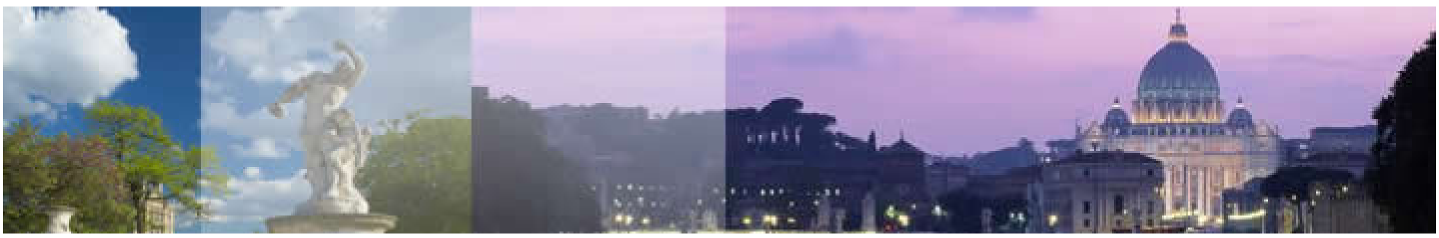
# Comparing Urban Air Quality Across Borders

## A review of existing air quality indices and the proposal of a common alternative



# Component 3

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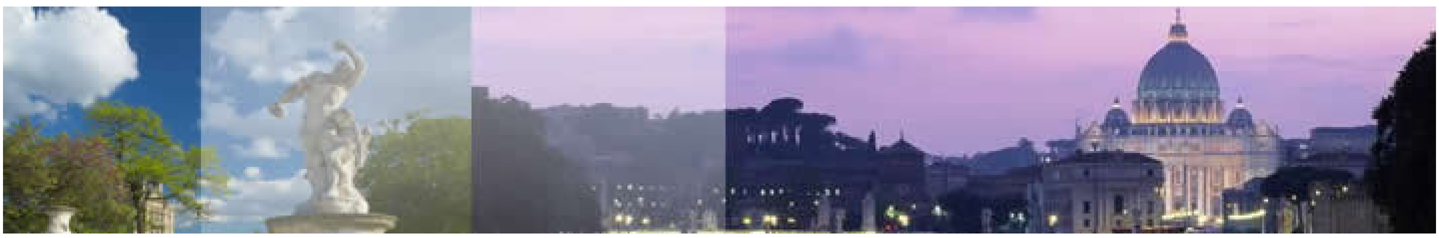

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# Foreword

This document is based on a paper presented in 2005 in Istanbul, during the 3rd International Symposium on Air Quality Management at Urban, Regional and Global Scales (Elshout, et al.). It is one of the products of the CITEAIR project (see annex 5).

The first four chapters follow the sections of the AQM2005 paper and present a review of a number of existing air quality indices (chapter 2); the difficulties of comparing cities in different countries in real time (chapter 3) and the proposal of a common, international, index that facilitates comparing cities in different countries in real time (chapter 4). The near real time index was part of a review by EEA.(de Leeuw and Mol, 2005). Chapter 5 is new and discusses the potential of an index characterising year average values. As the indices described in this document are the product of a project, chapter 6 dwells on the likely future developments. Lastly, an annex detailing a number of indices collected during the development of the CITEAIR common index is added.

This document and the proposed indices have been revised a number of times. It is still a work in progress but continuous revision of the indices is not an option once they are being used. This doesn't mean that this is final and comments are not welcome, it means that we will collect experiences and if there is a need for revision (see chapter 6) it will be done at the end of the CITEAIR project. Hence the cryptic description "draft final". Anyone considering to use the index is kindly requested to register their names (at caqi@airqualitynow.eu, see chapter 6). This way, users can be kept informed in case of developments concerning the index.

## Acknowledgements

Thanks are due to a number of people who have commented on the way the calculation of the grids was done: Frank de Leeuw from the European Topic Centre for Air Quality and Climate Change, Martin Lutz from the City of Berlin and Frans Fierens from the Belgian Interregional Cell for the Environment.

# 1 Introduction

The Framework directive and associated daughter directives on air quality in the European Union not only force member states to monitor and report on their air quality but also to actively inform the public on the status of the ambient air quality. The Aarhus convention (ratified by the EU in 2005) further enforces the concept that citizens have the right to be informed on the environmental conditions they live and work in. Over the past years a good number of cities and countries have started to display monitored or modelled air quality data on the internet. For most of the monitoring organisations, the internet is the easiest way to meet the dissemination of information requirements of the European (and/or national) legislation. The fact that so much air quality information is available on the internet makes it tempting to compare different cities in different countries. This proves particularly difficult. Apart from the European Environmental Agency's ozone website there are no possibilities to compare cities/countries side by side (EEA, web ref.). Even if one surfs from one site to the other, comparison is not easy: air quality is presented in different ways using different interpretation criteria and a different typology of stations, which is usually not clearly explained.

The most widespread way to interpret air quality on websites is the use of an index ranging from good to bad to make the detailed measurements in micrograms more understandable for the general public. A review of existing websites and the associated air quality indices shows that the way air quality is interpreted differs considerably across the world. More surprisingly, even amongst the EU member states who share common legislation, the indices used do vary. There are a number of reasons to explain these differences. Some of them are historical and conceptual: the index existed before the EU regulations came into force and the index was based on health and exposure criteria, e.g. the UK index (DEFRA, web ref.). The fact that air quality problems (sources, meteorological conditions, etc.) tend to differ is also one of the reasons. The indices tend to be calibrated to the local situation to make sure that there is some variation in the index from day to day (to make it entice repeated visits to a website) and that the typical range of pollutant conditions occurring locally is being covered.

To facilitate the international comparison of (near real time) air quality the CITEAIR[1] project has developed a common operational website (www.airqualitynow.eu) where cities can display their air quality information side by side. The project aims at making air quality comparable across Europe and www.airqualitynow.eu will be open for any city to join. The website will be available by mid 2006. The common website needs a common air quality index (CAQI). The CAQI is *not* aimed at replacing existing local indices. This would be an unrealistic ambition as in many cities the public has got used to the local, tailor-made index, and the CAQI will be, by the nature of the fact that is common, a non-specific compromise. CITEAIR envisages that there is room for two sources of air quality information on the internet: a local website[2], in the national language with a dedicated presentation (using a well established and known local index relying on more detailed air quality information); and a common website aimed at comparing - in near real time - the air quality in your own city to the air quality in other European cities. The comparison possibilities offered to the public are on an hourly, daily and yearly basis and the indices were developed keeping in mind that the general public is the end user.

[1] More information on CITEAIR and its products is available in annex 5 and at http://citeair.rec.org

[2] Occasionally, websites are used to inform people for pollution episodes. E.g. people with respiratory difficulties might want to adapt their behaviour and/or medication. We believe that this is a typical role for the local websites and not for www.airqualitynow.eu.

# 2 Review of air quality indices

There are a substantial number of different ways to interpret air quality in near real time. The most common way to do so is the use of an index, generally based on a number of sub-indices for individual pollutants[3]. There is a wealth of indices and even countries who share the same legislation, or sometimes areas/cities within the same country have different indices. Some of the differences can be explained by the local differences in the nature of the air quality problems. Some other differences are due to fundamentally different approaches. The UK index (and US-EPA) for example is strongly related to perceivable effects. The bands in the index are explained in health terms. This implies that the index covers a very wide range and that actual concentrations are very often in the "good" or "moderate" end of the scale. Air quality in Europe, fortunately, is rarely poor enough to cause acute health effects so any index based on health impacts tends to trail at the lower end of the scale for most of the time.[4]

Other indices take a different approach. For example the ATMO index, based on a national regulation concerning all French cities larger than 100 000 inhabitants (see: www.buldair.org) has bands that are somehow linked to values that are also used in the current EU directives. The alert thresholds in the directives tend to define the higher end of the scale. In these cases the top end of the index scale ends somewhere in the middle of the health effect based scales. For example the worst end (very poor) of the $NO_2$-index in France corresponds to 400 μg/m3. In the UK this is in the lower end of the "moderate" band and in the US it is even considered too low to calculate an index value.

Communication-wise the health-based indices have both a clear advantage and a disadvantage. The advantage is that the index value displayed at the website is easy to interpret: it does or does not cause health effects. The disadvantage is that the index is almost always indicating that air quality is good and pollution is low whereas the limit values for long-term exposure are often exceeded. This leads to an apparent paradox: a citizen regularly checking the local air quality website will always get the message that the air quality is good whereas at the end of the year local government puts out a report that he or she is living in a hotspot area for which an action plan is required. This is the paradox between short- and long-term air quality criteria. The criteria for short-term exposure are often met except for episodes, like for example in the summer of 2003. The criteria for long-term exposure are often not met in Europe's urban areas. The ATMO-type of indices provide some differentiation at the lower end of the scale to assure that the air quality is not always "good". However in this case it is very difficult to attach some kind of health interpretation to the index.

The differences between the two approaches vary from one pollutant to the other. On ozone, the agreement tends to be quite reasonable but for $NO_2$ and $SO_2$ the differences are substantial. For $PM_{10}$ the picture is mixed partly because the way $PM_{10}$ affects health and on what timescale this occurs is still subject to a lot of research. This implies that during typical summer episodes the indices tend to agree more or less. On days with less air pollution the interpretation gaps widen.

The long-term ↔ short-term paradox typically occurs on the internet. In an annual report the focus is on long term air pollution. On text TV pages dedicated to smog warnings the focus and interpretation is based on health effects. However, internet presentations often serve multiple roles: informing the public, but also making the public aware of air quality issues. In this case the paradox is difficult to resolve: highly variable hourly (or daily) data is being presented to assure an attractive and frequently changing presentation that encourages repeated visits. On the other hand, the most challenging limit values appear to be the criteria for the year average so interpreting commonly occurring hourly values in terms of good or bad is fairly arbitrarily. They are not bad from the short-term exposure point of view but might be bad from the long-term exposure point of view. An attempt to overcome this was described by

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[3] A list of indices collected in the course of the development of the CAQI is available in the annex.

[4] It should be mentioned that there is increasing evidence indicating that $PM_{10}$ has both short and long-term effects even at moderate concentration levels.

Elshout (2004). For $NO_2$ and $PM_{10}$ an expected hourly pattern is established for a whole year, based on historic data. This pattern is scaled (up or down) in such a way that it provides a reference pattern that would lead exactly to the limit value. In this way a, be it hypothetical, identification of hourly values that contribute to the exeedence of the year average limit value can be made.

Air quality indices aim to translate the chemical characteristics of a quite complex mixture of pollutants in the air into one single figure. From a scientific point of view this is obviously a gross generalisation but for communication purposes it is considered an essential generalisation. An index is also always a compromise between several objectives and potentially occurring situations. The trade-offs in developing the CAQI indices were made having in mind that they should be applicable over a wide range of conditions and interesting to the public. The latter has led, for example, to the use of an hourly time scale and a grid ranging from 1 to 100. This can be justified by the need for frequent changes but is rather overambitious when considering the accuracy of the individual measurements.

# 3 Comparing cities on the internet

Apart form the fact that the bands differ from one country/city/area to the other, the data behind the index also differ. Whereas most websites have a page explaining how the index is calculated, other methodological aspects are generally not explained. Does the index represent measurements at background stations, traffic stations, a mixture? And in case of PM, how is it monitored, if automated equipment is used is it corrected? In the UK the index for PM depends on the monitoring method (see DEFRA web ref.) but in most cases there is no way of knowing how PM concentrations were established.

CITEAIR aims to provide *one* index and make a difference between background and traffic stations. The potential of having one index will be apparent from the following example in which we try to compare air quality at a given day in four cities. The indices are described in table 1.

*Table 1: Indices used on the internet in Paris, Leicester, Rome and Rotterdam*

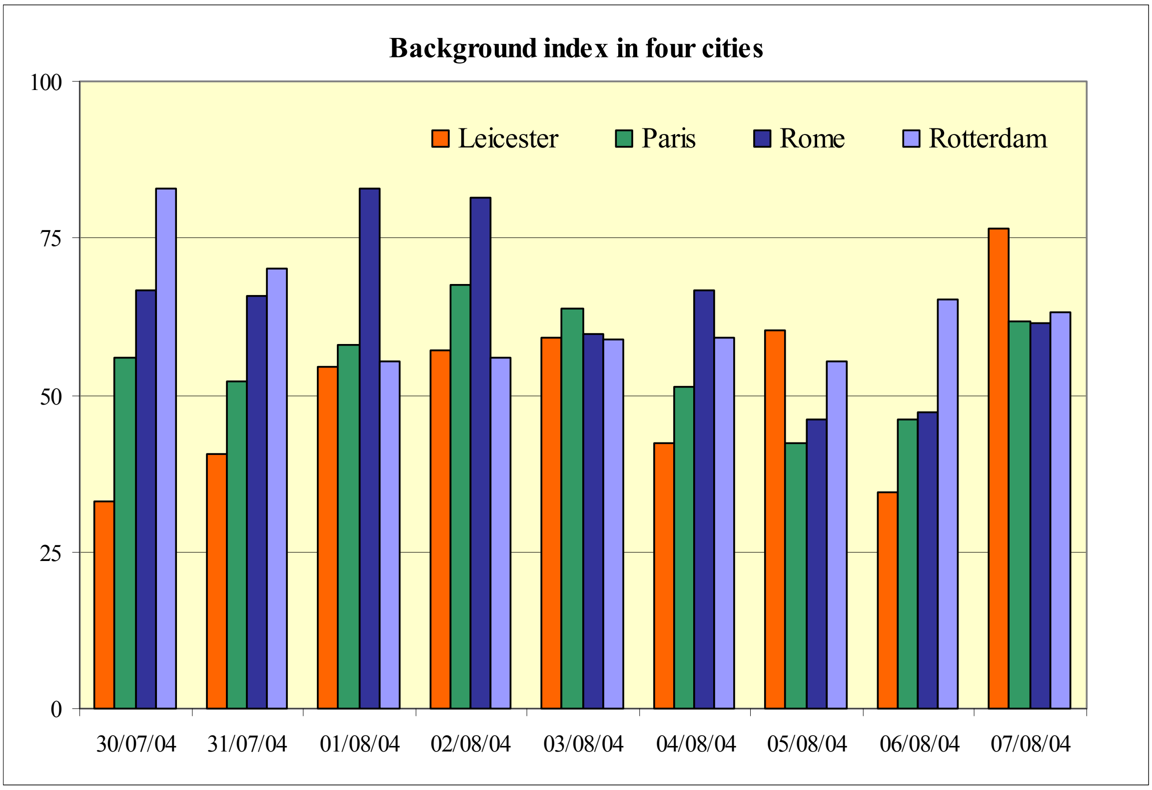
| **ATMO Paris** | ozone-1h | PM10-24h | NO2-1h | index | **UK** | ozone-8h | PM10-24h | NO2-1h | index |
|---|---|---|---|---|---|---|---|---|---|
| Very good | 29 | 9 | 29 | 1 | low | 32 | 21 | 95 | 1 |
| | 54 | 19 | 54 | 2 | | 66 | 42 | 190 | 2 |
| good | 79 | 29 | 84 | 3 | | 99 | 64 | 286 | 3 |
| | 104 | 39 | 109 | 4 | moderate | 126 | 74 | 381 | 4 |
| average | 129 | 49 | 134 | 5 | | 152 | 86 | 477 | 5 |
| mediocre | 149 | 64 | 164 | 6 | | 179 | 96 | 572 | 6 |
| | 179 | 79 | 199 | 7 | high | 239 | 107 | 635 | 7 |
| poor | 209 | 99 | 274 | 8 | | 299 | 118 | 700 | 8 |
| | 239 | 124 | 399 | 9 | | 359 | 129 | 763 | 9 |
| Very poor | >=240 | >=125 | >=400 | 10 | very high | >=360 | >=130 | >=764 | 10 |

| **Rome** | ozone-1h | PM10-24h | NO2-1h | index | **Rotter-dam*** | ozone-1h | PM10-24h | NO2-1h | index |
|---|---|---|---|---|---|---|---|---|---|
| good | 90 | 100 | 100 | 50 | good | | 20 | 100 | - |
| moderate | 135 | 150 | 150 | 75 | moderate | 180 | 40 | 200 | - |
| mediocre | 180 | 200 | 200 | 100 | bad | 240 | 60 | 400 | - |
| unhealthy | 360 | 400 | 400 | 200 | very bad | >240 | >60 | >400 | - |
| very unhealthy | > 360 | > 400 | > 400 | >200 | | | | | |

* Ozone classification from the national smog pages, other classes from a local traffic website.

Three out of four cities have an index, two indices range from 1 to 10, the other from 1 to 200. Two cities have 10 classes, one has 5, one has 4.Two describe air quality in terms of good and bad, one in terms of health and the fourth in terms of pollution levels. The class boundaries are very different. If someone would want to compare these four cities a given moment he or she would not only have to visit four websites but also be faced with four completely different presentations and qualifications.

*Figure 1: The CAQI applied to background stations in four cities July-August 2004*




As an example, look at the period end of July - early August 2004. The background index was quite high in all cities. On the 3rd of august the cities would have had a similar CAQI value. The cause of the elevated background concentrations was different though: PM10 in Leicester and Paris, and ozone in Rome and Rotterdam. If someone had looked at the four different websites he or she would have had no possibility of comparing the information. Paris looks substantial worse than Leicester as both seem to have a similar scale (1 to 10) and how to compare the score of 79 of Rome to the others: is it safe to assume that 79 out of 200 would amount to 4 on a 1 to 10 scale?

*Table 2: the CAQI and the local indices on a day with above average concentrations*

| | CAQI | Pollutant | Own city index | Pollutant | Own city classification |
|---|---|---|---|---|---|
| Leicester | 59 | PM10 | 4 | Ozone | low-moderate |
| Paris | 64 | PM10 | 6 | PM10 | mediocre |
| Rome | 60 | Ozone | 79 | Ozone | mediocre |
| Rotterdam | 59 | Ozone | - | PM10 | bad |

# 4 A common air quality index (CAQI)

## 4.1 Definition of the CAQI

The CAQI is calculated according the grid in table 3, by linear interpolation between the class borders. The final index is the highest value of the sub-indices for each component. As can be seen there are two CAQI-s: one for traffic monitoring sites and one for city background sites. The traffic index comprises $NO_2$ and $PM_{10}$, with CO as an auxiliary component. The background index obligatory comprises $NO_2$, $PM_{10}$ and $O_3$, with CO and $SO_2$ as auxiliary components. In most cities the auxiliary components will rarely determine the index (that is why they are auxiliary) but in a city with industrial pollution or a seaport $SO_2$ might occasionally play a role. Benzene is considered a long term exposure issue. The number of cities with online monitoring benzene are limited and it is therefore not included in the short term indices.

*Table 3: Pollutants and calculation grid for the CAQI*

| Index | Class | Traffic | | | City Background | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $NO_2$ | $PM_{10}$ | CO | $NO_2$ | $PM_{10}$ | O3 | CO | $SO_2$ |
| Very low | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 25 | 50 | 25 | 5000 | 50 | 25 | 60 | 5000 | 50 |
| Low | 25 | 50 | 25 | 5000 | 50 | 25 | 60 | 5000 | 50 |
| | 50 | 100 | 50 | 7500 | 100 | 50 | 120 | 7500 | 100 |
| Medium | 50 | 100 | 50 | 7500 | 100 | 50 | 120 | 7500 | 100 |
| | 75 | 200 | 75 | 10000 | 200 | 75 | 180 | 10000 | 300 |
| High | 75 | 200 | 75 | 10000 | 200 | 75 | 180 | 10000 | 300 |
| | 100 | 400 | 100 | 20000 | 400 | 100 | 240 | 20000 | 500 |
| Very High* | > 100 | > 400 | >100 | >20000 | > 400 | >100 | >240 | >20000 | >500 |

$NO_2$, $O_3$, $SO_2$: hourly value / maximum hourly value in µg/m3
CO 8 hours moving average / maximum 8 hours moving average in µg/m3
$PM_{10}$ hourly value / maximum hourly value in µg/m3**

* An index value above 100 is not calculated but reported as "> 100"
** If a city doesn't report hourly values but only 24 hour averages, these are used using a correction of 0.63 for the different averaging time. See section 4.2.

Comparing air quality in different cities is a tricky issue: is the air quality being determined in the same way (this mainly applies to particulate matter) and at comparable locations? This is not an issue that we, as the CITEAIR project and the proponents of the QACI, can solve. The website will take for granted whatever a city supplies as input in either category. However, as a first step to improve comparability, the index will be reported both for roadside and city background locations. This is considered an important improvement over city averages: some monitoring networks are designed to monitor or spot areas of poor air quality (with possibly a high number of roadside stations) whereas others are aimed at providing an average city picture.

The CAQI is used both for a daily index and for an hourly index. In the website the daily index will be shown for the past day (D-1). For the current day, the past 24 values of the hourly index will be available, to be updated every hour. A daily index for today would need forecasting or 'nowcasting' a facility that is not available in each city with a monitoring network, hence the option of an hourly index. The hourly index is also a reasonably dynamic parameter, enticing repeated visits to a website.

Participating cities are advised to submit average data from the stations they qualify as city background and traffic. The use of average data leads to better representativity and less missing data. However, if a city wants to select (or only has) one station in each category, that data will be used.

The choice of the classes in the CAQI is heavily inspired by the EU legislation and based on a compromise between the participating cities. The dividing line between medium and high is often linked mainly to the values mentioned in the directives: alert thresholds (SO2, $NO_2$, $O_3$) or air quality objectives when available on a daily basis (CO and $PM_{10}$). Class borders were regularly spaced for the main components. PM10 is an exception. To avoid that the CAQI is completely dominated by PM10 the value of 50 $\mu g/m^3$ as a daily average was positioned as the bordering line between low and medium. For the setting of the CO and $SO_2$ borders additional inspiration was sought from the DAPPS (Cairncross and John, 2004) index which aims to define the component sub-indices based on the relative risks attributed to each component.

The CAQI resembles the ATMO index discussed above and it differs substantially from for example the UK and US-EPA indices. It therefore shares the drawbacks of the ATMO (no clear link with health effects, fairly arbitrarily quality interpretation of hourly values). But it also shares its advantage: frequently changing index values that capture the hour-by-hour changes and make a website dynamic. The latter was of overriding importance as raising awareness is a key objective of the common website. De Leeuw and Mol (2005) compared the CAQI to a number of other indices.

## 4.2 Consistency between hourly and daily index

The calculation grid for the hourly and daily values is the same for most components. However, for $PM_{10}$ the averaging time increase from 1 to 24 hours and hence the concentration readings decrease. In the test period described in this paper, the four participating cities showed an average ratio of 0.63 between the highest hourly $PM_{10}$ reading and the daily average $PM_{10}$ concentration on the same day. See table 4. For hourly and daily index readings to be approximately consistent the calculation grid in table 3 for $PM_{10}$ has to be multiplied by 0.63. On average this seems to do justice to the four cities concerned but it doesn't solve the problem on a day-to-day basis as the ratios show a considerable range of variation. See the ranges in table 4. Using the maximum hourly $PM_{10}$ concentration (as for example with $NO_2$) is not attractive either as the $PM_{10}$ directives explicitly mention daily averages and therefore a good number of cities don't report hourly values (e.g. our project partner Rome).

*Table 4: Ratio between daily maximum and daily average concentration*

| | Leicester | Paris | Rome | Rotterdam | Weighted Average |
|---|---|---|---|---|---|
| Average concentration ratio:<br>Daily max. / daily average | 0.61 | 0.66 | 0.55 | 0.65 | 0.63 |
| Minimum<br>Maximum | 0.24<br>0.95 | 0.36<br>0.89 | 0.26<br>0.77 | 0.15<br>0.87 | |
| Number of observations | 344 | 355 | 120* | 365 | |

* Rome stopped reporting hourly data during the test so its ratio is based on a short period only.

As a solution, the website www.airqualitynow.eu uses both methods. For those cities which provide hourly data, the maximum hourly value of the day will be used in the daily index. This assures complete consistency. For cities that provide only daily averages, the daily average concentration is divided by 0.63 before it enters the calculation of the daily index. This way the change in averaging time is compensated.

## 4.3 Sample application of the CAQI

As cities join the website the exact bands might need reassessment to maintain an attractive comprise (see chapter 6). The current classes were derived based on the episodes of august 2003 and a recent year of data (April 2004 - March 2005) for the cities of Leicester, Paris, Rome and Rotterdam.

*Table 5: Percentage of hours that a pollutant determines the final index*

| Traffic Index | Leicester | Paris | Rome | Rotterdam |
|---|---|---|---|---|
| $NO_2$ | 85 | 53 | 31 | 49 |
| $PM_{10}$ | 14 | 47 | 69 | 51 |
| CO | 1 | 0 | 0 | 0 |
| | 100 | 100 | 100 | 100 |

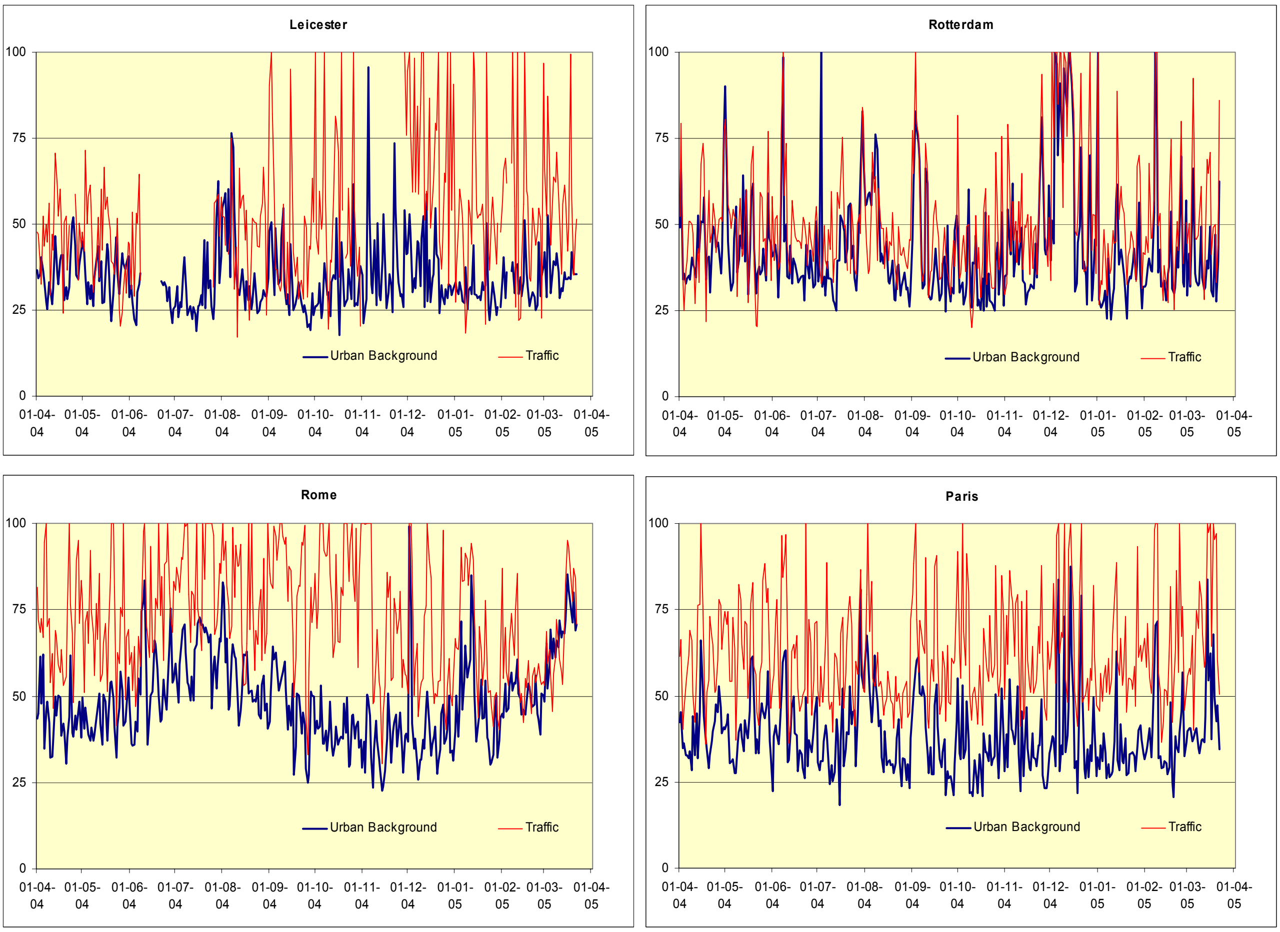
| City background Index | Leicester | | Paris | | Rome | | Rotterdam | |
|---|---|---|---|---|---|---|---|---|
| | main | main + auxiliary | main | main + auxiliary | main | main + auxiliary | main | main + auxiliary |
| $NO_2$ | 30 | 33 | 35 | 35 | 24 | 24 | 21 | 20 |
| $PM_{10}$ | 24 | 25 | 27 | 27 | 36 | 35 | 46 | 45 |
| $O_3$ | 46 | 42 | 38 | 38 | 40 | 42 | 34 | 26 |
| CO | | 0 | | 0 | | 0 | | 0 |
| $SO_2$ | | 0 | | 0 | | 0 | | 9 |
| | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

The tables show that in these four cities CO almost never plays a determining role in neither the traffic nor the background index. For the second auxiliary variable SO2 the situation is slightly different. In Rotterdam, with a seaport and a petrochemical industry, in 9 % of the hours SO2 would have determined the index[5].

Figure 2 shows the daily indices in the four test cities for a period of twelve months. The Rome background index shows a distinct seasonal pattern. In summer the background index is mainly determined by ozone, in winter by PM10 and, to a lesser extent, NO2. The seasonal pattern is absent in the other cities, though the shift in pollutants is fairly identical. The winter of 2004/2005 was rather mild so only some days with a higher index can be seen. The winter doesn't show up clearly. The traffic index is significantly higher than the background in Rome and Paris. This was to be expected in large cities with a big vehicle fleet, typical street-canyons, large ring roads, etc. In the much smaller city of Rotterdam the traffic index is only slightly higher than the background index. Leicester provides a mixed picture. With NO2 being the dominant traffic pollutant in Leicester, the traffic index is relatively low in summer and higher in winter.

[5] In fact even in Rotterdam this is exceptional. $SO_2$ determined the index in a short period with flares due to unexpected maintenance in a petrochemical plant and otherwise low concentrations.

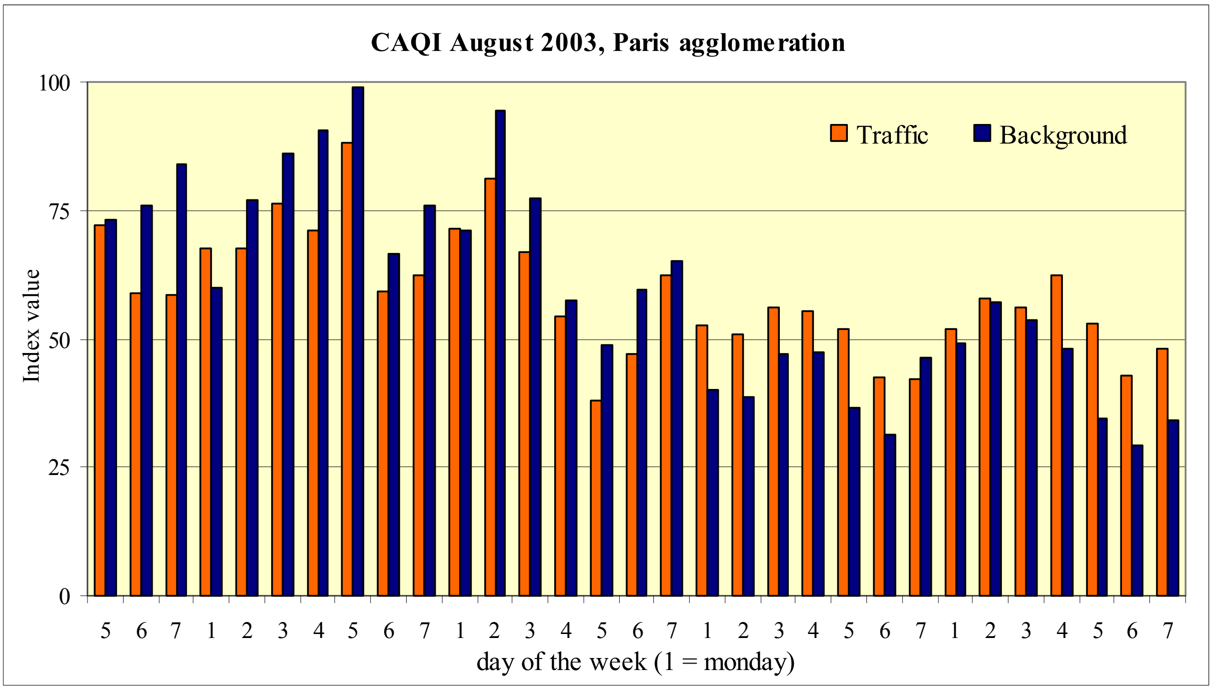
*Figure 2: The CAQI (traffic and background) in four cities*




The usefulness of a separate background and traffic index can be seen from figure 3 showing the daily index in Paris in August 2003. August 2003 was characterised by hot weather and poor dispersion conditions, leading to very high ozone concentrations. Except for a few days at the end of the month the background index was dominated by ozone. The traffic index was mainly determined by nitrogen dioxide with a few days of $PM_{10}$.

The poor dispersion conditions, combined with a large amount of imported ozone, are evident from the fact that the background index is similar or even higher than the traffic index, whereas normally (e.g. good dispersion conditions) there would be a gap of 15 to 25 index points between traffic and background. From the graph it can be seen that the traffic index drops in weekends (days labelled 6 and 7) whereas the background index rises. In this ozone-dominated month, the relative lack of fresh exhaust (NO) emissions, leads to higher ozone concentrations in the weekend. This weekend ozone effect is well known (Lawson, 2003).

*Figure 3: The traffic and background indices during an episode in Paris*



# 5 A year average index

## 5.1 Introduction

Year average indices are not very common in air quality reporting but they are nevertheless a useful indicator, facilitating the comparison of cities at a glance. Comparing cities by their individual pollutant levels is difficult as one city might be better on one pollutant and worse on the other. In addition, some cities might monitor other pollutants than others. Even comparing progress in a single city from one year to the other is difficult as progress might be made for one pollutant whereas in another field things might have deteriorated. E.g., was the progress on $NO_2$ more important than the drawback on $PM_{10}$? How to judge progress in such a case? The year average index is obviously a huge generalisation but it does provide an easy way to make some kind of relative assessment on the position of one city to the other or for one city from year to year.

A year average index can be devised according to a concentration grid in the same way as the traditional short-term indices discussed before. Akkan et al (2004) propose such an index for Baden-Württenberg in Germany (**L**ong-term **A**ir **Q**uality inde**x** - LAQx). This index uses long-term exposure (one year) health risks as a guiding principle for classifying air quality. Like the short-term exposure indices, the worst pollutant determines the index. Apart from its methodological merits, health (risks) being the main public concern, this is a very interesting approach.

Another way of making a (long-term) index is the “distance to target” principle. One advantage of the distance to target principle is that each parameter considered contributes to the index (unlike the principle where the worst parameter determines the index). A distance to target indicator calculates for each pollutant (or other parameter, in other disciplines) a ratio of how far the actual measurement is away from the target value, for example a limit value. The overall index/indicator is the average of the sub-indices. A distance to target index is based on policy targets or limit values and, as such, it has only an indirect link to health risks. Still, it is considered an appropriate way to present air quality in a European context. The limit values have important implications both for environmental policy makers and for the public[6].

The year average index presented in this paper and used on www.airqualitynow.eu is of the distance to target type.

## 5.2 Calculation and presentation

Like the hourly and daily index, the Year Average Common Air Quality Index (YACAQI) is calculated for traffic and city background sites. Preferably a city’s data for each index is based on the average of a number of sites, however it is up to each city what they want to contribute and how they determine their contribution[7]. The www.airqualitynow.eu website will accept whatever a city submits as their city year average concentrations for each pollutant for traffic and city background situations (or for one of the indices if they don’t want to supply both). In most cases, but this is up to individual cities, the data provided to the website will be based on the situation at one or more monitoring sites. This implies that it is not necessarily the complete and balanced picture a city reports under the EU-guidelines. Inferences

[6] In several countries all kind of economic developments, road construction and housing developments are being blocked by non-compliance to the limit values.

[7] Though all data analyses made in this document are based on monitored data, a city without a network for which modelled data are available (for instance delivered by the relevant authority) could even consider providing modelled year average concentrations for the sake of participating on the website and making themselves comparable relative to the other cities participating.

on city compliance should therefore be based on the official city report and not on the index values on the website as they might not paint the full picture. The website indices are a generalisation purely for comparison purpose, between cities in the same year or for a city from year to year.

The sub-indices are calculated as follows:

- For each index, sub-indices are calculated for each pollutant by dividing the actual year average by the EU limit value for the year average.
- For ozone the number of days with an 8-hour above 120 µg/m$^3$ are divided by 25 days. This is the provisional target value. The long-term target value is 0 days. Using the long term target in the calculation provides conceptual difficulties: all sub-indices have a value of 1 once the target value is reached, and drop below one if the air pollution drops even further. Using 0 exceedences for ozone would lead to an index of 0 once the target is achieved and the index cannot improve any further. By using the provisional target of 25 days to calculate the index, the calculation mechanism of the other sub-indices is mimicked.
- For $PM_{10}$ two criteria are used: the year average and the number of exeedences of the daily average of 50 µg/m$^3$. Though both criteria were originally meant to be more or less equivalent in many places the daily parameter appears to be a much more critical one. This unbalance is further aggravated if the distance-to-target parameter is calculated as the number of daily averages above 50 µg/m$^3$ divided by 35, the limit value. It appears that there is a relation between the number of exceedences of a daily average above 50 µg/m$^3$ and the year average concentration (See annex 8.4). A year average concentration of approximately 31 µg/m$^3$ seems to correspond to 35 days of exeedences. The sub-index is thus calculated as year average/31.
- For $SO_2$ the limit value for human health (a daily average of 125 µg/m$^3$ not to be exceeded for more than 3 times a year) should be used. However in many cities this would lead to a sub-index of 0. Alternatively the year average limit values for eco-systems could be used though this might be a difficult target for cities with a lot of old industries. For the time being the eco-system limit value is being used and depending on the actual readings in the subscribing this might be changed at a later date.
- For CO, no year average index is being calculated, as it is really a short-term exposure concern.

The calculation of the sub-indices is straightforward. See table 6.

*Table 6: Calculation basis for the year average index*

| Pollutant | Target value / limit value | Calculation |
|---|---|---|
| $NO_2$ | Year average is 40 µg/m$^3$ | Year average / 40 |
| $PM_{10}$ | Year average is 40 µg/m$^3$ | Year average / 40 |
| | Max. number of daily averages above 50 µg/m$^3$<br>35 days ≈ year average of 31 µg/m$^3$ | Year average / 31 |
| Ozone | 25 days with an 8-hour average value >= 120 µg/m$^3$ | # days with 8-hour average >=120 / 25 |
| $SO_2$ | Year average is 20 µg/m$^3$ | Year average / 20 |
| Benzene | Year average is 5 µg/m$^3$ | Year average / 5 |
| CO | - | Not calculated |

The overall city index is the average of the sub-indices for $NO_2$, $PM_{10}$ (both year average and daily averages) and ozone for the city background index. For the traffic year average index the averages of the sub-indices for $NO_2$ and $PM_{10}$ (both year average and daily averages) are being used. The other pollutants, if data are available, are used in the presentation of the YACAQI but do not enter the calculation of the city average index. They are treated as additional pollutants like in the hourly and daily indices. The main reason is that not every city is monitoring the full range of pollutants. Furthermore for

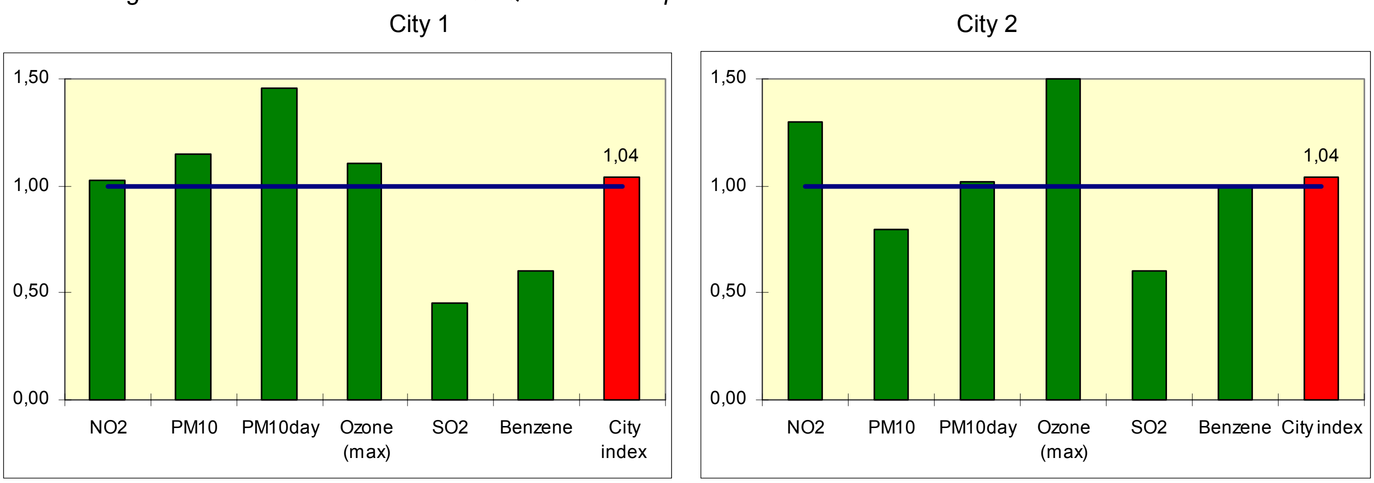
$SO_2$ we expect that the situation in different kinds of cities is very far apart, being no problem in most cities and a concern in others.

Table 7 presents an imaginary example for two cities. The two cities in the example have the same YACAQI but different air quality problems. This can be visualised by the bar charts shown in figure 4. The presentation provides valuable additional information when comparing two cities or the same city over two years. At a glance it becomes evident what the main problems are and where progress for the situation is satisfactory.

*Table 7: An example of the calculation of the YACAQI*

| | $NO_2$ | $PM_{10}$-year average | $PM_{10}$-exceedences daily average | Ozone | $SO_2$ | Benzene | Index = average of sub- indices |
|---|---|---|---|---|---|---|---|
| **Target value** | 40 | 40 | 31 | 25 | 20 | 5 | |
| year average city 1 | 41 | 46 | 46 | 28 | 9 | 3 | |
| year average city 2 | 52 | 32 | 32 | 38 | 12 | 5 | |
| **Target index** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.00 |
| Index city 1 | 1.0 | 1.2 | 1.5 | 1.12 | 0.5 | 0.6 | 1.04 |
| Index city 2 | 1.3 | 0.8 | 1.0 | 1.52 | 0.6 | 1.0 | 1.04 |

*Figure 4: Presentation of the YACAQI and its components*




## 5.3 The YACAQI applied to some cities in 2003

For several years the city of Lintz has been collecting year average air quality data from various cities in Europe (Sameh and Hager, 2003, 2004). Like www.airqualitynow.eu this is a bottom-up initiative to make air quality comparable. In the following figures and tables a selection of their data has been used to calculate the YACAQI as an example of the application of the index[8].

Concerning air quality, 2003 was a notoriously bad year. Comparing the YACAQI for 2002 and 2003 indeed shows that most indices (Milan being an exception) were better in 2002 than in 2003. The graphs show a city where the YACAQI hardly changed from 2002 to 2003 (Milan), and a city with a marked change (Lintz). The case of Lintz shows that if a city is in compliance with the limit

[8] The city of Lintz does not collect the number of days with an 8-hour average ozone concentration >= 120 µg/m$^3$. In this example the ozone index was calculated as the maximum hourly value divided by 180!

values in one year there is no guarantee that the air quality is satisfactory. In fact to be sure that the limit values will always be met one has to aim at air quality standards that are somewhat lower than the limit values. The Lintz graph also shows that all pollutants were higher in 2003 than in 2002, indicating that poor dispersion has probably played a major role.

*Figure 5: The YACAQI in 2002 (left) and 2003 (right) in the cities of Lintz and Milan*[9]

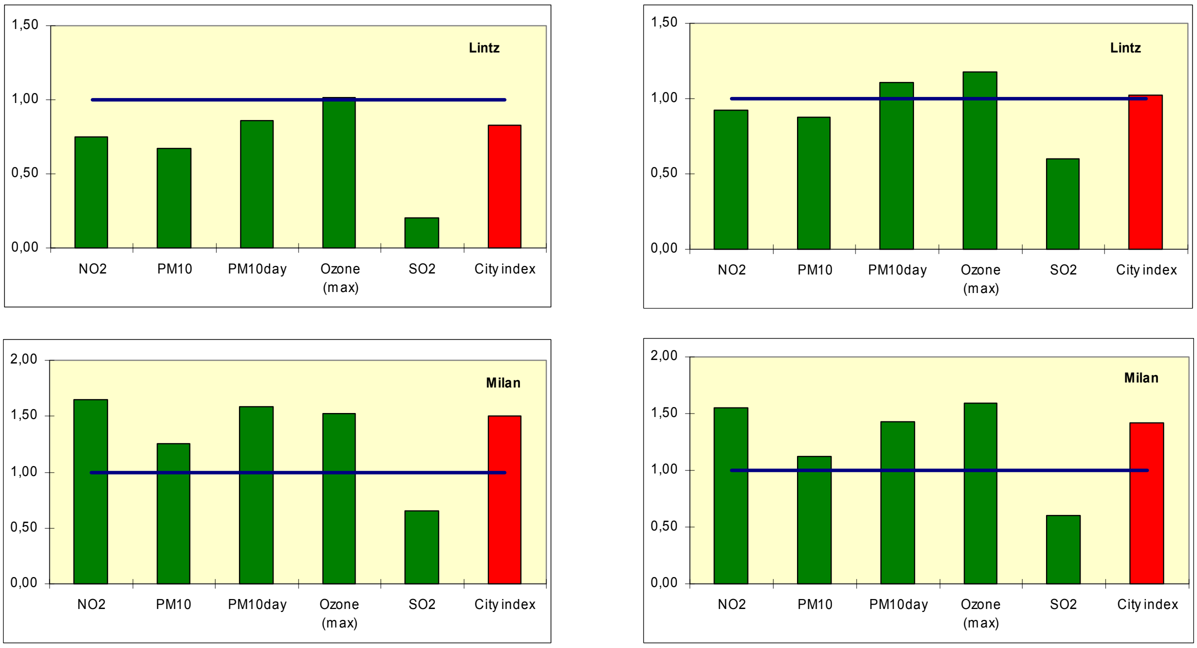



*Table 8: Year average index applied to data from 6 cities in the annual Lintz survey for 2002 and 2003 (see footnote).*

| 2003 | Sub-indices | | | | | City Index |
|---|---|---|---|---|---|---|
| | $NO_2$ | $PM_{10}$ | PM10-daily | Ozone (max) | $SO_2$ | |
| Brussels | 1,2 | 0,9 | 1,2 | 1,3 | 0,4 | 1,2 |
| Linz | 0,9 | 0,9 | 1,1 | 1,2 | 0,6 | 1,0 |
| London | 1,4 | 0,6 | 0,8 | 1,3 | 0,4 | 1,0 |
| Milan | 1,6 | 1,1 | 1,4 | 1,6 | 0,6 | 1,4 |
| Munich | 1,3 | 1,0 | 1,3 | 1,3 | 0,2 | 1,2 |
| Rotterdam | 1,1 | 1,1 | 1,4 | 1,6 | 0,7 | 1,3 |

| 2002 | Sub-indices | | | | | City Index |
|---|---|---|---|---|---|---|
| | $NO_2$ | $PM_{10}$ | PM10-daily | Ozone (max) | $SO_2$ | |
| Brussels | 1,0 | 0,9 | 1,1 | 1,2 | 0,4 | 1,0 |
| Linz | 0,8 | 0,7 | 0,9 | 1,0 | 0,2 | 0,8 |
| London | 1,2 | 0,6 | 0,7 | 1,0 | 0,4 | 0,9 |
| Milan | 1,7 | 1,3 | 1,6 | 1,5 | 0,7 | 1,5 |
| Munich | 1,2 | 0,8 | 1,0 | 1,0 | 0,2 | 1,0 |
| Rotterdam | 1,0 | 1,1 | 1,4 | 1,1 | 0,7 | 1,1 |

[9] The city of Lintz does not collect the number of days with an 8-hour average ozone concentration >= 120 µg/$m^3$. In this example the ozone index was calculated as the maximum hourly value divided by 180!

*Figure 6: Year average index applied to data from 6 cities in the annual Lintz survey for 2003*[10].


As can be seen from the graphs, in this sample of six cities the $PM_{10}$ exeedence of the daily average of 50 $\mu g/m^3$ seems to be the dominant problem. Furthermore, the daily parameter is much more restrictive than the annual (year average) parameter.

[10] The city of Lintz does not collect the number of days with an 8-hour average ozone concentration >= 120 $\mu g/m^3$. In this example the ozone index was calculated as the maximum hourly value divided by 180!

# 6 Future developments

The CAQI and YACAQI are developed in the course of the CITEAIR project. Both indices will be reviewed once at the end of the project, foreseen in 2007. Based on the experiences with their use the indices might undergo small changes (See for example the discussion on $SO_2$ in section 5.2). So far $PM_{10}$ appears to be the pollutant posing the greatest challenges in finding a compromise.

A potential important change is the anticipated arrival of a $PM_{2.5}$ limit value. It is likely that by 2007 a good number of cities are monitoring $PM_{2.5}$ and inclusion of it in the indices will be feasible. We expect that $PM_{2.5}$ will be included in the daily and hourly versions of the CAQI index. The YACACI already has two PM sub-indices and adding a third could be considered overdone. The most likely development will be that the $PM_{2.5}$ sub-index will replace the $PM_{10}$ year average sub-index.

The final version of this document will be made at the end of the project (2007) and will settle the matter as far as CITEAIR is concerned. In the mean time we hope that these common indices will be used beyond the project context and will become a kind of a reference index for international comparison purposes. In addition, the project team is exploring possibilities to establish an organisational framework to enable both the continuation and expansion (e.g. involving more cities) of the website and ensuring the further maintenance/development (revision of directives, new insights in air quality and health issues) of the indices and the web platform as appropriate.

Maintaining the CAQI implies that cities using this index need to be consulted about, and informed of any changes to the index otherwise there will be multiple versions of the CAQI and the very concept of one index to facilitate comparison across borders will be completely lost. If you consider using the CAQI and/or YACAQI please inform us at caqi@airqualitynow.eu.

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# Annex

## Annex 1 Review of some indices found on the internet

### Introduction

In the following tables you will find some of the indices found during the website review done by CITEAIR in late 2004 and early 2005.[11] The list is not exhaustive but the message is clear: everybody does something different, sometimes even within a country, so there is scope for a common index. Differences include the pollutants monitored, the class borders, the number of classes, etc.

Indices change so the data presented here might no longer be accurate by the time you read it. For example, since the review was done it was discovered that the UK index for PM now differs according to the monitoring method and that the Brussels index has a roadside and city background presentation that was not there before.

Care was taken to be as accurate as possible, though, especially on the sites without an english translation interpretation was sometimes difficult.

### Observations relative to the findings

- All the indexes are used to give a quality judgement for short-term exposure (generally a day).
- Some sites do not provide an overall index, just indexes for individual pollutants.
- In the case where an overall index is presented the worst of the sub-indexes is generally chosen. There is one exception: the DAPPS (Cairncross and John, 2004) from South Africa. DAPPS is based on quantitative health criteria and this provides a basis for summing the sub-indexes according to the authors (I disagree to some extend: both health effects and concentrations of different pollutants are not independent phenomena; SE)

- The US and UK indexes use very high concentration values as they are base on real health effects. Most other indices reviewed seem somehow inspired by EU limit values, at least for the main pollutants.
- (Short) descriptions of health effects are available in the US-EPA, UK and the NILU indices.
- On the US EPA website (http://cfpub.epa.gov/airnow/index.cfm?action=aqibroch.index) there is a document with good descriptions of health effects and messages one might use to communicate to the public.
- The DAPPS is, theoretically the most objective index in comparing health effects of different pollutants. The results, as they are presented here use the WHO data (as in the original paper). If one is to use the DAPPS concept correctly local RR-s and mortality data would have to be used. This would provide a powerful tool for comparing health impacts from one city to the other but would make it difficult to compare actual air quality measurements from one city to the other. It seems that the APHEIS project (Monitoring the Effects of Air Pollution Health in Europe) is doing something in this direction. See: http://www.apheis.net.

- In France ATMO has been declared a national standard. In the Netherlands and in Italy (for example) there are regional differences in the interpretation of air quality.
- ATMO France, the Brussels index and a number of others are very similar but not identical.

[11] For another review of air quality indices see Garcia and Colossio (2002).

- There are several indexes that don't use a 1 to 10 range. This avoids the confusing communication message that in some fields (education) the 10 points indicate the best and in the AQ business it indicates the worst situation.
- Emillia Romagna region now uses a classification based entirely on the short term exposure criteria in the EU guidelines.
- As has been observed by some people: presenting short-term exposure air quality interpretation might send a confusing message. In most instances short-term exposure at a certain site will not pose a problem throughout the year (e.g. moderate to good) and at the end of the year the site does not meet the criteria for the year average. This could be resolved by a few lines of text underneath the graph/table. E.g. "hourly concentrations from 50 to 100 do not pose an acute health threat but when concentrations in this range dominate the air quality is not likely to meet the criteria for long-term (a year or several years) exposure". There are technical ways to provide a long-term judgement for short time resolution measurements but they are difficult to implement. (See also main text chapter 3.)

## Annex 2 Summary of indices

NB: All concentrations in $\mu g/m^3$

| US EPA 1999 | ozone-8h | ozone-1h | PM2.5-24h | PM10-24h | CO-8h | SO2-24h | SO2-1h | NO2-1h | index | **Remarks** the index for each component is calculated as a linear interpolation between class borders; On the website there is a document with extensive health information: http://cfpub.epa.gov/airnow/index.cfm?action=aqibroch.index |
|---|---|---|---|---|---|---|---|---|---|---|
| good | 132 | - | 15 | 54 | 5302 | 94 | | - | 50 | Air quality is considered satisfactory, and air pollution poses little or no risk. |
| moderate | 174 | - | 40 | 154 | 11327 | 397 | | - | 100 | Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people. For example, people who are unusually sensitive to ozone may experience respiratory symptoms. |
| unhealthy sensitive | 215 | 339 | 65 | 254 | 14942 | 617 | | - | 150 | members of sensitive groups may experience health effects. This means they are likely to be affected at lower levels than the general public. For example, people with lung disease are at greater risk from exposure to ozone, while people with either lung disease or heart disease are at greater risk from exposure to particle pollution. The general public is not likely to be affected when the AQI is in this range |
| unhealthy | 256 | 421 | 150 | 354 | 18557 | 837 | | - | 200 | Everyone may begin to experience health effects when AQI values are between 151 and 200. Members of sensitive groups may experience more serious health effects. |
| very unhealthy | 773 | 835 | 250 | 424 | 36632 | 1663 | | 2455 | 300 | AQI values between 201 and 300 trigger a health alert, meaning everyone may experience more serious health effects. |
| hazardous | go to 1 h column | 1041<br>1248 | 350<br>500 | 504<br>604 | 48682<br>60732 | 2214<br>2765 | | 3247<br>4039 | 400<br>500 | AQI values over 300 trigger health warnings of emergency conditions. The entire population is more likely to be affected |

| WHO guidelines for exposure | ozone-8h | ozone-1h | PM2.5-24h | PM10-24h | CO-8h | SO2-24h | SO2-1h | NO2-1h | index |
|---|---|---|---|---|---|---|---|---|---|
| | 120 | | | | 10000 | 125 | | 200 | |

| ATMO Paris (current) | ozone-8h | ozone-1h | PM2.5-24h | PM10-24h | CO-8h | SO2-24h | SO2-1h | NO2-1h | index |
|---|---|---|---|---|---|---|---|---|---|
| very good | | 29 | | 9 | | | 39 | 29 | 1 |
| | | 54 | | 19 | | | 79 | 54 | 2 |
| Good | | 79 | | 29 | | | 119 | 84 | 3 |
| | | 104 | | 39 | | | 159 | 109 | 4 |
| Average | | 129 | | 49 | | | 199 | 134 | 5 |
| mediocre | | 149 | | 64 | | | 249 | 164 | 6 |
| | | 179 | | 79 | | | 299 | 199 | 7 |
| poor | | 249 | | 99 | | | 399 | 274 | 8 |
| | | 359 | | 124 | | | 599 | 399 | 9 |
| very poor | | >=360 | | >=125 | | | >=600 | >=400 | 10 |

**Remarks**: the index is based on 4 pollutants, the worst sub-index giving the final result.
Surprisingly, there are no precise, specific comments describing the health effects for specific target group associated to each index.
Index principle is based on specific values for crucial indexes (8 is related to the french "information to the public" hourly value, 10 is based on the alert hourly value.
Ozone and SO2 grids are currently under evolution (see new grid suggested).
Airparif worked also on a specific hourly PM grid allowing the use of Atmo on a hourly basis.

| New ozone 1h-grid | New SO2 1h-grid | Potential PM10 1h-grid |
|---|---|---|
| 29 | 39 | 5 |
| 54 | 79 | 20 |
| 79 | 119 | 30 |
| 104 | 159 | 45 |
| 129 | 199 | 65 |
| 149 | 249 | 85 |
| 179 | 299 | 100 |
| 209 | 399 | 125 |
| 239 | 499 | 179 |
| >=240 | >=500 | >=180 |

**Conversion between US EPA and Atmo for "interesting" days**

| Day | Pollutant | Value (µg/m3) | Atmo | US EPA |
|---|---|---|---|---|
| 08/08/2003 | O3 | 238 | Bad (8) | Very unhealthy (201, O3) |
| 10/02/2004 | NO2 | 139 | Mediocre (6) | Unhealthy sensitive (109, PM2.5) |
| 30/09/1997 | NO2 | 251 | Poor (8) | Moderate (85, PM10) |
| 03/02/1998 | NO2 | 204 | Poor (8) | Moderate (69, PM10) |
| 05/02/1998 | PM10 | 124 | Poor (9) | Moderate (87, PM10) |
| 11/08/1998 | O3 | 251 | Poor (9) | Very unhealthy (201, O3) |

| UK | ozone-8h | ozone-1h | PM2.5-24h | PM10-24h | CO-8h | SO2-24h | SO2-***15 min*** | NO2-1h | index | **Health** |
|---|---|---|---|---|---|---|---|---|---|---|
| low | 32 | | | 16 | | | 88 | 95 | 1 | effects are unlikely to be noticed even by individuals who know they are sensitive to air pollutants |
| | 66 | | | 32 | | | 176 | 190 | 2 | |
| | 99 | | | 49 | | | 265 | 286 | 3 | |
| moderate | 126 | | | 57 | | | 354 | 381 | 4 | mild effects, unlikely to require action, may be noticed amongst sensitive individuals |
| | 152 | | | 66 | | | 442 | 476 | 5 | |
| | 179 | | | 74 | | | 531 | 572 | 6 | |
| high | 239 | | | 82 | | | 708 | 635 | 7 | significant effects may be noticed by sensitive individuals and action to avoid or reduce these effects may be needed (e.g. reduce exposure, asthmatics use inhaler). |
| | 299 | | | 91 | | | 886 | 700 | 8 | |
| | 359 | | | 99 | | | 1063 | 763 | 9 | |
| very high | >=360 | | | >=100 | | | >=1064 | >=764 | 10 | Effects for 'high' may worsen |

| **DAPPS (South Africa)** | ozone-8h (max) | ozone-1h | PM2.5-24h | PM10-24h | CO-8h | SO2-24h | SO2 | NO2-1h | index | **Remarks** |
|---|---|---|---|---|---|---|---|---|---|---|
| based on RR : 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Class borders are such that the Relative Risk (RR) is the same in each class for each substance. See Caircross and John 2004, Section 3.2.4. Is not fully correct in my (SE) view. Concentrations are not fully independent and summing them might be wrong. |
| 1.015 | 30 | 33 | | 21 | 3900 | 38 | | 51 | 1 | |
| 1.031 | 60 | 67 | | 41 | 7900 | 77 | | 102 | 2 | |
| **1.046** | 90 | **100** | | 62 | 11800 | 115 | | 153 | 3 | |
| 1.061 | 120 | 133 | | 83 | 15700 | 153 | | 204 | 4 | The DAPPS was fixed to the UK system using the value of ozone at index class 3 (100) and the associated Relative Risk for each pollutant allows to fit the rest of the class borders into the system. |
| 1.077 | 150 | 167 | | 104 | 19700 | 192 | | 256 | 5 | |
| 1.092 | 180 | 200 | | 124 | 23600 | 230 | | 307 | 6 | |
| 1.107 | 210 | 233 | | 145 | 27500 | 268 | | 358 | 7 | |
| 1.123 | 241 | 267 | | 166 | 31500 | 307 | | 409 | 8 | |
| 1.138 | 271 | 300 | | 186 | 35400 | 345 | | 460 | 9 | |
| >1.153 | >=301 | >=333 | | >=207 | >= 39300 | >= 383 | | >= 511 | 10 | |

| Brussels | ozone-8h | ozone-1h | PM2.5-24h | PM10-24h | CO-8h | SO2-24h | SO2-1h | NO2-1h | Index |
|---|---|---|---|---|---|---|---|---|---|
| excellent | 30 | | | 10 | | 15 | | 25 | 1 |
| very good | 45 | | | 20 | | 30 | | 45 | 2 |
| good | 60 | | | 30 | | 45 | | 60 | 3 |
| fairly good | 80 | | | 40 | | 60 | | 80 | 4 |
| moderate | 100 | | | 50 | | 80 | | 110 | 5 |
| poor | 120 | | | 70 | | 100 | | 150 | 6 |
| very poor | 150 | | | 100 | | 125 | | 200 | 7 |
| bad | 200 | | | 150 | | 165 | | 270 | 8 |
| very bad | 270 | | | 200 | | 250 | | 400 | 9 |
| horrible | >270 | | | >200 | | >250 | | >400 | 10 |

| Nordrhein-Westfalen | ozone-8h | ozone-1h | PM2.5-24h | PM10-24h | CO-8h | SO2-24h | SO2-1h | NO2-1h | index |
|---|---|---|---|---|---|---|---|---|---|
| very good | 20 | 33 | | 10 | | | 25 | 25 | |
| | 50 | 65 | | 20 | | | 50 | 50 | |
| | 80 | 120 | | 35 | | | 120 | 100 | |
| | 120 | 180 | | 50 | | | 350 | 200 | |
| | 160 | 240 | | 100 | | | 500 | 400 | |
| very bad | >160 | >240 | | >100 | | | >500 | >400 | |

| NILU (Norway, powerpoint) | ozone-8h | ozone-1h | PM2.5-24h | PM10-24h | CO-8h | SO2-24h | SO2-1h | NO2-1h | index | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| good | | | 20 | 35 | | | | 100 | | No health effects |
| moderate | | | 35 | 50 | | | | 150 | | Asthmatics may experience health effects in streets with heavy traffic, especially during physical activities |
| poor | | | 60 | 100 | | | | 200 | | Asthmatics and people with serious hart- and bronchial diseases should avoid longer outdoor stays in areas with high air pollution |
| Very poor | | | >60 | >100 | | | | >200 | | Asthmatics and pe0ple with serious hart- and bronchial diseases should avoid areas with high air pollution. Healthy people may experience incidentally irritations in the muscular membrane and unpleasantness. |

| **Oslo** | ozone-8h | ozone-1h | PM2.5-24h | PM10-24h | CO-8h | SO2-24h | SO2-1h | NO2-1h | index |
|---|---|---|---|---|---|---|---|---|---|
| good | | | 40 | 50 | | | 150 | 100 | |
| moderate | | | 60 | 100 | | | 250 | 150 | |
| poor | | | 100 | 150 | | | 350 | 200 | |
| Very poor | | | >100 | >150 | | | >350 | >200 | |

| **Heaven Rotterdam/ Dutch smog guidelines** | ozone-8h | ozone-1h | PM2.5-24h | PM10-24h | CO-8h | SO2-24h | SO2-1h | NO2-1h | index |
|---|---|---|---|---|---|---|---|---|---|
| good | | | | 20 | | | | 100 | |
| moderate | | 180 | | 40 | | 350 | | 200 | |
| bad | | 240 | | 60 | | 500 | | 400 | |
| very bad | | >240 | | >60 | | >500 | | >400 | |

| **Province of Limburg (Netherlands)** | ozone-8h | ozone-1h | PM2.5-24h | PM10-24h | CO-8h | SO2-24h | SO2-1h | NO2-1h | index |
|---|---|---|---|---|---|---|---|---|---|
| very good | | 32 | | 9.9 | 999 | 24 | 24 | 24 | |
| good | | 64 | | 19.9 | 1999 | 49 | 49 | 49 | |
| reasonable | | 179 | | 49.9 | 9999 | 164 | 164 | 199 | |
| bad | | >180 | | >50 | >10000 | >165 | >165 | >200 | |

| **Rome** | ozone-8h | ozone-1h | PM2.5-24h | PM10-24h | CO-8h | SO2-24h | SO2-1h | NO2-1h | index |
|---|---|---|---|---|---|---|---|---|---|
| good | | 90 | | 100 | 5000 | | | 100 | 50 |
| moderate | | 135 | | 150 | 7500 | | | 150 | 75 |
| mediochre | | 180 | | 200 | 10000 | | | 200 | 100 |
| unhealthy | | 360 | | 400 | 20000 | | | 400 | 200 |
| very unhealthy | | > 360 | | > 400 | >20000 | | | > 400 | >200 |
| | | max 24 h | | | max 24 h | | | max 24h | |

| ARPA Toscane | ozone-8h | ozone-1h | PM2.5-24h | PM10-24h | CO-8h | SO2-24h | SO2-1h | NO2-1h | index |
|---|---|---|---|---|---|---|---|---|---|
| good | | 60 | | 25 | 2500 | | | 50 | |
| moderate | | 180 | | 50 | 15000 | | | 200 | |
| poor | | 360 | | 75 | 30000 | | | 400 | |
| bad | | >360 | | >75 | >30000 | | | >400 | |

| Emilia Romagna | ozone-8h | ozone-1h | PM2.5-24h | PM10-24h | CO-8h | SO2-24h | SO2-1h | NO2-1h | index |
|---|---|---|---|---|---|---|---|---|---|
| Below limit value/below information threshold | | 180 | | 50 | 10000 | 125 | 350 | 200 | |
| Margin of tolerance/ Information threshold | | 240 | | | | | | 250 | |
| Above limit value/ alarm threshold | | >240 | | >50 | >10000 | >125 | >350 | >250 | |

## Annex 3 Websites consulted during the review

Below a list of the web addresses of a number of sites showing air quality information, indices and related information. These sites were visited during the review (2004-2005). As with the indices: websites change so not all links might be operational.

http://www.irceline.be/
http://www.vmm.be/servlet/be.coi.gw.servlet.MainServlet/standard?toDo=open&amp
http://www2.dmu.dk/1_Viden/2_miljoe-tilstand/3_luft/4_maalinger/5_maaleprogrammer/oversigtskort_en.asp
http://www.umweltbundesamt.de/uba-info-daten/daten/aod.htm
http://www.hamburger-luft.de/Stationen/Uebersicht.asp
http://www.umwelt.schleswig-holstein.de/servlet/is/1448/
http://www2.lfu.baden-wuerttemberg.de/lfu/abt3/luft/aktuelle_luftmesswerte/index.html
http://62.8.156.193/cgi-bin/db4web_c.exe/Projekt3/Projekt3/index.htm?th=2&kn=250145&adresse=1
http://www.lua.nrw.de/luft/immissionen/aktluftqual/eu_luft_akt.htm
http://www.ytv.fi/english/air/now.html
http://www.airparif.asso.fr
http://www.atmo-alsace.net
http://ww.airpl.org
http://www.airmaraix.com
http://www.atmo-rhonealpes.org
http://members.chello.hu/dasy.kft/forecast/Budapest.htm
http://www.arpa.emr.it
http://www.arpalombardia.it/qaria/
http://www.arpat.toscana.it/aria/ar_monitoraggio.html
http://www.comune.torino.it/ambiente/inquinamento
http://www.arpa.umbria.it
http://www.arpa.veneto.it/aria.htm
http://www.lml.rivm.nl
http://www.dcmr.nl/lucht/
http://www.dcmr.nl/heaven/
http://www.luchtkwaliteit.limburg.nl/nl/html/algemeen/meetwaarden/dagwaarden/dagwaarden.asp
http://www.nilu.no
http://www.umweltbundesamt.at/umwelt/luft/luftguete_aktuell/tgl_bericht/
http://www.ooe.gv.at/umwelt/luft/luftguet
http://www.airquality.co.uk
http://www.londonair.org.uk/london/asp/PublicBulletin.asp
http://www.ivl.se/miljo/projekt/urban/intro.asp
http://www.slb.mf.stockholm.se
http://www.umwelt-schweiz.ch/buwal/de/fachgebiete/fg_luft/luftbelastung/aktuell/grafiken/
http://ozone.eionet.eu.int
http://www.epa.gov/airnow/
http://www.gemsnet.org/can/templates/mn_hometemplate.asp?id=h
http://www.ace.mmu.ac.uk/eae/english.html
http://airnet.iras.uu.nl/
http://www.esa.int/export/esaEO/SEM340NKPZD_index_0.html
http://europa.eu.int/comm/environment/air/index.htm
http://eos-aura.gsfc.nasa.gov

## Annex 4 The relation between the two $PM_{10}$ limit values

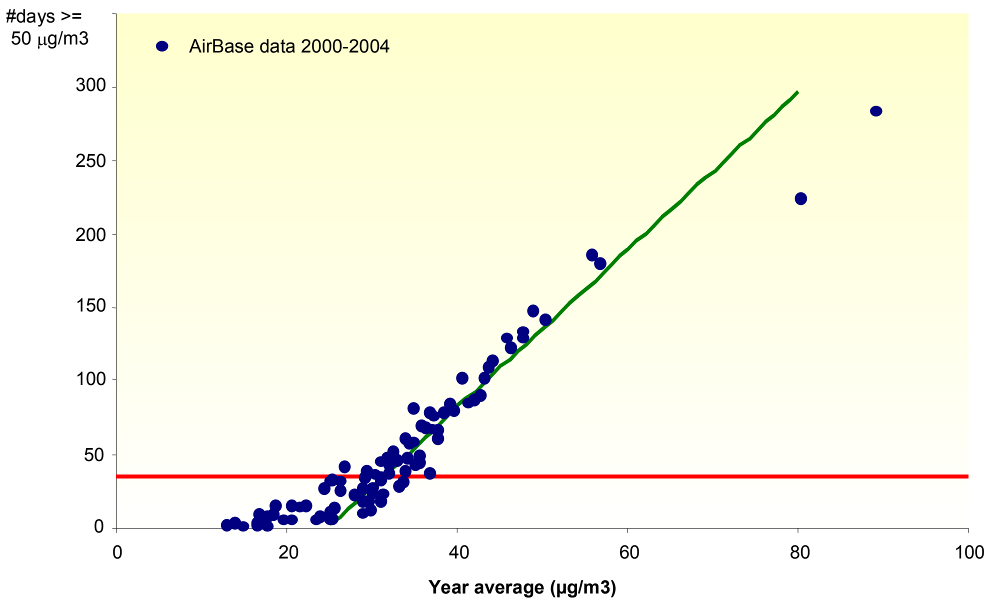
In section 5.2 it was mentioned that there seems to be a fairly generally applicable relation between the year average $PM_{10}$ concentration and the number of days with a daily average concentration above 50 μg/m$^3$. In the Netherlands this relation was empirically determined as:

Number of exeedences = 5.367 * year average concentration – 132.4

This linear relation is applicable for year average concentrations above 25 μg/m$^3$ and is applied in some of the air quality models that are prescribed for use in assessment of compliance with the EU directives. In fact, in the Netherlands a lognormal relation exists that applies over the full range of concentrations (Wesseling, p.c.). This is not surprising as lognormal distributions have since long been shown to be a fair approximation of air quality concentration distributions (e.g. Larsen 1971).

The above equation shows that a year average concentration of 31.2 μg/m$^3$corresponds to exactly 35 days with a daily average >= 50 μg/m$^3$. Various contacts suggested that a value of 31 or 31.5 μg/m$^3$ also applied in Belgium, France and Germany. However to test the general applicability of a single year average value a sample for a number of years, traffic and background stations and a number of countries was drawn from Airbase (airbase.eionet.eu.int) and analysed.

The data set includes 12 countries with 12 traffic stations and 11 background stations. The period considered was 2000-2004. Before 2000 there are few $PM_{10}$ measurements. At least 90% of the daily average observations had to be present for the station and the year to be included. This leads to 60 data pairs for the analysis[12]. The results are shown in the graph.




The diverse European data set also seems to adhere to a simple linear relation without too much scatter. The two most deviant points belong to one traffic station. A cross check with other stations from the same country revealed that they did fit in the general pattern. The equation describing the line is:

Number of exeedences = 4.448 * year average concentration – 99.4

[12] All in all there were 110 data pairs. The results from the full and the restricted set were almost identical.

The threshold value thus becomes 30,2 $\mu g/m^3$. Hence it was concluded that the number of exceedences of the limit value for the daily average concentration can be approximated by a year average concentration and the value of 31$\mu g/m^3$ was chosen to be used in the index calculation.

Dataset used

| Year | Country code | EU-code | Station | % daily averages | Year average | Daily average > 50 µg/m3 |
|---|---|---|---|---|---|---|
| 2000 | CH | CH0011A | Lugano (LUG) | 100 | 33,80 | 61 |
| 2000 | ES | ES1357A | ES1357A-BURGOS 2 (9059004) | 100 | 33,64 | 39 |
| 2000 | FI | FI0124A | Kallio 2 (425) | 99 | 14,67 | 1 |
| 2000 | SE | SE0024A | Uppsala (8783) | 99 | 26,14 | 32 |
| 2000 | CZ | CZ0018A | Chomutov (UCHMA) | 99 | 31,56 | 47 |
| 2000 | HU | HU0020A | Szeged (HUSE01) | 99 | 44,07 | 114 |
| 2000 | GB | GB0636A | CAMDEN KERBSIDE (CA1) | 98 | 33,62 | 31 |
| 2000 | FI | FI0092A | Leppävaara 2 (407) | 98 | 22,12 | 15 |
| 2000 | SE | SE0022A | Södermalm (8576) | 98 | 17,29 | 3 |
| 2000 | CZ | CZ0040A | Brno-Kroftova (BBNFA) | 97 | 28,80 | 10 |
| 2000 | CZ | CZ0063A | Plzen-stred (PPLEA) | 97 | 23,88 | 8 |
| 2000 | GB | GB0609A | SWANSEA (SWAN) | 97 | 25,51 | 13 |
| 2000 | ES | ES1394A | ES1394A-CONSTITUCIÓN (P.F.) (18087005) | 95 | 46,35 | 123 |
| 2000 | SK | SK0002A | Trnavske myto (112) | 93 | 39,04 | 84 |
| 2000 | SK | SK0005A | Namestie Slobody (211) | 92 | 32,94 | 46 |
| 2000 | CH | CH0021A | Zürich Schimmelstrasse (ZBW) | 92 | 35,47 | 44 |
| 2000 | PL | PL0012A | MpKrakowWIOSAKra6117 (MpKrakowWI) | 85 | 37,00 | 57 |
| 2000 | PL | PL0002A | LdLodzWSSEMWodna40 (LdLodzWSSE) | 73 | 45,75 | 86 |
| 2001 | SE | SE0024A | Uppsala (8783) | 100 | 25,05 | 33 |
| 2001 | CH | CH0011A | Lugano (LUG) | 99 | 31,90 | 43 |
| 2001 | CZ | CZ0018A | Chomutov (UCHMA) | 99 | 43,11 | 102 |
| 2001 | CZ | CZ0040A | Brno-Kroftova (BBNFA) | 99 | 28,77 | 18 |
| 2001 | PL | PL0012A | MpKrakowWIOSAKra6117 (MpKrakowWI) | 99 | 42,61 | 91 |
| 2001 | GR | GR0047A | PANORAMA (208) | 99 | 36,97 | 67 |
| 2001 | CZ | CZ0063A | Plzen-stred (PPLEA) | 99 | 12,77 | 2 |
| 2001 | GB | GB0636A | CAMDEN KERBSIDE (CA1) | 99 | 33,15 | 29 |
| 2001 | FI | FI0092A | Leppävaara 2 (407) | 99 | 24,98 | 32 |
| 2001 | ES | ES1394A | ES1394A-CONSTITUCIÓN (P.F.) (18087005) | 98 | 43,57 | 109 |
| 2001 | CH | CH0021A | Zürich Schimmelstrasse (ZBW) | 98 | 28,82 | 26 |
| 2001 | GR | GR0003A | ARISTOTELOUS (109) | 98 | 55,61 | 186 |
| 2001 | FI | FI0124A | Kallio 2 (425) | 97 | 16,39 | 3 |
| 2001 | SE | SE0022A | Södermalm (8576) | 96 | 17,46 | 1 |
| 2001 | HU | HU0020A | Szeged (HUSE01) | 96 | 47,66 | 129 |
| 2001 | EE | EE0013A | Viru (EE01) | 95 | 29,90 | 23 |
| 2001 | SK | SK0002A | Trnavske myto (112) | 94 | 35,80 | 70 |
| 2001 | GB | GB0609A | SWANSEA (SWAN) | 94 | 25,42 | 7 |
| 2001 | ES | ES1357A | ES1357A-BURGOS 2 (9059004) | 93 | 29,71 | 12 |
| 2001 | SK | SK0005A | Namestie Slobody (211) | 93 | 29,09 | 34 |
| 2001 | SI | SI0001A | Celje (E23) | 90 | 35,49 | 55 |
| 2001 | EE | EE0018A | Õismäe (EE03) | 83 | 18,07 | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2001 | SI | SI0002A | Maribor (E22) | 73 | 37,44 | 45 |
| 2001 | PL | PL0002A | LdLodzWSSEMWodna40 (LdLodzWSSE) | 71 | 42,12 | 66 |
| 2002 | EE | EE0018A | Õismäe (EE03) | 100 | 21,31 | 14 |
| 2002 | ES | ES1394A | ES1394A-CONSTITUCIÓN (P.F.) (18087005) | 100 | 37,57 | 61 |
| 2002 | CZ | CZ0040A | Brno-Kroftova (BBNFA) | 99 | 26,32 | 25 |
| 2002 | GB | GB0636A | CAMDEN KERBSIDE (CA1) | 99 | 30,77 | 18 |
| 2002 | CZ | CZ0018A | Chomutov (UCHMA) | 99 | 47,52 | 134 |
| 2002 | SE | SE0022A | Södermalm (8576) | 99 | 18,28 | 9 |
| 2002 | SI | SI0001A | Celje (E23) | 99 | 34,27 | 57 |
| 2002 | CH | CH0011A | Lugano (LUG) | 99 | 36,81 | 78 |
| 2002 | PL | PL0012A | MpKrakowWIOSAKra6117 (MpKrakowWI) | 99 | 89,08 | 284 |
| 2002 | SE | SE0024A | Uppsala (8783) | 99 | 34,65 | 82 |
| 2002 | FI | FI0092A | Leppävaara 2 (407) | 99 | 24,42 | 27 |
| 2002 | FI | FI0124A | Kallio 2 (425) | 99 | 16,86 | 9 |
| 2002 | CH | CH0021A | Zürich Schimmelstrasse (ZBW) | 98 | 30,90 | 33 |
| 2002 | GB | GB0609A | SWANSEA (SWAN) | 98 | 25,00 | 5 |
| 2002 | SK | SK0002A | Trnavske myto (112) | 98 | 34,90 | 59 |
| 2002 | EE | EE0013A | Viru (EE01) | 98 | 41,06 | 85 |
| 2002 | ES | ES1357A | ES1357A-BURGOS 2 (9059004) | 97 | 36,81 | 37 |
| 2002 | SK | SK0005A | Namestie Slobody (211) | 96 | 29,32 | 39 |
| 2002 | GR | GR0047A | PANORAMA (208) | 95 | 34,09 | 47 |
| 2002 | SI | SI0002A | Maribor (E22) | 95 | 37,47 | 66 |
| 2002 | CZ | CZ0063A | Plzen-stred (PPLEA) | 93 | 20,65 | 6 |
| 2002 | PL | PL0002A | LdLodzWSSEMWodna40 (LdLodzWSSE) | 76 | 41,56 | 71 |
| 2002 | HU | HU0020A | Szeged (HUSE01) | 74 | 49,94 | 113 |
| 2002 | GR | GR0003A | ARISTOTELOUS (109) | 60 | 54,79 | 111 |
| 2003 | HU | HU0020A | Szeged (HUSE01) | 100 | 48,70 | 148 |
| 2003 | EE | EE0013A | Viru (EE01) | 100 | 38,25 | 78 |
| 2003 | SK | SK0002A | Trnavske myto (112) | 99 | 32,25 | 48 |
| 2003 | FI | FI0124A | Kallio 2 (425) | 99 | 16,35 | 2 |
| 2003 | FI | FI0092A | Leppävaara 2 (407) | 99 | 20,62 | 15 |
| 2003 | GB | GB0636A | CAMDEN KERBSIDE (CA1) | 99 | 35,35 | 49 |
| 2003 | SK | SK0005A | Namestie Slobody (211) | 99 | 31,54 | 45 |
| 2003 | EE | EE0018A | Õismäe (EE03) | 98 | 19,39 | 6 |
| 2003 | GB | GB0609A | SWANSEA (SWAN) | 98 | 24,88 | 11 |
| 2003 | SE | SE0024A | Uppsala (8783) | 98 | 30,27 | 36 |
| 2003 | SI | SI0001A | Celje (E23) | 97 | 50,33 | 141 |
| 2003 | SE | SE0022A | Södermalm (8576) | 97 | 17,79 | 1 |
| 2003 | CZ | CZ0018A | Chomutov (UCHMA) | 96 | 41,89 | 87 |
| 2003 | CZ | CZ0063A | Plzen-stred (PPLEA) | 96 | 27,87 | 22 |
| 2003 | ES | ES1394A | ES1394A-CONSTITUCIÓN (P.F.) (18087005) | 95 | 29,55 | 18 |
| 2003 | ES | ES1357A | ES1357A-BURGOS 2 (9059004) | 95 | 31,31 | 23 |
| 2003 | PL | PL0012A | MpKrakowWIOSAKra6117 (MpKrakowWI) | 93 | 80,17 | 224 |
| 2003 | CH | CH0011A | Lugano (LUG) | 93 | 36,24 | 68 |
| 2003 | SI | SI0002A | Maribor (E22) | 93 | 56,61 | 180 |
| 2003 | PL | PL0002A | LdLodzWSSEMWodna40 (LdLodzWSSE) | 84 | 43,46 | 93 |
| 2003 | GR | GR0047A | PANORAMA (208) | 76 | 33,19 | 30 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2003 | CZ | CZ0040A | Brno-Kroftova (BBNFA) | 62 | 30,72 | 28 |
| 2003 | GR | GR0003A | ARISTOTELOUS (109) | 62 | 56,42 | 120 |
| 2004 | HU | HU0020A | Szeged (HUSE01) | 100 | 40,47 | 102 |
| 2004 | CZ | CZ0018A | Chomutov (UCHMA) | 100 | 30,84 | 45 |
| 2004 | EE | EE0018A | Õismäe (EE03) | 99 | 17,64 | 8 |
| 2004 | CH | CH0011A | Lugano (LUG) | 99 | 30,81 | 34 |
| 2004 | FI | FI0124A | Kallio 2 (425) | 99 | 13,90 | 3 |
| 2004 | SK | SK0002A | Trnavske myto (112) | 98 | 37,17 | 76 |
| 2004 | FI | FI0092A | Leppävaara 2 (407) | 97 | 18,53 | 15 |
| 2004 | SK | SK0005A | Namestie Slobody (211) | 97 | 32,38 | 52 |
| 2004 | CZ | CZ0063A | Plzen-stred (PPLEA) | 97 | 23,47 | 5 |
| 2004 | SI | SI0002A | Maribor (E22) | 96 | 45,70 | 129 |
| 2004 | ES | ES1394A | ES1394A-CONSTITUCIÓN (P.F.) (18087005) | 96 | 31,92 | 37 |
| 2004 | GB | GB0636A | CAMDEN KERBSIDE (CA1) | 96 | 34,95 | 43 |
| 2004 | SI | SI0001A | Celje (E23) | 95 | 39,69 | 79 |
| 2004 | CH | CH0021A | Zürich Schimmelstrasse (ZBW) | 94 | 29,88 | 28 |
| 2004 | SE | SE0022A | Södermalm (8576) | 93 | 17,24 | 3 |
| 2004 | SE | SE0024A | Uppsala (8783) | 92 | 26,66 | 42 |
| 2004 | ES | ES1357A | ES1357A-BURGOS 2 (9059004) | 89 | 33,23 | 29 |
| 2004 | GR | GR0047A | PANORAMA (208) | 87 | 31,97 | 25 |
| 2004 | PL | PL0002A | LdLodzWSSEMWodna40 (LdLodzWSSE) | 64 | 34,21 | 33 |
| 2004 | PL | PL0012A | MpKrakowWIOSAKra6117 (MpKrakowWI) | 62 | 69,68 | 132 |

Larsen, R . I. *A Mathematical Model for Relating Air Quality Measurements to Air Quality Standards.* U.S. Environmental Protection Agency Research Triangle Park, North Carolina Publication Number AP-89,1971.

# Annex 5 Description of the CITEAIR project

### Introduction

The development of Europe's urban centres is in many ways linked with the development of sustainable mobility options. Changes in behaviour, economic growth or recession and structure of the population are factors that have an immediate impact on transport and mobility patterns. Cities and regions are the place where the most complex challenges in transport and environment need to be solved.

Air quality has unquestionably adverse effects on human health. Because the dominant source of environmental impacts in most urban areas is traffic, local and regional authorities must find efficient and integrated solutions for their environmental and traffic problems to increase the quality of life for its citizens. The pressure on European cities and regions to implement the related EU regulations on air quality has led to a multitude of initiatives to develop a concrete sustainability perspective, which compromises between environmental quality and economic growth.

However, the absence of a common approach for the implementation of these regulations has led to isolated solutions, which requires an initiative for a) developing better solutions, b) more efficient solutions, c) solutions that go beyond the obligations of the related EU directives, d) creating synergies and e) sharing the expertise, knowledge and experiences.

The core cities Leicester (UK), Paris (FR), Prague (CZ), Rotterdam (NL), Rome (I) and most of the follower cities Munich (DE), Coventry (UK), den Hague (NL), Bratislava (SK) and Brussels (BE) have a solid base of previous and ongoing work in the area of transport and environmental management, as part of their efforts to obtain sustainable development for their regions. In most of the cities, there exists policies, an infrastructure of hardware and software tools, an excellent knowledge about environmental effects and appropriate abatement methods.

The region of Emilia-Romagna Region (I) will also be involved in the project as a Transfer Region, where better environmental and traffic solutions are required. Here, the knowledge and experiences of the core cities will be transferred.

The overall objectives of CITEAIR are:

- to jointly develop better and more efficient solutions for assessing the impact of traffic on air quality in large urban areas using Information Society Technologies,
- to inform professional users and the public on the environmental situation based on common guidelines and
- to give guidance on efficient measures to abate adverse environmental situations through close co-operation, experience exchange and joint developments with European Cities and Regions.

### The products

The CITEAIR project aims to support European Cities and regions in their efforts to abate adverse environmental situations and is committed to develop a variety of products. These products, briefly described below, will have the potential for a wide application, as they will meet the needs of potential users beyond the parties actually involved in the project.

The five core cities of this project developed and are operating tools integrated into a Decision Support System (DSS) that assess the environmental impacts of urban traffic in near real-time. Emilia-Romagna Region (I) has an urgent need to adopt a DSS to abate adverse environmental situations throughout the whole region. The guidebook *Transferring a traffic-environmental models chain* will analyse the procedures for transferring existing systems from the core cities to Emilia-Romagna Region. The main component will be an implementation plan for the establishment of a DSS, meeting the needs and requirements of the Emilia-Romagna region, as well as guidance for future transfers to other European cities and regions.

The guidebook *Air Quality Management* will propose solutions for efficient environmental management and will draw as much as possible on tried and tested experiences - derived from case studies – and where necessary identify gaps in knowledge and strategies. Solutions for reducing emissions and redistributing traffic emissions etc. will be covered, with examples of traffic demand management strategies (TDMS) and urban planning, suitable for a range of city environments.

The EU Framework Directive on ambient air quality and the Aarhus Convention on making environmental information available to the public, impose obligations on local authorities to inform the public on the environmental situation. Beyond these obligations most cities have already put efforts into activities to inform to inform the public via different media including the World Wide Web. The guidebook *City Annual Air Quality Reports* proposes a common reporting format. It is supported by a partly automated report generator, producing reports both in English and a local language (translation not made by CITEAIR). The guidebook *Communicating Air Quality* is an introduction to communication theory and provides examples of air quality communication. Central to both the reporting and communication guidebooks is the conversion and interpretation of existing technical air quality data into accessible, interesting and comprehensible data for the public. The development of a Common Air Quality Index (described in the document Comparing Urban Air Quality across Borders) and the introduction of the website *www.airqualitynow.eu* facilitate the comparison of air quality across borders. The website www.airqualitynow.eu is a platform for cities to show easily comparable air quality data (both year averages and near real time) derived from urban background and roadside stations.