_2[5]	SO_2	SO_2[5]
averaging time	24h mean	daily max of 1h means	daily max of 1h means	15 minute means[4]	daily max of 1h means	1h mean	1h mean
component			CO	CO	CO[5]	CO	CO[5]
averaging time			daily max of 8h running means	daily max of 8h running means	daily max of 8h running means	8h running mean	8h running mean

Table 1, footnotes:

(1) In the UK and by Citeair the classes are labelled by semi-quantitative terms (from *Low/Very low* to *High).* In Begium, France and Germany the classes are labelled in a less neutral, more qualitative way (from *excellent/tres bon/sehr gut* to *horrible/tres mauvais/sehr schlecht*).

(2) The given description of the Citeair index is not clear. In the proposal it reads that for PM_{10} "*max hourly value or daily average value or daily maximum*" is used. This point is under discussion within Citeair. Some of the cities participating in Citeair present only daily averaged PM10 values. On the other hand, hourly values will clearly demonstrate the impact of rush hours and are seen as a better approach in a forecasted AQI. Citeair is now re-analysing their datasets in search for a pragmatic solution. In this report the hourly mean value is used to calculate the index on a hourly basis. When calculating the index on a daily basis, the PM_{10} daily mean value is used. Note that the use of the daily maximum hourly concentration will result in a systematic higher index value.

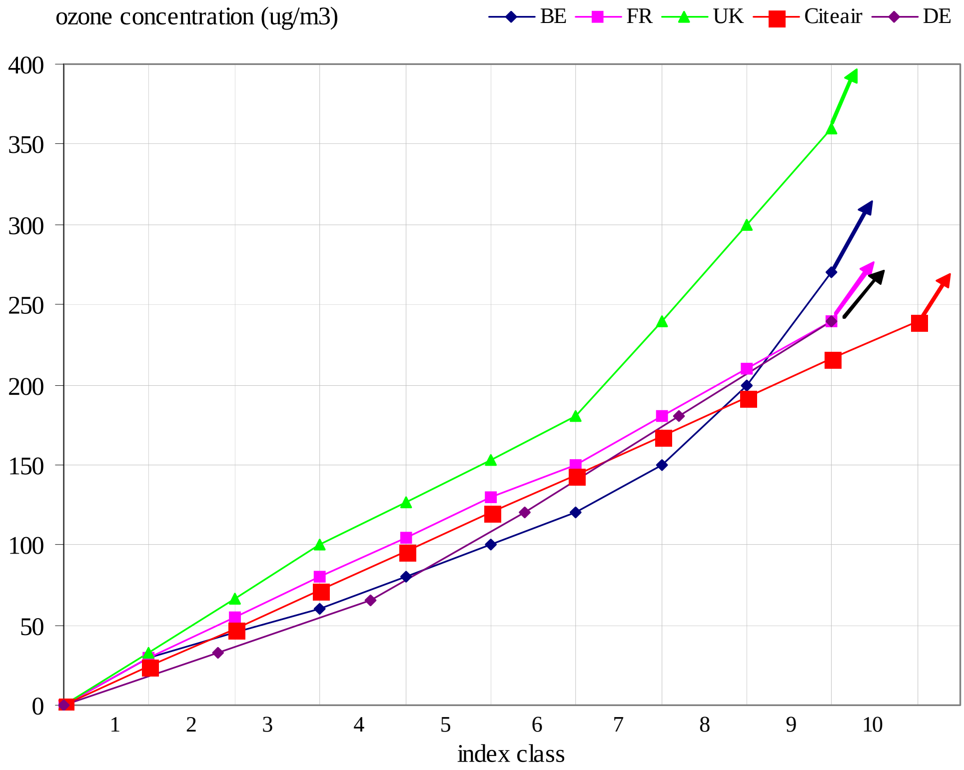
(3) To calculate the hourly sub-index value for ozone, the maximum of the 8 hourly and hourly mean is used. In calculating the daily ozone sub-index, the maximum value of the daily maxima of hourly means and 8 hourly running means is used.

(4) 15 minute mean values are not available in AIRBASE. In this paper we assumed that the maximum 15 minute mean is 20% higher than the hourly mean value.

(5) In the Citeair index , CO and SO_2 are labelled as "additional pollutants".

(6) In the Citeair proposal the index value runs from zero to a maximum of "more then hundred", see footnote 5, page 14. To make these index values more comparable with the other indices, all Citeair index values presented in this report have been divided by 10.

(7) Note that the UK index defines two sets of boundary values for PM_{10} depending on the measuring principle (gravimetric or TEOM). In this report we adopted the numbers given for the gravimetric method as it is assumed that the data delivered to AIRBASE have been converted when appropriate.



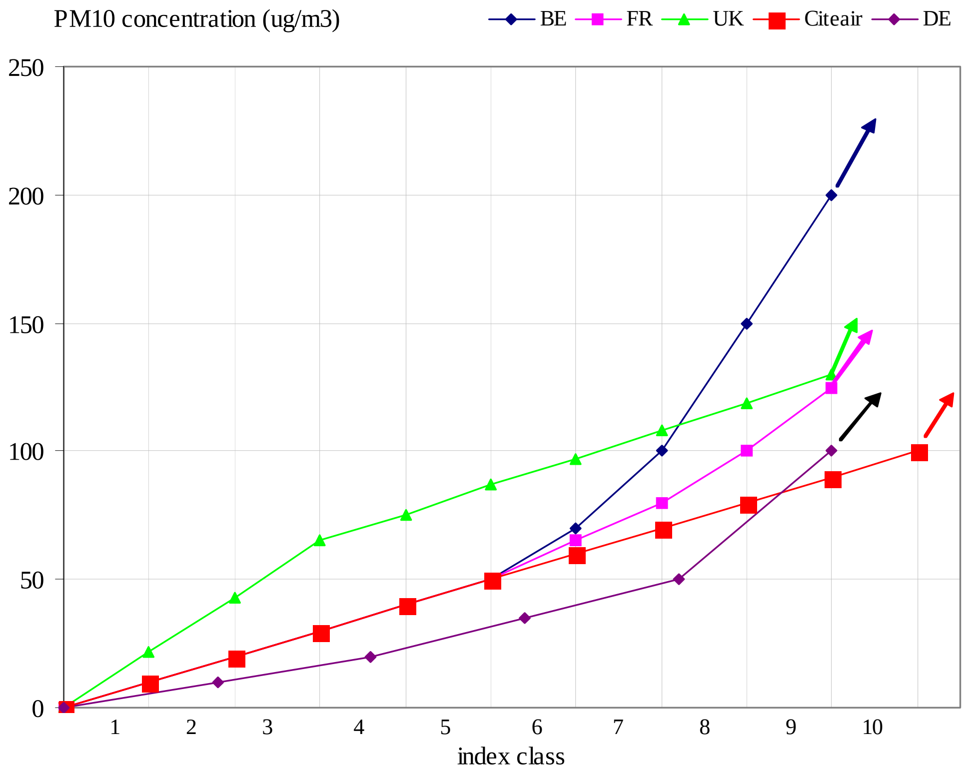


Figure 1. Boundaries between index points for O_3, PM_{10} and NO_2 for each of the selected AQIs. The Citeair and German AQI-classes have been scaled to make them comparable with the other AQIs. The Citeair index has no upper value; the other AQIs have a maximum value of 10 (or, for the German AQI, 6).

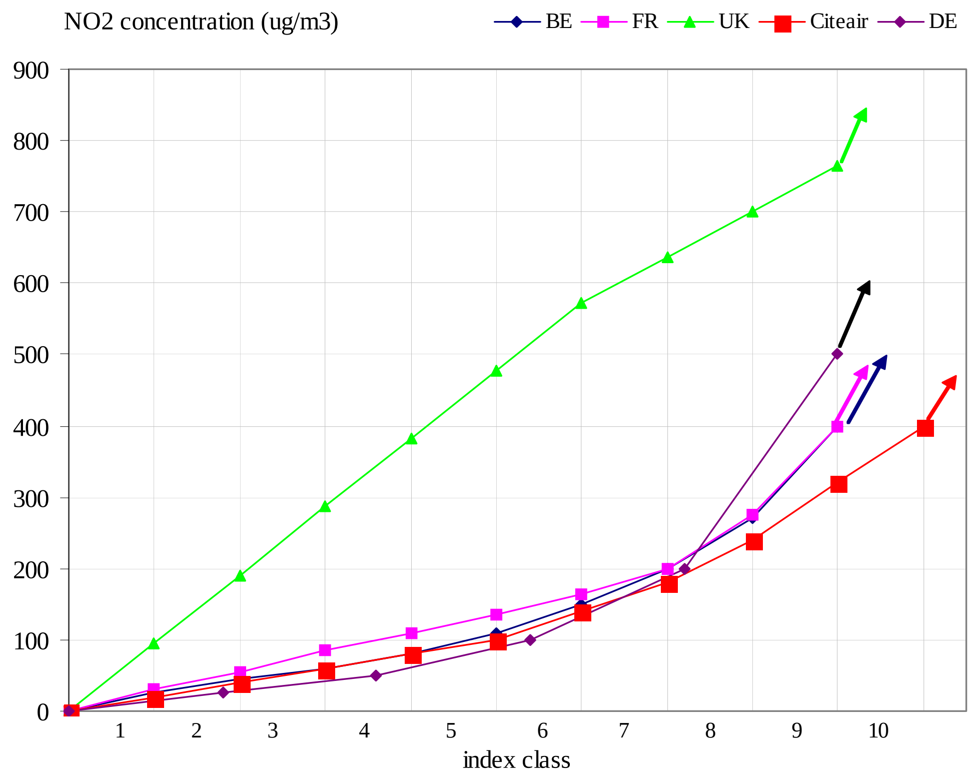


Figure 1. continued.

The general concept of the indices implies that the direct relation between final index value and concentration value of the individual pollutant is lost. From one day to the next different pollutants may be responsible for the index value. One index value can therefore not be associate with one specific air pollutant mix let alone with a specific health effect. The link between index value and possible effects on human health is lost. Index values can only be related to health effects in more general terms.
A second shortcoming of the index approach is that synergistic or antagonistic effects by exposure to a pollutant mixture are neglected. Not the mixture itself but the pollutant having the highest concentration determines the index value. The index may therefore not be a measure of adverse effects. However, as the class bands are usually related to air quality standards, the index identifies the pollutant which is anticipated to have the largest health-effect for that specific day.

The indices are used for providing on-line information to the public and a frequent update of the index is required. The procedure of the UK and Citeair indices enable an hourly update, the daily value equals the maximum hourly value. The other indices are designed for a daily update; an hourly update might be made by using moving 24h-values instead of the daily (0-24h) values. A hourly update of a daily index gives a much more smoothed time series. An hourly may show strong variations caused by large concentration fluctuations in one pollutant, for example PM_{10} or NO_2 shows strong peak during the rush hours.

Table 2 shows that four indices are subdivided in 6 (Germany) or 10 discrete classes. The presentation of the Citeair index differs strongly from the other four indices. It has a continuous scale without an upper limit while the other have discrete values with a well-defined maximum. The advantage of a continuous over a discrete scale is not clear. The

uncertainties in the air quality measurements do not allow to make a difference in an AQI-value of, say, 5.5 and 5.8 which corresponds to a difference in PM10 or ozone concentrations of 3 and 7 µg/m^3, respectively. By using discrete classes this problem is largely overcome. Defining an upper limit for the index value is advisable. Application of the Citeair procedure may result in extreme index values. Further, it is very sensitive for measuring artefacts. In the examples presented below (Chapter 4) , a value of more than 90 is found caused by a reported hourly PM_{10} concentration of 958 µg/m^3. As this is the first valid number after the monitor had an off-line period of more than two days, this might be an artefact. However, during our calculations we have found several more examples giving an index of 20 – 40[5].
In the Belgium and German index the colour codes and the verbal classes parallel the numerical levels. In the UK index each colour is one-to-one associated with an verbal description but one colour/verbal class covers 2-3 numerical levels. In the Citeair index each colour is one-to-one associated with verbal class; having a continuous scale, it is obvious that many index values will fall within one colour/verbal class. The upper and lower bands of the index value for each colour/verbal class are well defined. In the French ATMO index the relations are more complex having ten numerical levels, 3 colours and 6 verbal terms.

The AQI have three components (O_3, NO_2 and PM_{10}) in common. SO_2 is included in all although this component is seen as "additional" in the Citeair index. CO is not included in the Belgium and French ATMO index; it a an additional component in the Citeair index.

The boundaries between index point as shown in Figure 1 shows the difference between the AQI approaches. The figure suggests that, for ozone, the UK index clearly has the least stringent classification. For an ozone concentration of 100-150 µg/m3, the ozone sub-index has a difference of two index points, the low end being given by the UK index while the high end is defined by the Belgian index. However, the comparison is hampered by the differences in averaging period. Belgium applies the daily maximum of the 8h running mean values which is systematically 10-20% lower than the daily maximum hourly values used in the other indices.

The upper boundary of the PM_{10} classification is equal for the Citeair and German index. However, the Citeair description is not clear which PM_{10} parameter should be used here, see also the comments in Table 1; when using the daily maximum of 1h means the Citeair index has the most stringent classification. Considering the 20-25% difference between the daily mean and the daily maximum of 24h running means the UK index will be in line with the German index. The French and to a larger extend the Belgium index, both based on daily mean – have the most relaxed classification. For a PM_{10} concentration of 50 µg/m^3 the subindex ranges from 3 (UK, "low pollution", on a 10-pointscale) to 5 (DE, "bad air quality" on a 6-point scale).

There is consensus on the time averaging of NO_2: all indices are based on the daily maximum of 1h means., however for NO_2 concentrations of 100-200 µg/m^3 a difference in 5-6 index points is found. The upper boundaries in the Belgium, French and Citeair index are equal although the levels of the lower classes differ somewhat. The German and certainly the UK NO_2-subindices are less stringent.

[5] In a later discussion with the Citeair-group (Brussels, 30 September 2005) it became clear that this problem has been solved. In case an index value larger then 100 is calculated it is maximized to a value of 100 and presented to the public as "> 100". In this paper we have not implemented this modification.

4. An AQ Index in my neighbourhood?

The interest in the development of indices for providing information on actual air pollution level is demonstrated by the number of publication on this topic. Within the "in your neighbourhood" project (iYN) one of the goals is to provide information on the state of environment at a local scale anywhere in Europe. With respect to air pollution a start to provide information to the public on the current ozone concentrations has been made several years ago by OzoneWeb (see: http://ozone.eionet.eu.int). Currently work is in progress to extend OzoneWeb with more stations and at the longer run with more pollutants. Parallel with this the ETC/ACC is developing methods for interpolation of air pollution levels which enables the assessment of air quality at location where monitoring data is missing.
When more then one pollutant is available the message to the public becomes more complex and an index approach might be selected. An AQI proving information at the European level as on the iYN-web sites should for a certain area give the same message as the AQI provided by the local air quality monitoring organisation. When large differences are found it will hard to explain to the public why – starting with the same health-related standards – the interpretation is so different at local and at European level. As discussed above, a number of AQI approaches are in use in Europe. The assumptions (Table 2, Figure 1) made in class bands, averaging times, components are so different that an application of the different AQI to the same set of "real-life" air quality data is the only way to compare the AQI's.
From AIRBASE (http://airbase.eionet.eu.int) stations have been selected where all 5 pollutants are measured. To fulfil the requirements for the UK and Citeair AQI, only stations with hourly PM10 data have been selected. Stations have been selected in different regions, see Table 3. The 2003 data has been used to evaluate the AQI's. A characterisation of the selected stations is given in Table 3. As peak concentrations are the most important for the AQI, the station sare characterised by peak concentrations related to the EU limit or target values set for the protection of human health. The UK index requires a 15 minute averaged for SO2. In AIRBASE this value is not available; the hourly mean, increased with 20% was used as proxy for the 15 minute values.
To facilitate the intercomparison in the remaining of this paper the Citeair and German AQI have been scaled with a factor (1/10) and (10/6), respectively.

In a first analysis the AQI have been calculated with and without including the CO and SO2 concentration data. For the selected stations, final index values are only incidentally determined by CO or SO_2 concentrations. Comparing the maximum CO and the 4th highest SO_2 concentration given in Table 3 with the class boundaries given in Annex 1, it is seen that the sub-index both for CO and SO_2 will never be larger than 4, that is, in the class indicated as *low to moderate*. A more detailed analysis on the daily AQI showed that on station GB0566A being the most sensitive for including CO and SO_2 in the AQI, CO and SO_2 determine the final index on about 50-55 days. This will be the days having lower index values and on many days other pollutants will co-determine the final index. Excluding CO and SO_2 change the annual mean index with less than one hundredths index point.

<u>AQI on hourly data</u>.
The UK and Citeair indices are the only two indices which can be applied with a time resolution of one hour. Figure 2 and 3 shows typical results of the hourly development of the two AQI's. Its clear that the UK index is systematically lower that the Citeair-index. The correlation between the two varies between 0.47 to 0.71. As Figure 3 shows there are many confusing situations in which one index qualifies the air pollution as *high to very high* while the other index qualifies it as *very low to low* and vice versa.

Table 3. Selected stations from AIRBASE used in the intercomparison of AQI.

EoI-code	CZ0065A	ES0125A	ES1426A	GB0566A	GB0620A
Station name	Pha5-Smichov	VILLAVERDE	MORATALAZ	LONDON BLOOMSBURY	LONDON N. KENSINGTON
Type of station	Traffic	Traffic	traffic	background	background
Type of area	Urban	Suburban	Urban	urban	Urban
Peak concentrations (1)					
PM_{10}	102.8	68.5	52.1	39.8 (*)	48.2
O_3	108.8	126.6	103	88.8	107.8
NO_2	145	175	147	130	140
SO_2	35.9	20.0	31.8	25.8	21.4
CO	3.27	5.20	4.71	1.76	2.46
EoI-code	GB0682A	GR0035A (2)	NL0204A (3)	NL0248A	NL0249A
Station name	LONDON MARYLEBONE ROAD	Lykovrisi	Amsterdam-Florapark	Breukelen-Snelweg	Wekerom-Riemterdijk
Type of station	traffic	unknown	background	traffic	background
Type of area	Urban	suburban	Urban	Rural	rural
Peak concentrations (1)					
PM_{10}	71	88.8	59.0	61.3	58.0
O_3	52.8	142	100.1	95.5	121.1
NO_2	285	135	114	138	83.8
SO_2	28.5	42.6 (*)	11.3	11.7	8.0
CO	3.74	4.0	2.81	1.64	1.17

(1) Peak concentrations (in μg/m3, CO in mg/m3) related to EU limit or target values are given. For PM_{10} the 36th highest daily mean, for O_3 the 26th highest maximum daily 8h running mean, for NO_2 the 19th highest hourly concentration, for SO_2 the 4th higest daily mean, for CO the maximum value is given.
(2) SO2 concentration data taken from the nearby located (urban traffic) station GR0032Q, Patision.
(3) CO not measured here; CO data is taken from the urban background station NL0208A, Amsterdam Cabeliaustraat.
(*) less then 75% data coverage

AQI on daily basis

Annual mean values of the daily AQI are given in Figure 4. Evidently, the lowest index value is calculated using the UK approach while the highest index values are obtained by the German approach. The Belgium, French and Citeair indices are on an annual basis more or less equivalent. Correlation between the latter three AQI is high (> 0.90); the worst correlation (generally less then 0.7) is found between the UK and German indicator.
The correspondence between indices becomes less when looking in more detail. The pollutant most frequently determining the final index varies from station to station. At the Prague station CZ0065A, PM10 is blamed according to all AQI as the most important, certainly for days with index values higher then 5. At the London-Marylebone Road station, GB0682A, conclusions are less clear. According to the UK index, air pollution is dominated by PM10, according to the BE, FR and Citeair index there is a NO2 problem while following the DE index it is a combined NO2/PM10 problem. Also at the other stations the UK index underestimates the importance of NO2 in comparison with the other AQI. Difference between AQI are even better seen at daily basis; differences as larges as 3 to 4 index points are noted; it is not uncommon that the AQI put the blame on different pollutants.

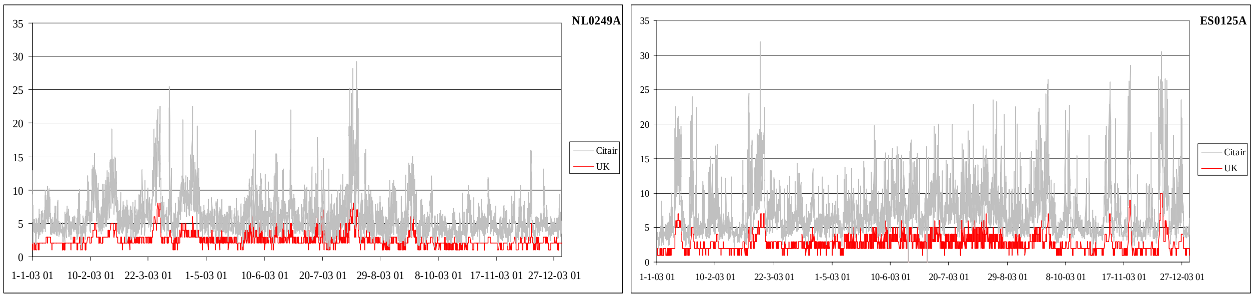


Figure 2. Hourly variation of the UK and Citeair index at the stations NL0249A (rural background) and ES0125A (suburban traffic).

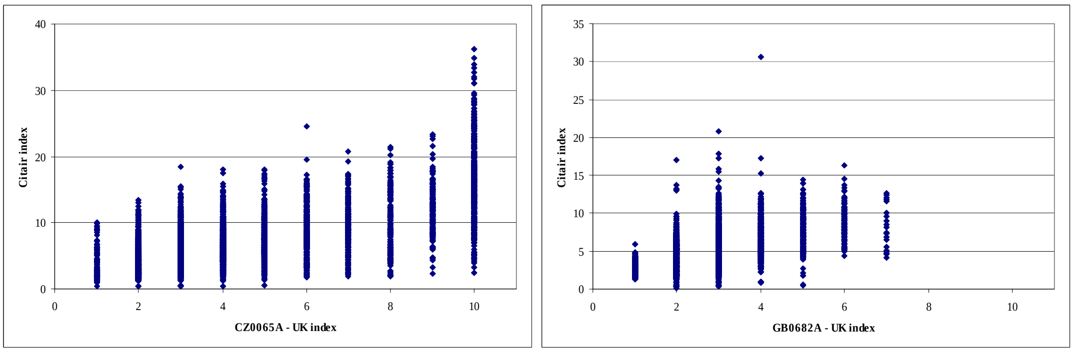


Figure 3. Scatter plots of the UK versus the Citeair index values (hourly data) for the station CZ0065A.

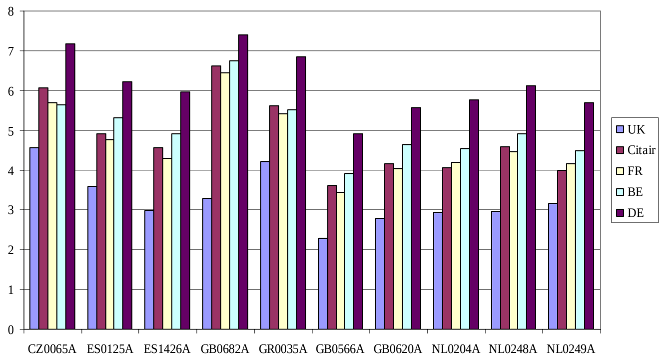


Figure 4. Annual mean values of the AQI (based on daily values) calculated for the selected monitoring stations.

5. Discussion & Conclusions

Air Quality Index is a relatively simple instrument which enables the communication with the general public on air quality. AQI generally use 6-10 different classes where the class bands are based on some health-related standards. An index value combined with a short qualitative description and the use of colours will strengthen the message. A more extensive description of possible health effects for each of the classes should be part the information package made available to the public. This will be a difficult task as widely different air pollution mixtures leading to different effects, may result in the same index value.

A summary of AQI in use in various European countries shows that although the basic concepts are similar, the AQI show large differences in practical implementation. Differences are found in nearly all conceptual parts: number of index classes, their associated colour and descriptive terms, in the pollutants considered, in class bounds, in averaging times, in update frequency. When applying the AQIs on a common set of air quality data extracted from AIRBASE, large differences in index value and the determining pollutant are found. When for one region an air quality index is provided both by the local environmental agency as well as on the European level by the EEA, it is to be expected that the public receives conflicting, at least confusing messages when both agencies use different AQI-methodologies. There is a need for a more harmonised Air Quality Index which enables an easy comparison between regions in Europe.

The systematic review of health aspects of air pollution[6], prepared by WHO for the EU-CAFE programmer, clearly showed that, with respect to health impacts the long-term exposure to air pollution, in particular of particulate matter and ozone is of more concern than the short-term exposure. These long-term effects are generally not well covered by the Air Quality Indices and a revison of the AQI might be needed.

None of the AQI discussed in this paper includes PM2.5. However, by the growing evidence on the health impact of smaller particles and the growing number of PM2.5 monitoring stations it might be considered to include in the AQI a PM2.5 sub-index. This might either be in addition to or in stead of the PM10 sub-index.

The development of the AQI over time might not a correct representation of the changes in air quality. The index is determined by the pollutant having the highest sub-index. When the problems with this pollutant are rather persistent (like for PM10), improvements in air quality caused by lower concentrations of other pollutants are not reflected in the AQI.

Given the definition of the current AQI, CO and SO2 are of minor importance in determining the final index values. In setting up a near on-line data exchange programme between member countries focus should be on ozone, PM10 and NO2.

All AQI studied here are based on the maximum value of sub-index values calculated for each of the pollutants considered. If calculating the index value for a certain area, the maximum value at all operational monitoring station is taken. Basing the index on maximum values makes it prone to monitoring errors. In on-line applications, working with non-validated data increases this risk. On the other hand, when an upper index value is defined, the impact of extreme measurements is damped. When applying the index to an urban agglomeration, it is recommended to use concentrations averaged over several stations. In this way, the index value will be more representative for the urban region as a whole and it will be less sensitive for monitoring artefacts.

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[6] See: http://www.euro.who.int/eprise/main/WHO/Progs/AIQ/activities/20030528_3

As alternative a cumulative index based on the addition of scaled concentrations of 4-6 pollutants has been proposed. When using monitoring data, a cumulative index is very sensitive for missing values and should therefore not be regarded.

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Annex 1. Examples of Air Quality Indices

Short descriptions of Air Quality Indiced as in use by France, United Kingdom , Belgium and Germany. This information has recently been extracted from the national air quality web sites. If no English version was available at the internet, the descriptions have not been translated to avoid any subjective (mis)interpretation of the terminology of the indices.
The aim of this annex is to illustrate the different approaches used by the various countries to construct an air quality index. This annex is not aiming at presenting a complete overview of the air quality indices in use in Europe and other region. More extended review are presented by Garcia and Colosio (2002) and US-EPA (2002).

France: the ATMO Index

(http://www.airparif.asso.fr/page.php?article=atmo&rubrique=indices; a daily AQI calculated for each of the 40 French networks is available on: http://www.buldair.org; this web site, specially developed to serve the general public provides further background information on air quality and a link to the web sites of the local networks)

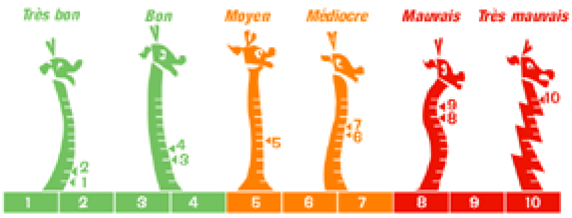
ATMO : un chiffre pour tout savoir

L'indice ATMO caractérise la qualité de l'air globale pour l'ensemble de l'agglomération parisienne

L'indice ATMO concerne toutes les grandes agglomérations de plus de 100 000 habitants. Cet indice et son mode de calcul sont précisément définis au niveau national par l'**arrêté du Ministère de l'Écologie et du Développement durable du 22 juillet 2004** (qui annule et remplace les précédents arrêtés relatifs à l'indice de qualité de l'air du 10 janvier 2000 et du 25 juillet 2001, voir ATMO change de peau.

Cet indice est déterminé à partir des niveaux de pollution mesurés au cours de la journée par les stations de fond urbaines et périurbaines de l'agglomération et prend en compte les différents polluants atmosphériques, traceurs des activités de transport, urbaines et industrielles.

Le type de site de mesure pris en compte est précisément défini : il s'agit de sites de fond situés dans les zones fortement peuplées de l'agglomération parisienne.



Dans son calcul interviennent :

- le dioxyde de soufre (d'origine industrielle)
- les poussières (d'origine industrielle, liée au transport et au chauffage)
- le dioxyde d'azote (lié aux transports, aux activités de combustion et de chauffage)
- l'ozone (polluant secondaire issu principalement des transports et de l'utilisation des solvants et des hydrocarbures)

Pour chaque polluant un sous-indice est calculé. Chaque sous-indice est déterminé chaque jour à partir d'une moyenne des niveaux du polluant considéré sur l'ensemble des stations retenues.
Pour les particules, on prend la concentration moyenne journalière sur chaque site.
Pour le dioxyde de soufre, le dioxyde d'azote et l'ozone, c'est la concentration maximale horaire du jour qui est relevée sur chaque site.
C'est le sous-indice maximal qui est choisi comme indice ATMO final caractérisant le qualité de l'air globale de la journée considérée.

cliquez ici pour accéder à la grille des sous-indices

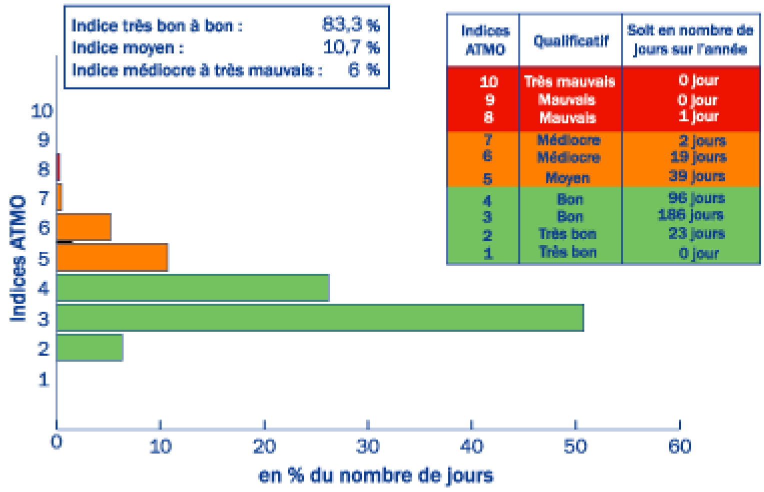
L'indice de qualité de l'air ATMO est en fait un chiffre allant de 1 à 10 associé à un qualificatif (de très bon à très mauvais)

Chaque jour à 11h30, une prévision de l'indice ATMO est réalisée pour le jour même et pour le lendemain disponible sur internet. Un bilan de l'indice à la mi-journée est calculé à 17h00. L'indice définitif de la journée est connu le lendemain dès 9h30.

L'indice prévu pour la journée en cours et le lendemain est par ailleurs annoncé chaque jour à la fin du journal régional de France 3, sur le télétexte de France 2 et dans différents quotidiens (le figaro, le parisien, ...), repris par de nombreuses radios qui émettent en Ile-de-France (Skyrock, BFM, ...) et sur les 170 panneaux d'information de la Ville de Paris.

Une information sur la qualité de l'air est diffusée quotidiennement depuis 1992 par AIRPARIF et s'est vue remplacée depuis 1995 par l'indice national ATMO.

Répartition de l'indice ATMO selon ses différentes classes pour l'année 2004



Grilles - Microsoft Internet Explorer

Grilles de calcul des 4 sous-indices

Moyenne des moyennes journalières des différents sites

sous-indice Particules	seuil min. en µg/m3	seuil max. en µg/m3
1	0	9
2	10	19
3	20	29
4	30	39
5	40	49
6	50	64
7	65	79
8	80	99
9	100	124
10	> = 125	

Moyenne des maximas horaires des différents sites

sous-indice NO2	seuil min. en µg/m3	seuil max. en µg/m3
1	0	29
2	30	54
3	55	84
4	85	109
5	110	134
6	135	164
7	165	199
8	200	274
9	275	399
10	> = 400	

Moyenne des maximas horaires des différents sites

sous-indice O3	seuil min. en µg/m3	seuil max. en µg/m3
1	0	29
2	30	54
3	55	79
4	80	104
5	105	129
6	130	149
7	150	179
8	180	209
9	210	239
10	> = 240	

Moyenne des maximas horaires des différents sites

sous-indice SO2	seuil min. en µg/m3	seuil max. en µg/m3
1	0	39
2	40	79
3	80	119
4	120	159
5	160	199
6	200	249
7	250	299
8	300	399
9	400	499
10	> = 500	

United Kingdom: Air Quality Index

(source: http://www.airquality.co.uk/archive/standards.php#band)

Air Pollution Bandings and Index and the Impact on the Health of People who are Sensitive to Air Pollution

Banding	Index	Health Descriptor
Low	1, 2, 3	Effects are unlikely to be noticed even by individuals who know they are sensitive to air pollutants
Moderate	4, 5, 6	Mild effects, unlikely to require action, may be noticed amongst sensitive individuals.
High	7, 8, 9	Significant effects may be noticed by sensitive individuals and action to avoid or reduce these effects may be needed (e.g. reducing exposure by spending less time in polluted areas outdoors). Asthmatics will find that their 'reliever' inhaler is likely to reverse the effects on the lung.
Very High	10	The effects on sensitive individuals described for 'High' levels of pollution may worsen.

Boundaries Between Index Points for Each Pollutant

Band	Index	Ozone		Nitrogen Dioxide		Sulphur Dioxide		Carbon Monoxide		PM10 Particles	
		8 hourly running mean or hourly mean*		hourly mean		15 minute mean		8 hour running mean		24 hour running mean	
		µgm-3	ppb	µgm-3	ppb	µgm-3	ppb	mgm-3	ppm	µgm-3 (Grav. Equiv.)	µgm-3 (TEOM)
Low											
	1	0-32	0-16	0-95	0-49	0-88	0-32	0-3.8	0.0-3.2	0-21	0-16
	2	33-66	17-32	96-190	50-99	89-176	33-66	3.9-7.6	3.3-6.6	22-42	17-32
	3	67-99	33-49	191-286	100-149	177-265	67-99	7.7-11.5	6.7-9.9	43-64	33-49
Moderate											
	4	100-126	50-62	287-381	150-199	266-354	100-132	11.6-13.4	10.0-11.5	65-74	50-57
	5	127-152	63-76	382-477	200-249	355-442	133-166	13.5-15.4	11.6-13.2	75-86	58-66
	6	153-179	77-89	478-572	250-299	443-531	167-199	15.5-17.3	13.3-14.9	87-96	67-74
High											
	7	180-239	90-119	573-635	300-332	532-708	200-266	17.4-19.2	15.0-16.5	97-107	75-82
	8	240-299	120-149	636-700	333-366	709-886	267-332	19.3-21.2	16.6-18.2	108-118	83-91

	9	**300-359**	**150-179**	**701-763**	**367-399**	**887-1063**	**333-399**	**21.3-23.1**	**18.3-19.9**	**119-129**	**92-99**
Very High											
	10	**360 or more**	**180 or more**	**764 or more**	**400 or more**	**1064 or more**	**400 or more**	**23.2 or more**	**20 or more**	**130 or more**	**100 or more**
* For ozone, the maximum of the 8 hourly and hourly mean is used to calculate the index value.											

The overall index describes air pollution on the basis of the highest band for any individual pollutant.

“Belgium Air Quality Index

source: http://www.irceline.be/~celinair/english/abindex_en.html

Definition of the air quality index

The index gathers as one representative number the concentrations of several polluants in ambient air. It is scaled from 1 (excellent air quality) to 10 (awful quality). The computation is performed by using data obtained from the telemetric networks that measure continuously the air quality in the 3 Regions. The index is thus a understandable representation of the measurement technical results for most of the public, allowing a global understanding of the ambient air quality.

Two indicies by Region

Two indices are computed daily for each Region : the general air pollution index and the urban air pollution index. The general index deals with the whole territory of the Region whereas the urban index deals with the urban centers of the main cities in the Region.

Which pollutants are used to compute the index?

The two indices (general as well as urban) are based on the concentrations of O3, NO2, SO2 and PM10 particles. A "characteristic value" is computed every day for these 4 pollutants and then compared to a concentration scale.
The concentration scales are based on the new European guidelines concerning the assessment and management of ambient air quality.
Based on the number of allowed exceedances of the new European limit values, an index value of 6, 7 or 8 is assigned to that limit value. The other scale divisions were defined by evaluating the range of concentrations measured in the telemetric networks of the three Belgian Regions.
The table below shows, for each pollutant, the relation between the measured concentrations mesured (in µg/m³), the index value and the corresponding scale.

Pollutant		µg/m³										
SO_2	24h average	0	15	30	45	60	80	100	125	165	250	> 250
NO_2	hourly max	0	25	45	60	80	110	150	200	270	400	> 400
O_3	max 8-hour average	0	30	45	60	80	100	120	150	200	270	> 270
PM10	24h average	0	10	20	30	40	50	70	100	150	200	> 200
	index	1		2	3	4	5	6	7	8	9	10
	rating	exellent		very good	good	fairly good	moderate	poor	very poor	bad	very bad	horrible

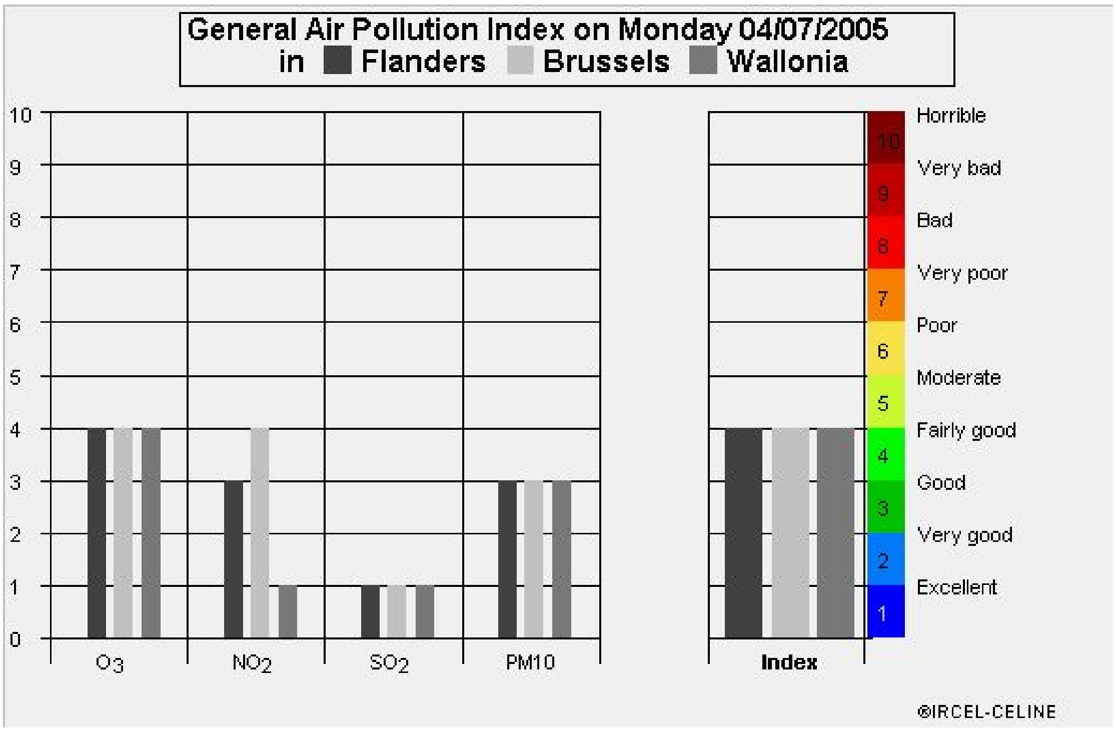
Which stations are used to compute the index ?

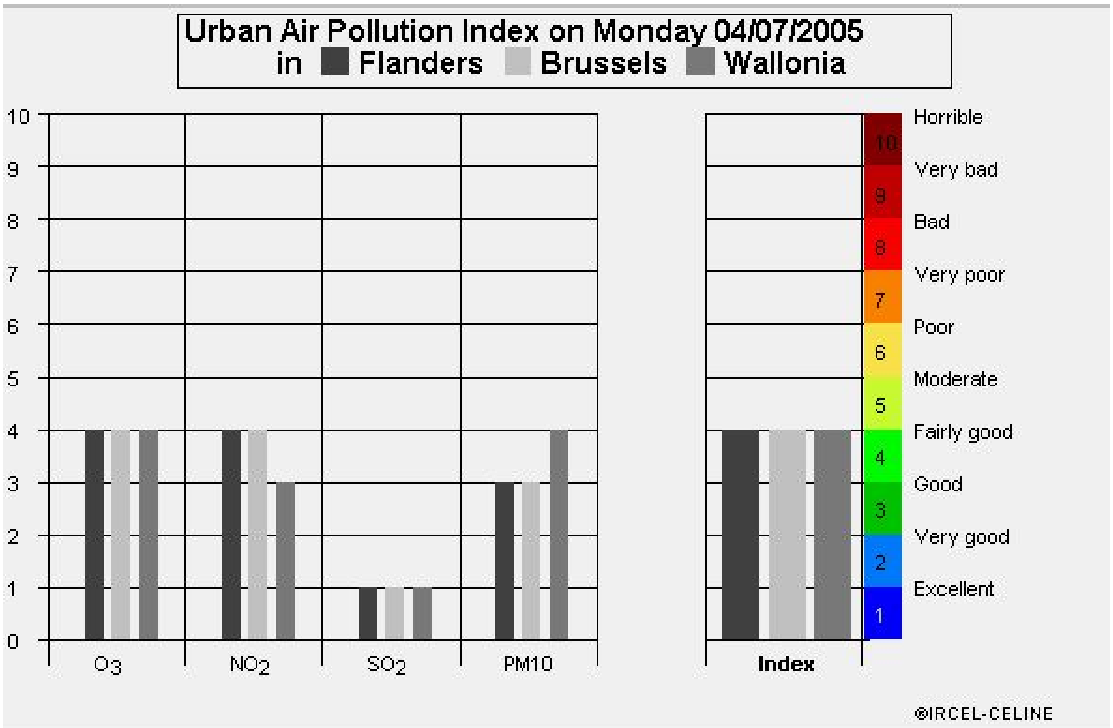
The "characteristic value" for a given pollutant, for the whole Region or for the urban centers is obtained by computation of the average of the concentrations measured in some representative stations. As far as the general index is concerned, all the stations of the Region are involved in the computation but for the urban index, one only uses the stations that are located in the urban centres. The characteristic value for each pollutant (also called sub-index) is presented, by Region, in the first four columns of the graphics. The characteristic value is however not computed when more than one half of the data are missing. The quality index is equal to the highest sub-index (i.e. the worst air quality) of the sub-indices of the 4 pollutants. The index is not computed whenever a sub-index is missing.

Warning

The index is only a qualitative representation of the ambient air quality. It has little scientific meaning. Reports, studies and other scientific interpretations should only be performed by using measurement data.

Some examples:





Germany: Air Quality Index

Source: http://www.umwelt.niedersachsen.de/master/C9751204_N9725376_L20_D0_I598.html

Definition und Berechnungsverfahren

Der Luftqualitätsindex (LQI) ist ein aggregierter Indikator, der auf der Basis von Einzelschadstoffmessungen für die Luftschadstoffe Stickstoffdioxid (NO2), Schwefeldioxid (SO2), Kohlenmonoxid (CO), Ozon (O3) sowie der Schwebstaubfraktion PM10 gebildet wird. Der LQI berücksichtigt insbesondere die gesundheitliche Relevanz der einzelnen Luftschadstoffe. Die an ausgewählten stationären Messstationen gemessenen Konzentrationen der Schadstoffe werden täglich jeweils in eine von 6 Indexklassen eingruppiert, die an das Schulnotensystem angelehnt sind. Die Indexkassen sind dabei für jeden der 5 Luftschadstoffe unter Berücksichtigung epidemiologischer und toxikologischer Untersuchungen sowie Eu-Grenzwerten nach der Luftqualitäts-Rahmenrichtlinie 96/62/EG und deren Tochterrichtlinien abgeleitet. der Kurzzeit-Luftqualitätsindex ist dann definiert als der höchste Einzelstoff-Indexwert

Klassengrenzen für den Luftqulitätsindex LQI

Bewertung	Index	NO2 1-h-Mittelwert (µg/m³)	SO2 1-h-Mittelwert (µg/m³)	CO 8-h-Mittelwert (mg/m³)	O3 1-h-Mittelwert (µg/m³)	PM10 24-h-Mittelwert (µg/m³)
sehr gut	1	0 - 24	0 - 24	0 - 0,9	0 - 32	0 - 9
gut	2	25 - 49	25 - 49	1,0 - 1,9	33 - 64	10 - 19
befriedigend	3	50 - 99	50 - 119	2,0 - 3,9	65 - 119	20 - 34
ausreichend	4	100 - 199	120 - 349	4,0 - 9,9	120 - 179	35 - 49
schlecht	5	200 - 499	350 - 999	10,0 - 29,9	180 - 239	50 - 99
sehr schlecht	6	500 -	1000 -	30,0 -	240 -	100 -

- Es werden die an einem Tag gemessenen maximalen 1-Stunden-Mittelwerte von NO2, SO2 und O3, der maximale gleitende 8-Stunden-Mittelwert von CO sowie der 24-Stunden-Mittelwert für die Schwebstaubfraktion PM10 herangezogen.
- Die jeweiligen Konzentrationswerte der einzelnen Luftschadstoffe werden entsprechend den abgeleiteten Klassengrenzen in eine Indexklasse eingeordnet.
- Der Luftqualitätsindex wird definiert als die höchste besetzbare Indexklasse, in die ein oder mehrere Luftschadstoffe eingeordnet wurden.
- Der Luftqualitätsindex wird als Indexzahl (ohne Nachkommastelle) zusammen mit der Bewertungskategorie angegeben.
- Zur genaueren Information werden die beiden am höchsten eingeordneten Schadstoffe mit ihrer Indexklasse angegeben, z.B. LQI: 5 "schlecht" (O3: Indexklasse 5; NO2: Indexklasse 3).
- Zur Ermittlung der Rangordnung bei mehreren Luftschadstoffen in der höchsten Indexklasse, zur Verdeutlichung der Lage eines Konzentrationswertes innerhalb einer Indexklasse (z.B. bei graphischen Darstellungen) und zur Ermittlung von Durchschnittswerten über einen längeren Zeitraum werden durch lineare Interpolation innerhalb der Indexklasse Zwischenwerte (gerundet auf eine Nachkommastelle) berechnet.

Index	Information	Spezifische Information zu einzelnen Luftschadstoffen

1	Keine nachteilige Wirkung auf die Menschliche Gesundheit	-
2	Keine nachteilige Wirkung auf die Menschliche Gesundheit	-
3	Kurzfristige nachteilige Wirkungen auf die Menschliche Gesundheit sind unwahrscheinlich; allerdings können Gesundheitseffekte durch Luftschadstoffkombinationen und langfristige Einwirkung des Einzelstoffes nicht ausgeschlossen werden	-
4	In Kombination mit weiteren. Luftschadstoffen in höherer Konzentration oder weiteren eine Reaktion der Atemorgane auslösenden Reizen, können geringgradige Gesundheitseffekte bei empfindlichen Personengruppen auftreten	Empfindliche Personengruppe: SO_2: Asthmatiker (Verstärkung von Symptomen z.B. in Verbindung mit Pollenexposition möglich) NO_2: Asthmatiker (Verstärkung von Symptomen z.B. in Verbindung mit Pollenexposition möglich) CO: Patienten mit koronarer Herzkrankheit (Verstärkung von Symptomen möglich) O_3: Ozonempfindliche Personen (sind in allen Bevölkerungsgruppen etwa gleich häufig) Verstärkung von Symptomen bei zusätzlich bestehenden Erkrankungen der Atemwege möglich PM_{10}: Asthmatiker (Verstärkung von Symptomen z.B. in Verbindung mit Pollenexposition möglich) Verhaltensempfehlungen: Empfindliche Personengruppen sollten längerdauernde körperliche Anstrengungen im Freien reduzieren
5	Es können nachteilige Gesundheitseffekte bei empfindlichen Personengruppen sowie in Kombination mit weiteren Luftschadstoffen auch bei weniger empfindlichen Personen auftauchen	Empfindliche Personengruppe: SO_2: Asthmatiker (Verstärktes Auftreten von Symptomen wahrscheinlich) NO_2: Asthmatiker (Verstärktes Auftreten von Symptomen wahrscheinlich) CO: Patienten mit koronarer Herzkrankheit (Verstärktes Auftreten von Symptomen wahrscheinlich) O_3: Ozonempfindliche Personen (sind in allen Bevölkerungsgruppen etwa gleich häufig) (Verstärktes Auftreten von Symptomen an den Atemwegen wahrscheinlich) PM_{10}: Asthmatiker (Verstärktes Auftreten von Symptomen wahrscheinlich) Verhaltensempfehlungen: Empfindliche Personengruppen sollten körperliche Anstrengungen im Freien vermeiden, andere Personengruppen sollten längerdauernde körperliche Anstrengungen im Freien vermeiden

6	Nachteilige Gesundheitseffekte bei empfindlichen Personengruppen sind wahrscheinlich und auch weniger empfindlichen Personen möglich	Empfindliche Personengruppe: SO_2: Asthmatiker (Verstärktes Auftreten von Symptomen wahrscheinlich) und weniger empfindliche Personen (Atemwegssymptome bei Personen mit Herz-/Lungenerkrankungen wahrscheinlich) NO_2: Asthmatiker (Verstärktes Auftreten von Symptomen wahrscheinlich) und weniger empfindliche Personen (Atemwegssymptome bei Personen mit Herz-/Lungenerkrankungen wahrscheinlich) CO: Patienten mit koronarer Herzkrankheit (Auslösung von Symptomen wahrscheinlich) und weniger empfindliche Personen (geringgradige Wirkung auf Funktionen des Zentralnervensystems) O_3: Ozonempfindliche Personen (sind in allen Bevölkerungsgruppen etwa gleich häufig) (Auslösung von Symptomen an den Atemwegen wahrscheinlich) und weniger empfindliche Personen (Auslösung von Atemwegssymptomen möglich) PM_{10}: Asthmatiker (Verstärktes Auftreten von Symptomen wahrscheinlich) und weniger empfindliche Personen (Symptome insbesondere bei Personen mit Herz-/Lungenerkrankungen wahrscheinlich) Verhaltensempfehlungen: Empfindliche Personengruppen sollten körperliche Anstrengungen im Freien vermeiden, andere Personengruppen sollten den Aufenthalt im Freien reduzieren

Aktueller Tages-Luftqualitätsindex (TQL)
für den ....

TQL: 4 (ausreichend)

Wirkungen:

In Kombination mit weiteren. Luftschadstoffen in höherer Konzentration oder weiteren eine Reaktion der Atemorgane auslösenden Reizen, können geringgradige Gesundheitseffekte bei empfindlichen Personengruppen auftreten

Empfindliche Personengruppe:

Ozonempfindliche Personen (sind in allen Bevölkerungsgruppen etwa gleich häufig) Verstärkung von Symptomen bei zusätzlich bestehenden Erkrankungen der Atemwege möglich

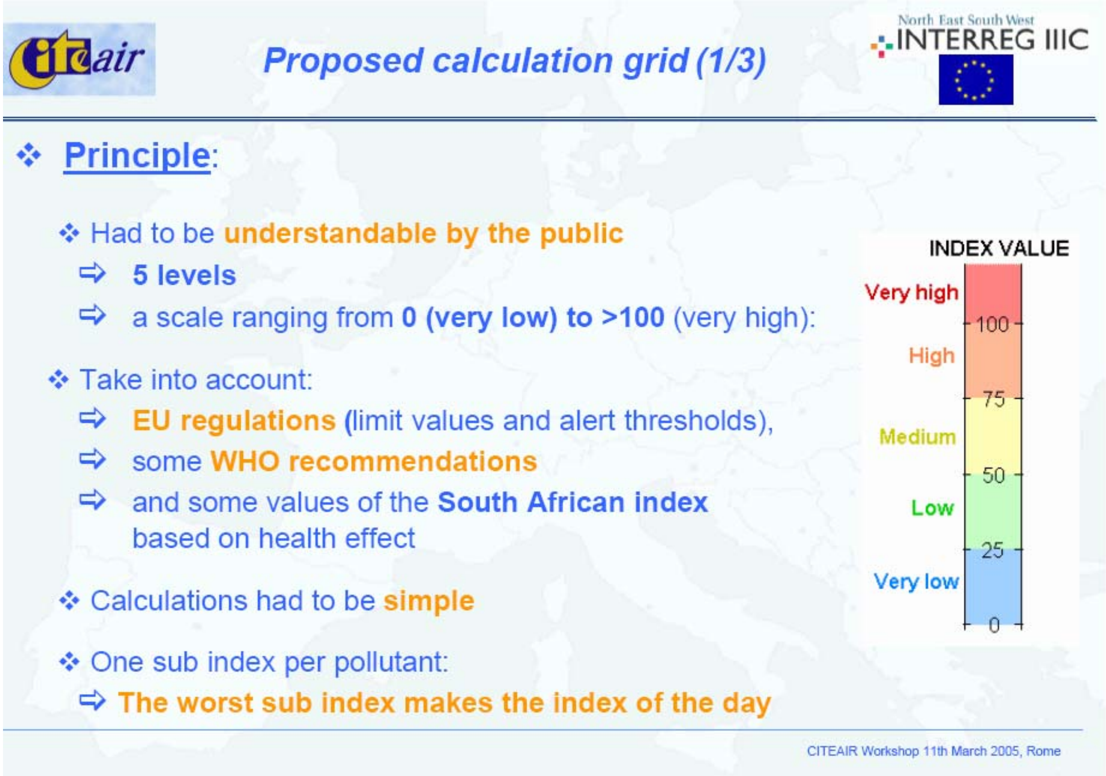
Verhaltensempfehlungen:

Empfindliche Personengruppen sollten längerdauernde körperliche Anstrengungen im Freien reduzieren

1: sehr gut, **2:** gut, **3:** befriedigend, **4:** ausreichend, **5:** schlecht, **6:** sehr schlecht

CITEAIR

Within the CITEAIR-project (see http://citeair.rec.org/index.html for further information) the following air quality index has been proposed (see http://citeair.rec.org/downloads/Workshop-Rome/Session2-AQ-Index-Karine-Leger.pdf)



Proposed calculation grid (2/3)

North East South West INTERREG IIIC

Index	Class	Main pollutants			Additional pollutants	
		NO2	O3	PM10	CO	SO2
Very low	0	0	0	0	0	0
	25	50	60	25	5000	50
Low	25	50	60	25	5000	50
	50	100	120	50	7500	100
Medium	50	100	120	50	7500	100
	75	200	180	75	10000	300
High	75	200	180	75	10000	300
	100	400	240	100	20000	500
Very high	> 100	>400	> 240	> 100	> 20000	> 500

- NO2, O3, SO2: max hourly value
- PM10: max hourly value or daily average value or daily maximum
- CO : 8 hours moving average maximal value

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Proposed calculation grid (3/3)

North East South West INTERREG IIIC

Conversion between the concentration and the sub-index by pollutant

[SO2] : hourly maximal value
- For 0 < [SO2]< 50 and 50 < [SO2]< 100 → *index = ½ [SO2]*
- For 100 < [SO2]< 300 and 300 < [SO2]< 500 → *index = 1/8 [SO2]+37.5*
- For and [SO2]> 500 → *index = 1/5 [SO2]*

[NO2] : hourly maximal value
- For 0 < [NO2]< 100 → *index = ½ [NO2]*
- For 100 < [NO2]< 200 → *index = 1/4 [NO2]+25*
- For 200 < [NO2]< 400 → *index = 1/8 [NO2]+50*
- For [NO2]> 400 → *index = 1/4 [NO2]*

[O3] : hourly maximal value

→ *index = 5/12 [O3]*

[PM10] : daily maximal value

→ *index = [PM10]*

[CO] : 8hours moving average maximal value
- For 0 < [CO]< 5000 → *index = 1/200 [CO]*
- For 5000 < [CO]< 7500 and 7500 < [CO]< 10000 → *index = 1/100 [CO]-25*
- For 10000 < [CO]< 20000 → *index = 1/400 [CO]+50*
- For [CO]> 20000 → *index = 1/200 [CO]*

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