

Air4EU

Air Quality Assessment for Europe: from local to continental scale



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Priority 8.1 Topic 1.5 Task 2

Individual case study report: Trend analysis of NO₂/NO_x and PM₁₀ exceedance of daily limit values in Rotterdam

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1. Executive Summary

In order to implement local measures to improve air quality, local authorities require information on the local contribution to air quality levels. In this case study both trend analysis and statistical methods are demonstrated to estimate the local contribution to the urban background of NO₂ and PM₁₀ respectively. Monitoring data from urban background and regional stations over the period 1986-2005 have been analysed in Rotterdam.

Despite significant decrease of NO_x emissions in this period, NO₂ concentrations remain at the same level since the end of the nineties. Trend analysis revealed that the ozone/NO_x equilibrium is a more important factor than increasing direct NO₂ emissions from traffic. The latter has recently been identified as an additional NO₂ source due to the introduction of soot filters in diesel vehicles. From the results of this trend analysis it was estimated that in Rotterdam direct NO₂ emissions by urban sources increased from 9% in 1986 to 13% in 2005. It is concluded that local NO_x emissions in Rotterdam need to be reduced by 50% before lower NO₂ urban background levels can be achieved.

The second subject in the case study is related to PM₁₀ exceedances at urban background stations. Analysis of PM₁₀ exceedances both at regional and urban stations indicate that both the background and the local contribution are increased on days when the limit value of 50 µg/m³ PM₁₀ is exceeded. It is concluded that local short-term measures may significantly reduce the number of days exceeding the daily limit values. However, in view of public health protection, it is advised to focus on long-term measures directed to reduce the annual urban background of PM₁₀.

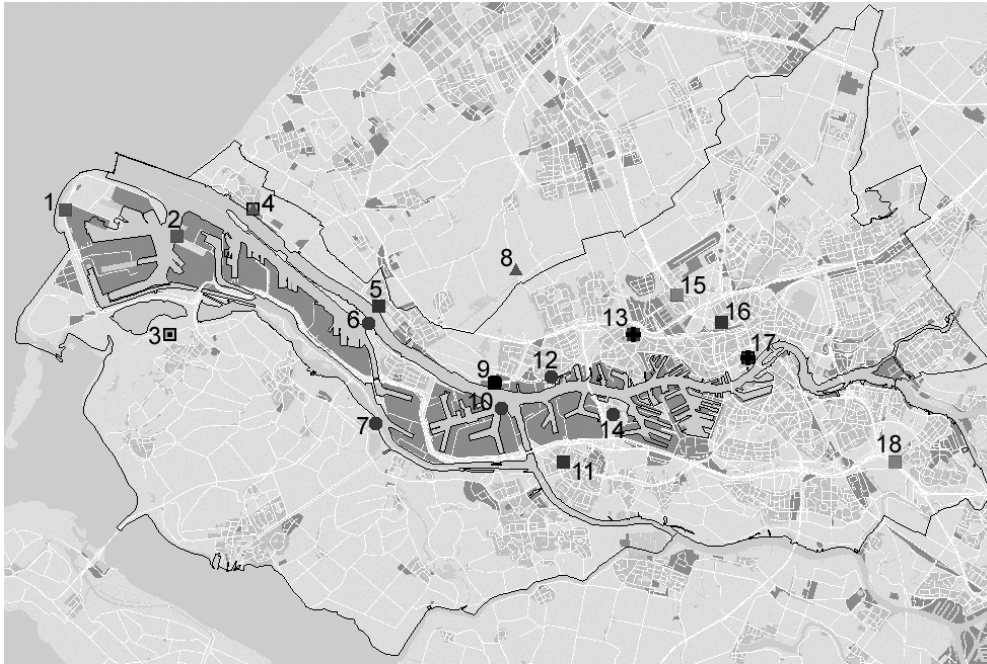
2. Case study description

2.1 Background

The effectiveness of local measures to control AQ limit values for NO₂ and PM₁₀ is questioned in view of the impact of long-range transport to these pollutants. For NO₂, the contribution of local NO_x emissions to NO₂ levels is largely controlled by ozone levels. Ozone concentrations mainly depend on large scale emissions of precursors and meteorological conditions. In general, for PM₁₀ long range transport is the main contributor to local PM₁₀ levels. In order to implement effective local measures, local authorities require information both on the contribution of local sources as well as large scale effects on NO₂ and PM₁₀ concentrations.

2.2 Aim and description

In cooperation with the City of Rotterdam - DCMR, the case study demonstrates trend analysis and statistical analysis as instruments to study urban and regional background NO₂ and PM₁₀ concentrations. Monitoring data of NO_x, NO₂, ozone and PM₁₀ in and around Rotterdam are used as input for the study. The monitoring network of DCMR is provided in Figure 1.



1) Maasvlakte	10) Botlek
2) Markweg;	11) Hoogvliet
3) Oostvoorne	12) Vlaardingen 2
4) Hoek van Holland	13) Schiedam
5) Maassluis	14) Pernis
6) Rozenburg;	15) Overschie
7) Zwartewaal	16) Bentinkplein
9) Vlaardingen 1	17) Rotterdam
	18) A16-Ridderkerk

Figure 1: Monitoring stations in and around Rotterdam (Rijnmond area; the Netherlands): in the west the North Sea, in the east the residential area of Rotterdam and in the centre the river with harbours/industries.

2.3 Relevance to recommendations in Air4EU

The case study Rotterdam on trend analysis refers to recommendations in Air4EU-D6.2 [3] background report on air quality assessment at urban (Part II) and regional (Part IV) scales. Especially, relevant are the following basic requirements and best practices on trend analysis:

- There are many variables that can cause year-to-year variations in monitored pollutant levels. Identifying air quality trends can be a difficult matter with a small database of representative years. **It is recommended for a trend analysis with complete data records extend over five years or more.**

- Analysis of trends depends heavily on the consistency of measurements over time. This relates to aspects such as monitoring equipment, calibration methods, network design. **It is recommended to take into account monitoring consistency in trend analysis.**
- **It is recommended to make a clear distinction between meteorological trends and variability and trends due to changes in emissions.**

3. Methodology

In general, trend analysis is applied to study changes in air quality over a period of time. For a proper trend analysis, the basic requirements to collect adequate monitoring data are as follows:

- 1) *Time series*; Time series must be long enough if possible 8-10 years or more;
- 2) *Data Quality Objectives*; Data from the monitoring network should comply with QA/QC procedures described in the EU Directive. Especially, data coverage should be at least 75%;
- 3) *Monitoring locations*; Changes in the monitoring locations (during the time series) can have profound effect on the concentrations, and consequently will introduce an artefact in the trend analysis. This holds particularly for sites near sources;
- 4) *Equipment*; Similar to changes in locations, also changes in monitoring methods should be avoided; but if this occurs then equivalence must be shown
- 5) *Environment*; Particularly in urban areas trends can be introduced due to changes in the physical environment over the years. This may involve buildings, roads, redirecting traffic flows etc. It is almost impossible to avoid such developments but it should be considered when the validity of trends is analysed.

There is extensive literature on trend analysis (for an overview, see: Roemer, 2001 [1]). The following is a description of the basic steps in analysing time series.

- 1) *Visual inspection of monitoring data*; Plotting the monitoring data in segments of one year each allows the detection of outliers, offsets, drifts, and other irregularities. This is useful information prior to statistical analyses;
- 2) *Annual variation*; Check the normal/lognormal distribution of the data and compute the average, median and range of the annual data as well as for summer and winter. This provides information on the annual variation of the data and whether it is required to treat separately a part of the annual data;
- 3) *Spatial variation*; In studies concerning several monitoring stations, the results obtained under 2) should be compared to results from neighbouring sites. This provides information on the area of spatial representation of the trend analysis;
- 4) *Trend significance*; The robustness of the trend is tested by the margins at the 95% confidence level. A simple test is the effect on the trend when 2 years at the end or beginning of the time series are left out. Basically, the trend should remain within the margins of the 95% confidence level, if not the trend is not robust;
- 5) *Meteorological variation*; Fluctuating meteorological conditions have two effects on trends: it increases the uncertainty levels and it may contribute to the trend itself. The last aspect should be reduced if trends in air quality are to be compared with trends in emissions. There are various methods to correct for meteorological variations in particular for ozone: Roemer, 2001 [1].

4. Results

4.1 NO₂/NO_x trends

The first objective in the case study of Rotterdam is to investigate the NO_x trends. The emphasis is on the NO₂ trend, which is trailing the trend in NO_x emissions. The input data concerns monitoring data of NO_x, NO₂ and ozone over the period 1986-2005 at the urban background stations in Schiedam, Maassluis and Hoogvliet presented in Figure 1. In addition data is used from the regional stations in Zierikzee and Kollumerwaard at the coast, respectively in the south and north of the Netherlands. The data in Zierikzee and Kollumerwaard are retrieved from the National Air Quality Monitoring Network managed by RIVM in the Netherlands. In Figure 2, the trends for the annual average NO, NO₂ and O₃ concentrations at the urban background station in Schiedam are presented.

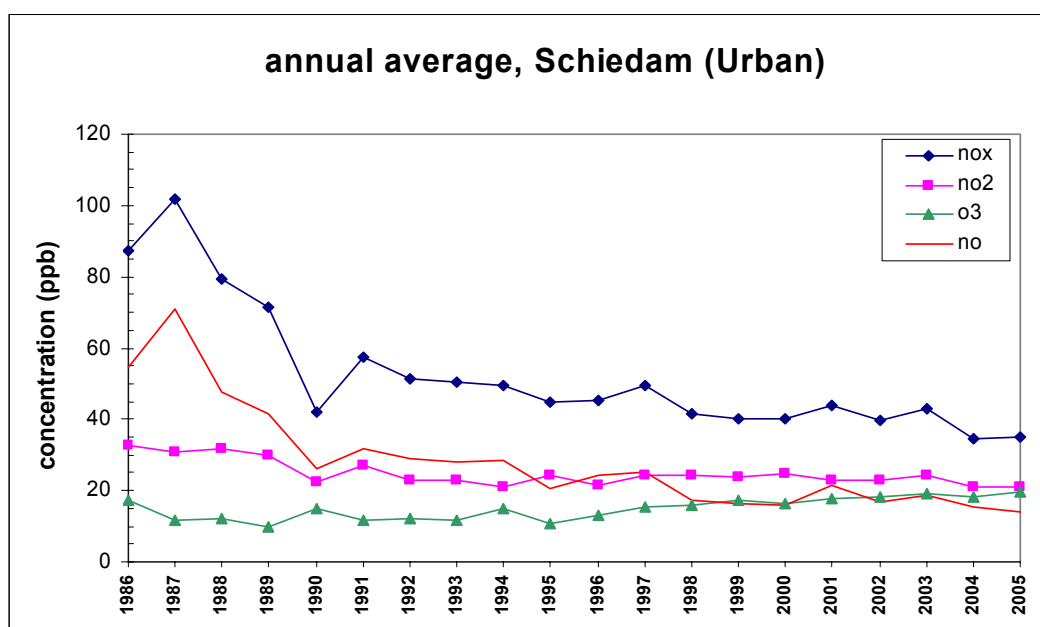


Figure 2: Annual concentrations of NO, NO₂, NO_x and O₃ in Schiedam (1986 – 2005).

The trends in Figure 2 show that NO_x concentrations in Schiedam decreased considerably, especially in the period from 1987 to 1991. During this 4 year period the NO_x concentrations decreased with almost 40%. This is attributed to the large scale introduction of 3-way catalysts, which significantly reduced NO_x emissions of road traffic. From 1991 onwards to 2005, the NO_x concentrations further decreased gradually with 30% in 15 years. The variation from year-to-year in the trend is mainly caused by varying meteorological conditions but this variation is small compared by the long-term trend in NO_x concentrations.

The trends in Figure 2 also shows that for NO₂ the relative trend (in % per year) is smaller than for NO and NO_x. In the 4 year period 1987 to 1991 NO₂ decreased by about 10%. This is in contrast with the remaining period of 15 years from 1991 to 2005, when NO₂ concentrations hardly decreased in Schiedam. Hence, at the urban background station in Schiedam, the annual NO₂ concentration remains at around 35 µg/m³ and consequently the annual NO₂ air quality limit value will be often exceeded near heavy traffic locations. In view of the high traffic intensity in Rotterdam and the

Rijnmond area, in general, this is a problem for the local environmental agency DCMR. Thus, DCMR is interested in the factors controlling the urban background NO_2 concentrations.

4.1.1 NO_x , NO_2 and ozone equilibrium

One hypothesis for the constant NO_2 concentrations, despite the reduction in NO_x emissions, is an increasing ozone background concentration. Another hypothesis is an increase in direct NO_2 emissions due to the introduction of oxidising particle trap catalysts for diesel vehicles. The trend analysis in Figure 2 shows an increase in ozone concentrations at the urban background station in Schiedam from 1991 to 2005, which reflects the reduction of NO_x emissions. So, increasing ozone seems to be a likely explanation for the trend of NO_2 concentrations. In order to study the “ozone-hypothesis”, the NO_2 concentration as function of NO_x over 1986 – 2005 at urban background and rural stations in the Netherlands are presented in Figure 3.

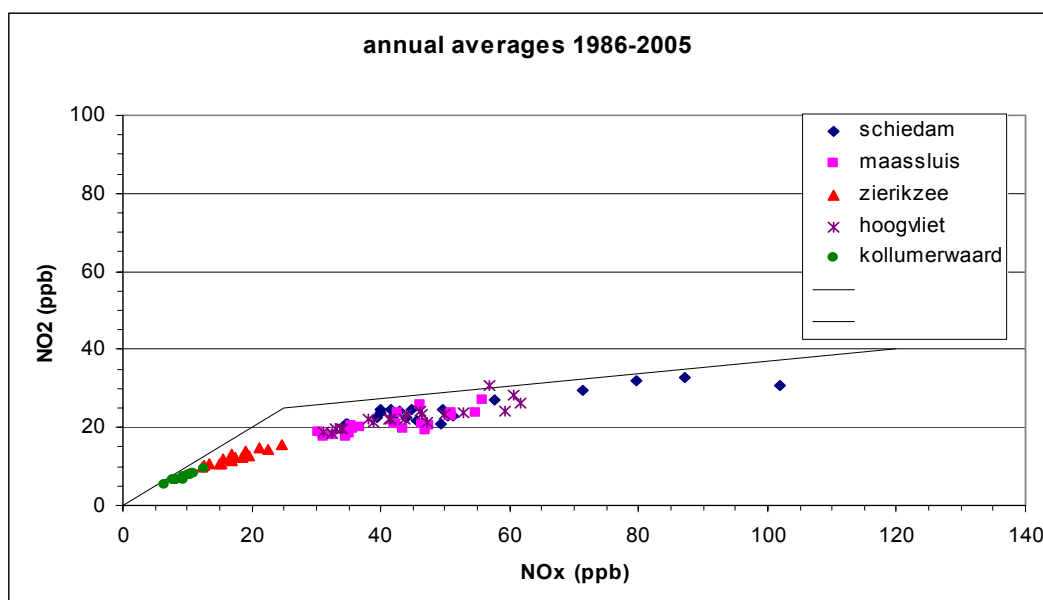


Figure 3: Annual average NO_2 as a function of NO_x for a range of monitoring sites: Schiedam, Maassluis and Hoogvliet (urban background stations in Rijnmond) and Zierikzee and Kollumerwaard (regional background station in the Netherlands) over 1986 – 2005.

Figure 3 shows that NO_2 concentrations at the rural sites (Kollumerwaard and Zierikzee) are a factor of 2 lower than at the urban background sites in Rijnmond. Figure 3 also illustrates that one may distinguish two NO_x /ozone regimes: one at regional background stations with higher ozone concentrations than NO_x concentrations (unpolluted sites) and one at urban background stations and hotspots with lower ozone than NO_x concentrations (polluted sites):

- Under *very clean* conditions, the equilibrium of NO_2 , NO_x and ozone results in equal concentrations of NO_2 and NO_x . In relatively unpolluted conditions (for instance coastal sites in western Europe), there is more NO_2 than NO in the atmosphere. In Figure 3 the straight line up to 25 ppb NO_2 indicates the theoretical one-to-one relation of NO_2 and NO_x concentrations at unpolluted sites. The “cleanest” data at Kollumerwaard (a “true” regional background station) fits this relation best. It is seen that at Zierikzee (a more polluted regional background station) deviation from this one-to-one relation is increasing.

- Under *polluted* conditions, there is a lack of ozone because ozone has reacted with “fresh” NO emitted from combustion sources. Thus NO₂ concentrations are controlled by the regional background NO₂ (25 ppb) plus addition of direct NO₂ emissions. Average direct NO₂ emissions by road traffic are assumed to be 5% of the total NO_x emission in the period 1985 – 2000; recently the amount of direct NO₂ emissions is increased upto 10%. This will be further discussed under the next section. The second straight line is calculated by the function:

$$\text{NO}_2 = 25 + 0.05 * (\text{NO}_x)$$

Depending on the regional background concentration of NO₂ and the percentage of direct NO₂ emissions the function should be modified. The data at the urban background stations fit more or less this relation.

- The two straight lines in Figure 3 have been applied instead of a fit with the photo-stationary state solutions for reasons of simplicity. The photo-stationary relation would require for example assumptions regarding light intensity over the whole year. To demonstrate the importance of the NO_x/ozone equilibrium to control the NO₂ concentrations, it is sufficient to apply this simplified method and plot the monitoring results of urban and regional background sites.

From Figure 3 it is concluded that at urban background sites in Rotterdam the formation of NO₂ from emitted NO is restricted by the lack of ozone. In order to reduce NO₂ levels, NO (e.g. NO_x) emissions in urban areas still need further reduction. Only when NO_x concentrations are below ozone concentrations will further reduction of NO_x emissions result in lower NO₂ levels. At present, NO_x concentrations at urban background in Rotterdam are in the order of 40 ppb, while ozone is at 20 ppb. Hence, NO_x emissions have to be reduced still by 50% before a further reduction of NO₂ can be established in the Rotterdam/Rijnmond area. It is concluded that the NO_x/ozone equilibrium is the most likely reason for the trend of NO₂ in the Rijnmond area.

In the next section, the possibility of increased direct NO₂ emissions by road traffic is studied.

4.1.2 Direct NO₂ emissions

A method to research the possible contribution of increasing direct NO₂ emissions by local sources is based upon the use of the “oxidant” concentration. The oxidant concentration (Ox) is the sum of the ozone and NO₂ concentrations. Under the NO_x/ozone equilibrium Ox should be constant. Due to direct NO₂ emissions by local sources in an urban area, Ox increases when comparing urban Ox to (regional) background Ox. Thus, the delta Ox from an urban and a regional background stations over the years is a method to identify direct NO₂ emissions: Carslaw, 2005 [2]. The method is demonstrated using Rotterdam hourly monitoring data and consists of the following steps:

1. the delta Ox and NO_x of Schiedam (urban) minus Zierikzee (regional background) are calculated from the monitoring data for each year 1986 to 2005;
2. the delta Ox is plotted against the delta NO_x per year;
3. the slope of the regression line is the amount of direct NO₂ emission per year;
4. the slope for each year is plotted against each year from 1986 to 2005: this trend quantifies the increasing direct NO₂ emissions in this period.

In Figure 4 the delta Ox and NO_x for the urban background (Schiedam) in Rotterdam is presented for the year 2002.

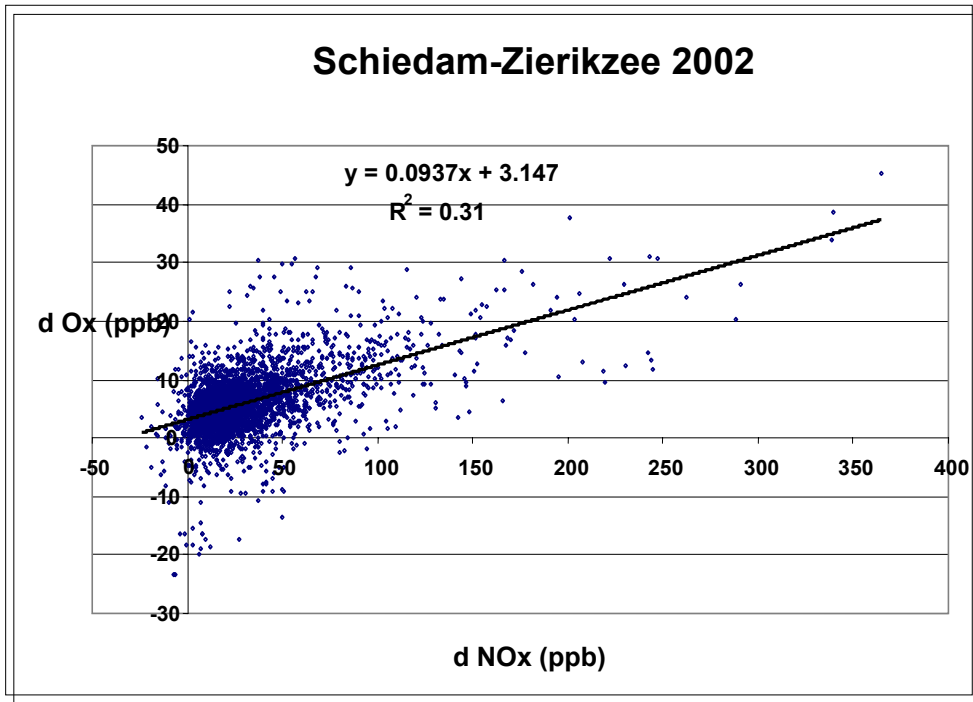


Figure 4: The delta Ox (sum of ozone and NO_x) as a function of delta NO_x for Schiedam (urban) and Zierikzee (regional background) in 2002.

The slope is 0.09 which is an indication that 9% of NO_x is emitted directly as NO₂. Similar to 2002, the slope has also been estimated for the years 1986 to 2006. The results are shown in Figure 5.

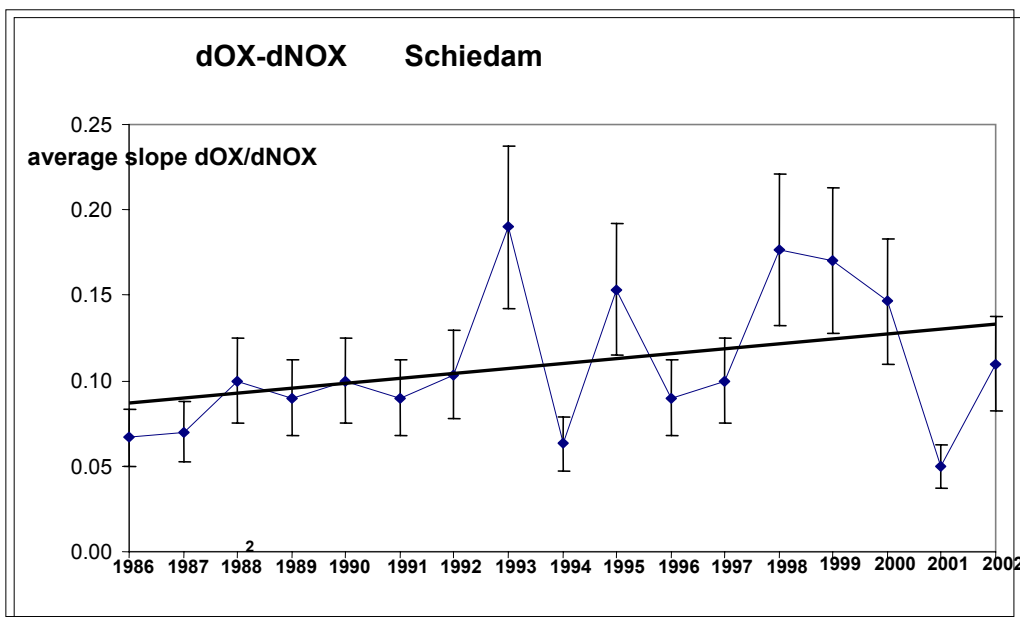


Figure 5: The trend in direct NO₂ emissions at the urban background at Schiedam (Rotterdam) from 1986 to 2005 including the average standard deviation with in 95% confidence level.

Despite some variation from year to year, the method results in a positive trend of direct NO₂ emissions in 1986 of 9 % to 13% in 2002. In London a trend was identified from 5-6% direct NO₂ road traffic emissions in 1997 to 17% in 2003: Carslaw, 2005 [2]. One notes that computation of only the 2002 data in Figure 4 would result in a 9% increase, while the trend analysis indicates a value of 13%. This illustrates the importance of long data series for trend analysis. Recently, the emission factor of road traffic for direct NO₂ emissions in the Netherlands has been increased from 5% to 10% and more. This case study in Rotterdam underlines the need for this modification.

In this case study in Rotterdam, the slopes of the dOx/dNO_x are based on relatively small differences in O_x and NO_x concentrations between urban and regional environment. The range is typically in the order of 0-100 ppb. In the London study, which was directed at direct emissions by road traffic and included traffic and urban background stations, the range is more in the order of 0-1000 ppb. In other words: the contribution of the traffic compared to the background (and the variability therein) is in the Rijnmond area much smaller than in London. Consequently, uncertainty in the slope and temporal development in the slope is larger. These results of the Rijnmond area may therefore be regarded as indicative.

4.1.3 Ozone hypothesis versus direct NO₂ emissions

The data analysis of the Rotterdam case shows that the trend in measured NO₂ trails the trend in NO_x concentrations. Two hypotheses have been explored:

- 1) Due to the high NO/O₃ ratio the reduction in NO_x leads to lower NO but less to lowering the NO₂ concentrations;
- 2) Due to increasing direct NO₂ emissions by traffic which results in higher NO₂ concentrations.

The data confirms that the NO/O₃ ratio is high at urban background sites, and this causes NO₂ concentrations to decrease less than NO_x concentrations. The data furthermore indicates, albeit with relative large uncertainties, that direct emission of NO₂ by traffic has increased from 9 to 13% (as fraction of the NO_x emission).

Is it possible to assess the importance of both developments relative to each other?

This was explored for the data in 1986 and 2002 for Schiedam and Zierikzee. At Schiedam, the NO₂ concentration is determined by the regional background, the direct NO₂ emission and the conversion from NO to NO₂:

- *regional background at Schiedam*; From the measured NO₂ at Zierikzee, the regional background at Schiedam is estimated at **13.8** (1986) and **10.7** (2002) ppb NO₂;
- *direct NO₂ emission at Schiedam*; The fraction of direct NO₂ estimated from the trend analysis is respectively 9% (1986) and 13% (2002). The contribution of direct NO₂ emission (to NO₂ concentrations at Schiedam) can be estimated from the delta NO_x (urban minus regional background) multiplied with the fraction NO₂. From the monitoring data, the delta NO_x for Schiedam is calculated as 68.1 (1986) and 24.1 (2002) ppb NO_x. Thus direct NO₂ emissions contributes **6.1** (9% from 68.1; 1986) and **3.2** (13% from 24.1; 2002) ppb NO₂ at the urban background site at Schiedam.
- *NO to NO₂ conversion at Schiedam*; The fraction of NO from NO_x emissions is 91% (1986) and 87% (2002). Using the delta NO_x at Schiedam as 68.1 (1986) and 24.1 (2002), this results in a concentration of 62.0 (91% from 68.1; 1986) and 21.0 (87% from 24.1; 2002) ppb NO. The measured regional background at Zierikzee is 6.3 (1986) and 4.9 (2002) ppb NO. This results in an expected value of NO at Schiedam of 66.3 (62.0 + 6.3; 1986) and 25.9 (21 + 4.9; 2002) ppbNO. The measured value of NO at Schiedam was 54.6 (1986) and 16.9 (2002). The difference between expected and measured values is an estimate of the conversion of NO into NO₂: **13.7** (66.3 – 54.6; 1986) and **9** (25.9 – 16.9; 2002) ppb NO₂;

- *total NO₂ concentration at Schiedam*; The total NO₂ concentration at Schiedam in 1986 and 2002 can be estimated from the regional background and contributions from direct NO₂ emissions and conversion of NO into NO₂. This results for 1986 and 2002 in respectively 33.6 and 22.9 ppb NO₂. The measured data was respectively 33.5 and 23.1 ppb NO₂. The estimated and measured data show good agreement, which illustrates the validity of the method.

In Table 1, a summary is provided of the aforementioned data.

Table 1: The NO₂ budget for Schiedam at 1986 and 2002 based upon the regional background, direct NO₂ emissions and NO to NO₂ conversion.

Unit: ppb	1986	2002	1986-2002
NO ₂ background at Schiedam	13.8	10.7	-3.1
Fraction NO ₂ (%)	9	13	+4
Direct emission NO ₂ at Schiedam	6.1	3.2	-2.9
Conversion of NO into NO ₂ at Schiedam	13.7	9	-4.7
Concentration NO ₂ estimated at Schiedam	33.6	22.9	-10.7
Concentration NO ₂ measured at Schiedam	33.5	23.1	-10.4

The table shows that chemical conversion is and remains the dominant contributor of local sources of NO₂: 13.7 ppb NO₂ in 1986 against ppb $\mu\text{g}/\text{m}^3$ NO₂ in 2002. The fraction of directly emitted NO₂ in percentage may have gone up but the total amount of emitted NO_x has decreased substantially. This results in a contribution of 3.2 ppb NO₂ in 2002 by direct NO₂ emissions while in 1986 this was still 6.1 ppb NO₂.

In conclusion: the increase of the NO₂ fraction in the NO_x emission makes some difference, but it is not the main reason why the NO₂ trend in Schiedam does not fit with the NO_x trend. The main reason is the NO/NO₂/O₃ equilibrium as explained in 4.1.1.

4.2 Urban contribution to PM₁₀ during days with daily PM₁₀ exceedances

In the period 2002 – 2004, PM₁₀ concentrations were measured at the rural background station in Oostvoorne and the urban background station in Rotterdam. The stations are shown in Figure 1. The local authorities would like to know whether they can reduce the number of days exceeding the daily limit value of PM₁₀ by local measures. Therefore, the trend of exceedances at both the rural and urban background station were analysed in the case study of Rotterdam.

The annual average values and number of days exceeding the daily limit value of 50 $\mu\text{g}/\text{m}^3$ PM₁₀ are presented in Table 2.

Table 2: Annual average PM_{10} ($\mu\text{g}/\text{m}^3$) and number of days with daily PM_{10} exceeding $50 \mu\text{g}/\text{m}^3$.

	2002	2003	2004
	PM_{10} ($\mu\text{g}/\text{m}^3$)		
Rotterdam (urban)	38	42	32
Oostvoorne (rural)	28	29	26
	# of days: $PM_{10} > 50 \mu\text{g}/\text{m}^3$		
Rotterdam (urban)	74	90	38
Oostvoorne (rural)	28	38	18

The annual average of PM_{10} during all days at the urban background site is about 30% higher than at the rural location which is an indication for local sources contributing to PM_{10} levels in Rotterdam. The number of days exceeding the daily limit value at the urban location are more than a factor of 2 higher than at the rural site. Exceeding daily values at the rural location reflects the impact of large scale effects on PM_{10} concentrations such as transport of high background PM_{10} and meteorological conditions favouring high pollution. Twice as many days exceeding the daily limit at the urban location demonstrates the contribution of local urban sources to PM_{10} .

In order to quantify the contribution by local sources, the following three steps are followed:

1. Firstly, for each year the days with PM_{10} concentrations exceeding $50 \mu\text{g}/\text{m}^3$ at the urban background station are selected together with the corresponding day at the rural station.
2. Secondly, a value of 50 is subtracted from both the PM_{10} concentrations at the urban and rural station. This results in positive values for the urban site, but sometimes in negative values at the rural site. The latter corresponds to days with no exceedances of the daily limit of PM_{10} at the rural station, while at the urban site the daily value of PM_{10} is exceeded.
3. Thirdly, for each year the data computed under step 2 are presented in a plot. For the case study in Rotterdam, this is presented for the years 2002, 2003 and 2004 in Figure 6.

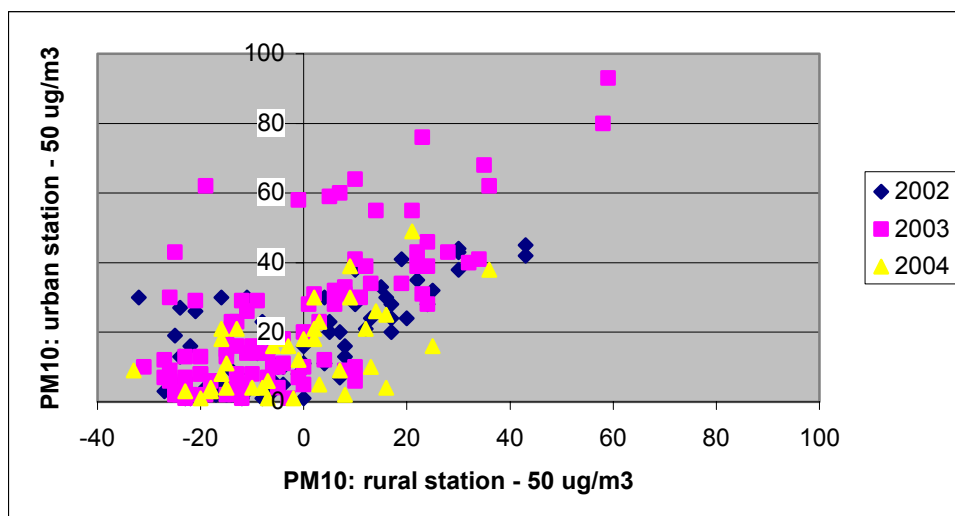


Figure 6: Increment over $50 \mu\text{g}/\text{m}^3$ at the urban station (Rotterdam) and at the rural station (Oostvoorne) during days with exceedances at the urban station for 2002, 2003 and 2004.

In Figure 6 one notices at the rural site negative and positive increments of PM_{10} concentrations. The former indicates no exceedances at the rural site, while the latter indicates that at both the rural and urban site the daily values of PM_{10} are exceeded. The number of days with exceedances at both locations have been presented in Table 2: 28 (2002), 29 (2003) and 26 (2004). During these days the PM_{10} concentrations at the urban site exceed the one-to-one relation with the rural site. This demonstrates that on top of the regional station exceeding the daily limit value of PM_{10} , urban sources result in still higher PM_{10} concentrations at the urban site. In Table 3 the average PM_{10} concentrations at both stations for various conditions are presented

Table 3: Average PM_{10} concentrations at the urban station (Rotterdam) and the rural station (Oostvoorne) at days with PM_{10} exceeding the daily limit of $50 \mu\text{g}/\text{m}^3$ at the urban station.

	2002	2003	2004
rural station (all days)	48	48	49
urban station ($\text{PM}_{10} > 50$)	67	74	65
Urban contribution	19	26	16
rural station($\text{PM}_{10} > 50$)	66	67	62
urban station ($\text{PM}_{10} > 50$)	76	89	71
Urban contribution	11	22	10
rural station ($\text{PM}_{10} < 50$)	36	35	39
urban station ($\text{PM}_{10} > 50$)	60	64	59
Urban contribution	24	29	20

From Table 3, it is concluded that the average PM₁₀ concentrations at the rural background site is rather constant (48-49 µg PM₁₀/m³) over the period 2002-2004. While, at the urban site, the average PM₁₀ concentrations during days with exceedances varies from 65 to 74 µg PM₁₀/m³ in the same period. Hence, urban sources contribute in the range of 16-26 µg PM₁₀/m³ to the average urban background during days with daily exceedances. This is about 30% of the mean PM₁₀ concentration during days with exceedances. Hence, this amount may be controlled by local measures to reduce the number of days exceeding the daily limit value of PM₁₀.

5. Conclusion and discussion

5.1 Assessment of the case study

In the case study in Rotterdam, two topics were studied: 1.) the trend of NO₂/NO_x and 2.) the urban contribution to urban background levels of PM₁₀ during days exceeding the daily limit value of 50 µg/m³. At the urban background in Rotterdam the number of days with exceedances was respectively, 74 (2002), 90 (2003) and 38 (2004). This is far above the accepted number of 35 days per year. Trend analysis was used to research these topics.

- On the NO₂/NO_x trend it was noted that NO_x concentrations decreased in the period 1986-2005, but the NO₂ concentrations at urban background stations in Rotterdam remained constant, while ozone concentrations increased. One hypothesis tested was that increasing ozone is the main reason for the trend observed, while another hypothesis was increasing direct NO₂ emissions by road traffic. Analysis revealed that the ozone/NO_x/NO₂ equilibrium is the most likely reason for the observed trend. Direct emissions of NO₂ by urban sources increased from 9% in 1986 to 13% in 2005. Further reduction with almost 50% of the present NO_x emissions is required to decrease urban background levels of NO₂ in Rotterdam.
- On the PM₁₀ trend it was concluded that the regional background concentrations of PM₁₀ are rather constant in the period 2002 – 2004. During days exceeding the daily limit value, urban sources contribute to PM₁₀ in the range of 16-26 µg PM₁₀/m³. The urban contribution is about 30% of the PM₁₀ concentration during these days. This amount may be controlled by local measures to reduce the number of days exceeding the daily limit value of PM₁₀.

5.2 Improvements in assessment derived from case study

The case study demonstrates the use of simple statistical analysis combined with trend analysis to study monitoring data from urban background and rural sites on NO_x/NO₂ and PM₁₀. For both NO_x and PM₁₀ information is derived on the local, urban contribution to NO₂ and PM₁₀ levels at the urban background.

5.3 Recommendations resulting from the case study

Basic requirements for trend analysis are the availability of long term data sets from both rural and urban background stations. It is important that these stations meet the requirements for site locations, adequate data coverage and comparable QA/QC procedures at both sites.

It is recommended to apply trend analysis as a first estimate of the relative contribution of urban sources to PM₁₀ at the urban background during days exceeding the daily limit. A second application illustrates the use of trend analysis to estimate the required level of abatement of NO_x emissions in order to reduce NO₂ at the urban background.

5.4 Suitability for implementation in other cities

The case study in Rotterdam describes trend analysis based upon simple statistical analysis and availability of monitoring data at an urban background and a regional site. This type of analysis may be applied by cities which have monitoring data sets for a period of five year or more. Application of the method has been demonstrated on the effectiveness of local measures to control NO_x and PM₁₀ emissions in order to meet the NO₂ annual limit value and the PM₁₀ daily limit value.

5.5 References

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 - Part I: Overview and structure
 - Part II: Spatial assessment in urban areas
 - Part III: Spatial assessment at local/hot spot scale
 - Part IV: Spatial assessment at regional/continental scale