# INTERPRETING AIR QUALITY IN REAL TIME

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## ABSTRACT

There is a need for public information on the environment (the obligation to inform the public is part of the EU guidelines on air quality, the Aarhus convention, etc.) Several organisations present pollutant concentrations in real time on the internet. Apart from showing the data, there is a need for real time interpretation: the public wants to know whether the air quality is good or bad. However, air quality standards are often based on yearly averages. Judging hourly values by the yearly average standard is not feasible as most concentrations show daily and seasonal patterns. Some web sites address this problem by showing moving (24 hours) averages. However, this makes the presentation less attractive and informative as it becomes rather static. This paper proposes a method of interpreting the quality of an hourly value by using a statistical hourly distribution of the yearly average limit value. The method assesses the likelihood of a certain air quality at a given time of the day, day of the week and month of the year. This creates flexible criteria to judge hourly measurements. For example, NO2 is expected to be less on a Sunday afternoon in summer than on a Monday morning rush hour in winter, and a relatively high rush hour value may get adequate compensation at another moment. Therefor expected values are used as a flexible measure to determine whether air quality at a particular moment is adequate or not.

## INTRODUCTION

Air quality data are increasingly being communicated to the public in an automated, near real time fashion, on the internet or through other modern communication instruments (teletext, sms message in case of episodes, etc.). The focus of this paper is on the information that is constantly available on the internet.

The way air quality information is presented differs considerably. Some organizations provide a general quality assessment (an index) for a larger area. The index might be linked to a colour coded map to provide some spatial detail. Others accompany their index with a further description explaining likely differences between urban, rural and roadside settings. A second group of organizations provide the actual (unvalidated) concentration readings from their monitoring network (modelling system) either as such or in combination with a quality index. The concentration data are presented as tables or graphs or interpolated on maps. In addition to the current situation most web sites publish some kind of (index) forecast.

Though most web sites present a considerable amount of technical detail relevant to professional users, their primary interface seems to be directed to the general (lay) public. There are two main reasons for presenting air quality information to the public. Firstly, people have the right to know the quality of the air they breathe. For people with certain health problems, especially in polluted areas, the information or the forecast is of direct relevance and someone might decide to adjust his activities or plans. In general, people might want to seek confirmation on a web site if they experience an episode of poor air quality. Furthermore, this kind of information fits in with “right to know” initiatives on environmental issues. The second reason for wanting to make the public aware of the air pollutant concentrations is that the public is as much a victim as one of the main sources of pollution, particularly in urban areas. Information on air pollution and the mechanisms that drive it, might contribute to increased awareness and contribute to finding ways of abating pollution. Local authorities or EPA-s publish this information to educate the public and thereby back-up generally unpopular policies like curbing or taxing the use of private motor vehicles, investments in park and ride initiatives, etc.

If we want to exploit this educational aspect of providing air quality information we have to assure that our web sites are not only visited by people who have a professional or personal interest in monitoring air quality data but they should also attract repeated visits of the general public. In order to achieve this, the information on the web site has to be specific (high spatial resolution) and dynamic e.g. showing concentrations with a small averaging time (hourly). Though the latter is technically feasible for most pollutant species, the question now arises how to judge whether the air quality at a particular hour is good or bad. Several commonly used indexes (see table 1.) have certain limitations if one wants to be consistent with, for example, the new EU legislation on air quality. In this paper I will describe this problem and propose a way of how to deal with it. The discussion will concentrate on $PM_{10}$ and $NO_2$, the two principal pollutant species in the Netherlands.

## LIMIT VALUES FOR SHORT TERM AND LONG TERM EXPOSURE

The EU air quality directives [1] generally define two types of air quality criteria. One is aimed at long term exposure, which is expressed as a limit value for the yearly average concentration, and one for short term exposure, expressed as a limit value for hourly ($NO_2$) or daily ($PM_{10}$) concentrations. These two limit values differ considerably and this poses a problem when presenting air quality on the internet: a situation can arise that whereas the hourly values are depicted as good throughout the year, the limit value for the yearly average might be exceeded. This can be seen from Table 1, which summarizes some of the air quality indexes found on the web. Supposing that we have a site with a $NO_2$ concentration ranging from 30 to 70 $\mu g/m^3$ throughout the year with an average of 50 $\mu g/m^3$. A concerned citizen, looking at his local internet site on a regular basis is likely to be surprised that, while being in the good to very good range throughout the year, at the end of the year his house is in a spot which is deemed unfit for living. An abatement plan has to be made and further construction of houses is prohibited unless we can show that these plans will reduce $NO_2$ concentrations to below 40 $\mu g/m^3$ by 2010. This applies to any web site using an index similar to the ones in Table 1.

Though the indexes in Belgium and in Paris differ slightly at the lower end of the scale, the categories for bad and very bad are the same. They are based on the EU limit values for hourly concentrations. The UK categories are based on actual health effects during pollution episodes and reflect the degree to which people can experience and/or are affected by air pollution during episodes (Paul Willis, p.c.). Looking at the above example and at Table 1. it seems that there is an interpretation difficulty at the lower end of the scale.

<table>
<tr><td rowspan="2">index</td><td colspan="2">Paris [2]</td><td colspan="2">Belgium [3]</td><td colspan="2">UK [4]</td></tr>
<tr><td>μg/m³</td><td>description</td><td>μg/m³</td><td>description</td><td>μg/m³</td><td>description</td></tr>
<tr><td>1</td><td>0-29</td><td rowspan="4">good</td><td>0-25</td><td rowspan="4">good</td><td>0-95</td><td rowspan="3">low</td></tr>
<tr><td>2</td><td>30-54</td><td>25-45</td><td>96-190</td></tr>
<tr><td>3</td><td>55-84</td><td>45-60</td><td>191-286</td></tr>
<tr><td>4</td><td>85-109</td><td>60-80</td><td>287-381</td><td rowspan="3">moderate</td></tr>
<tr><td>5</td><td>110-134</td><td>moderate</td><td>80-110</td><td>moderate</td><td>382-476</td></tr>
<tr><td>6</td><td>135-164</td><td rowspan="2">poor</td><td>110-150</td><td rowspan="2">poor</td><td>478-572</td></tr>
<tr><td>7</td><td>165-199</td><td>150-200</td><td>573-635</td><td rowspan="3">high</td></tr>
<tr><td>8</td><td>200-274</td><td rowspan="2">bad</td><td>200-270</td><td rowspan="2">bad</td><td>636-700</td></tr>
<tr><td>9</td><td>275-399</td><td>270-400</td><td>701-763</td></tr>
<tr><td>10</td><td>>=400</td><td>very bad</td><td>>400</td><td>very bad</td><td>>=764</td><td>very high</td></tr>
</table>

NB: the EU yearly average limit value (in 2010) is 40 μg/m$^3$.

Table 1: $NO_2$ concentration indexes for hourly measurements on three web sites[1]

There are two solutions to resolve the inconsistency between the short term and the long term exposure limit values. The first option would be to simply use the EU limit values for the yearly average as the dividing line between good and moderate air quality (40 μg/m$^3$, both for $NO_2$ and $PM_{10}$). However, this is not very attractive as the two main pollutants in the Netherlands both exhibit seasonal, daily and hourly variation (see the figures in box 1). So, an hour with a concentration above 40 μg/m$^3$ might not be bad if this hour finds adequate compensation at another moment in the year. If the main variation is diurnal, moving to the presentation of a 24-hour moving average might solve this problem. Though the 24-hour moving average for $NO_2$ does not capture the seasonal variation of the pollutant, one of the air quality web sites for Rotterdam presents the moving 24-hour average $NO_2$ concentration to somehow reduce the inconsistency between short and long term exposure criteria. See table 2. For $PM_{10}$ a moving 24-hour average does capture most of the variation as the seasonal component is much weaker than in $NO_2$.

| index | hourly $NO_2$ concentration (μg/m$^3$) | 24-hour moving average $NO_2$ concentration (μg/m$^3$) | 24-hour moving average $PM_{10}$ concentration (μg/m$^3$) |
|---|---|---|---|
| good | 0-100 | 0-20 | 0-20 |
| moderate | 100-200 | 20-40 | 20-40 |
| bad | 200-400 | 40-80 | 40-60 |
| very bad | >400 | >80 | >60 |

Table 2: Index currently used on the traffic related air quality web site in Rotterdam [5]

[1] As the table shows, even though the three countries are ruled by the same EU-legislation, there are marked differences. In the INTERREG IIIc funded CITEAIR project (2004-2007) a number of major European cities will collaborate to see if some level of harmonisation can be achieved (http://citeair.rec.org).

*Box 1. Urban background expected concentration patterns (Rotterdam area, average 1999 - 2003)*

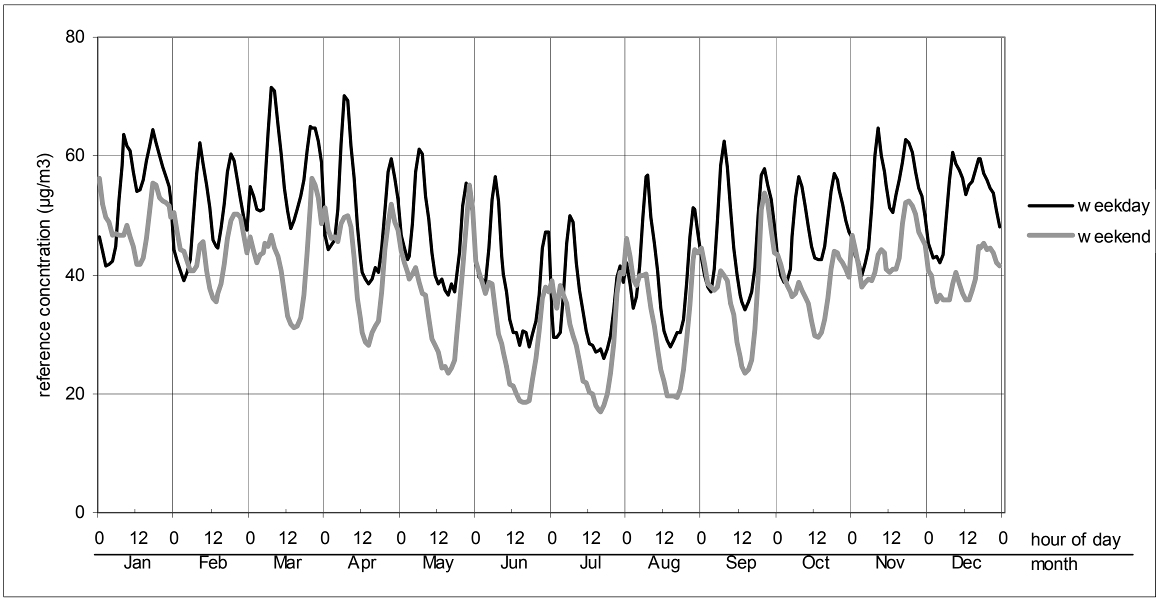


Figure 1: Average daily $NO_2$ concentrations in every month of the year in Schiedam

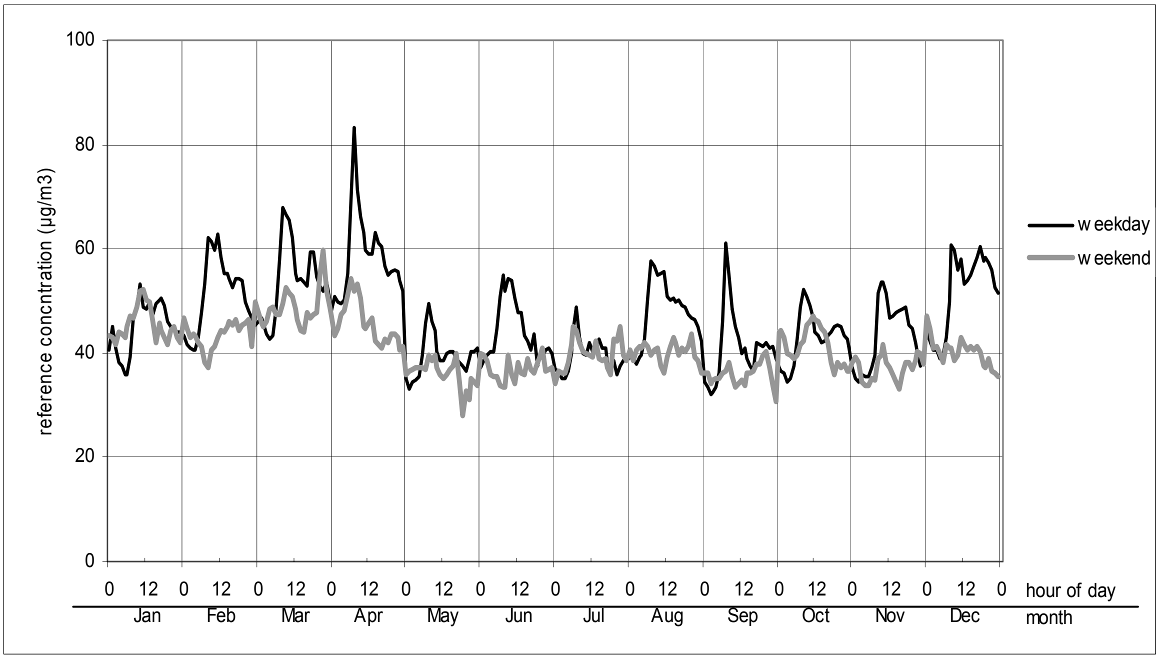


Figure 2: Average daily $PM_{10}$ concentrations in every month of the year in Schiedam

The graphs show the diurnal pattern in each month (NB: Jan - 12, means noon on an average day in January and **not** 12th of January), both for weekdays and for weekends. It is clear than on weekends concentration levels are less than on weekdays. On all days there are peaks in the morning and the evening (related both to rush hours and the combination of mixing height and atmospheric chemistry) and especially $NO_2$ shows a strong seasonal pattern.

To be fully consistent with the EU limit values for short term exposure one would have to present a moving yearly average concentration. Though this is feasible for the percentiles of exceedences (e.g. the number of days in the past 365 days with a daily average $PM_{10}$ concentration above 50 $\mu g/m^3$) it would be a very dull indicator for the hourly concentration. It would certainly not entice people to come back to the web site to see if the concentration has changed. Even the 24 hour moving averages are fairly dull to monitor on a regular basis, and what is more important: the relation between the physical event (e.g. the rush hour) and the concentration data displayed on the internet is somewhat lost: the peak is not as high as you would expect and it arrives with a delay of several hours. See the figures in box 2.

If one wants to use the internet in an educational or advocative way, the visitors to the web site should be able to link the events that they might actually be observing (rush hour, bad air quality) to the concentrations they see displayed on the site. In this case the moving averages are not an attractive solution so the second option is based on a reference pattern to interpret hourly values and assure some sort of consistency between the short and long term limit values. It is presented in the next section.

*Box 2. Hourly patters and 24 hour moving averages*

The distinct peaks in the $NO_2$ concentration, which are partly related to the traffic conditions, on a Friday do not show up in the moving average until early morning Saturday. And whereas the hourly weekend concentrations are less, as would be expected, the moving average remains high on Saturday, still being influenced by Friday. The relation between the 24-hour moving average and what is happening is poor.

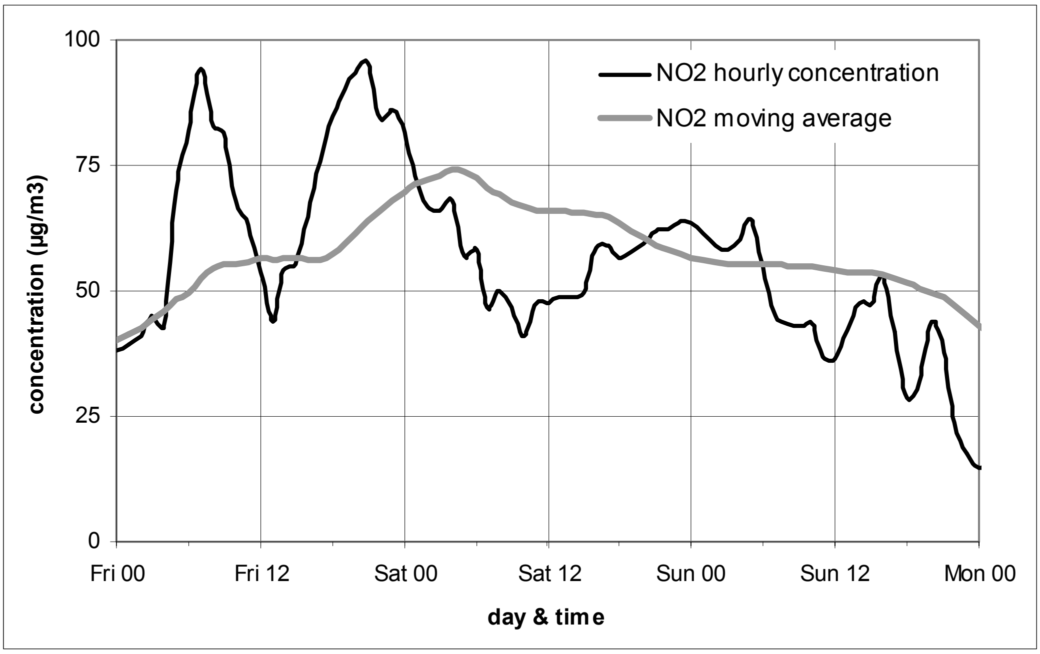

Figure 3: Hourly and 24-hour average $NO_2$ concentrations from Friday to Sunday, city background.

The most extreme example of a moving average being out of sync with the events can be seen from the $PM_{10}$ concentrations during New Years night as shown in figure 4. Whereas there is a dramatic peak in the first hour of the year in the hourly concentrations, the moving average depicts a level not uncommon to a regular calm (winter) day.

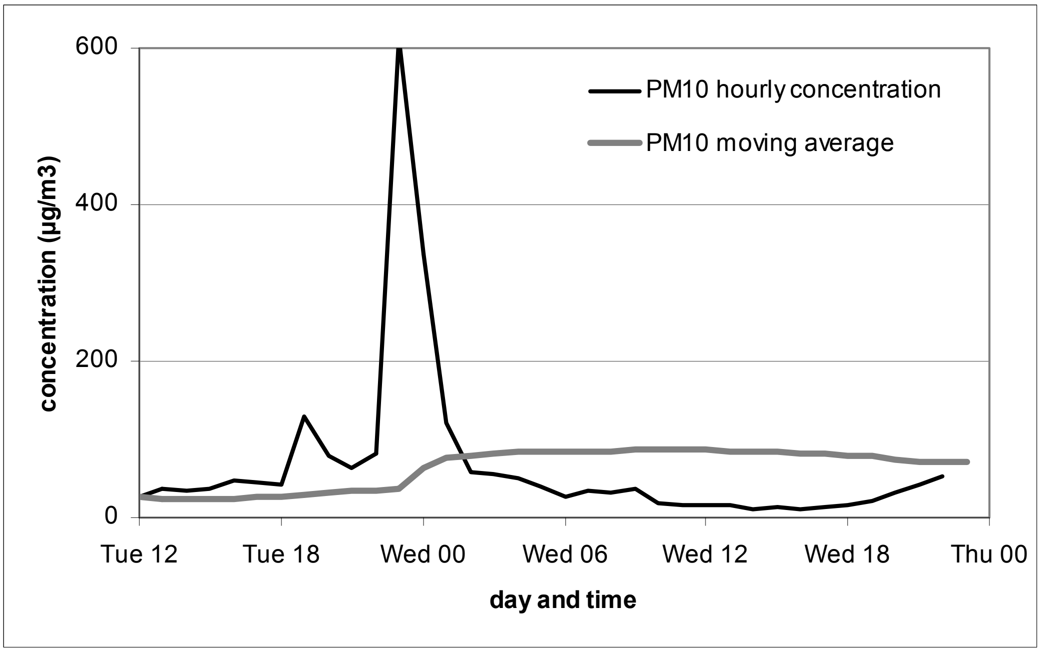


Figure 4: $PM_{10}$ concentrations on New Years night 2002 – 2003, urban background site.

COMBINING SHORT AND LONG TERM EXPOSURE CRITERIA INTO SINGLE INDEX FOR HOURLY VALUES

In the Netherlands, the national network [6] provides hourly concentrations for most pollutant species. No index or quality interpretation is being provided. DCMR [7] shows hourly concentrations on its web site for the Rotterdam area. The graphs are presented without a quality indication. but a description of what people might expect as a normal concentration at a certain hour of the day, day of the week and season, is being attached to each graph. This was not very satisfactory and DCMR was looking for some kind of solution to interpret hourly measurements, while avoiding the potential confusion between the criteria for short and long term exposure.

The solution, which is currently being implemented on the DCMR web site is based on the observed patterns in the concentrations as shown in box 1. The quality of a certain concentration on a given hour is judged as adequate if the hour fits in a pattern that will lead to the maximum allowable yearly average concentration. In other words, hour by hour, an assessment is made whether the observed concentration fits into the reference pattern leading to 40 μg/m$^3$ (the limit value) or is likely to contribute to the exceedence of the yearly average limit value.

Take the example of $NO_2$. The average pattern of the concentrations over the past five years is shown in Figure 1. For each hour and each type of day (week/weekend), in each month of the year the pattern is available. If the daily patterns, are put in the correct order (observing weekdays and weekends as they occur throughout the year) the expected yearly pattern can be established. See the example of Figure 5. The repeated day/week pattern is visible, as is the change of one month to the next.

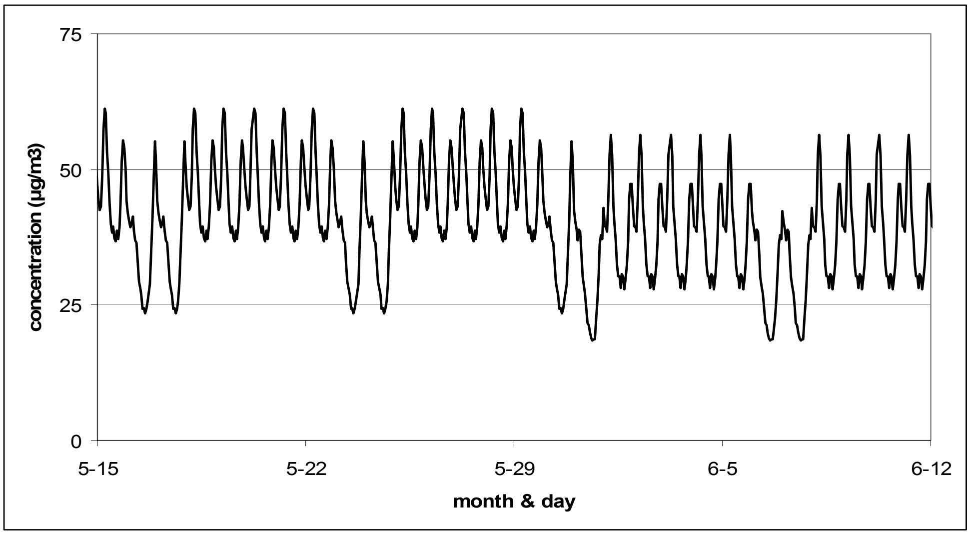


Figure 5: Example of the expected (average) pattern of $NO_2$ for the period May 15-June 12, 2004.

The average urban background $NO_2$ concentration of the past five years (the line that is shown partly as an example in Figure 5.) would lead to a yearly average concentration of 45.5 μg/m$^3$. This line of expected concentrations can be scaled down to arrive at a reference line leading exactly to a year average of 40 μg/m$^3$. For every hour (h) in the year the calculation in equation (1) is made:

$$\text{Reference concentration}_{(h)} = \text{expected concentration}_{(h)} * 40 / \text{expected yearly average} \qquad (1)$$

In our case all expected values are multiplied with 40/45.5. Using this new line as a reference, it is clear that an hourly value above this line is unlikely to be compensated at another moment in the year so this hourly $NO_2$ concentration is labelled as mediocre. A concentration below the line is labelled as adequate. See figure 6.

If the observed concentrations follow the top of the green area, throughout the year, the yearly average will be 40 μg/m$^3$. As can be seen from Figure 6. the air quality interpretation using the reference pattern is more strict on Sunday afternoon than on a weekday morning. Likewise, it is more strict in summer and less so in winter. The example shows that the actual concentrations do follow the broad pattern. In the approach chosen, an hourly concentration above 40 μg/m$^3$ on Tuesday evening is interpreted as adequate whereas a concentration below

40 µg/m$^3$ on Saturday afternoon is mediocre because statistically it is not likely to be compensated by an hour with a lower concentration later in the year.

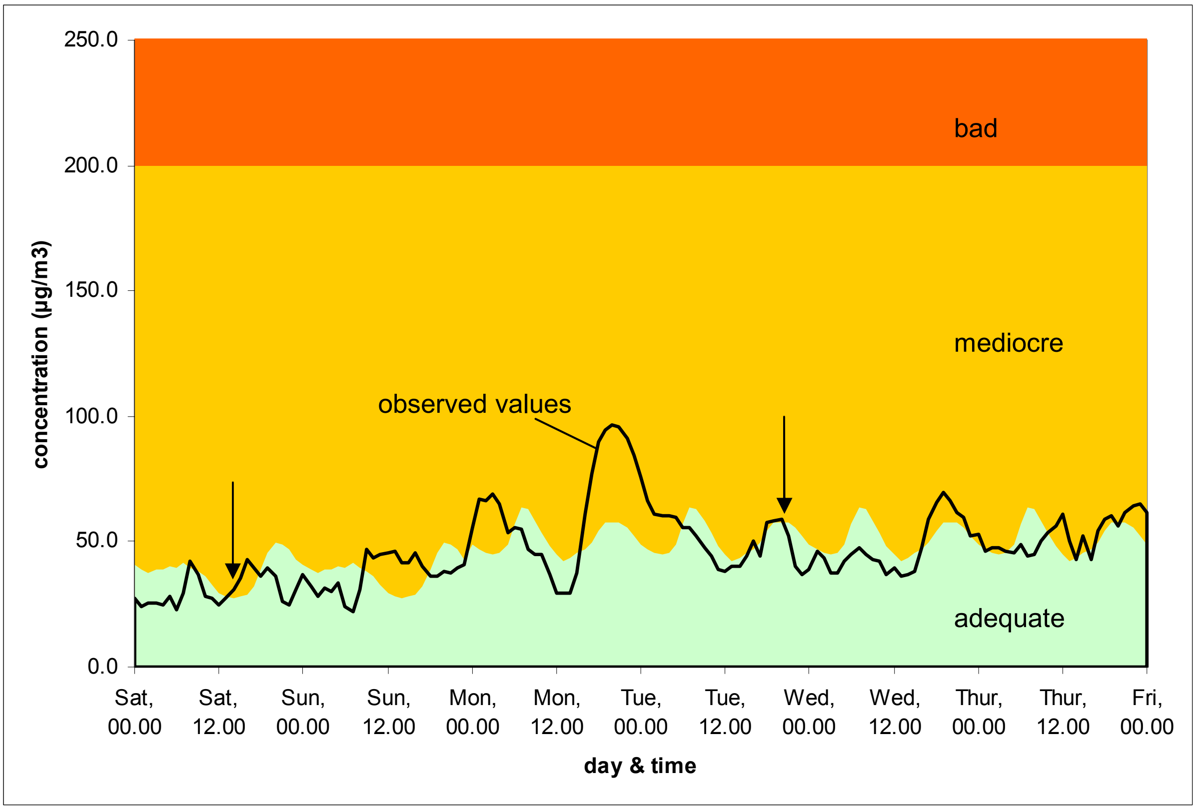


Figure 6: Hourly $NO_2$ concentration interpreted using a reference pattern in the low pollution part of the scale.

The upper limit of the mediocre zone is set at a fixed level of 200 µg/m$^3$. Similarly, the border between 'bad' and 'very bad' is fixed at 400 µg/m$^3$. For these concentrations the hourly limit values as found in the EU directives are used.

The use of a reference concentration for the lower end of the scale of the quality indicator of the hourly concentrations seems appealing: in one glance a person can see what the expected pattern of a certain pollutant species is and how it links to events he/she can relate to (e.g. rush hour, consumption of energy, etc.); it gives an impression of whether or not one is close to achieving the yearly average limit values; and it provides a frequently changing picture something which might be visited repeatedly. This is of particular importance in situations where the concentrations are close to the limit values for the yearly average. In this case some differentiation in the zone below 200 µg/m$^3$ (in case of $NO_2$) is needed to be able to continue to attract people's attention.

For $NO_2$ and $PM_{10}$ the reference line is based on the average data for five years in an urban background situation[2]. The period of five years was arbitrarily chosen reasoning that it should

[2] For $PM_{10}$ it is currently based on three years for lack of more data at the reference site.

not be too short to avoid that exceptional weather or incidents in a certain year influence the pattern. On the other hand it should not be too long to assure that it reflects current patterns instead of historic patterns. The reference pattern for other components ($SO_2$, VOC-s) are based on a yearly average daily pattern. The ozone concentrations are too dependent on the actual weather conditions to be able to establish a reference pattern. In the case of ozone fixed values are used (120, 180 and 240 $\mu g/m^3$ mark the borders between adequate, mediocre, bad and very bad respectively).

## SUMMARY & CONLUSION

Public information on air quality is in many cases a statutory obligation. In most countries it is also a service to target groups sensible to air pollution. However, public information on air quality might also be used in an educational way: often the public is as much a victim, as a source of air pollution. To capture the public attention to web sites showing air quality data in near real-time it is necessary that the data is dynamic and that there is a potential link between what people experience and the information they get through the internet. This calls for the shortest possible time resolution.

To bridge the conceptual gap between the criteria used for long term exposure (generally based on fairly low yearly average concentrations) and the much higher concentrations used to judge the risk of short term exposure, reference concentrations based on the yearly average limit value are calculated. They are used for the interpretation, at the lower and of the pollution scale, of hourly concentration measurements.

The use of a reference pattern conveys a lot of information on the expected and desired behaviour of the pollutant measurements at a glance, it leads to frequently changing situations that might tempt people to visit the web site frequently. This is of importance in areas where yearly average limit values are almost met, and where influencing people's behaviour is necessary to make the difference.


## ACKNOWLEDGEMENTS

The author wants to thank Johan Voerman and Leo Hermans for comments and Michael Ameling for work on the web site.


## REFRENCES


[1] Framework Council Directive 96/62/EC, First Daughter Directive (1999/30/EC), Second Daughter Directive (2000/69/EC) & Third Daughter Directive (2002/3/EC) at: http://europa.eu.int/comm/environment/air/ambient.htm
[2] www.airparif.asso.fr
[3] www.irceline.be
[4] www.airquality.co.uk
[5] www.luchtkwaliteit.rotterdam.nl
[6] www.lml.rivm.nl
[7] www.dcmr.nl/lucht