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Evaluation of the representativeness of the Dutch national Air Quality Monitoring Network

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Abstract

Evaluation of the representativeness of the Dutch national Air Quality Monitoring Network

As a general rule, the Dutch Air Quality Monitoring Network (LML) is representative for the Netherlands. They fulfill the criteria of EU Directive 2008/50/EC for representativeness of measurement sites. However, the Dutch classification of measurement sites, which is a simple classification with only three types of stations, rural, urban background and street, does not always positively correlate to the measurement data. Any interpretation of the measurements of the LML must take this aspect into consideration.

A number of rural stations were found to have peak concentrations for one component, for example ammoniac in Vredepeel as a result of agricultural activities in this area, and a number of street stations are actually located on a highway (for example at Breukelen). In addition, rural station in an urbanized area had distinctly higher concentrations than other rural stations, while one station in a suburb of Groningen had lower concentrations than urban stations located in the western industrialized area of the Netherlands. At one measurement station, the flow around the inlet was obstructed by a close building, while at other locations, the flow around the inlet was affected by trees (which have been since pruned).

These are the conclusions of the evaluation of the representativeness of the LML which has been performed by the RIVM by request of the Ministry of Housing, Spatial Planning and the Environment (VROM). For this study, measurements data of the RIVM from 2007 of nitrogen oxide, nitrogen dioxide, carbon monoxide, particulate matter, ozone, ammoniac and sulfur dioxide were used. The results of this screening were then compared with the screening that used data from 1994; this comparison served as a check of the consistency of the observed results which seems to be good. The effect of pruning overgrown trees at two locations was studied in more detail and in both cases, no effect on the concentration was found. To prevent any obstruction of the air inlet it is recommended to prune trees which grow in close proximity to monitoring stations.

Key words:
air quality, monitoring, representativeness

Rapport in het kort

Evaluatie van de representativiteit van het Landelijk Meetnet Luchtkwaliteit

In het algemeen zijn de meetlocaties van het LML representatief voor Nederland. Ze voldoen hiermee op dit onderdeel aan de Europese Richtlijn 2008/50/EG. Wel sluit de eenvoudige Nederlandse standaardindeling in drie type stations, regionaal, stadsachtergrond en straatstations, niet bij elke situatie aan. Bij de interpretatie van resultaten van het LML moet hiermee rekening worden gehouden.

Zo is er bij enkele regionale stations een piekwaarde voor één stof gemeten, zoals ammoniak in Vredepeel als gevolg van landbouwactiviteiten in de omgeving. Ook bestaan er straatstations buiten de stad waarbij meetlocaties langs de snelweg lopen, zoals bij Breukelen. Daarnaast vertonen regionale stations in een verstedelijkt gebied hogere concentraties dan andere regionale stations. Tegelijkertijd vertoont een voorstadstation bij Groningen juist lage meetresultaten ten opzichte van stedelijke stations in de Randstad. Voor één locatie wordt de 'vrije aanzuiging' van lucht, die nodig is voor de metingen, gehinderd door een nabij gelegen gebouw. Op een aantal locaties werd de aanzuiging gehinderd door bomen, die inmiddels zijn gesnoeid.

Dit blijkt uit een evaluatie van de representativiteit van het LML die het RIVM in opdracht van het ministerie van VROM heeft uitgevoerd. Hiervoor zijn meetdata van het RIVM van stikstofoxide, stikstofdioxide, koolmonoxide, fijn stof, ozon, ammoniak en zwaveldioxide uit 2007 gebruikt. Om de consistentie van de resultaten te checken, zijn ze vergeleken met de metingen uit 1994, die overeen bleken te komen. Specifiek is gekeken naar het effect van het snoeien van uitbundige begroeiing op een tweetal locaties. In beide gevallen is geen effect op de concentraties waargenomen. Om vrije aanzuiging van lucht te waarborgen, wordt toch aanbevolen te snoeien.

Trefwoorden:
luchtkwaliteit, LML, monitoring, representativiteit

Contents

Summary

By request of the Ministry of Housing, Spatial Planning and the Environment (VROM) the RIVM has evaluated the representativeness of the Dutch national Air Quality Monitoring Network (LML). Two studies were performed in parallel within the framework of this evaluation: an assessment of the micro/macro scale of the monitoring sites and a screening of the measurement results by principal components analysis (PCA) in combination with other techniques (wind roses and diurnal analyses). The study of the micro/macro scale compared the monitoring sites with the criteria of the Directive; the PCA analyses identified sites that were notably distinguishable from other sites within their own classification. Additional measurement techniques, such as wind roses and diurnal analyses and the Google Map application (photographs of the direct vicinity), were used to analyse the observed distinguishing parameters in more detail. For this study, the measurements of nitrogen oxide (NO), nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matter (PM), ozone (O_3), ammoniac (NH_3) and sulphur dioxide (SO_2) for 2007 were used. The results of this screening of 2007 measurement data were also compared to the results from the screening of the measurement data for 1994 – as a check on the consistency of the observed results.

The evaluation reveals that, in general, the LML fulfils the criteria of the EU Directive 2008/50/EC very well and that the character of the stations has not been changed over the last 13 years. No irregularities were observed in the measurements for NH_3 (all at rural stations). The overgrowth around stations 722 (Eibergen) and 520 (Amsterdam–Florapark), which was removed in 2007-2008, did not result in noticeable trends in the concentrations measured at these stations.

The evaluation also identifies a number of issues that require attention, leading to the following recommendations:

- Good housekeeping: trees which grow in close proximity to monitoring stations have to be pruned regularly to prevent obstruction of the inlet.
- The vegetation around stations 722 and 520 should be pruned regularly.
- The location of site 137 may not be optimal for the measurement of urban background concentrations because this station is located very close to a building and a representative sampling of air from a large area can not be guaranteed. Because the data analysis has not proven that the current location affects the representativeness of this station, it is not necessary to replace this station immediately. However, when this station is renewed, the new monitoring station should be placed at a more suitable place in this area.
- Classification: compared to the AIRBASE classification, the Dutch classification is simple. The PCA analysis shows that the more sophisticated AIRBASE classification provides a more precise description for a number of stations in the LML. This aspect is very relevant and should be taken into account when the measurement data are interpreted or used for validation.
    - Street station 641 (Breukelen–snelweg) is located on a highway and clearly differs from the other street stations. This difference is reflected in airborne background concentrations. The classification Rural Traffic is more representative.
    - Street station 545 (Amsterdam–A10 west) is located on a highway and differs clearly from other street stations.
    - Station 938 (Groningen–Nijensteinheerd) is classified as an urban background (UB) station (suburb for O_3), but it is clearly different from other urban stations in more densely populated areas.
    - Stations 441(Dordrecht–Frisostraat) and 520 (Amsterdam–Florapark) are on the outside edge of the Rotterdam and Amsterdam agglomerations, respectively and therefore classified as suburb stations for O_3. In AIRBASE, these stations are classified as urban background, also for O_3. The evaluation shows that the results are not very different from stations in the centre of the agglomerations.
- Completion of the documentation: three sites – 441 (Dordrecht–Frisostraat, UB station), 446 (Den Haag–Bleriotlaan, UB station) and 447 (Leiden–Willem de Zwijgerlaan, Street station) –

are currently not shown in the Google Maps application. Completion of this application by adding the omitted sites is necessary.

1 Introduction

In accordance with EU legislation, the air quality in the Netherlands is monitored by the Dutch national Air Quality Monitoring Network (LML). The stations are classified as rural-, urban background- respectively street stations. For air quality data from different stations to be comparable, monitoring sites must be representative. By request of the Ministry of Housing, Spatial Planning and the Environment (VROM), the National Institute for Public Health and the Environment (RIVM) has assessed the representativeness of this monitoring network. This evaluation comprised two studies performed in parallel:

- A study of the micro/macro status of the stations.
- A study of the representativeness of the classification using the following strategy:
  - screening of the measurement results by means of PCA (principal components analysis)
  - selection of extreme results or results that may be inconsistent with other results
  - detailed analyses of the selected measurement locations according to wind rose, diurnal variations and other analyses

The measurement data on NO, NO_2, CO, PM, O_3, NH_3 and SO_2 for 2007 were screened and the results compared to the screening of the data for 1994 as a check of the consistency of the observed results

The results of these studies are presented in this document where they are used for evaluating the representativeness of the measurement stations for the various components. The results also form the basis for recommendations regarding various actions that can be undertaken, such as maintenance work/pruning of vegetation, among others.

2 Documentation of the Dutch Air Quality Monitoring network

The directive 2008/50/EC on ambient air quality and cleaner air for Europe (subsequently referred to as 'the Directive') includes criteria relevant to the documentation and review of site selection. The following statement is found in Annex IIID of the Directive:
'The site-selection procedures shall be fully documented at the classification stage by such means as compass-point photographs of the surrounding area and a detailed map. Sites shall be reviewed at regular intervals with repeated documentation to ensure that selection criteria remain valid over time'.

One proposal is for a review of the DAQMN at regular intervals of 5 years.
Documentation in 1998 and 2002/2003 has been compiled and recorded in the archives. A Google Maps application was utilized for an update of the documentation and a review of the site selection. The application shows:
- exact compass points
- at least four photographs of the direct vicinity
- (optional) one panorama photograph of the site (a photograph from the roof of the cabin)

Almost all of the existing sites of the Dutch national Air Quality Monitoring Network and a selection of monitoring sites of local authorities are shown in the application.
The link to this application is:

http://maps.onsite360.nl/index.php?key=18.93.0f7134915416d8af8cc1759d04946d91andpage=15

3 Study of the micro and macro status of the stations

3.1 Criteria for selection of the monitoring sites

The Directive provides a distinct description of the criteria to be satisfied in terms of the positions of sampling points used for the evaluation of ambient air quality. These criteria are stated in Annex III of the Directive.

The Directive distinguishes between micro- and macro-scale siting requirements for sampling points, with different criteria for each scale. These criteria are given in Appendix 1 of this report. In short, the criteria include:
- unrestricted airflow
- no sources in the immediate vicinity of the site
- inlet height between 1.5 and 4 m
- for all pollutants, traffic-oriented sampling probes shall be at least 25 m from the edge of major junctions and no more than 10 m from the kerbside

The criteria to be applied depend both on the compounds of interest (for example, O_3 and PM) and the scope of the measurement strategy, such as:
- traffic related
- urban located
- protection of vegetation
- point sources or diffuse sources

3.2 Quick scan of the monitoring sites

3.2.1 Traffic-orientated sampling sites (kerbside)

One restriction in the Directive for traffic-orientated sampling of SO_2, NO_x, PM, lead, benzene and CO in ambient air is that the measurement site must be at least 25 m from the edge of major junctions and no more than 10 m from the kerbside. In the case of a highway (motorway) where a kerbside is not available, this review has chosen a distance of at least 30 m from the edge of the highway.
There are 17 traffic-oriented sampling sites in the LML, all of which are located at least 25 m from the edge of major junctions and no more than 10 m from the kerbside. Consequently, all of the criteria stated in the Directive for traffic-oriented sampling points are fulfilled. Sites 136 (Heerlen–Looierstraat) and 447 (Leiden–Willem de Zwijgerlaan) require some maintenance work because of (temporary) obstruction of the inlet tube (due to trees).
The O_3 concentrations are also measured at several traffic-orientated locations for modelling purposes. In accordance with the criteria for evaluations of O_3 concentrations, as stated in Annex VIII of the Directive, the O_3 concentrations measured at these sites are not used for evaluation of the air quality.

3.2.2 Urban background sampling sites

The environmental limit values are set for the protection of human health. Consequently, the urban background locations are of especially interest. The Directive states that the urban background locations shall be located so that their 'pollution level is influenced by the integrated contribution from all sources upwind of the station. The pollution level should not be dominated by a single source unless such a situation is typical for a larger urban area. Those sampling points shall, as general rule, be representative for several square kilometres'.

The evaluation reported here is based on expert judgment. One recommendation aimed at improving the 2014 review is to adjust the set of evaluation criteria when an urban background location is typical of a larger urban area. For example, the criteria should take the wind directions into account. In the Netherlands the PM-limit values are mainly exceeded under conditions of a calm easterly wind. The most common wind direction is, however, (south) westerly and consists of higher parts of sea salt, which is probably of less interest in terms of an effect on human health.

The urban background sampling sites in the LML are not dominated by a single source, and they are representative of several square kilometres. However, a number of sites clearly require some adaptation/maintenance work; for example, the flow around the inlets may not be unrestricted, or there may be an external structure (such as buildings or trees) that directly influences the measurements. Such sites are 137 (Heerlen–Nicolayestraat), 418 (Rotterdam–Schiedamsevest) and 520 (Amsterdam–Florapark). The location of site 137 is not optimal for taking measurements of urban background concentrations because this station is located very close to a building and, consequently, a representative sampling of air from a large area cannot be guaranteed. The overgrowing trees at station 520 were pruned in 2007, and the current situation meets the requirements for unrestricted air flow.

The criteria for classifying and locating sampling points for the evaluation of O_3 concentrations as mentioned in Annex VIIIB of the Directive "to ensure the inlet probe is well away from such sources as furnaces and incineration flues and more than 10 meters from nearest road, distance increasing as a function of traffic intensity" are fulfilled by the urban background stations of the LML.

3.2.3 Rural sites

The rural sites are positioned such that the protection of human health and vegetation can be assessed. The sites are therefore located in small settlements or open-area sites. The sites have to be representative on a regional scale. In this review, the compass-point-photographs plotted in a Google Maps are used for the evaluation.

The results of the Quick scan are shown in Appendix 2.

3.3   Good housekeeping

To guarantee that the position of the measurement sites and the criteria as specified in the Directive are fulfilled, a strict protocol for 'Good Housekeeping' of the DNAQMN is needed. A number of factors may necessitate that the measurement locations be changed, such as the renovation/urban development of an area or micro-scale changes.

4 Study of the representativeness by means of principal component analysis

4.1 Method

4.1.1 Principal component analysis

In the screening analyses, a typical data set consists of a matrix of 40 stations × 8760 hourly values. The information can therefore be described in a mathematical space with at least 40 dimensions. Such a space in itself can not be visualized; to this end, multivariate data visualization tools have been developed. Principal component analysis (PCA) is a well-known data visualization/data reduction tool that is often applied in such large analyses. The first principal component (PC-1) is defined as the linear combination of the original variables that describes the maximum amount of variation present in the data set. The second principal component (PC-2) is similarly defined as the linear combination of the original variables that describes the maximum amount of the remainder of the information found in the data set. This process continues in this fashion for the higher order of components. The samples in this study, i.e. the measurement locations, can be projected on the principal components (PCs). These projections, usually called scores, can be shown as two-dimensional plots; for example, the plot of the scores of PC-1 vs. PC-2, which is the linear two-dimensional projection of the data set with a maximum amount of variation.

In addition, the relation between the original variables and the PCs, usually called loadings, facilitates the interpretation of the phenomena observed.

4.1.2 Scaling and centring

When the variables in the data set a priori equalize in terms of potential information content, a scaling factor is usually applied to the variables to equalize the amount of variation by dividing the data for each variable by its standard deviation. In accordance with this same line of reasoning, without prior knowledge, the centroid of the data set is usually removed by subtracting of the mean of the data set (mean centring). The combination of centring and scaling is performed using the autoscale function of the PLS Toolbox in Matlab.

If the autoscale operation as described above is applied on the data set with hourly values, the potential influence of each hour on the PCA will be equal. However, if the raw data are used in the PCA, the influence of hours with large concentrations will be larger than that of hours with low concentrations. In extreme cases, the plot may even be dominated by a small selection of hours with high concentrations. The scaling also influences the interpretation of the plots produced. In general, the interpretation of the plots based on PCA without scaling is more straightforward than that of the auto-scaled data.

It is therefore evident that calculations with and without scaling both have their own distinct advantages and disadvantages. Consequently, the data sets are evaluated both with and without scaling.

4.1.3 Data sets

The first step in our evaluation was to screen the hourly concentrations of NO, NO_2, CO, PM, O_3, NH_3 and SO_2 measured in 2007. Three input data sets were then prepared for each component from the measured hourly concentrations:
- Data set of hourly data: in this data set, the measured hourly concentrations were used as such. Missing data are filled up using the following algorithm:

$$x_{ij} = \frac{\sum\limits_{k=1}^{N} x_{i,k(k \neq j)}}{\sum\limits_{n=1}^{8760} \sum\limits_{k=1}^{N} x_{n,k(k \neq j, n \neq i)}} * \sum\limits_{n=1}^{8760} x_{n,j(n \neq i)}$$

where x_{ij} is the estimated concentration of time i at monitoring station j.

For N monitoring stations, this data set is an N-by-8760 matrix.
- Data set of diurnal variation. For each hour, the average concentration over the whole year is calculated .This data set is an N-by-24 matrix.
- Data set of average concentration roses. The wind rose is divided into 12 sectors, and the average concentration in each wind sector is calculated. The data set is an N-by-12 matrix. See Appendix 3 for the calculation of average concentration roses.

Data for 1994 were also analysed to determine whether there have been any major changes during the last 13 years. For this analysis, a PCA method was selected from the above analyses.

Additional analyses that focused on traffic (concatenated matrix of NO and NO_2, NO, NO_2, CO hourly concentrations) and agriculture (NH_3) were also carried out.

4.2   Screening results using data from 2007

The first step in our study of the representiveness of the measurement stations for the selected air quality components was to screen measured concentrations by PCA. As described in the Method section, the screening can be performed using different options for scaling and compressing the measurement data. Here, NO_2 will be studied as an example.

4.2.1 NO_2

Hourly data: PCA results obtained with autoscaled data and with original data
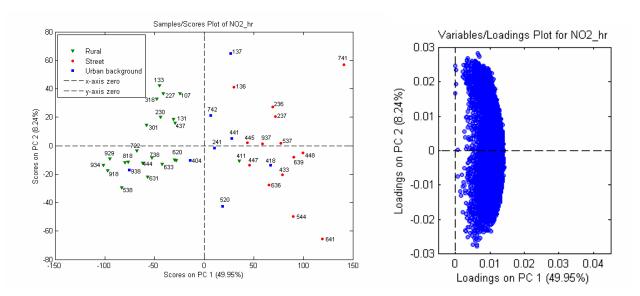
Figure 1 and 2 Scores and loadings plots for the first two PCs for NO_2 hourly concentration, with autoscaling of the hourly data. The scores plot shows distinct clusters of stations, a number of stations standing out.

Note: Street station 445 (Den Haag–Veerkade) was out of operation from July 2007 to June 2009 and has been replaced. Since 18 June 2009, this station has once again been in operation; the station has since been replaced and is no longer located in the middle of the street (Appendix 5 shows the old location of station 445).
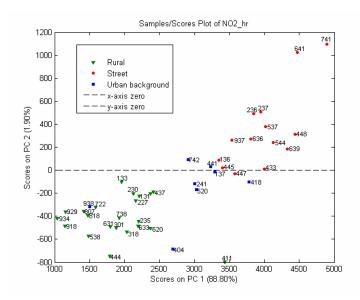
Figure 3 Scores plot of the first two PCs obtained with PCA analysis using NO₂ hourly data <u>without</u> autoscaling. This plot also shows distinct clusters of stations. There are more variations on this plot than on that obtained with autoscaled data (Figure 1).

Figures 1 and Figure 3 show that different scores plots were obtained depending on whether original or autoscaled hourly data were used. When original hourly data are used, the separation occurs along both PCs; when autoscaled hourly data are used, the separation occurs mostly along the PC-1. Despite this difference, the results of both analyses are similar in that both scores plots show clear clusters of different types of stations. However, there are a number of differences as well, including the following:

- Urban background station 938 (Groningen–Nijensteinheerd) resembles a rural station due to is location in a suburb of Groningen (Appendix 4).
- Rural station 411 (Schipluiden) resembles an urban background station. The average concentration rose of this station (Figure 6) shows that a high concentration is measured at this location when the wind is south-easterly, indicating that this station is influenced by inland activities in the Rotterdam area.
- Urban background station 418 (Rotterdam–Schiedamsevest) resembles a street station. The concentration rose of this station (Figure 6) shows that the NO₂ concentration measured at this station is contributed by the Rotterdam harbour.
- Urban background station 520 (Amsterdam–Florapark) differs from other urban background stations (Figure 1) in that the concentration rose of this station (Figure 6) is influenced by the IJ-tunnel.
- Street stations 641 (Breukelen–snelweg) and 741(Nijmegen–Graafseweg) are clearly different from other stations. The differences at station 641can be explained by the location of this station on a highway; as such, it is not a 'normal' street station. Station 741 is located nearby a traffic circle, but the distance from the monitoring station to the traffic circle is about 100 m (see Appendix 5). Consequently this location still satisfies the criteria in the Directive for traffic-orientated monitoring stations.

The advantage of Figure 3 over Figure 1 is that the former provides the possibility to make a straight forward interpretation. In Figure 3, the distance of the projections from each station to the origin of the plot (PC-1 = 0, PC-2=) is correlated with the average concentration. In addition, the projection of the hours on the PC is correlated with the average concentration for that hour. The autoscaling in Figure 1 has resulted in such interpretations being relatively more complex. An obvious disadvantage of both

Figure 1 and Figure 3 is the interpretation of the projection of the hours on the PCs (loadings). Due to the large number of hourly values (8760), the plots are very crowded. To solve this problem, the number of variables should be reduced, preferably with a minimum loss of information. To this end, we now explore two reduction approaches. The first approach is based on the assumption of diurnal consistency and involves averaging the concentrations for each hour of the days sampled, yielding a data set of 24 variables. The second approach is based on the assumption of consistency in terms of the wind direction during the hour of the measurement

Reduction approach based on diurnal variation: PCA results obtained with and without autoscaling of the data set
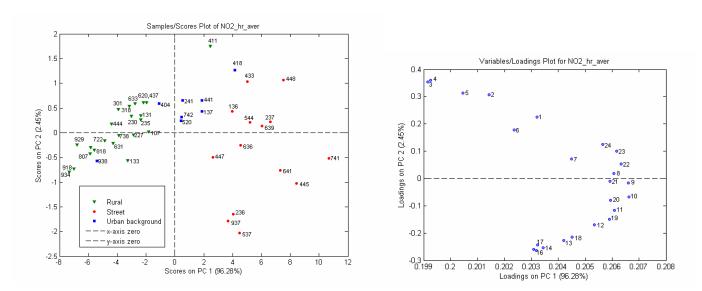
Figure 4A and 4B Scores and loading plots for the first two PCs for diurnal variation of NO₂ <u>with</u> autoscaling of the data set.

The scores in Figure 4A again show the street stations (high concentrations of NO_2) on the right of the plot and the rural stations (low concentrations) on the left. When combined with the loadings in Figure 4B, all hours are consistently projected on the positive site of PC-1. In the projection of the stations on PC-2, the positive site is dominated by stations in the Rotterdam area (411, 418, 433 and 448), while a number of street stations throughout the Netherlands (236, 937 and 537) dominate the negative site. Combining the projection with the loading plot suggests that in the Rotterdam area, NO_2 concentrations during the night are relatively higher than those at other locations (consistent with non-stop industrial activities in the Rotterdam area, such as industry and the harbour). Concentrations at the street stations are relatively higher in the afternoon.
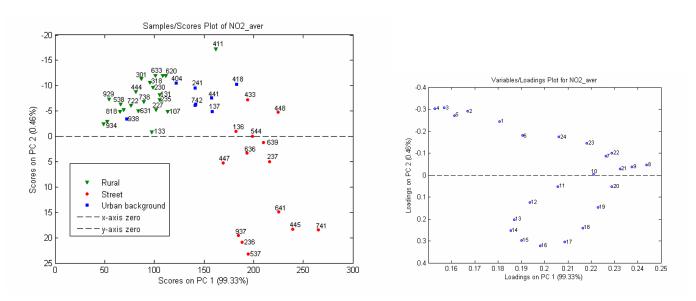
Figure 4C and 4D Scores and loading plots for the first two PCs for diurnal variation of NO₂ <u>without</u> autoscaling of the data set.

The results of the analyses performed with diurnal variation without autoscaling confirm that the higher annual NO_2 concentration results in a higher PC-1 score. The loadings plot, 4D, shows that the NO_2 concentration in the morning is higher than that during the night (the morning hours have a higher loading on PC-1). To check the interpretations of the PCA analyses, we should look closely at Figure 4E, which shows the diurnal pattern in NO_2 concentrations for a number of interesting stations. The station with the highest average diurnal pattern is 741 in Nijmegen, a result which is consistent with its highest score on PC-1. When station 411 (Rotterdam) is compared with station 236 (Eindhoven), the former has a higher annual NO_2 concentration during the night, while that for the street in Eindhoven is higher in the afternoon, which again is consistent with the scores on PC-2.

In plot 4C, again all stations in the Rotterdam area fall within the upper right quadrant, indicating a typical day–night pattern in this area, as can also be seen for a number of other stations in plot 4F. A comparison of the Rotterdam stations reveals that 448 > 433 > 418 in order of decreasing measured NO_2 concentrations, which is consistent with their scores on PC-1.
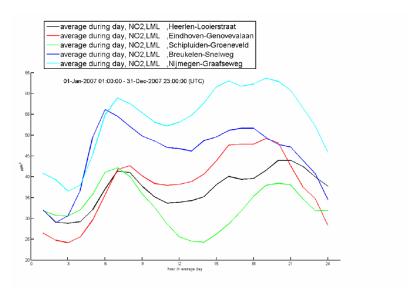
Figure 4E Diurnal variation of NO$_2$ at a number of typical stations.

black: 136 (Heerlen–Looierstraat), green: 411 (Schipluiden), blue: 641 (Breukelen–snelweg), red: 236 (Eindhoven–Genovevalaan), blue: 741 (Nijmegen–Graafseweg)
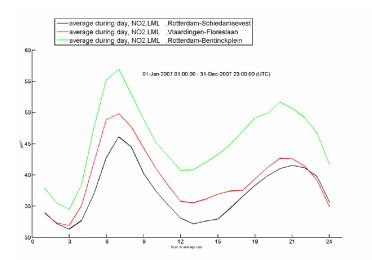

Figure 4F Diurnal variation of NO$_2$ at stations in the Rotterdam area

black: 418 (Rotterdam–Schiedamsevest), green: 448 (Rotterdam–Bentinckplein), red: 433 (Vlaardingen–Floreslaan)

Reduction approach using concentration roses: PCA results obtained with and without autoscaling of the data set

The second approach used to combine the 8760 hourly values is obtained by averaging the hourly values over the prevailing wind direction.
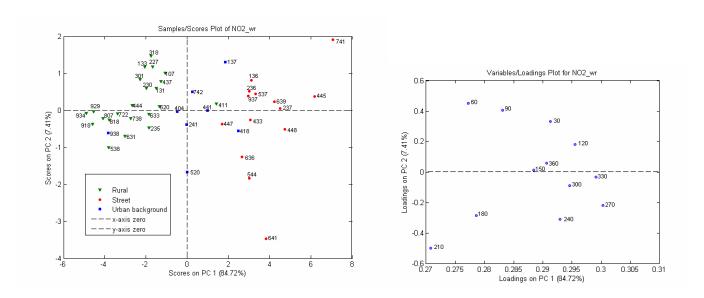
Figure 5A and 5B Scores and loadings plot for the first two PCs for average NO₂ concentration roses <u>with</u> autoscaling of the data set.
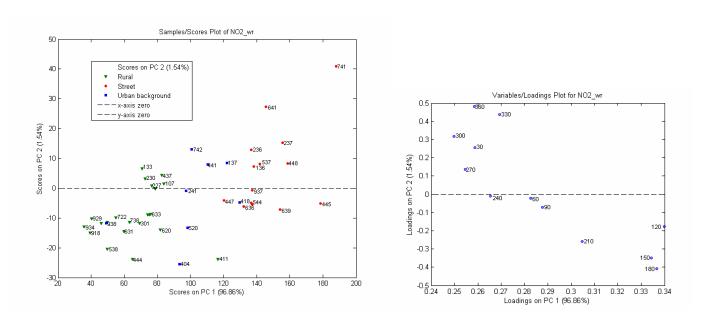
Figure 5C and 5D Scores and loadings plot for the first two PCs for average NO₂ concentration roses without autoscaling of the data set.

![rivm logo]

The scores plot obtained with the data set without autoscaling (Figure 5C) again shows the high NO_2 concentrations on the right-hand site and the low concentrations on the left. . In general it can be interpreted form the loadings that In NO_2 concentrations with south-easterly wind directions (120, 150 and 180) are relatively high and those with north-westerly directions (270, 300, 330, 360 and 30) are relatively low. An examination of the position of station 411 on both PCs emphasizes this phenomenon. From the loadings plot (Figure 5D), it can be seen that the NO_2 concentration at this station is high when the wind is south-easterly, as can be confirmed by the concentration rose in Figure 6. This station is clearly influenced by inland activities in the Rotterdam area.
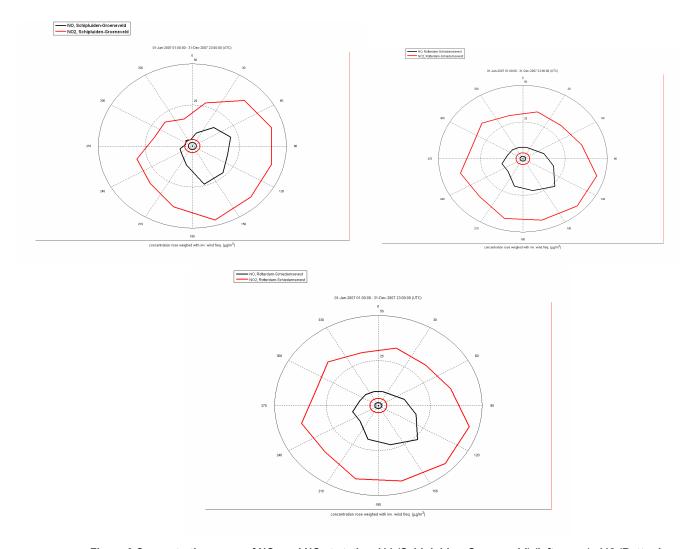
Figure 6 Concentration roses of NO₂ and NO at station 411 (Schipluiden–Groeneveld) (left upper), 418 (Rotterdam–Schiedamsevest) (right, upper) and 520 (Amsterdam–Florapark) (under), respectively.

Results of the PCA analysis of NO_2

Two PCA analyses of NO_2 were performed: in one, we use hourly data and diurnal variation and in the other, concentration roses. Two analyses were also performed for each of these data sets: without and with autoscaling of the data. The results of these analyses show that:
- Autoscaling of the data does not improve the results of the PCA analysis. The plot obtained with the original data shows more variations than that obtained with autoscaled data.
- Comparable results were obtained with hourly data and average concentration roses.

The results obtained with the diurnal variation are very comparable to those obtained with hourly data, with one minor exception: in the former analysis, the distinction between stations 641 and 741 is less clear while station 445 is even more distinct.

Strategy for PCA analysis of other components

Based on the results obtained here with NO_2, screening for the remaining components examined in this review (NO, PM_{10}, CO, O_3, NH_3 and SO_2) is based on diurnal variation <u>without</u> autoscaling. A major advantage to using diurnal variation over hourly data is the conveniently arranged loadings plot of this analysis, which provides additional information that can be useful. To ensure that all relevant information is shown, the score plot of the PC-3 is also shown.

Because SO_2 is a pollutant with a typical concentration pattern (comprising many peaks), this component is studied using both diurnal variation and average concentration roses.

In addition to the analyses performed with individual components, as described in the Method section, we also analysed traffic (concatenated matrix of NO and NO_2 and concatenated matrix of NO and NO_2 and CO concentrations). Because the concentration of CO is not at the same magnitude as that of the other substances, CO concentration was divided by 10 before it was combined with the NO and NO_2 concentrations.
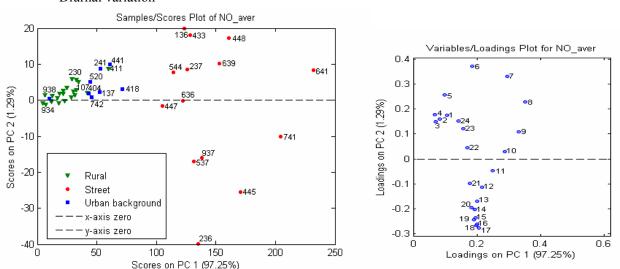
4.2.2 NO

Diurnal variation

Figure 7A and 7B Scores and loadings plots for the first two PCs for diurnal variation of NO. This analysis also shows distinct clusters of stations. The results are in line with the results obtained with NO_2.
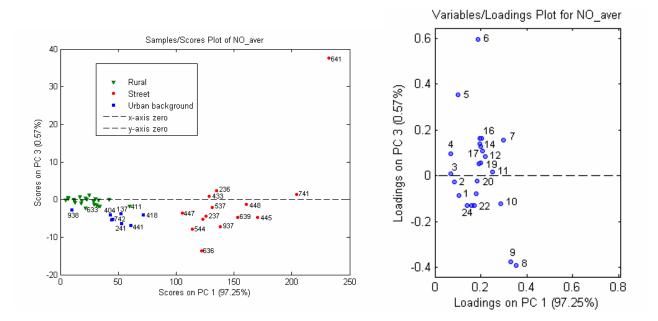
Figure 7C and 7D: Scores and loadings plot for the third PC for diurnal variation of NO, showing a clear difference for station 641 which is less pronounced in the first two PCs.
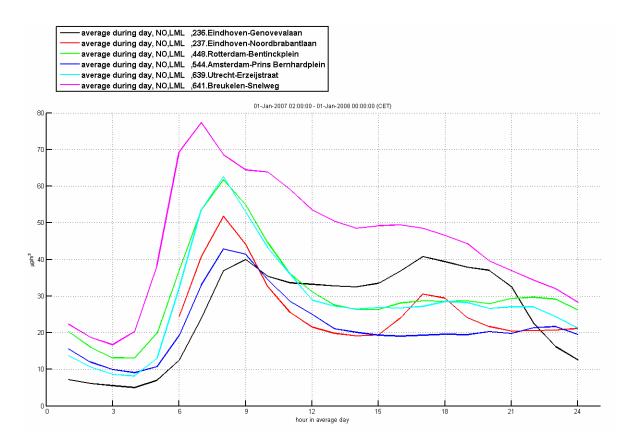

Figure 7E: Diurnal variation of NO at some street stations.

Figure 7A confirms important observations from the NO analysis. Urban background station 938 in Groningen shows NO concentrations similar to those of rural stations, and rural station 411 in the Rotterdam area shows NO concentrations similar to those of most urban background stations. The difference between street stations and background stations is more pronounced. Station 641 is very different on PC-3.

Assessment of the loadings plot of PC-3 (Figure 7D) leads to the interpretation that there is a relatively high concentration of NO at station 641 between 05.00 and 06.00 hours (the peak hour on a highway is earlier than that on a normal street), as can be confirmed by Figure 7E.

4.2.3 PM$_{10}$

Diurnal variation
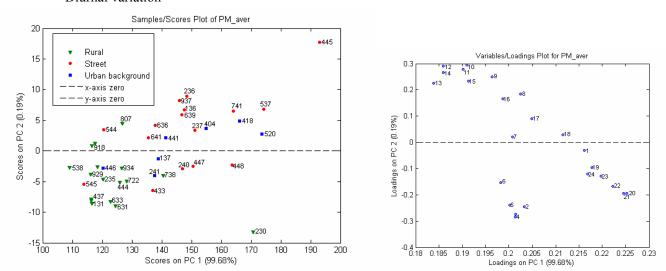
Figure 8A and 8B Scores and loadings plots for the first two PCs for diurnal variation of PM$_{10}$ (Note: data coverage at station 520 in 2007 is less than 50%, and station 445 has been non-operational since July 2007).

This analysis does not show distinct clusters of street and urban background stations, which is in line with the fact that traffic has only a very limited effect on PM$_{10}$ concentration. Stations with a high annual concentration have a higher PC-1 score. The loadings plot shows that stations with a high PC-2 score (e.g. station 445) have a high concentration of PM$_{10}$ during the middle of the day (10–15 hours), while stations with a low PC-2 score (e.g. station 230) have a high PM$_{10}$ concentration during the night (20–24 hours) and in the early morning (02–06 hours), as can be confirmed by the diurnal variation plot of these two stations (Figure 8C).
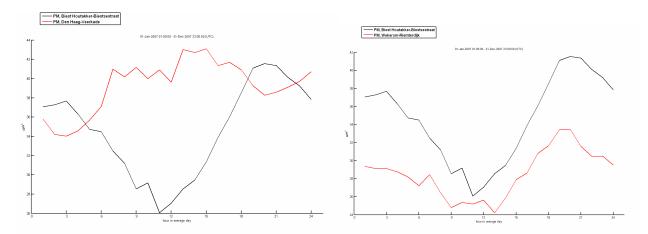
Figure 8C Diurnal variation in PM_{10} **at stations Biest (230, black) and Den Haag–Veerkade (445, red).**

Figure 8D Diurnal variation in PM_{10} **at Biest (230, black) and Wekerom (738, red).**

The most remarkable observations are:

- Station 545 (Amsterdam–A10) resembles a rural station. This observation can be explained by the fact that this station is located on a highway rather than in a normal street and that part of the PM increment found at a normal street station (e.g. PM emission due to fireworks, open fires etc.) is not present along a highway.
- Station 230 (Biest Houtakker–Biestsestraat) is clearly different from other rural stations (Figure 8A).The loadings plot shows that the PM_{10} concentration at this station is high during the night, as can be confirmed by the diurnal plot in Figure 8D. This profile is consistent with the presence of local sources; due to the stable atmosphere during the night, the pollutants can not be dispersed, resulting in a concentration peak at night.

Street station 445 (Den Haag–Veerkade) is distinct from other stations, but this station has not been in operation since July 2007.
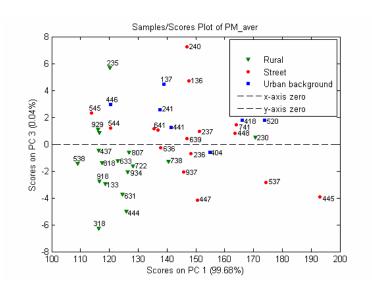The scores plot of the third PC (Figure 8E) does not provide any extra information.

Figure 8E: Scores plot for the third PC.
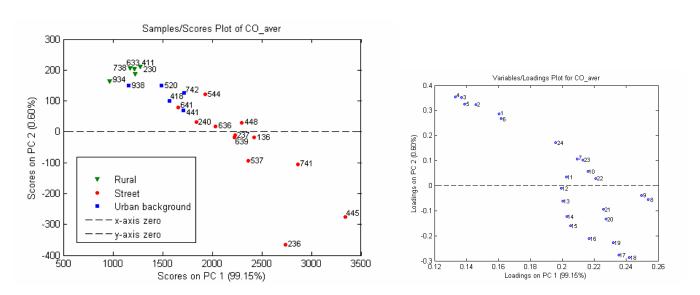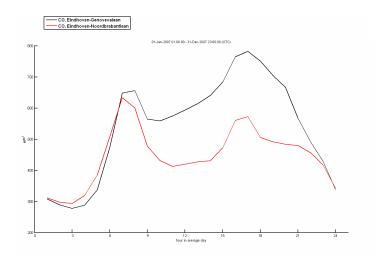
4.2.4 CO

Diurnal variation

Figure 9A and 9B Scores and loading plots for the first two PCs for diurnal variation of CO. (Note: data coverage of CO at station 445 in 2007 was less than 50%).

This analysis also shows distinct clusters of stations. Those stations with a high annual CO concentration have a high PC-1 score, while the PC-2 score represents the pattern of diurnal variation. In addition to showing the difference between stations 938 and 641, this analysis also distinguishes station 236 (Eindhoven–Genovevalaan) from the other stations (i.e. it is clearly separate from other stations based on the PC-2). The loadings plot shows that there is a high concentration of CO at this station between 16

![rivm logo]

and 19 hours. This is confirmed by the diurnal plot (Figure 9C); the amount of traffic in this street is not symmetrical, with significantly more traffic in the afternoon than in the morning.
The loadings plot also shows that, as expected, there is a high concentration of CO at the street stations during the day (between 08 and 18 hours).
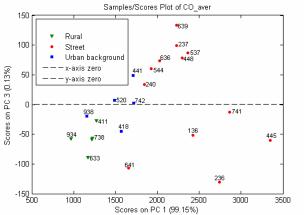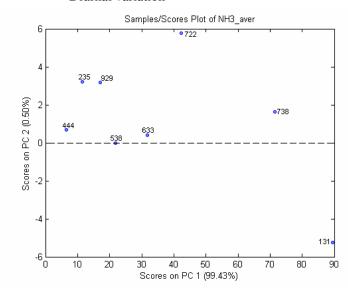The score plot of the third PC (Figure 9D) does not provide any extra information.

Figure 9C Diurnal variation at stations 236 (Eindhoven–Genovevalaan) (black) and station 237 (Eindhoven–Noordbrabantlaan) (red).

Figure 9D Scores plot for the third PC.

4.2.5   NH$_3$

Diurnal variation
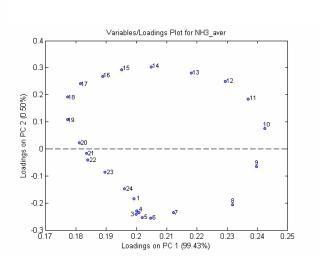
Figure 10A and 10B Scores and loadings plots for the first two PCs for diurnal variation of NH$_3$.

Stations with high annual concentrations of NH$_3$ have high PC-1 scores. The two extreme stations (131, Vredepeel and 738, Wekerom) are located in areas with high NH$_3$ emissions (intensive agriculture). The difference between diurnal variation patterns is given by PC-2. An analysis of the loadings plot reveals that there is a high concentration of NH$_3$ at station 131 during the night, while there are high NH$_3$ concentrations at stations 722, 235 and 929 during the day, as can be confirmed by Figure 10C.
The concentration profile of stations 131(Vredepeel) and 738 (Wekerom) are typical of locations with hot spots. The more stable atmosphere during the night results in a reduced dispersion of pollutants and, consequently, a higher NH$_3$ concentration.
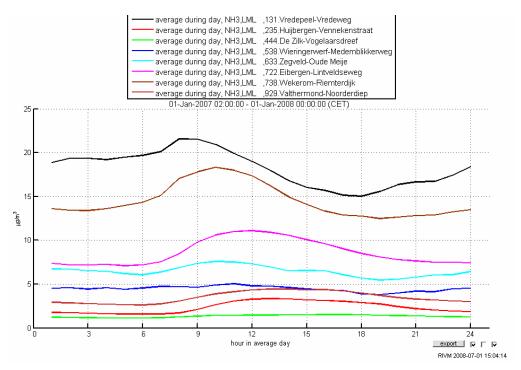

Figure 10C Diurnal variation of NH$_3$ at the monitoring stations.

The distinctive position of station 738 is shown more clearly on the score plot of the third PC (Figure 10D). From the loadings plot of this PC it can be interpreted that the NH$_3$ concentration at this station is relatively high in the morning (08–10 hours), while at other stations, the NH$_3$ concentration is relatively high in the afternoon (16–17 hours).
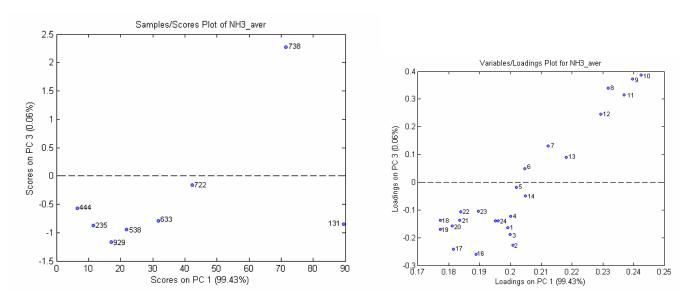
Figure 10D and 10E Scores and loadings plots for the third PC for diurnal variation of NH$_3$.

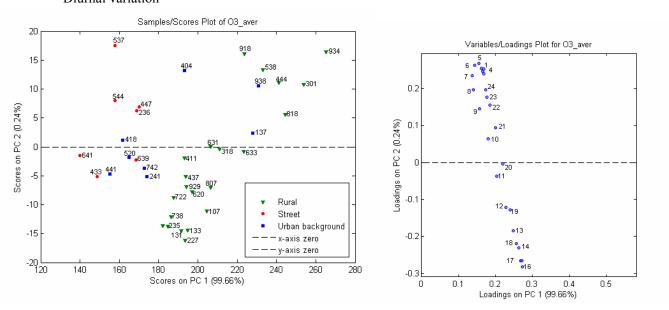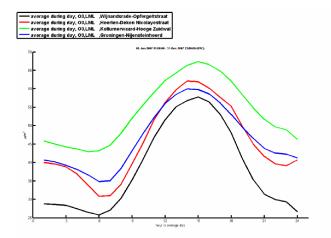### 4.2.6 O$_3$

Diurnal variation

Figure 11A and 11B Scores and loading plots for the first two PCs for diurnal variation of O$_3$. For O$_3$, stations 441, 520, 938, 411 and 133 are classified as suburban.

This analysis shows distinct clusters of rural stations while urban background and street stations are intermixed. Stations with high (annual) O$_3$ concentrations (i.e. the rural stations) have a high PC-1score. The most distinctive findings are stations 938 (as already shown by previous analyses) and 137 (Heerlen–Deken Nicolayestraat), with the latter differing from other urban background stations. Contrary to expectations, the concentration of O$_3$ measured at station 137 is even higher than that

measured at rural station 133. In Figure 11A, station 137 is above and to the right of rural station 133, while station 938 is under and to the left of rural station 934. The scores plot of the third PC (Figure 11D) also shows that station 137 is different, and Figure 11C shows that the station 137 has a different diurnal variation. We currently cannot explain this difference, and it is unclear as to whether it is caused by the building near this station 137 because such a difference is not observed with the other components.

The loadings plot shows that stations with a negative PC-2 score have peak O_3 concentrations in the afternoon (14–18 hours). These stations are located in the south-eastern part of the Netherlands. Compared to station 133 (south-east Netherlands), station 934 (located in the northern part of the Netherlands) has a higher average O_3 concentration, but station 133 has more peak concentrations.

Figure 11C Diurnal variation of O_3 at station 934 (Kollumerwaard, rural) (green), station 133 (Wijnandsrade, rural) (black), station 137(Heerlen, urban background) (red), station 938 (Groningen, urban background) (blue).

Figure 11D Scores plot for the third PC of O_3.

Stations 938 (Groningen), 441 (Dordrecht–Frisostraat) and 520 (Amsterdam–Florapark) are currently classified as suburban. Suburban stations are important because it is precisely in the suburbs of major cities that many inhabitants can be exposed to O_3 concentrations that are higher than those found in city centres. High O_3 concentrations, comparable to those measured at rural locations, were found at the station in Groningen (938). Stations 441 and 520 are classified as suburban because both of these measurement stations are located some distance from the centre of the city/agglomeration. The PCA analysis (Figure 11A) shows that these stations are not very different from those of other urban background stations. Based on the PCA analysis, station 404 (Den Haag) would seem to be an appropriate station to monitor suburban concentrations.
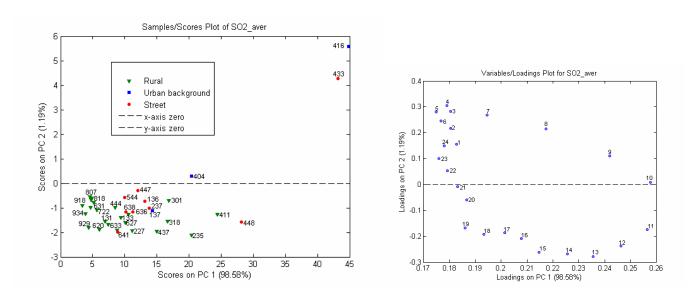
4.2.7 SO₂

Diurnal variation

Figure 12A and 12B Scores and loadings plots of the first two PCs for diurnal variation of SO₂.

There are no distinct clusters of urban background and street stations, which is in line with the fact that SO₂ is not a traffic-related pollutant. A number of stations lie outside the group: 433 (Vlaardingen–Floreslaan), 416 (Vlaardingen–Lyceumlaan) and 448 (Rotterdam–Bentinckplein).
The loadings plot (Figure 12B) shows that there are high concentrations of SO₂ in the early morning at stations with a positive PC-2 score (stations 416 and 433), while high concentrations at other stations occur during the day (12–18 hours). This distribution is confirmed by the diurnal plot in Figure 12C.
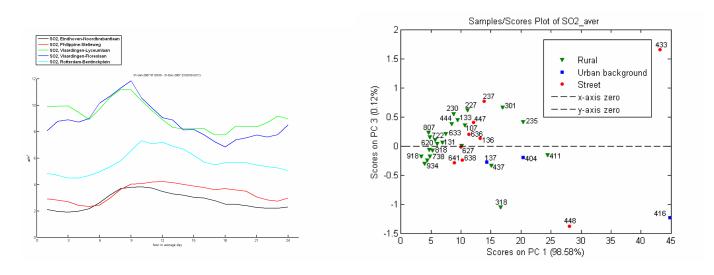

Figure 12C Diurnal variation of SO₂ at a number of typical stations.

Figure 12D Scores plot for the third PC of SO₂.
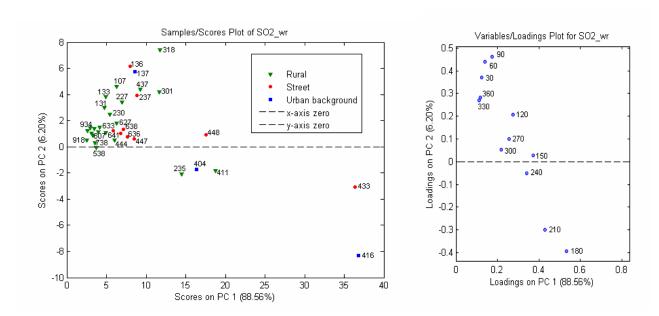
Average concentration roses

Figure 12E and 12F Scores and loadings plots of the first two PCs for average concentration roses of SO₂.

The upper left quadrant of the scores plot shows those stations in the southern part of the Netherlands; those stations around Rotterdam are shown in the bottom right quadrant. The loadings plot shows that the concentration of SO_2 at, for example, stations 107, 133 and 136 is high when the wind is north-easterly, while there is a high SO_2 concentration at station 416 when the wind is from the south, as can be confirmed by the wind roses in Figure 12G and 12H. High concentrations of SO_2 are found for the stations around Rotterdam; these are attributed to the contribution from Pernis and the Rotterdam harbour.
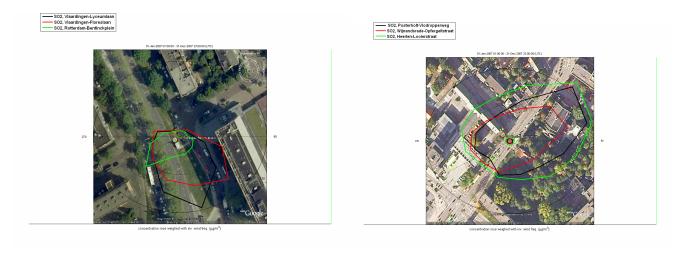

Figure 12G Average concentration roses at stations around Rotterdam.

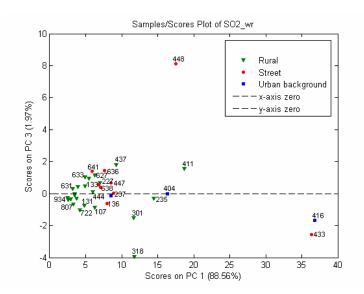**Figure 12H Average concentration roses at stations in the southern part of the Netherlands.**

Figure 12I Scores and loadings plots for the third PC for average concentration roses of SO₂. The distinctiveness of stations 318 and 448 is shown more clearly by the third PC.

4.3 Analysis performed with data from an earlier year (1994)
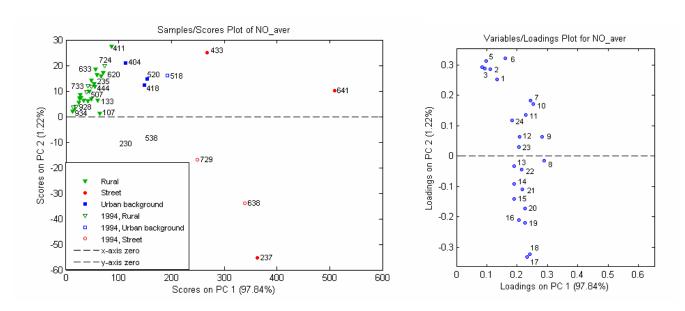
4.3.1 NO

Figure 13A and 13B Scores and loading plots for the first two PCs for diurnal variation of NO in 1994. The stations marked with '1994' are no longer operational. Most of these stations were rural stations, and two were street stations.

No major observable change has occurred between 1994 and 2007 in terms of measurable NO concentrations (Figure 7Aand B). Station 641 is also distinct from other street stations in the 1994 data set (shown more clearly by the third PC). The pattern of the loadings plot for 1994 is comparable to that for 2007.
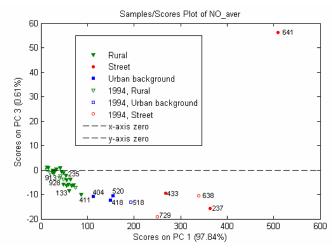

Figure 13C Scores plot for the third PC. The distinctiveness of station 641 (which is located on a highway) is also shown clearly here by the third PC.
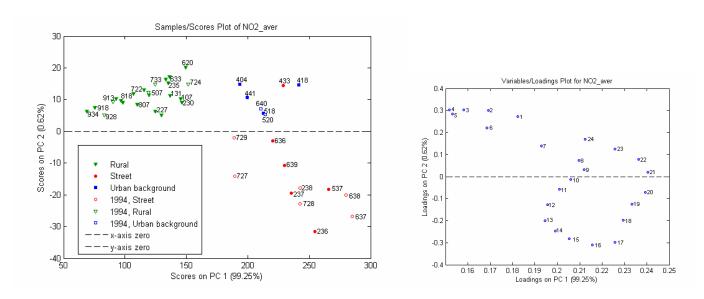
4.3.2   NO$_2$

Figure 14A and 14B Scores and loadings plots for the first two PCs for diurnal variation of NO$_2$ in 1994.

In terms of NO$_2$, the 1994 results shown in Figure 14A and 14B are comparable to those for 2007 (Figure 4A and B). Both loadings plots have comparable patterns. As in 2007, in 1994 the urban background station 418 (Rotterdam–Schiedamsevest) resemble a street station in terms of NO$_2$ concentration.
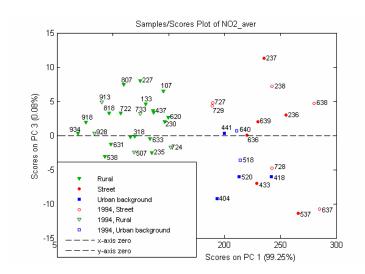
Figure 14C Scores and loadings plots for the third PC for diurnal variation of NO$_2$ in 1994. No additional information was obtained.
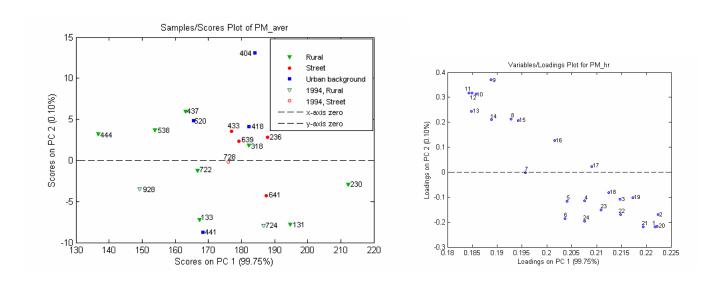
4.3.3 PM$_{10}$

Figure 15A and 15B Scores and loadings plots for the first two PCs for diurnal variation of PM$_{10}$ in 1994.

The results obtained for 1994 are comparable to those for 2007. As in 2007, the PM$_{10}$ concentration at station 230 (Biest Houtakker–Biestsestraat) in 1994 is also higher than those at other rural stations, as evidenced here by the higher PC-1 score.
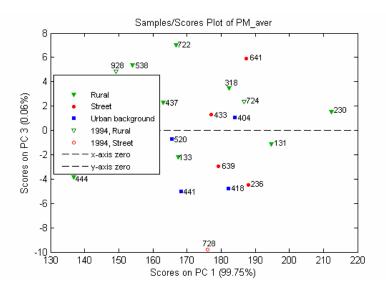
Figure 15C Scores plot for the third PC for diurnal variation of PM$_{10}$. No extra information is shown.
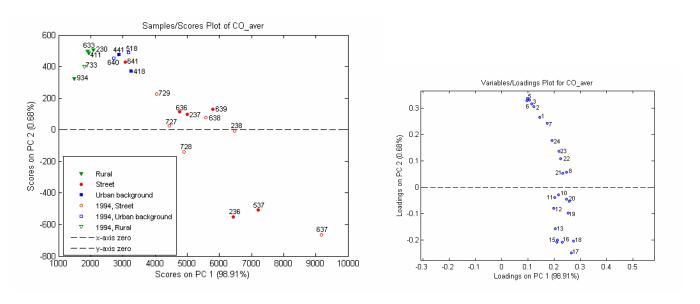
4.3.4 CO

Figure 16A and 16B Scores and loadings plots for the first two PCs for diurnal variation of CO in 1994.

As in 2007, the scores and loadings plots for 1994 also show distinct clusters of stations. The CO monitoring network has undergone major changes in the 15 years between 1994 and 2007, primarily in terms of the removal of a large number of street stations from the network and the addition of many new stations to it. For those stations which were already operational in 1994, there is no major difference between the situation then and the current situation in terms of CO levels. The loadings plot for 1994 has more or less a comparable pattern to that for 2007.
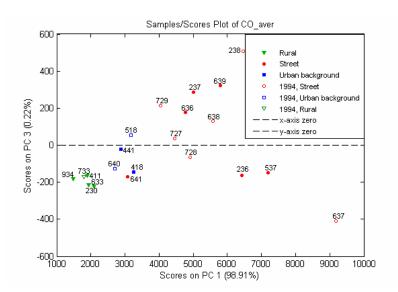
Figure 16C Scores and loadings plots for the third PC for diurnal variation of CO in 1994.

4.3.5 NH$_3$

Figure 17A and 17B Scores and loadings plots for the first two PCs for diurnal variation of NH$_3$ in 1994.

Compared to 2007 (Figure 10B), the most remarkable change in the 1994 analysis is the loadings plot, which clearly shows a change in the diurnal variation of NH$_3$. This is indeed confirmed by the diurnal variation plots in Appendix 7.
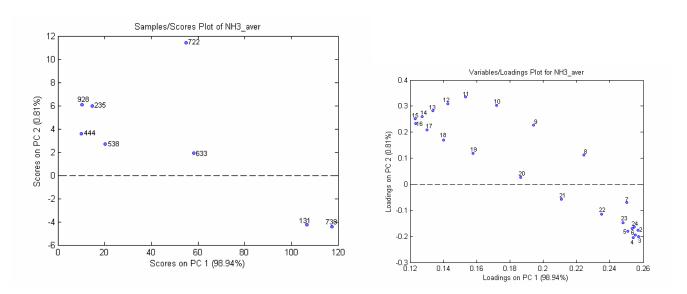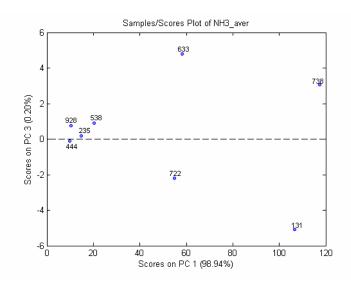
Figure 17C Scores plot for the third PC for diurnal variation of NH$_3$ in 1994.

4.3.6 O$_3$
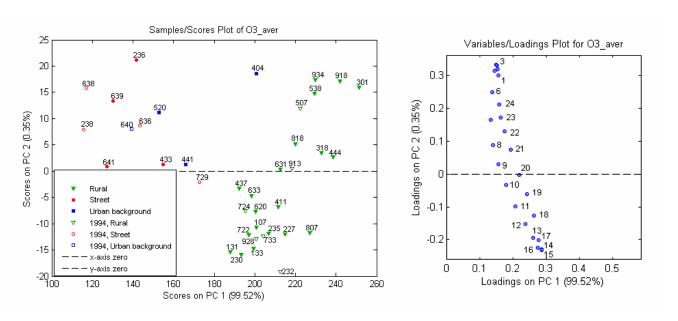
Figure 18A and 18B Scores and loadings plots for the first two PCs for diurnal variation of O$_3$ in 1994.

No major change is observed between the analysis for O$_3$ in 1994 and that in 2007 (Figure 11A and B). As in 2007, in 1997, the rural stations form a distinct cluster (with higher annual concentration and high PC-1 scores), while the urban background and street stations are mixed. The pattern of the loadings plot for 1994 is also comparable to that for 2007.

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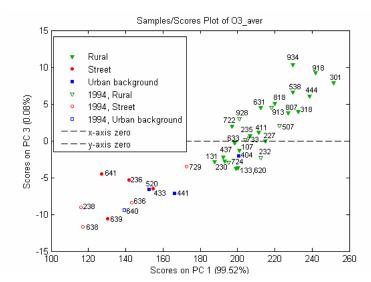
Figure 18C Scores plot for the third PC for diurnal variation of O$_3$ in 1994.

4.3.7   SO$_2$
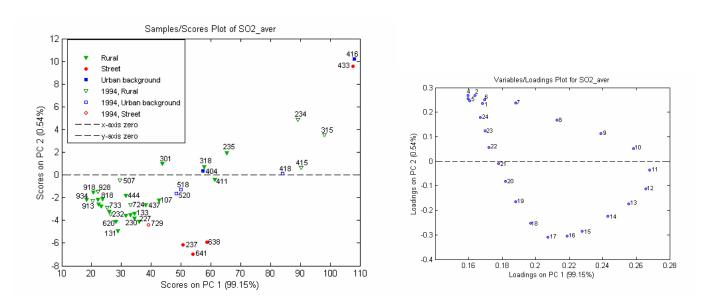
Figure 19A and 19B Scores and loadings plots for the first two PCs for diurnal variation of SO$_2$ in 1994.

In both 1994 and 2007, two stations, namely, 433 and 416, are distinct from the other stations. Compared to 2007 (Figure 12A and B), however, in the 1994 plots these two stations are less distinct from the other stations because at that time there were also four other stations with more or less the same character (418, Rotterdam–Schiedamsevest; 415, Maasssluis–Vlaardingsedijk; 315, Sas van Gent–Westkade); 234, Putte–Larikslaan). A second difference is the clear distinction of the street stations in 1994, indicating the effect of traffic on the SO$_2$ concentration at that time.
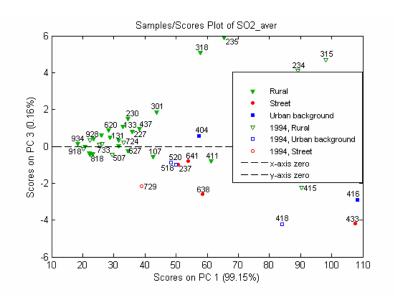
Figure 19C Scores plot for the third PC for diurnal variation of SO₂ in 1994. In this plot also, the distinction of the stations 416 and 433 is clear.

4.4 Pollutants from traffic

4.4.1 Combination of NO and NO₂

Diurnal variation
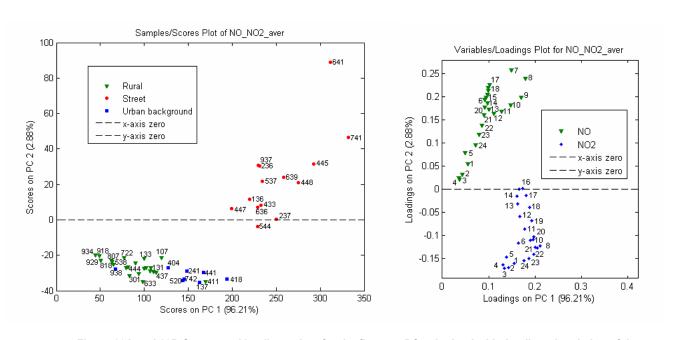
Figure 20A and 20B Scores and loadings plots for the first two PCs obtained with the diurnal variation of the combination NO and NO₂.

Distinct clusters of stations are shown, with the most distinct being stations 938, 641, 411 and, to a less extent, stations 741 and 418. Our general conclusion is that this analysis accurately portrays the information obtained by the analysis of each of these two components individually. Two observations based on the combination analysis are that average concentrations are higher for NO_2, and that the difference between traffic and background locations is greater for NO.

Figure 20C Scores plot for the third PC obtained with the diurnal variation of the combination NO and NO_2. No new information is obtained with this plot.

4.4.2   Combination of NO, NO_2 and CO

Diurnal variation
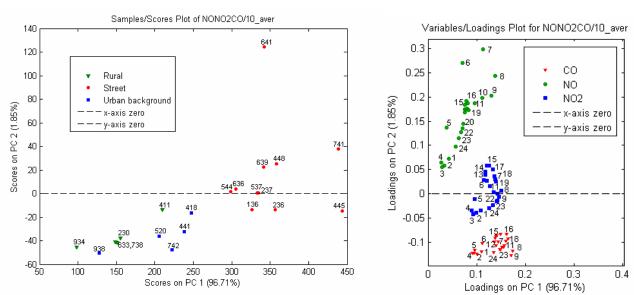
Figure 21A and 21B Scores and loadings plots for the first two PCs obtained with the diurnal variation of the combination NO, NO_2 and CO. Station 445 has been non-operational since July 2007.

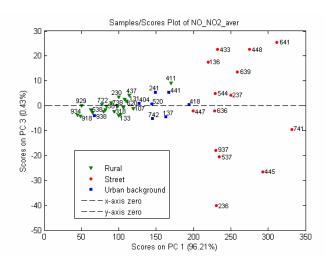Distinct clusters of stations are shown, with the most distinct being stations 938, 411, 641, 741 and 445, as already observed in the analyses of these components separately. Station 641 is located on a highway and clearly differs from other street stations. The observed distinctiveness of stations 445 and 741 can be explained by the different locations of these stations: station 445 is located in the middle of the street and station 741 is located nearby a traffic circle.

The ratio between CO and NO emissions is dependent on the age of the vehicles. The cars making up the traffic around stations 641, 544, 448 and 537 are more modern than those around stations 636, 639, 237, 236 and 136. In the PCA analysis, station 641 (highway) is clearly different, but the other stations do not show a systematic difference in terms of pattern.

Because the loadings plot is dominated by station 641, the same plots are shown in Figure 21C and D for the data set without station 641. The loadings plot 21D shows that there is relatively more NO and more CO at street stations (except during the night) than at the background stations. The loadings plot in Figure 21D also shows a correlation between NO and NO_2, as expected.
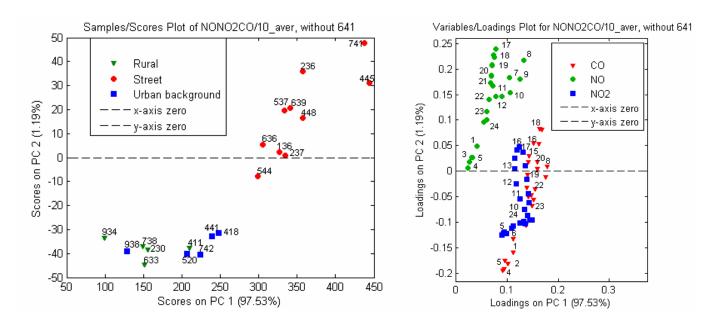

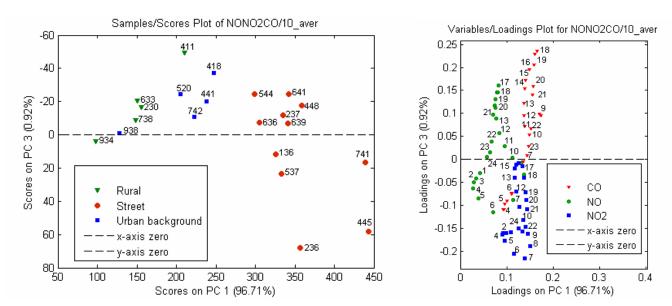**Figure 21C and 21D Scores and loadings plots without station 641.**

Figure 21E Scores plot for the third PC obtained with the diurnal variation of the combination NO and NO$_2$ And CO. This plot does not show any extra information.

4.5 Agriculture-related pollutant (NH$_3$)

This study does not reveal any irregularities at the NH$_3$ monitoring stations. Compared to 1994, the NH$_3$ concentration in 2007 is approximately 30% lower. In addition, at locations with intensive agriculture (131, Vredepeel; 738, Wekerom), NH$_3$ emissions are currently much more dispersed than in the past (Appendix 7). This change occurred around 2002, as can be seen in Appendix 7, which shows the diurnal variation of NH$_3$ at Vredepeel over the period 1994–2007. The average concentration roses at stations 131 and 738 (Appendix 8) show that the source of station 131 is located to the north-east of this station and that the source of station 738 is located to the north-west of this station.

The diurnal variation at station 633 (Zegveld) has also changed since 1994. This change took place around 2001, and since that year the concentration has decreased during the night, resulting in a small peak in the morning. The diurnal variation at this station over the period 1994–2007 is shown in Appendix 7.

Despite the overgrowth around station 722 (Eibergen) neither the PCA analyses nor the diurnal variation plots reveal any noticeable trends in the concentration measured at this station. This is illustrated in Appendix 7, which shows the diurnal variation at this station over the last 7 years.

4.6 Conclusions of the screening by means of PCA

This analysis shows that there is a good distinction between the rural stations and other stations. Urban background and the street stations can be clearly distinguished based on the concentration of traffic-related pollutants (e.g. NO, NO$_2$, CO). For the other pollutants (O$_3$, PM, SO$_2$), as can be expected, there is no clear distinction among these stations. A number of stations are distinct from others within their own group. Most of these observations can be explained using screening techniques other than PCA,

such as wind roses analyses, photographs, among others. An overview of these observations is given in Table 1.

Table 1: Overview of PCA screening results.

Station Nr.	Type	Remarkable observation	Observed with components	Possible cause of observed distinction
938 (Groningen–Nijensteinheerd)	UB	More like a rural station	NO,NO$_2$,CO, PM,O$_3$	Located in the suburb of Groningen
411 (Schipluiden–Groenveld)	R	More like an urban background station	NO,NO$_2$	Contribution of inland activities
418 (Rotterdam–Schiedamsevest)	UB	More like a street station	NO$_2$	Contribution of the Rotterdam harbour
445 (Den Haag-Veerkade)	S	Distinct from other street stations	NO$_2$	Located in the middle of the street (has been replaced in 2009)
520 (Amsterdam–Florapark)	UB	Distinct from other UB stations	NO$_2$	Influenced by the traffic from the IJ-tunnel
641 (Breukelen-Snelweg)	S	Distinct from other street stations	NO,NO$_2$,CO	Located on a high way
741 (Nijmegen–Graafseweg)	S	Distinct from other street stations	NO,NO$_2$,CO	Located nearby (±100 m) a traffic circle. The distance to the traffic circle is, however, larger than the restriction of 25 m
230 (Biest Houtakker–Biestsestraat)	R	Distinct from other rural stations	PM	Diurnal variation shows hotspots of PM
545 (Amsterdam–A10 west)	S	More like a rural station	PM	Located on a highway (Amsterdam A10)
416 (Vlaardingen–Lyceumlaan)	UB	Distinct from other stations	SO$_2$	Contribution from Pernis/Rotterdam harbour
433 (Vlaardingen–Floreslaan)	S	Distinct from other stations	SO$_2$	Contribution from Pernis/Rotterdam harbour
448 (Rotterdam–Bentinckplein)	S	Distinct from other street stations	SO$_2$	Contribution from Pernis/Rotterdam harbour
131(Vredepeel), 738 (Wekerom)	R	Distinct from other stations	NH$_3$	Diurnal variation shows hotspots of NH$_3$
441 (Dordrecht–Frisostraat), 520 (Amsterdam–Florapark)	Suburb (*)	More like UB	O$_3$	
137 (Heerlen–Nicolayestraat)	UB	Differs from other UB stations	O$_3$	Not clear yet

Notes (*): only for O$_3$. For other components, these stations are UB stations

Abbreviations: R: Rural; UB: Urban background; S: Street

This study shows that, in general, the monitoring stations of the LML represent the current classification well and that the character of the stations has not been changed markedly over the study period. No irregularity was observed for NH$_3$ (all at rural stations). The overgrowth around station 722 (Eibergen) does not result in noticeable trends in the NH$_3$ concentration measured at this station, and the pruning of trees in the spring and autumn of 2008 also did not have an effect on the NH$_3$ concentration profiles of station 722 in comparison with those of other rural stations (see chapter 5).

This study reveals that for some of the measurement stations, some interpretations of the data may not be consistent with the current classification. These stations are:

- Two street stations (641, 545) that are located on a highway; these clearly differ from other street stations.
- Station 938, which is located in a suburb of Groningen and classified as an urban background station (suburb for O_3). The PCA performed in this study shows that this station has the character of a rural station.
- Although stations 441 (Dordrecht–Frisostraat) and 520 (Amsterdam–Florapark) are currently classified as suburb stations for O_3, the PCA analysis performed here shows that these stations do not differ from other urban background stations. In AIRBASE, these stations are also classified as urban background also for O_3.

5   Influence of vegetation (trees and shrubs)

Vegetation has different effects on the measurement of pollutants. In some cases, the representativeness of a monitoring station can be negatively affected by the presence of vegetation around it; however, these effects are complex and depend on the components of interest:

- Trees can hamper the unrestricted air flow around inlet points, but it is not easy to estimate the impact of trees based on the number of trees around a monitoring station
- If the percentage of tree cover is large enough, the presence of vegetation may reduce the air temperature and the quantity of HV-light around the monitoring station. Consequently, O_3 formation, which occurs via the reaction $NO_2+HV+O_2 \rightarrow NO+O_3$, is reduced
- Some tree species can also emit volatile organic compounds (VOCs) that contribute to the formation of O_3. If this occurs around an urban/rural station, the measurement at that station may not be representative of the air quality of the larger area. Poplar, oak and willow are only some of the tree genera that have the highest standardized isoprene emission rate (Nowak, 1999)

In principle, a tree can remove air pollutants through absorption of the gaseous pollutant (NO_2, O_3, SO_2) in the water film inside the leaf or by adsorption on the plant surface (PM). However, the effect is generally limited. The RIVM (Wesseling et al., 2008) has studied the effect of vegetation on the concentrations of PM_{10} in and around cities. The conclusion of this study was: 'The presence of vegetation can either increase or decrease the concentrations of ambient PM_{10}.Vegetation growing along a road or planted in the median (islands) has the effect of lowering the average wind speed, possibly resulting in increasing local concentrations of PM_{10} (negative effect).Conversely, the presence of vegetation may filter out the (larger) particles, thereby lowering PM_{10} concentrations (positive effect). The net effect of these processes on air quality is, however, generally limited'. The adsorption effect of leaves on the NO_2 levels is also negligible.

There are two stations in the LML where measurements may have been influenced by the presence of trees: station 722 (Eibergen) and 520 (Amsterdam–Florapark).

Station 722 (Eibergen), rural station
This monitoring station is a rural background station and is located on an area with a lot of vegetation. There were a number of large trees in the close proximity of the station that had not been pruned for many years. Despite the presence of these trees, however, the PCA analysis (chapter 4) and the diurnal variation of NH_3 at this station during the last 7 year does not reveal any effect of this overgrowth. To ensure a good measurement at this station, some maintenance work was carried out in 2008 (Figures 22A–C):

- In the spring of 2008 (between 18 March and 15 April; exact date is unknown), the twigs and the trees which leaned against the inlet of the station were removed
- In the autumn of 2008 (exact date is not known), a second maintenance was carried out, and a number of trees around this station were removed

Figures **22A (upper): Photograph made on 18 March 2008, before the first pruning**
22B (middle): Photograph made on 15t April 2008: some twigs and trees were removed
22C (bottom): Photograph made on 3 March 2009: more trees were removed

![rivm]

The effect of pruning on the concentration of NH_3 at the Eibergen station is shown in Figure 23 as average monthly concentrations of NH_3 and O_3 before and after the pruning took place: January–February 2008, before the first pruning; May 2008, after the first pruning; December 2008–June 2009, period after the second pruning

When the concentrations measured at other monitoring stations are compared to those at the Eibergen station, it is clear that pruning has had no observable effect on the measurement of NH_3. We can therefore assume that the possible effect of vegetation on the monitoring results of NH_3 and O_3 is negligible at Eibergen.
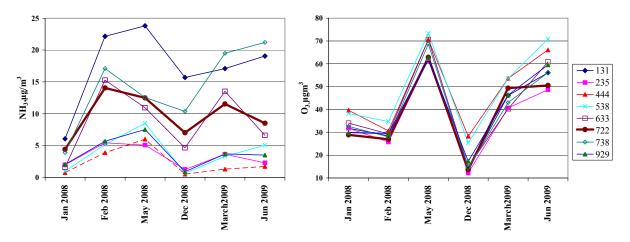

Figure 23 Average monthly concentration of NH_3 (left) and O_3 (right) at Eibergen (station 722) before and after the two prunings.

Station 520 (Amsterdam–Florapark), urban background station
This station is located on an area with large mound of vegetation. A portion of the vegetation was removed on 3 and 4 December 2007 during maintenance work at this location. The NO_2 concentrations at this station and at station 544 (Amsterdam–Prins Bernhardplein) in this period are shown in Figure 24. This figure does not show any change in the concentration of NO_2 measured at this station after the maintenance.
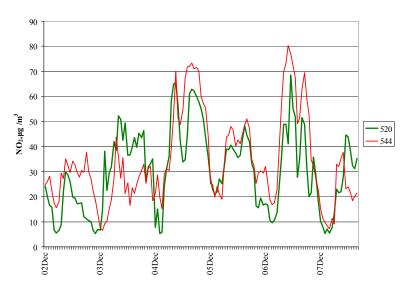
Figure 24 Concentration of NO$_2$ at Amsterdam–Florapark (station 520) before and after the pruning. There is no O$_3$ measurement for this period.

6 Discussion

6.1 Classification

Compared to the AIRBASE classification, the Dutch classification is a simple one in which stations are divided into three classes – rural (R), urban background (UB) and street (S), with an extra classification 'suburban' for O_3. The AIRBASE classification has three zone classes – rural, urban and suburban – and three station types – background, traffic and industrial. The PCA analysis performed in this study shows that, for a number of stations in the LML, the more detailed AIRBASE classification is more representative. For example, station 938 (UB), which is located in a suburb of Groningen, has the class 'suburban background' in AIRBASE; station 411(R) has also the class 'suburban background' in AIRBASE; station 641 (street), which is located on a highway, has the classification 'traffic rural' in AIRBASE. This classification aspect is relevant and should be taken into account when the measurement data are validated; for example, the measurement data of station 938 should be compared with caution to the concentrations measured at another urban background station.

Another confounding factor is that even a sophisticated classification can never fully describe the character of a measurement station because this character depends on the component of interest. For example, 'rural' station 131 (Vredepeel) is clearly influenced by the local NH_3 hotspot, and 'rural' station 231 (Biest) may be influenced by PM hotspots. However, in terms of other components, these stations have indeed the character of a 'rural' station. Likewise, the stations in the Rotterdam area are influenced by SO_2 hotspots. A detailed knowledge of these characteristics is relevant for modelling purposes and for data validation. An overview of these characteristics is given in chapter 7. For street stations, a more detailed description of the street and the effect of their geometry on the CAR results can be found in the RIVM report on the CAR model (Wesseling et al., 2007).

6.2 Representativeness

In practice it is not easy to investigate whether a station is representative or not. The criteria on macro and micro sitings listed in Annex III of the Directive are only global guidelines. These guidelines do not provide answers to the following specific questions:
- Does the building nearby the station 137 influence the representativeness of this station?
- Does the presence of the vegetation around stations 722 and 520 influence the representativeness of these stations?

It is not evident that these stations are not representative because of the above factors (see chapters 4 and 5). On the other hand, it is also possible that these factors have some effect on the measurements that is not revealed by the data analysis because of other processes. Therefore, rigorous changes at these stations are not necessary, although regular pruning is recommended. Recent pruning did not show a noticeable effect on the measured concentrations. While it is not necessary to replace station 137 immediately, when this station has to be renewed, the new monitoring station should preferably be placed at a more suitable place in this area.

7   Conclusions

The evaluation of the LML has resulted in several observations, and an overview of these is given in table 2. Some of these observations are only informative in nature. However, the evaluation has also identified a number of issues that require more attention. These issues concern good housekeeping practices, the location of the monitoring station (site 137), the classification of the monitoring station (4 sites) and the documentation of the LML.

The following is recommended:

- Good housekeeping: trees growing in close proximity to monitoring stations have to be pruned regularly to prevent obstruction of the inlet.
- The vegetation around stations 722 and 520 must be pruned regularly; in fact, adequate measures have already been taken.
- The location of site 137 may not be optimal for the measurement of urban background concentrations because this station is located very close to a building, and a representative sampling of air from a large area can not be guaranteed. Because the data analysis has not proven that the current location affects the representativeness of this station, it is not necessary to replace this station immediately. However, when this station is renewed, the new monitoring station should preferably be placed at a more suitable site in this area.
- Classification: compared to the AIRBASE classification, the Dutch classification is a simple one. The PCA analysis shows that the more detailed AIRBASE classification is more representative for a number of stations in the LML. This aspect is very relevant and should be taken into account when the data of the measurements are interpreted.
    - Street station 641 (Breukelen–snelweg) is located on a highway and differs clearly from other street stations. This difference is reflected in airborne background concentrations. The classification Rural Traffic is more representative.
    - Street station 545 (Amsterdam–A10 west) is located on a highway and differs clearly from other street stations.
    - Station 938 (Groningen–Nijensteinheerd) is classified as an urban background (UB) station (suburb for O_3), but it would be better classified as a rural/suburb station.
    - Stations 441(Dordrecht–Frisostraat) and 520 (Amsterdam–Florapark) are currently classified as suburb stations for O_3. In AIRBASE, these stations are classified as urban background, also for O_3. The evaluation shows that this classification is more representative.
- Completion of the documentation: three sites – 441(Dordrecht–Frisostraat, UB station), 446 (Den Haag–Bleriotlaan, UB station) and 447 (Leiden–Willem de Zwijgerlaan, Street station) – are currently not shown in the Google Maps application. Completion of this application with omitted sites is necessary.

Table 2: Results of the evaluation of the representativeness of the DAQMN (see also Appendix 9 for more details).

Rural	Number	SO₂	PM10	NH₃	CO	O₃	NO	NO₂	Netherlands NL-simple	Netherlands Ozone	R/U/SU	AIRBASE T/I/B	AIRBASE Ozone	Micro obs	Screening results
Posterholt-Vlodropperweg	107					x	x	x	Rural		R	B	R		
Vredepeel-Vredeweg	131	x	x	x		x	x	x	Rural		R	B	R	Farm E	Diurnal variation shows NH₃ hotspots
Wijnandsrade-Opfergeltstraat*	133	x	x			x	x	x	Rural	Suburb	SU	B	SU		
Budel-Toom	227					x	x	x	Rural		R	B	R		
Biest Houtakker-Biestsestraat	230		x		x	x	x	x	Rural		R	B	R		Diurnal variation shows PM hotspots
Huijbergen-Vennekenstraat	235	x	x	x		x	x	x	Rural		R	B	R		
Zierikzee-Lange Slikweg	301					x	x	x	Rural		R	B	R		
Philippine-Stelleweg	318	x	x			x	x	x	Rural		R	B	R		
Schipluiden-Groenveld*	411	x			x	x	x	x	Rural	Suburb	SU	B	SU		Windrose shows inland activities
Westmaas-Groeneweg	437		x			x	x	x	Rural		R	B	R		
De Zilk-Vogelaarsdreef	444	x	x	x		x	x	x	Rural		R	B	R		
Wieringerwerf-Medemblikkerweg	538	x	x	x		x	x	x	Rural		R	B	R		
Cabauw-Zijdeweg	620	x				x			Rural		R	B	R		
Bilthoven-Van Leeuwenhoeklaan	627	x							Rural		SU	B			
Biddinghuizen-Hoekwantweg	631		x			x	x	x	Rural		R	B	R		
Zegveld-Oude Meije	633	x	x	x	x	x	x	x	Rural		R	B	R		
Eibergen-Lintveldseweg	722	x	x	x		x	x	x	Rural		R	B	R	Surrounded by trees	
Wekerom-Riemterdijk	738		x	x	x	x	x	x	Rural		R	B	R		Diurnal variation shows NH₃ hotspots
Hellendoorn-Luttenbergerweg	807		x			x	x	x	Rural		R	B	R		
Barsbeek-De Veenen	818		x			x	x	x	Rural		R	B	R		
Balk-Trophornsterweg	918	x	x			x	x	x	Rural		R	B	R		
Valthermond-Noorderdiep	929	x	x	x		x	x	x	Rural		R	B	R		
Kollumerwaard-Hooge Zuidwal	934	x	x		x	x	x	x	Rural		R	B	R		

Urban Background	Number	SO₂	PM10	NH₃	CO	O₃	NO	NO₂	NL-simple	Ozone	R/U/SU	T/I/B	Ozone	Micro obs	Screening results
Heerlen-Deken Nicolayestraat	137		x			x	x	x	UB		U	B	U	Close to building	Ozone: different pattern
Breda-Bastenakenstraat	241		x			x	x	x	UB		SU	B			
Den Haag-Rebecquestraat	404	x	x			x	x	x	UB		U	B	U		
Vlaardingen-Lyceumlaan	416	x							UB		U	B		Nearby building at 50°	Contribution from Pernis/Rotterdam harbour
Rotterdam-Schiedamsevest	418		x		x	x	x	x	UB		U	B		Inlet temporary obstructed by trees	Contribution from Rotterdam harbour
Dordrecht-Frisostraat*	441		x		x	x	x	x	UB	Suburb	U	B	U		Ozone: UB instead of Suburb?
Den Haag-Bleriotlaan	446		x						UB		SU	B			
Amsterdam-Florapark*	520		x		x	x	x	x	UB	Suburb	U	B	U	Surrounded by trees	Ozone: UB instead of Suburb?
Nijmegen-De Ruyterstraat	742		x		x	x	x	x	UB		U	B	U		
Groningen-Nijensteinheerd*	938				x	x	x	x	UB	Suburb	SU	B			Locates in the sub urban of Groningen. Rural instead of UB?

Street	Number	SO₂	PM10	NH₃	CO	O₃	NO	NO₂	NL-simple	Ozone	R/U/SU	T/I/B	Ozone	Micro obs	Screening results
Heerlen-Looierstraat	136	x	x		x				Street		U	T		Building and trees on short distance of inlet (<5m)	
Eindhoven-Genovevalaan	236		x		x	x	x	x	Street		U	T	U		
Eindhoven-Noordbrabantlaan	237	x	x		x				Street		U	T			
Breda-Tilburgseweg	240		x		x				Street		SU	T			
Vlaardingen-Floreslaan	433	x	x			x	x	x	Street		U	T	U		Contribution from Pernis/Rotterdam harbour
Leiden-Willem de Zwijgerlaan	447		x			x	x	x	Street		U	T	U	Building and trees on short distance of inlet (<5m)	
Rotterdam-Bentinckplein	448	x	x				x	x	Street		U	T			Contribution from Pernis/Rotterdam harbour
Haarlem-Amsterdamsevaart	537		x		x	x			Street		U	T			
Amsterdam-Bernhardplein	544	x	x		x	x	x	x	Street		U	T	U	Trees <10m	
Amsterdam-A10 west	545		x						Street		U	T		Highway	
Utrecht-de Jongweg	636		x		x		x	x	Street		U	T	U		
Utrecht-Vleuteseweg	638	x							Street		U	T			
Utrecht-Erzeijstraat	639		x			x	x	x	Street		U	T	U		
Breukelen-Snelweg	641	x	x		x	x	x	x	Street		R	T	R	Highway	Highway. Rural Traffic instead of Street?
Nijmegen-Graafseweg	741		x		x		x	x	Street		U	T		Keizer Karel junction	
Groningen-Europaweg	937		x						Street		U	T	U	Stands on a slope	

*) Sub urban for ozone

Legend (colour key, left to right):
Agricultural hotspot | PM hotspot | Harbor/Industrial | Traffic circle etc. | Effect of micro-siting? | Differs from other stations | Looks like rural | Looks like UB | Looks like street

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Appendix 1 Criteria on micro and macro scale

Micro scale

In so far as is practicable, the following shall apply:

1) the flow around the inlet sampling probe shall be **unrestricted** (free in an arc of at least 270°) without any obstructions affecting the airflow in the vicinity of the sampler (normally some metres away from buildings, balconies, trees and other obstacles and at least 0.5 m from the nearest building in the case of sampling points representing air quality at the building line),

2) in general, the inlet sampling point shall be **between 1.5 m (the breathing zone) and 4 m above the ground**. Higher positions (up to 8 m) may be necessary in some circumstances. Higher siting may also be appropriate if the station is representative of a large area,

3) the inlet probe shall **not be positioned in the immediate vicinity of sources** in order to avoid the direct intake of emissions unmixed with ambient air,

4) the sampler's exhaust outlet shall be positioned so that recirculation of exhaust air to the sampler inlet is avoided,

5) for all pollutants, traffic-orientated sampling probes shall be **at least 25 m from the edge of major junctions and no more than 10 meter from the kerbside.**

The following factors may also be taken into account: interfering sources, security, access, availability of electrical power and telephone communications, visibility of the site in relation to its surroundings, safety of the public and operators, the desirability of co-locating sampling points for different pollutants, planning requirements.

Macro scale

On macro scale there is a distinction between protection of human health and protection of vegetation and natural ecosystems. Citation of the guideline:

1. Protection of human health

(a) Sampling points directed at the protection of human health shall be sited in such a way as to provide data on the following:

- o the areas within zones and agglomerations where the **highest concentrations occur** to which the population is likely to be directly or indirectly exposed for a period which is significant in relation to the averaging period of the limit value(s),
- o levels in **other areas** within the zones and agglomerations **which are representative of the exposure of the general population**,

(b) Sampling points shall in general be sited in such a way as to avoid measuring very small micro-environments in their immediate vicinity, which means that a sampling point must be sited in such a way that the air sampled is representative of air quality for a street segment no less than 100 m length at traffic-orientated sites and at least 250 m × 250 m at industrial sites, where feasible;

(c) Urban background locations shall be located so that their pollution level is influenced by the integrated contribution from all sources **upwind** of the station. The pollution level should not be dominated by a single source unless such a situation is **typical for a larger urban area**. Those sampling points shall, as a general rule, be representative for several square kilometres;

(d) Where the objective is to assess rural background levels, the sampling point shall not be influenced by agglomerations or industrial sites in its vicinity, i.e. sites closer than five kilometres;

(e) Where contributions from industrial sources are to be assessed, **at least one sampling point shall be installed downwind of the source in the nearest residential area. Where the background concentration is not known, an additional sampling point shall be situated within the main wind direction;**

(f) Sampling points shall, where possible, also be representative of similar locations not in their immediate vicinity;

(g) Account shall be taken of the need to locate sampling points on islands where that is necessary for the protection of human health. L 152/18 EN Official Journal of the European Union 11.6.2008

2. Protection of vegetation and natural ecosystems

Sampling points targeted at the protection of vegetation and natural ecosystems shall be sited **more than 20 km away from agglomerations or more than 5 km away from other built-up areas**, industrial installations or motorways or major roads with traffic counts of more than 50 000 vehicles per day, which means that a sampling point must be sited in such a way that the air sampled is representative of air quality in a surrounding area of at least 1 000 km^2. **A Member State may provide for a sampling point to be sited at a lesser distance or to be representative of air quality in a less extended area, taking account of geographical conditions or of the opportunities to protect particularly vulnerable areas.** Account shall be taken of the need to assess air quality on islands.
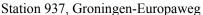
Appendix 2 Quick scan of the Dutch national Air Quality Network

Traffic-orientated sites (kerbside)

ID	Site	Zone	Distance major junction (m) approximately	Distance kerbside (m)	Remarks
136	Heerlen-Looierstraat	Heerlen	100 - 250	<5	Building and trees on short distances of inlet (< 5 meter)
236	Eindhoven-Genovevalaan	Eindhoven	100 – 250	<5	
237	Eindhoven-Noordbrabantlaan	Eindhoven	50-100	<5	
240	Breda-Tilburgseweg	Zuid	100 – 250	5 – 10	
433	Vlaardingen-Floreslaan	Rotterdam	> 250	< 5	
447	Leiden-W. de Zwijgerlaan	Den Haag	> 250	< 5	Building and trees on short distance of inlet (< 5 meter)
448	Rotterdam-Bentinckplein	Rotterdam	50-100	<5	
537	Haarlem-Amsterdamsevaart	Amsterdam	25-50	< 5	
544	Amsterdam-Bernardplein	Amsterdam	50	5 – 10	Trees <10 m
545	Amsterdam-A10 west	Amsterdam	> 250	< 5	Highway
636	Utrecht-de Jongweg	Utrecht	100 – 250	5 - 10	
638	Utrecht-Vleuteseweg	Utrecht	100 - 250	<5	
639	Utrecht-Erzeijstraat	Utrecht	100 - 250	< 5	
641	Breukelen-A2	Midden	> 250	5 - 10	Highway
741	Nijmegen-Graafseweg	Midden	50 – 100	< 5	Keizer Karel junction
937	Groningen-Europaweg	Noord	50 -100	< 5	Stands on a slope

The kerbside sites fulfil the criteria as mentioned in the 'Directive'. The station 937 stands on a slope, consequently the inlet at this station is relatively lower than the inlet at other Dutch monitoring station. However the criterion for the sampling point (between 1.5-4 m above the ground) is still met.

Station 937, Groningen-Europaweg

Urban background sites

ID	Site	Zone/ Agglomoration	Number samplers	Number citizens	Representative for larger area	Remarks
137	Heerlen-Nicolayestr	Heerlen	5	240326	To be discussed	Inlet obstructed
241	Breda-Bastenakenstr	Zuid	3	170029	Yes	No
404	Den Haag-Rebecquestraat	Den Haag	5	**1061200**	Yes	No
416	Vlaardingen-Lyceumlaan	Rotterdam	1	**1279364**	Yes	50° building
418	Rotterdam-Schiedamsevest	Rotterdam	5	**1279364**	Yes	Air flow restriction by trees
441	Dordrecht-Frisostraat	Rotterdam	5	**1279364**	Yes	No
446	Ypenburg-Bleriotlaan	Den Haag	1	**1061200**	Yes	No
520	Amsterdam-Florapark	Amsterdam	1	1538435	Yes	Air flow restriction by trees
742	Nijmegen-De Ruyterstraat	Midden	5	160215	Yes	No
938	Groningen	Noord	3	181171	Yes	No

(Bold is number of inhabitants in agglomeration, based on statistics 2005)

The station 137 in Heerlen locates very close to a building (see photo below) which may restrict the sampling of air from a large area. Sites 418 and 520 need some attention because of restriction of the airflow by trees. The other urban background sites fulfil the criteria as mentioned in the 'Directive'.

Site 137, Heerlen-Nicolayestraat

Rural sites

Id	Site	Number of samplers	Representative for regional level
107	Posterholt-Vlodropperweg	3	Yes
131	Vredepeel-Vredeweg	6	Yes
133	Wijnandsrade-Opfelgertstraat	5	Yes
227	Budel-Toom	3	Yes
230	Biest Houtakker -Biestsestraat	8	Yes
235	Huijbergen-Vennekenstraat	6	Yes
301	Zierikzee-Lange Slikweg	3	Yes
318	Philippine-Stelleweg	5	Yes
411	Schipluiden-Groeneveld	5	Yes
437	Westmaas-Groeneweg	5	Yes
444	De Zilk-Vogelaarsdreef	7	Yes
538	Wieringerwerf-Medemblikkerweg	6	Yes
620	Cabauw-KNMI	3	Yes
627	Bilthoven-Van Leeuwenhoeklaan	1	Yes
631	Biddinghuizen-Hoekwantweg	4	Yes
633	Zegveld-Oude Meije	8	Yes
722	Eibergen-Lintveldseweg	7	Yes
738	Wekerom-Riemterdijk	6	Yes
807	Hellendoorn-Luttenbergerweg	4	Yes
818	Barsbeek-De Veenen	4	Yes
918	Balk-Trophornsterweg	4	Yes
929	Valthermond-Noorderdiep	6	Yes
934	Kollumerwaard-Hooge Zuidwal	8	Yes

Site 235 Huijbergen and site 722 Eibergen are surrounded with trees. There is no obstruction of the inlet.

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Appendix 3 Calculation of average concentration rose

The wind rose is the distribution of the wind frequency over different wind sectors. By default, there are 12 wind sectors of 30°, but the user can choose more or less wind sectors. Let

N : number of hours with valid wind and concentration data

h_{ij} = 1, if wind in hour i is in sector j

= 0, if wind in hour i is not in sector j.

N_j : number of hours that wind is in sector j: $N_j = \sum_{i=1}^{N} h_{ij}$.

f_j : wind frequency for sector j: $f_j = \dfrac{1}{N} \sum_{i=1}^{N} h_{ij} = \dfrac{N_j}{N}$,

   i.e. the ratio of the number of hours that wind is in sector j to the total number of hours.

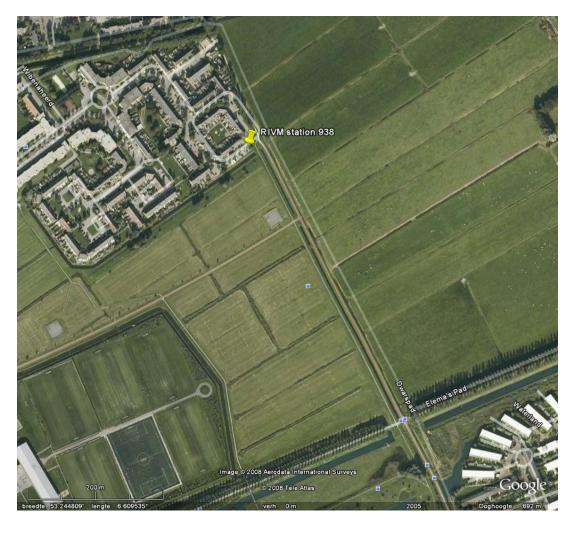f_j^c : value of concentration rose for sector j: $f_j^c = \dfrac{1}{N} \sum_{i=1}^{N} h_{ij} c_i$

f_j^w : **value of average concentration rose for sector j:**

$$ f_j^w = \frac{1}{f_j} f_j^c = \frac{1}{f_j} \frac{1}{N} \sum_{i=1}^{N} h_{ij} c_i = \frac{1}{N_j} \sum_{i=1}^{N} h_{ij} c_i . $$
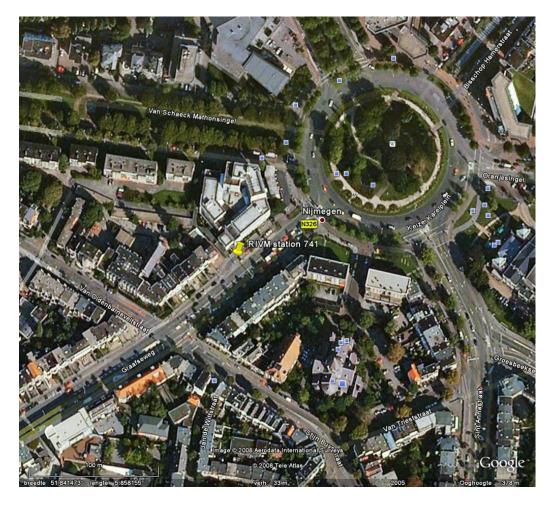
In this study the following KNMI stations were used in the calculation of average concentration roses

LML	KNMI
404	210
444	210
445	210
447	210
520	240
537	240
544	240
633	240
641	240
538	267
918	267
631	269
818	269
929	280
934	280
937	280
938	280
722	290
807	290
301	310
318	310
411	344
416	344
418	344
433	344
437	344
441	344
448	344
620	260
636	260
639	260
738	260
230	350
235	350
241	350
227	370
236	370
237	370
131	375
741	375
742	375
107	380
133	380
136	380
137	380

Appendix 4 Locations of sites 938 in Groningen
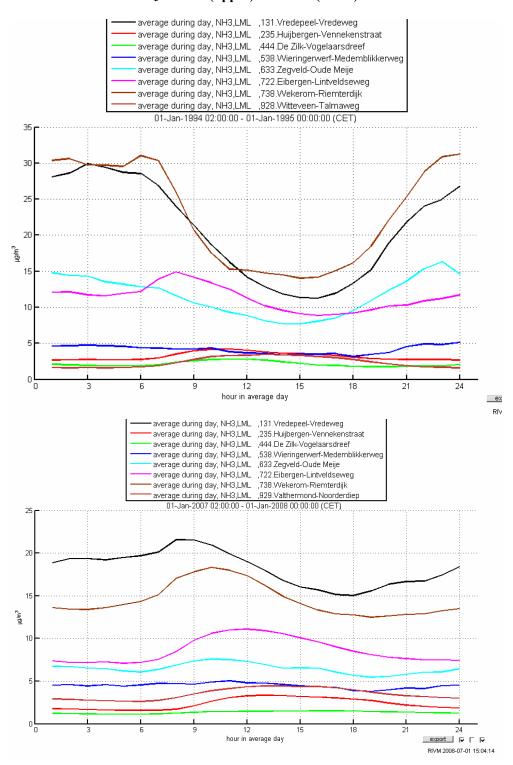
Appendix 5 Location of site 741 in Nijmegen

Appendix 6 Old location of monitoring station 445 (Den Haag-Veerkade)
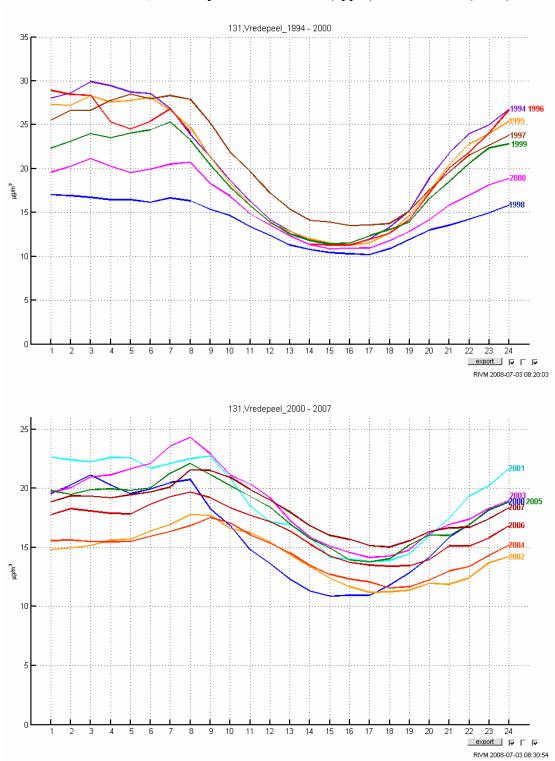
Appendix 7 Diurnal variation of NH₃

Diurnal variation of NH₃ in 1994 (upper) and 2007 (lower)
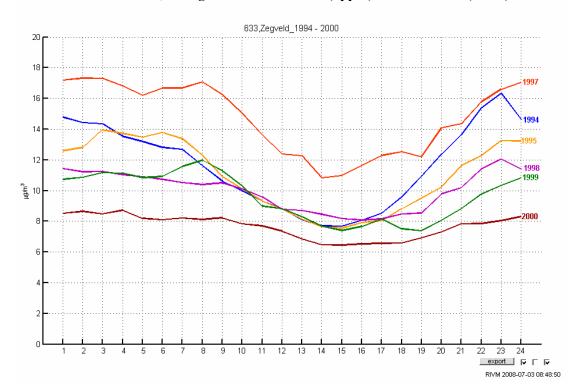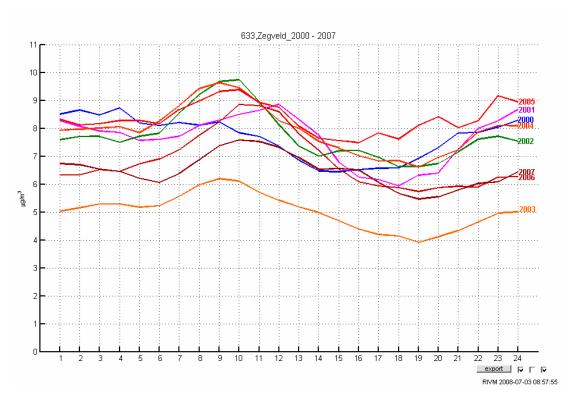
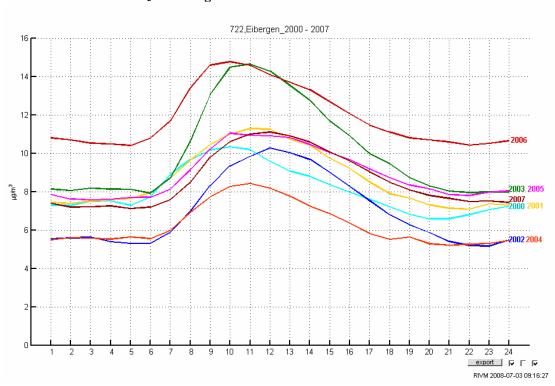**Diurnal variation of NH₃ at Vredepeel over 1994-2000 (upper) and 2000-2007 (lower)**

Diurnal variation of NH₃ at Zegveld over 1994-2000 (upper) and 2000-2007 (lower)

Diurnal variation of NH₃ at Eibergen since 2000

722,Eibergen_2000 - 2007

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Appendix 8 Average NH₃ concentration roses of 131 (Vredepeel) and 738 (Wekerom)

Appendix 9 List of LML stations used in this study

Rural	Number	X	Y	Latitude	Longitude
Posterholt-Vlodropperweg	107	200900	347900	51°07'13"N	06°02'35"O
Vredepeel-Vredeweg	131	187300	394700	51°32'28"N	05°51'13"O
Wijnandsrade-Opfergeltstraat*	133	189800	323700	50°54'11"N	05°52'56"O
Budel-Toom	227	167100	364200	51°16'03"N	05°33'42"O
Biest Houtakker-Biestsestraat	230	138400	392200	51°31'10"N	05°08'56"O
Huijbergen-Vennekenstraat	235	83600	383300	51°26'06"N	04°21'37"O
Zierikzee-Lange Slikweg	301	53200	406100	51°38'08"N	03°55'01"O
Philippine-Stelleweg	318	40800	368500	51°17'43"N	03°44'58"O
Schipluiden-Groenveld*	411	79000	445500	51°59'41"N	04°16'50"O
Westmaas-Groeneweg	437	90400	422400	51°47'15"N	04°27'03"O
De Zilk-Vogelaarsdreef	444	95200	479100	52°17'53"N	04°30'37"O
Wieringerwerf-Medemblikkerweg	538	132200	535200	52°48'17"N	05°03'03"O
Cabauw-Zijdeweg	620	123400	442300	51°58'17"N	04°55'35"O
Bilthoven-Van Leeuwenhoeklaan	627	141900	459100	52°07'15"N	05°11'44"O
Biddinghuizen-Hoekwantweg	631	170700	495700	52°26'58"N	05°37'10"O
Zegveld-Oude Meije	633	117400	461300	52°08'20"N	04°50'18"O
Eibergen-Lintveldseweg	722	238500	456600	52°05'33"N	06°36'21"O
Wekerom-Riemterdijk	738	176990	458220	52°06'45"N	05°42'31"O
Hellendoorn-Luttenbergerweg	807	224200	489500	52°23'21"N	06°24'13"O
Barsbeek-De Veenen	818	197700	518700	52°39'18"N	06°01'05"O
Balk-Trophornsterweg	918	167600	547900	52°55'05"N	05°34'26"O
Valthermond-Noorderdiep	929	259100	544300	52°52'36"N	06°56'00"O
Kollumerwaard-Hooge Zuidwal	934	214300	594200	53°19'54"N	06°16'39"O
Urban Background	Number				
Heerlen-Deken Nicolayestraat	137	196525	321840	50°53'05"N	05°58'38"O
Breda-Bastenakenstraat	241	112990	401770	51°36'12"N	04°46'51"O
Den Haag-Rebecquestraat	404	79600	454700	52°04'41"N	04°17'21"O
Vlaardingen-Lyceumlaan	416	84200	436900	51°55'03"N	04°21'26"O
Rotterdam-Schiedamsevest	418	92600	436600	51°54'54"N	04°28'49"O
Dordrecht-Frisostraat*	441	105500	424200	51°48'19"N	04°40'08"O
Den Haag-Bleriotlaan	446	84482	450542	52°02'21"N	04°21'33"O
Amsterdam-Florapark*	520	123100	489400	52°23'31"N	04°55'04"O
Nijmegen-De Ruyterstraat	742	187200	427800	51°50'16"N	05°51'16"O
Groningen-Nijensteinheerd*	938	236556	585140	53°14'48"N	06°36'32"O
Street	Number				
Heerlen-Looierstraat	136	196049	322190	50°53'17"N	05°58'14"O
Eindhoven-Genovevalaan	236	160900	386600	51°28'11"N	05°28'22"O
Eindhoven-Noordbrabantlaan	237	159000	383900	51°26'43"N	05°25'44"O
Breda-Tilburgseweg	240	116050	400660	51°35'37"N	04°49'30"O
Vlaardingen-Floreslaan	433	82000	436400	51°54'41"N	04°19'37"O
Leiden-Willem de Zwijgerlaan	447	94826	464771	52°10'04"N	04°30'27"O
Rotterdam-Bentinckplein	448	91335	438010	51°55'37"N	04°27'42"O
Haarlem-Amsterdamsevaart	537	104700	488400	52°22'54"N	04°38'53"O
Amsterdam-Bernhardplein	544	123134	484634	52°20'55"N	04°55'10"O
Amsterdam-A10 west	545	117800	483600	52°20'21"N	04°50'29"O
Utrecht-de Jongweg	636	137000	457400	52°06'22"N	05°07'31"O
Utrecht-Vleutenseweg	638	135500	456100	52°05'38"N	05°06'11"O
Utrecht-Erzeijstraat	639	136700	453300	52°04'08"N	05°07'16"O
Breukelen-Snelweg	641	127700	468300	52°12'11"N	04°59'19"O
Nijmegen-Graafseweg	741	187500	428200	51°50'29"N	05°51'32"O
Groningen-Europaweg	937	234600	581900	53°13'04"N	06°34'44"O

*) Sub urban for ozone