National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Evaluation of the representativeness of the Dutch air quality monitoring stations

The National, Amsterdam, Noord-Holland, Rijnmond-area, Limburg and Noord-Brabant networks

National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Evaluation of the representativeness of the Dutch air quality monitoring stations

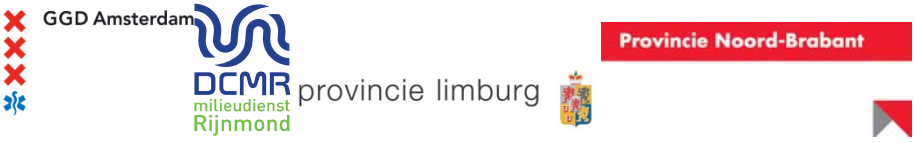
The National, Amsterdam, Noord-Holland, Rijnmond-area, Limburg and Noord-Brabant networks

RIVM Report 680704021/2012

Colophon

P.L. Nguyen, RIVM
G. Stefess, RIVM
D. de Jonge, GGD Amsterdam
A. Snijder, DCMR
P.M.J.A. Hermans, Province of Limburg
S. van Loon, Province of Noord-Brabant
R. Hoogerbrugge, RIVM

Contact:
R. Hoogerbrugge
Centre for Environmental Monitoring
Ronald.Hoogerbrugge@rivm.nl



This investigation has been performed by order and for the account of Directorate-General for Environmental Protection, within the framework of 680704 Reporting Air Quality

Abstract

Evaluation of the representativeness of the Dutch air quality measurement stations

In the Netherlands, stations measuring air quality for various measurement networks are sub-categorised as follows: rural, urban and street stations. This distinction is necessary for the interpretation of measurements and is based on where the station is located. A study by the National Institute for Public Health and the Environment (RIVM) has shown that for most stations, this classification is correct. In some cases, however, due to local activities, the classification does not hold for all components. For example, if a farm is located nearby a rural station, then the concentration of most components may correspond to the background concentrations but the concentration of ammoniac may be high. This information is necessary when modelled concentrations are compared with measurements . This study has also investigated which stations from other networks can be used on a national scale, for example, for the production of the Dutch concentration map.

The difference in measurements between the various types of station was particularly prominent for nitrogen dioxide (NO_2). At the same time, stations in the same category showed comparable concentrations of nitrogen dioxide. For particulate matter (PM_{10}) the distinction between the background and traffic stations was less clear. At some stations, the influence of industrial sources was clearly observed by the concentrations of particulate matter that were measured.

For this study, data from all the measurement stations of the Dutch National Quality Monitoring Network were used. In addition, data provided by the networks of the Municipal Health Service (GGD) Amsterdam, the Environmental Protection Agency Rijnmond (DCMR), the provinces of Noord-Brabant and Limburg, were used. The vicinity of measurement stations was assessed by using photographs and maps of these stations.

Keywords:
air quality, representativeness, LML, GGD-Amsterdam, DCMR

Rapport in het kort

Evaluatie representativiteit Nederlandse luchtkwaliteitmeetstations

Nederlandse meetstations voor de luchtkwaliteit van diverse Meetnetten Luchtkwaliteit worden onderverdeeld in bepaalde categorieën: regionale, stadsachtergrond- en straatstation. Dit onderscheid is nodig om de meetresultaten te kunnen interpreteren en wordt gemaakt op basis van de omgeving van de stations. Deze 'classificatie' klopt bij de overgrote meerderheid van de meetstations, zo blijkt uit onderzoek van het RIVM. In sommige gevallen gaat de classificatie door lokale omstandigheden niet op voor alle gemeten stoffen. Als er bijvoorbeeld een boerderij in de buurt van een achtergrondstation is komen te staan, kunnen de meeste stoffen overeenkomen met de achtergrondwaarden maar kan de ammoniakconcentratie hoog zijn. Deze informatie is nodig bij het vergelijken van luchtkwaliteitsmodellen met de meetresultaten. In het onderzoek is ook vastgesteld welke stations van andere meetnetten dan het Landelijk Meetnet Luchtkwaliteit (LML) voor landelijke doeleinden zijn te gebruiken, zoals voor de grootschalige concentratiekaart Nederland (GCN).

Vooral bij stikstofdioxide (NO_2) was het verschil tussen de stationstypen duidelijk terug te zien in de gemeten waarden. Tegelijkertijd gaven gelijksoortige stations door heel Nederland vergelijkbare concentraties stikstof aan. Bij PM10 (fijn stof) was het onderscheid tussen de achtergrond- en verkeerstations minder duidelijk. De invloed van verkeer op de hoeveelheid fijn stof is minder groot. Bij sommige stations was wel de invloed van industriebronnen duidelijk terug te zien in de gemeten PM10-waarden.

Voor dit onderzoek zijn data gebruikt van alle LML-stations, die in beheer zijn van het RIVM. Daarnaast zijn gegevens gebruikt die de meetnetten van de GGD Amsterdam, de Milieudienst Rijnmond (DCMR), de provincie Noord-Brabant en de provincie Limburg beschikbaar hebben gesteld. De omgeving van de stations is beoordeeld op basis van foto's en landkaarten van deze locaties

Trefwoorden:
luchtkwaliteit, representativiteit, LML, GGD-Amsterdam, DCMR

Contents

Summary—9

1 Introduction—12

2 Documentation of studied Air Quality Monitoring networks—13

3 Study of the micro and macro status of the stations—17

4 Study of the representativeness by means of principal component analysis—19
4.1 Method—19
4.2 Data sets—19

5 Screening results of NO_2 and PM_{10} measured in five monitoring networks—21
5.1 NO_2—21
5.2 PM_{10}—29

6 Screenings results obtained with measurements in monitoring networks of RIVM, GGD Amsterdam and DCMR—35
6.1 NO_2—35
6.2 NO—36
6.3 PM_{10}—38
6.4 CO—38
6.5 O_3—39
6.6 SO_2—42
6.7 Pollutants from traffic—45
6.8 Agriculture-related pollutant (NH_3)—48

7 Results of the PCA analysis—51

8 Discussion—55
8.1 How consistent is this evaluation—55
8.2 Classifications—55
8.3 Representativeness—56

9 Conclusions and recommendations—57

References—65

Appendix 1 Criteria on micro and macro scale—67

Appendix 2 Calculation of average concentration rose—69

Appendix 3 NO_2 wind rose at station Ossendrecht in Noord-Brabant and the location of this station—70

Appendix 4 Locations of measurement stations in the industrial area IJmond (Noord-Holland)—71

Appendix 5 Location of some typical stations—72

Appendix 6 Locations and wind roses of measurement stations in Rijnmond—74

Appendix 7 Diurnal variation of PM_{10} at station 230 (Biest) and some other stations in Noord-Brabant—75

Appendix 8 Photographs of deviating measurement stations in Amsterdam—76

Summary

The RIVM (National Institute for Public Health and the Environment) has evaluated the representativeness of five monitoring networks: the Dutch national Air Quality Monitoring Network (LML) and four monitoring networks of local authorities. These are monitoring networks of the Municipal Health Service Amsterdam (GGD Amsterdam), the Environmental Protection Agency Rijnmond (DCMR), the province of Limburg and the province of Noord-Brabant.

The study was performed by means of principal components analysis (PCA) in combination with other techniques such as wind roses, diurnal analyses and Google Map application (photographs of the direct vicinity). Information about the micro/macro scale of local monitoring networks was supplied by local authorities. In an earlier study (Nguyen et al., 2009), the same techniques were used to study the representativeness of the LML, using measurement data of 2007. In this study measurement data of 2010 were used.

Two analyses were performed in this study. In an extensive analysis hourly data of nitrogen dioxide (NO_2) and particulate matter (PM_{10}) measured in five monitoring networks were used. The second analysis was performed with a smaller selection of monitoring stations; however, data of more components were used: nitrogen oxide (NO), nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matter (PM_{10}), ozone (O_3), ammoniac (NH_3) and sulphur dioxide (SO_2).

The evaluation reveals that, in general, all monitoring networks fulfil the criteria of the EU Directive 2008/50/EC very well. Beside the stations which are currently used in the production of the GCN map, four stations, 488 (DCMR, Rotterdam-Zwartewaalstraat), 556 (PNH, de Rijp), 246 (Fijnaart-Zwingelspaansedijk) and 549 (Laren-Jagerspad), seem suitable too.

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

- The location of station 137 (Heerlen-Deken Nicolayestraat) 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 cannot 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.
- The location of station 17 (GGD Amsterdam, Stadhouderskade) is not optimal (too close to a junction). If this station has to be renewed the new monitoring station should preferably be placed at a more suitable location on this street.
- Measurements of DCMR, GGD and RIVM give comparable yearly average PM_{10} concentration at Berghaven and Overtoom, the difference between diurnal variation at station 496 (DCMR, Berghaven) and station 432 (Hoek van Holland-Berghaven), and between station 14 (GGD Amsterdam, Vondelpark) and 543 (Amsterdam-Overtoom) is very likely due to the measurement method. The difference is not relevant for limit values that are based on yearly or daily averages but might influence other analysis.

- Classification:

In addition to the AIRBASE classification in the Netherlands a simple classification is used. The PCA analysis shows that in general stations cluster nicely also in the simple classification; however, in some cases the more detailed AIRBASE classification is more representative. This aspect is relevant and should be taken into account when the data of measurements are interpreted.
A table is include with particular remarks on individual stations including:

  - Station 938 (Groningen-Nijensteinheerd), which is located in the suburb of Groningen, is classified as an Urban Background station (suburb for ozone). The measurement results at this station resemble rural stations but are presumably representative for the urban population in the northern part of the country. 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 (station 441 has been replaced in November 2010). Based on the PCA analysis, station 404 (Den Haag-Rebecquestraat) and station 3 (GGD Amsterdam, Nieuwendammerdijk) seem to be appropriate stations to monitor suburban concentrations in these areas.
  - The classification Industry or Urban is more suitable for station 486 (DCMR, Pernis-Soetermanweg) than the classification Street.
  - For stations along a highway in remote areas (for example station 641) the classification Rural Traffic is more representative than the classification Street. Generally, measurements at stations along a highway should not be compared to a regular Street station.

- Completion of documentation:
  - RIVM: update of the Google maps application of LML stations is recommended. DCMR: addition to the current map with locations of measurement stations with photographs of the surrounding areas is recommended.

1 Introduction

In accordance with EU legislation, the air quality in the Netherlands is monitored by measurements. A major part of these measurements are part of the Dutch national Air Quality Monitoring Network (LML) of the National Institute for Public Health and the Environment (RIVM). In addition to the national Air Quality Monitoring Network, the Municipal Health Service Amsterdam (GGD Amsterdam) and the Environmental Protection Agency Rijnmond (DCMR) have their own monitoring networks to monitor the air quality in these densely populated areas. In other areas local authorities have smaller networks.

In the LML the stations are classified basically as rural, Urban Background and Street stations respectively. Apart from the above classification, local monitoring networks also have stations which are classified as industrial stations because they are located in industrial areas. Some monitoring stations are located in a complex area and don't have a classification ('not defined'-station).

Earlier study using data in 2007 (Nguyen et al.,2009) showed that the LML fulfilled criteria of the EU Directive 2008/50/EC. Some remarks were made to inform air quality modellers on special features for some stations.
These conclusions need to be updated. On top of that, within the frame of the cooperation between RIVM, GGD Amsterdam and DCMR, measurement data of these three institutes are frequently used mutually. For correct interpretations of air quality measurement data from different stations, the representativeness of the monitoring sites must be documented.

In this study measurement data in 2010 of RIVM, GGD Amsterdam, DCMR, the province of Limburg and the province of Noord-Brabant were combined and analysed, using the same technique. Measurement data of the province of Gelderland were not included because this network does not have hourly data in 2010.

The objective of this study is as follows:

- to investigate if the current classification of the Dutch measurement stations corresponds to the character of these stations;
- to identify relevant issues while using measurement data;
- to check if there are issues that required more attention;
- to identify background stations that are suitable for the production of the GCN map.

2 Documentation of studied Air Quality Monitoring networks

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*.'
The documentation of the national Air Quality Monitoring Network has been described in Nguyen et al. (2010). This network utilizes a Google Maps application for an update of the documentation and a review of the site selection. This application shows compass point and panoramic views of the direct vicinity of each station and is being renewed. The current link (10/1/2013) to this application is:
http://www.onsite360.nl/projecten/rivm/startpagina/
The network of the GGD Amsterdam is described by de Jonge (2012). On the website of the GGD Amsterdam (http://www.luchtmetingen.amsterdam.nl) a map with locations of monitoring stations can be found. Each station is shown with photos of the location. The stations of the Province of Noord-Holland are also controlled by the GGD Amsterdam and similarly presented (www.luchtmetingen.noord-holland.nl) and included in this report. The website of DCMR (http://www.dcmr.nl/luchtkwaliteit/index.htm) and the website of the province of Limburg (http://luchtkwaliteit.limburg.nl/) also show maps with locations of monitoring stations. Measurements at these stations are shown but there are no photos of the location.

Table 1 shows a list of all stations used in this study. The first column shows the station number of monitoring stations. The structure of these numbers is as follows:

- LML: the starting number depends on the locations of the station:
  - Stations in the provinces of Friesland, Groningen and Drenthe have number 9xx
  - Stations in the province of Overijssel have number 8xx
  - Stations in the province of Gelderland have number 7xx
  - Stations in the province of Utrecht have number 6xx
  - Stations in the province of Noord-Holland have number 5xx
  - Stations in the province of Zuid-Holland have number 4xx
  - Stations in the province of Zeeland have number 3xx
  - Stations in the province of Noord-Brabant have number 2xx
  - Stations in the province of Limburg have number 1xx
- GGD: stations in Amsterdam have numbers up to 022. Stations outside Amsterdam have numbers 5xx (Noord-Holland) or 7xx.
- DCMR: all stations of DCMR have starting number 4
- One station of the province of Noord-Brabant is used in this study. This station does not have a number. For convenience in this analysis a number (999) is assigned to this station.
- Stations of the province of Limburg have the numbers 1, 2 and 3. To prevent mixing up with another station 002 (station Haarlemmerweg in

Amsterdam), in this study the numbers 1001,1002 and 1003 were assigned to these stations.

The last two columns of Table 1 show the corresponding meteorological stations from the KNMI. These meteorological stations are used in the calculation of concentration roses and details of the stations are described on *http://www.knmi.nl/klimatologie/metadata/stationslijst.html.*

Table 1: Monitoring stations used in this study

St.nr.	Type	Name	Network	Components		Meteo station	
107	R	Posterholt - Vlodropperweg	RIVM	NO_2		377	Ell
131	R	Vredepeel - Vredeweg	RIVM	NO_2	PM_{10}	375	Volkel
133	R	Wijnandsrade - Opfergeltstraat	RIVM	NO_2	PM_{10}	380	Maastricht
227	R	Budel - Toom	RIVM	NO_2		377	Ell
230	R	Biest Houtakker - Biestsestraat	RIVM	NO_2	PM_{10}	350	Gilze-Rijen
235	R	Huijbergen - Vennekenstraat	RIVM	NO_2	PM_{10}	340	Woensdrecht
301	R	Zierikzee - Lange Slikweg	RIVM	NO_2		323	Wilhelminadorp
318	R	Philippine - Stelleweg	RIVM	NO_2	PM_{10}	319	Westdorpe
411	R	Schipluiden - Groeneveld	RIVM	NO_2		344	Rotterdam
437	R	Westmaas - Groeneweg	RIVM	NO_2	PM_{10}	344	Rotterdam
444	R	De Zilk - Vogelaarsdreef	RIVM	NO_2	PM_{10}	210	Valkenburg
538	R	Wieringerwerf - Medemblikkerweg	RIVM	NO_2	PM_{10}	249	Berkhout
620	R	Cabauw - Zijdeweg	RIVM	NO_2		356	Herwijnen
631	R	Biddinghuizen - Hoekwantweg	RIVM	NO_2	PM_{10}	269	Lelystad
633	R	Zegveld - Oude Meije	RIVM	NO_2	PM_{10}	356	Herwijnen
722	R	Eibergen - Lintveldseweg	RIVM	NO_2	PM_{10}	283	Hupsel
738	R	Wekerom - Riemterdijk	RIVM	NO_2	PM_{10}	275	Deelen
807	R	Hellendoorn - Luttenbergerweg	RIVM	NO_2	PM_{10}	278	Heino
818	R	Barsbeek - De Veenen	RIVM	NO_2	PM_{10}	273	Marknesse
918	R	Balk - Trophornsterweg	RIVM	NO_2	PM_{10}	267	Stavoren
929	R	Valthermond - Noorderdiep	RIVM	NO_2	PM_{10}	279	Hoogeveen
934	R	Kollumerwaard - Hooge Zuidwal	RIVM	NO_2	PM_{10}	277	Lauwersoog
137	UB	Heerlen - Deken Nicolayestraat	RIVM	NO_2	PM_{10}	380	Maastricht
241	UB	Breda - Bastenakenstraat	RIVM	NO_2	PM_{10}	350	Gilze-Rijen
247	UB	Veldhoven - Europalaan	RIVM	NO_2	PM_{10}	370	Eindhoven
404	UB	Den Haag - Rebecquestraat	RIVM	NO_2	PM_{10}	210	Valkenburg
418	UB	Rotterdam - Schiedamsevest	RIVM	NO_2	PM_{10}	344	Rotterdam
441	UB	Dordrecht - Frisostraat	RIVM	NO_2	PM_{10}	344	Rotterdam
442	UB	Dordrecht - Bamendaweg	RIVM	NO_2	PM_{10}	344	Rotterdam
520	UB	Amsterdam - Florapark	RIVM	NO_2	PM_{10}	240	Schiphol
742	UB	Nijmegen - Ruyterstraat	RIVM	NO_2	PM_{10}	375	Volkel
938	UB	Groningen - Nijensteinheerd	RIVM	NO_2		280	Eelde
446	UB	Den Haag - Bleriotlaan	RIVM		PM_{10}	344	Rotterdam
543	UB	Amsterdam - Overtoom	RIVM	NO_2	PM_{10}	240	Schiphol
240	S	Breda - Tilburgseweg	RIVM		PM_{10}	350	Gilze-Rijen
447	S	Leiden - Willem de Zwijgerlaan	RIVM		PM_{10}	210	Valkenburg
545	S	Amsterdam - A10 west	RIVM		PM_{10}	240	Schiphol
136	S	Heerlen - Looierstraat	RIVM	NO_2	PM_{10}	380	Maastricht
236	S	Eindhoven - Genovevalaan	RIVM	NO_2	PM_{10}	370	Eindhoven
237	S	Eindhoven - Noordbrabantlaan	RIVM	NO_2	PM_{10}	370	Eindhoven
433	S	Vlaardingen - Floreslaan	RIVM	NO_2	PM_{10}	344	Rotterdam
445	S	Den Haag - Amsterdamse Veerkade	RIVM	NO_2	PM_{10}	210	Valkenburg
448	S	Rotterdam - Bentinckplein	RIVM	NO_2	PM_{10}	344	Rotterdam
537	S	Haarlem - Amsterdamsevaart	RIVM	NO_2	PM_{10}	240	Schiphol
544	S	Amsterdam - Prins Bernhardplein	RIVM	NO_2	PM_{10}	240	Schiphol
636	S	Utrecht - Kardinaal De Jongweg	RIVM	NO_2	PM_{10}	260	De Bilt
639	S	Utrecht - Constant Erzeijstraat	RIVM	NO_2	PM_{10}	260	De Bilt
641	S	Breukelen - Snelweg	RIVM	NO_2	PM_{10}	260	De Bilt
741	S	Nijmegen - Graafseweg	RIVM	NO_2	PM_{10}	375	Volkel
937	S	Groningen - Europaweg	RIVM	NO_2	PM_{10}	280	Eelde
243	n.d.	De Rips - Blaarpeelweg	RIVM		PM_{10}	375	Volkel

St.nr.	Type	Name	Network	Components		Meteo station	
244	n.d.	De Rips-Klotterpeellaan	RIVM		PM_{10}	375	Volkel
245	n.d.	Moerdijk-Julianastraat	RIVM	NO_2	PM_{10}	350	Gilze-Rijen
246	n.d.	Fijnaart-Zwingelspaansedijk	RIVM	NO_2	PM_{10}	340	Woensdrecht
312	n.d.	Axel - Zaaidijk	RIVM		PM_{10}	319	Westdorpe
319	n.d.	Nieuwdorp-Coudorp	RIVM		PM_{10}	319	Westdorpe
432	n.d.	Hoek van Holland-Berghaven	RIVM		PM_{10}	330	H v Holland
547	n.d.	Hilversum - J. Gerardtsweg	RIVM	NO_2	PM_{10}	260	De Bilt
548	n.d.	Bussum - Ceintuurbaan	RIVM	NO_2	PM_{10}	260	De Bilt
549	n.d.	Laren - Jagerspad	RIVM	NO_2	PM_{10}	260	De Bilt
728	n.d.	Apeldoorn - Stationstraat	RIVM		PM_{10}	275	Deelen
743	n.d.	Kootwijkerbroek - Drieenhuizerweg	RIVM		PM_{10}	275	Deelen
744	n.d.	Barneveld - Scherpenzeelseweg	RIVM		PM_{10}	275	Deelen
556	R	PNH, De Rijp	GGD		PM_{10}	249	Berkhout
565	R	PNH, Oude Meer	GGD	NO_2	PM_{10}	240	Schiphol
703	R	HAMS, Amsterdam-Spaarnwoude	GGD	NO_2	PM_{10}	240	Schiphol
3	UB	GGD A'dam, Nieuwendammerdijk	GGD	NO_2		240	Schiphol
14	UB	Vondelpark	GGD	NO_2	PM_{10}	240	Schiphol
16	UB	GGD Amsterdam,Westerpark	GGD		PM_{10}	240	Schiphol
19	UB	GGD Amsterdam, Oude Schans	GGD	NO_2		240	Schiphol
21	UB	GGD Amsterdam, Kantershof	GGD	NO_2		240	Schiphol
22	UB	GGD A'dam, Sportpark Ook Meer	GGD	NO_2		240	Schiphol
701	UB	ZNSTD, Zaandam	GGD	NO_2	PM_{10}	240	Schiphol
2	S	GGD Amsterdam,Haarlemmerweg	GGD	NO_2		240	Schiphol
7	S	GGD Amsterdam,Einsteinweg	GGD	NO_2	PM_{10}	240	Schiphol
12	S	GGD Amsterdam,Van Diemenstraat	GGD	NO_2	PM_{10}	240	Schiphol
17	S	GGD Amsterdam,Stadhouderskade	GGD	NO_2	PM_{10}	240	Schiphol
20	S	GGD Amsterdam,Jan van Galenstraat	GGD	NO_2		240	Schiphol
704	I	HAMS Hoogtij	GGD	NO_2	PM_{10}	240	Schiphol
551	I	PNH, IJmuiden	GGD	NO_2	PM_{10}	240	Schiphol
553	I	PNH, Wijk aan Zee	GGD	NO_2	PM_{10}	240	Schiphol
546	I	Zaanstad-Hemkade	GGD	NO_2	PM_{10}	240	Schiphol
572	I	PNH, Staalstraat	GGD		PM_{10}	240	Schiphol
573	I	PNH, Reijndersweg	GGD		PM_{10}	240	Schiphol
570	n.d.	PNH, Beverwijk-West	GGD		PM_{10}	240	Schiphol
564	n.d.	PNH, Hoofddorp	GGD	NO_2	PM_{10}	240	Schiphol
561	n.d.	PNH, Badhoevedorp	GGD	NO_2	PM_{10}	240	Schiphol
494	UB	DCMR,Schiedam-Alphons Ariensstr	DCMR	NO_2	PM_{10}	344	Rotterdam
485	UB	DCMR, Hoogvliet-Leemkuil	DCMR	NO_2	PM_{10}	344	Rotterdam
495	UB	DCMR, Maassluis-Kwartellaan	DCMR	NO_2	PM_{10}	330	H v Holland
488	UB	DCMR, Zwartewaalstraat	DCMR	NO_2	PM_{10}	344	Rotterdam
491	S	DCMR, Overschie-Oostsidelinge	DCMR	NO_2	PM_{10}	344	Rotterdam
489	S	DCMR, Ridderkerk-Hogeweg	DCMR	NO_2	PM_{10}	344	Rotterdam
493	S	DCMR, Statenweg-Statenweg	DCMR	NO_2	PM_{10}	344	Rotterdam
483	S	DCMR, Botlek (A15)-Botlektunnel	DCMR	NO_2		344	Rotterdam
487	S	DCMR, Pleinweg-Pleinweg	DCMR	NO_2	PM_{10}	344	Rotterdam
490	S	DCMR, Maasboulevard	DCMR	NO_2	PM_{10}	344	Rotterdam
486	S	DCMR, Pernis-Soetemanweg	DCMR	NO_2		344	Rotterdam
496	I	DCMR, Berghaven	DCMR	NO_2	PM_{10}	330	H v Holland
482	I	DCMR, Markweg	DCMR		PM_{10}	330	H v Holland
999	R	Ossendrecht	N Brabant	NO_2		999	Ossendrecht
1004	S	Maastricht A2	Limburg	NO_2	PM_{10}	380	Maastricht
1005	S	Roermond	Limburg	NO_2		377	Ell
1001	I	Buggenum	Limburg	NO_2		377	Ell
1002	I	Geleen Vouershof	Limburg	NO_2		380	Maastricht
1003	I	Geleen Asterstraat	Limburg	NO_2	PM_{10}	380	Maastricht

3 Study of the micro and macro status of the stations

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, ozone and particulate matter) and the scope of the measurement strategy, such as:

- traffic related
- urban located
- protection of vegetation
- point sources or diffuse sources

The micro and macro status of the LML stations have been studied earlier (Nguyen et al., 2009). Since this study the following changes have taken place at some LML monitoring stations or their surrounding:

- The highway A2 (monitoring station 641 in Breukelen) was broadened from two times three to two times five lanes. The broadening was performed in the direction away from the station. The work took place in 2009 till mid-2010.
- Monitoring station 445 (Den Haag-Amsterdamse Veerkade) has been replaced. The new station (started up in June 2009) is located at a small distance from the old location, between the road and the bike lane. Compared to the old location (in the middle of the road) the new location is more suitable for modelling with the CAR model.
- Mid November 2010 measurements at the monitoring station 441 (Dordrecht-Frisostraat, an Urban Background station) were stopped. The new monitoring station (station 442) which has data from 8 December 2010, is located a few kilometres away from the old station.

The micro and macro status of the monitoring stations of GGD Amsterdam and DCMR are investigated by these institutes. Relevant observations are given briefly in the overview Table 2 in chapter 7. A more detailed description of monitoring network of the GGD Amsterdam can be found in de Jonge (2012).

4 Study of the representativeness by means of principal component analysis

4.1 Method

In this study the representativeness of the monitoring stations is studied by means of Principal component analysis (PCA). This method was also used in earlier study and is a well-known data visualization/data reduction tool that is often applied in analyses of large data sets. For example the data set of hourly data of 40 stations 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 cannot be visualized; to this end, multivariate data visualization tools have been developed. 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-2 vs. PC-1, 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. The results of the first three principle components were studied. In general the third component was not very informative and only the first two are shown in this report.

The analysis tool used in this study is the PLS Toolbox of Eigenvector Research Incorporated for use with MATLAB® (Wise et al., 2006).

4.2 Data sets

4.2.1 Measurement data used in this study

Two analyses were performed in this study:
In an extensive analysis, data of all stations in five monitoring networks (monitoring network of RIVM, GGD Amsterdam, DCMR, province of Limburg and province of Noord-Brabant), including stations without classification, were used. The analysis was performed with nitrogen dioxide (NO_2) and particulate matter (PM_{10}) hourly concentrations. The results of this analysis are shown in chapter 5.

A second analysis was performed with hourly concentrations of nitrogen monoxide (NO), nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matter (PM_{10}), ozone (O_3), ammonia (NH_3) and sulphur dioxide (SO_2) using a smaller data set. Only data of RIVM, GGD Amsterdam and DCMR were used and stations without classifications were not included. The results of this analysis are shown in chapter 6.

4.2.2 Types of data used in PCA analysis

In earlier study several data sets were used in the screening to find out the best strategy for the PCA analysis. Based on these results the PCA analysis in this

study was performed with diurnal variation data without autoscaling[1] . For each hour of the day, an average concentration over the whole year was calculated. For each component the data set of N stations is an N-by-24 matrix. To ensure that all relevant information is shown, both score plots of the PC-2 and PC-3 are shown.
Because SO_2 is a pollutant with a typical concentration pattern (comprising many peaks), this component has been studied using both diurnal variation and average concentration roses.
The average concentration roses were calculated as follows:

- First, for each monitoring station the closest weather station of the Royal Netherlands Meteorological Institute (KNMI) was selected.
- For each of 12 wind roses the average concentration over the whole year was calculated, taking into account the number of hours with wind from that wind rose. In Appendix 2 the calculation of average concentration roses is shown.

The data set of concentration roses is an N-by-12 matrix.

In addition to the analyses performed with individual components, we also analysed pollutants from traffic (concatenated matrix of NO and NO_2 and concatenated matrix of NO, 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.

[1] When autoscaling is applied the data of each variable will be subtracted with the mean and divided by its standard deviation

5 Screening results of NO_2 and PM_{10} measured in five monitoring networks

In this chapter the results of the analyses performed with NO_2 and PM_{10} concentrations measured in the monitoring networks of RIVM, GGD Amsterdam, DCMR, province of Limburg and province of Noord-Brabant are shown.

5.1 NO_2

Figures 1 and 2 show the results of the analysis performed with diurnal variation of NO_2 concentration. At some stations measurements were only performed in part of 2010:

- Due to reconstruction in Dordrecht station 441 (Dordrecht-Frisostraat) had to be removed. This station was operational until 15 November 2010. The new station (442, Dordrecht-Bamendaweg), which is located a few kilometres meters away from the old location, has obtained data since 8 December 2010. Due to limited data of station 442 the result is not representative for this station.
- Station 490 (DCMR, Maasboulevard) has data from 22 July 2010 and station 565 (province of Noord-Holland (PNH), Oude Meer) has data from 13 September 2010.

In Figure 1 the plots for the first two PCs for diurnal variation of NO_2 are shown. Stations with a high annual concentration have a higher PC-1 score while the PC-2 represents the pattern of diurnal variation.

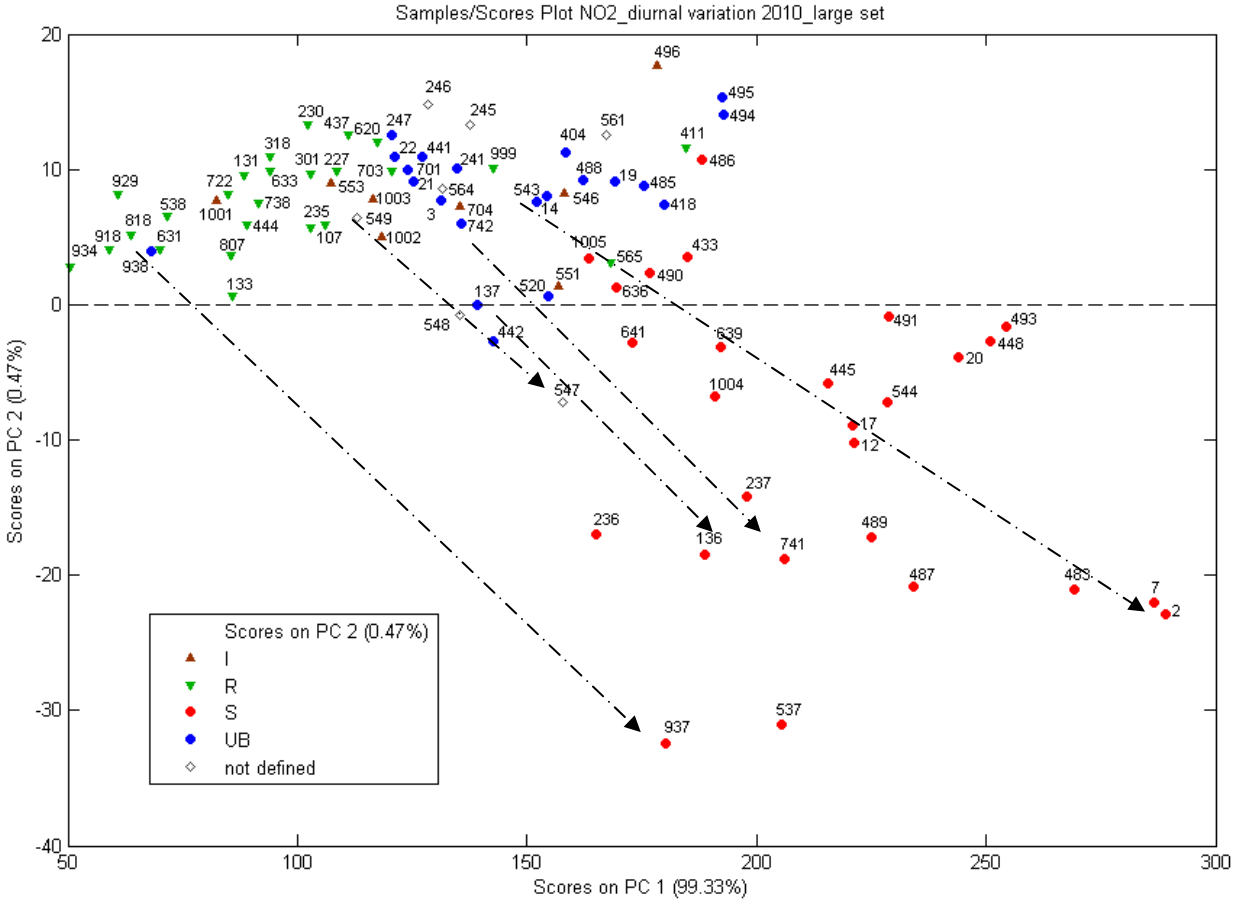


Figure 1 Score plot for the first two PCs for diurnal variation of NO_2
The plot shows distinct clusters of stations. The arrows show the shift from a background station to a traffic station.

The shift from a background station to a Street station in the same area depends on the contribution from traffic The shift shown in Figure 1 is as follows:

	Measured NO_2 shift in 2010, µg/m^3	Calculated NO_2 shift in 2010, µg/m^3 (data NSL2011)
937 versus 938	36-14=22	32.9-14.7=18.2
136 versus 137	38-28=10	38.9-25.5=13.4
741 versus 742	42-28=14	68.8-27.6=41.2 (see note 1)
2 versus 14	59-31=28	43.0-31.6=11.4
547 versus 549	32-23=9	n.d. (see note 2)

Notes:

1. The calculated NO_2 concentration at station 741 is much higher than the measured concentration. The reported traffic number at this location (NSL-monitoring data for 2010) seems not accurate (more than 12% of heavy traffic).
2. There is no calculation performed for station 547 because the location of this monitoring station (between two driving lanes, see Figure 2) is not suitable to be calculated by the 'standaard rekenmethode' (SRM).

Figure 2 Monitoring station 547 (Hilversum, Geradtsweg)

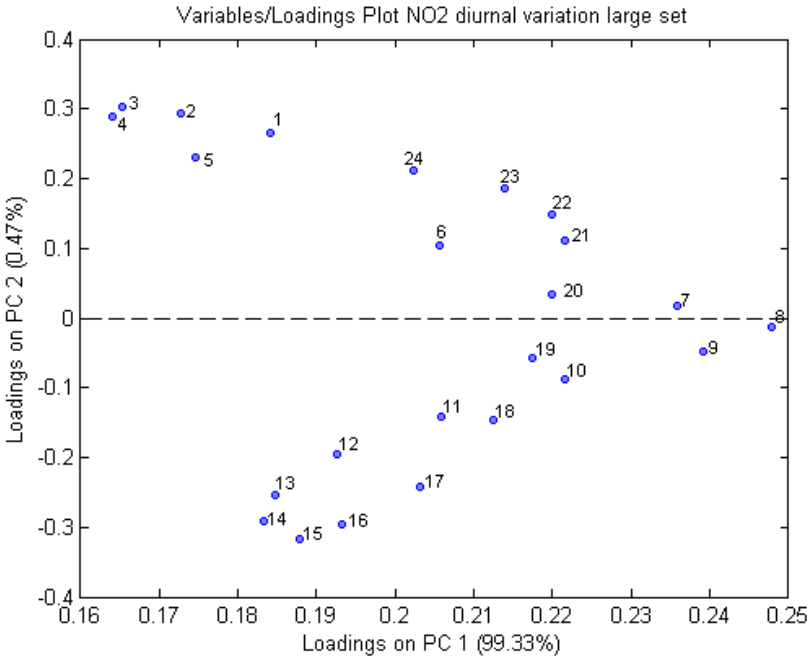


Figure 3 Loadings plots for diurnal variations of NO_2

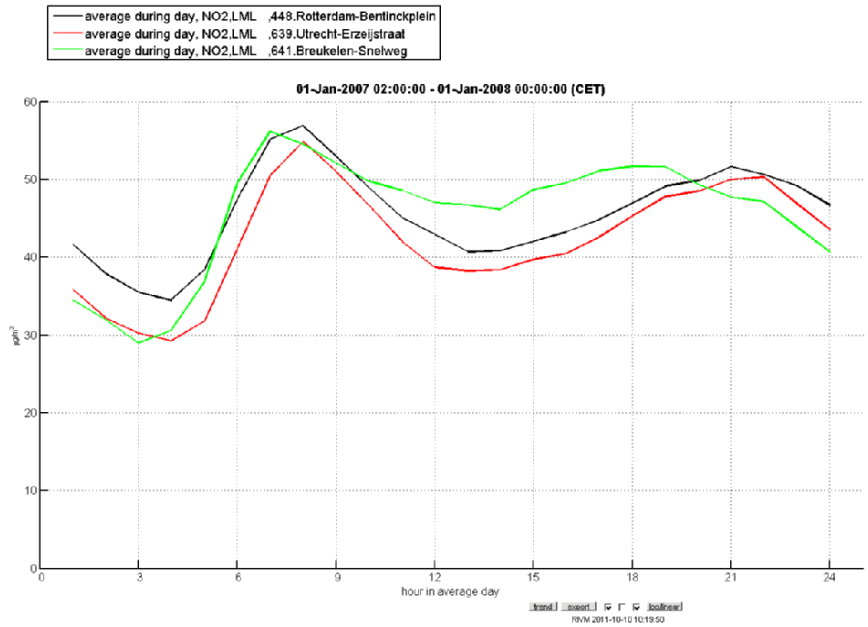
Results:

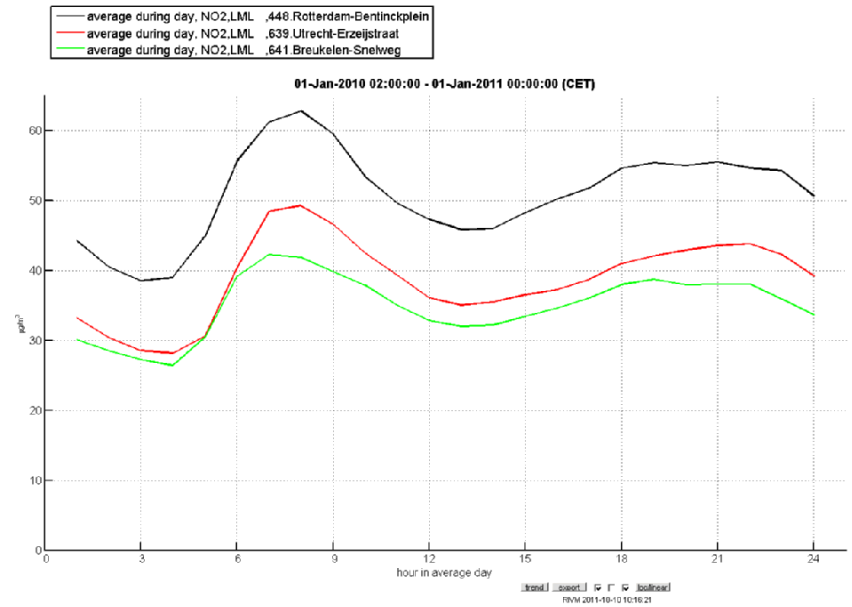
- There are clear clusters of different types of stations (R,UB,S).

- There is a good correspondence between measurements of GGD Amsterdam and RIVM at Overtoom/Vondelpark (station 14 versus station 543).
- There is a good correspondence between measurements of DCMR and RIVM at Bentinckplein/Statenweg (station 448 versus station 493).
- Two LML stations are outside the cluster of their classification type:
    - Urban background station 938 (Groningen–Nijensteinheerd) resembles a rural station. This is very likely due to its location in a suburban of a city, Groningen, in a clean environment.
    - Rural station 411 (Schipluiden-Groeneveld) resembles an urban environment. This is very much due to the density of green houses and other influences of the Rijnmond area.

  These differences were also found in earlier analysis using data in 2007 (Nguyen et al., 2009).
- Station 999 (Ossendrecht-Noord-Brabant) is classified as rural but the NO_2 concentration at this station is higher than at other rural stations (Figure 1). The wind rose at this station (Figure 3.1 in Appendix 3) shows high NO_2 concentration when the wind is south-easterly (160-200 degrees) suggesting contribution from Antwerp (Figure 3.2 in Appendix 3).
- Station 565 (PNH, Oude Meer) is a rural station but this station has higher concentrations than other rural stations (Figure 1), probably due to contribution from the highways A4 and A5 which are about 2 km away from this station. However, the result might be not representative because this station only has data from September and generally, NO_2 concentration in the winter is higher than in the summer.
- In this study the station 486 (DCMR,Pernis-Soetermanweg) is classified as a Street station. However, there is nearly no local traffic near this location. The traffic emission at this location comes from the highway A4 which is about 600 m west of this station. In Airbase this station is classified as 'Urban Industry'. According to the amount of traffic and the results, also in the Dutch classification system, the classification 'Industry' or 'Urban' might be more suitable for this station.
- Earlier study using data in 2007 showed clearly difference between the diurnal pattern of station 641 (Breukelen-Highway) and other Street stations. Data of 2010 do not show difference of station 641. Figure 4 shows that the diurnal variation at this station changed after the highway was broadened. Before the broadening traffic was limited by the capacity of this highway, even outside the rush hours. Consequently typical concentration peaks in the morning and in the afternoon at a Street station was less evident at station 641. After broadening of this highway the diurnal variation at this station shows the normal profile of a Street station. Measured concentrations at this station are decreased because the highway was broadened in the direction away from the station.
- The score plot in Figure 1 shows that stations 7 (GGD Amsterdam, Einsteinweg), 2 (GGD Amsterdam, Haarlemmerweg) and 483 (DCMR, Botlek(A15)-Botlektunnel) have higher concentrations than other Street stations. Combining with the loadings plot suggests that these three stations have comparable diurnal variation (comparable PC-2 score). This is confirmed by Figure 4.
- A few Street stations are located near a highway. These stations are: 641 (Breukelen-Highway), 7 (GGD Amsterdam, Einsteinweg (A10)), 483 (DCMR, Botlek(A15)-Botlektunnel), 491 (DCMR, Overschie-Oost

Sidelinge, A13), 489 (DCMR, Ridderkerk-Hogeweg (A15)), 1004 (Prov Limburg, Maastricht A2). This analysis does not show a separate cluster of Highway stations.





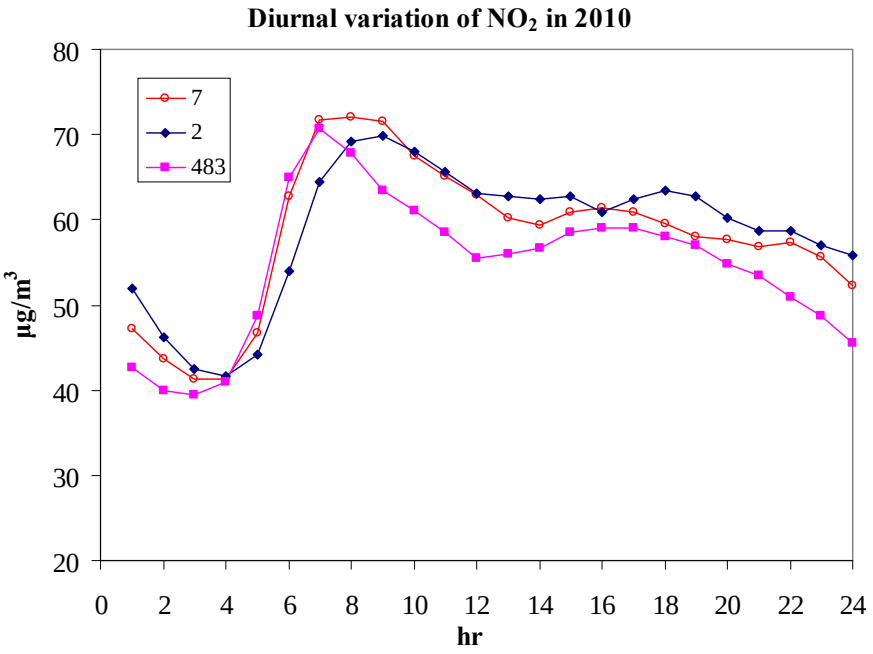


Figure 4: Diurnal variation at some typical stations
First two plots from above: Diurnal variation of NO_2 in 2007 and 2010 respectively at 448 (Rotterdam-Bentinckplein), 639 (Utrecht-Erzeijstraat) and 641 (Breukelen-Highway)
In 2007 there weres almost no concentration peaks at station 641 because this highway(A2) was always congested.
Bottom: Comparable diurnal variation at stations 2 (GGD Amsterdam, Haarlemmerweg), 7 (GGD Amsterdam, Einsteinweg) and 483 (DCMR, Botlek(A15)-Botlektunnel)

The loadings plot in Figure 3 shows that the NO_2 concentration in the morning is higher than the concentration during the night (morning hours have higher loadings on PC-1).

With respect to Industry-stations the following observations were found:

- Stations 1001 (Buggenum), 1002 (Geleen-Vouershof) and 1003 (Geleen-Asterstraat) are Industry-stations located in rural areas. Figure 1 does not show distinction between these stations and other rural stations indicating negligible influence of industry on the NO_2 concentration measured at these stations.
- Station 553 (PNH, Wijk aan Zee) is an Industry-station which is set up to measure the concentration in the industrial area of IJmond. Figure 1 does not show distinct diurnal differences between this station and rural stations. However the PCA analysis performed with wind roses (Figures 5 and 6) show indeed the contribution from south-south easterly direction on this station as can be expected from the location of this station (see also Appendix 4 for the location of Industry stations in the IJmond).
- Station 551 (PNH, IJmuiden) is located in an urban area. The PCA analysis (Figures 1 and 4) does not show distinction between this station and Urban Background stations. The effect of industry on the NO_2 concentration measured at this station seems not significant.
- Stations 546 (PNH, Hemkade) and (704 (PNH, Hoogtij) are located in an unpopulated area. Due to contribution from the ships on the North Sea

canal these stations have higher NO_2 concentration than rural stations (Figure 1). The PCA performed with wind roses (Figures 5 and 6) show the contribution from the south direction as expected from the location of these stations (northerly of the canal).

- Station 496 (DCMR, Berghaven) is an Industry station located near the harbour in Rotterdam. The PCA analysis does not show distinction between this station and other background stations in Rotterdam. This is due to the fact that background stations in Rotterdam are also influenced by port industrial area and the harbour as can be shown by the wind roses in Appendix 6.

The results of 'not defined' stations are:

- Station 549 (Laren-Jagerspad) resembles a rural station (Figure 1). This result is in agreement with the location of this station (Figure 5.1 in Appendix 5).
- Stations 547 (Hilversum-Gerardtsweg) and 548 (Bussum-Ceintuurbaan) both have contributions from traffic. According to the municipal data more than 10.000 vehicles drive over these streets per day. Figure 1 shows a small shift from the background station 549 to these two stations (shift toward the right bottom corner of the plot); the contribution of traffic at these stations is not very large. The PCA performed with wind roses does not show contribution from a specific direction. Station 547 (Hilversum-Geradtsweg) is located in an urban area; due to the contribution from traffic this station can be classified as 'street'. Station 548 (Bussum-Ceintuurbaan) is located in a more remote area (Figure 5.2, Appendix 5); despite the contribution from traffic, this station differs from normal Street stations. The classification 'Rural Traffic' in Air Base might be more suitable for this station.
- Stations 245 (Moerdijk-Julianastraat) and 246 (Fijnaart-Zwingelspaansedijk) are located in remote areas, but these stations have higher concentrations than other rural stations, probably due to the contribution from various highways at distances of 1-3 km and to the industrial area of Moerdijk (Figure 5.3 in Appendix 5).
- Stations 564 (PNH, Hoofddorp) and 561 (PNH, Badhoevedorp) are located in unpopulated areas but have higher NO_2 concentrations than rural stations (Figure 1). Station 564 has contributions from airplanes from the airport Schiphol and the highway A5 (at 1 km distance); station 561 has contributions from the highways A4 (at 1 km distance) and A9 (0.5 km).

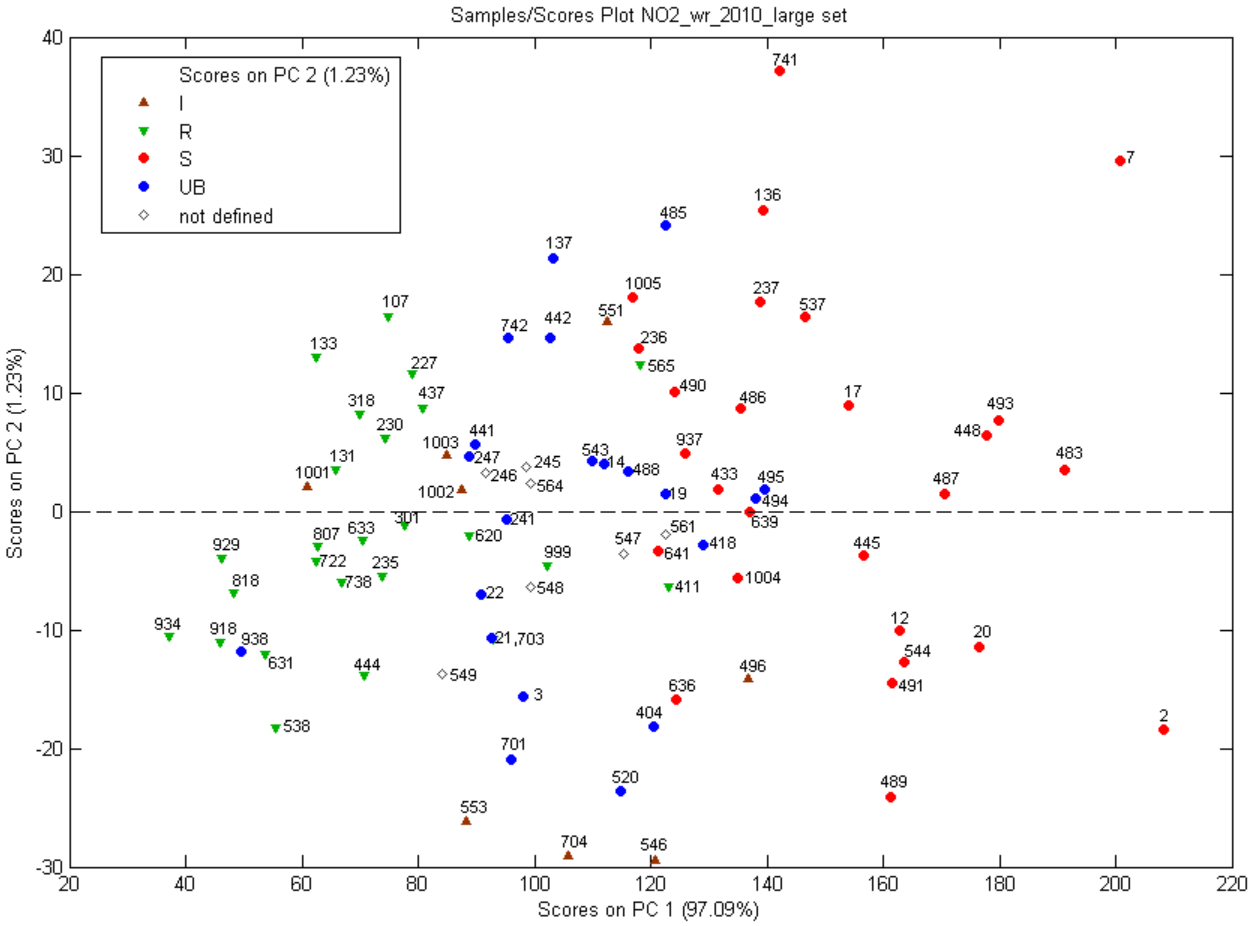


Figure 5 Score plot for the first two PCs for wind roses of NO_2.

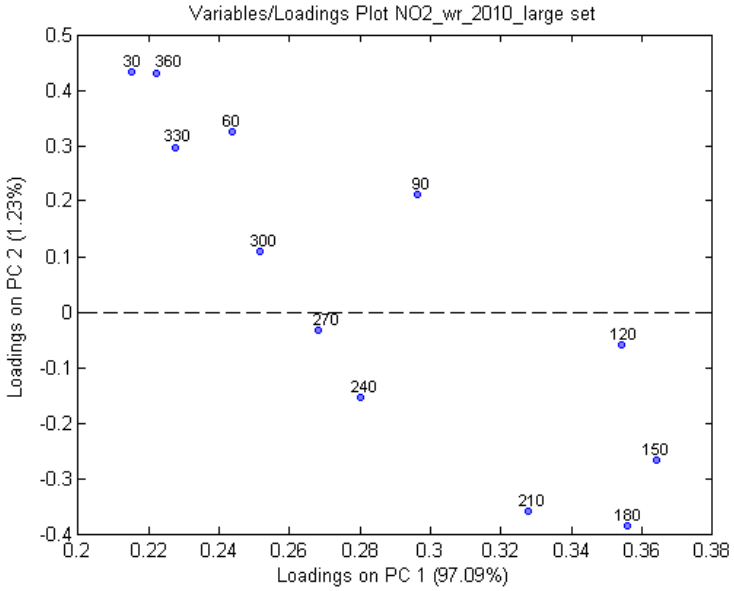


Figure 6 Loadings plots for wind roses of NO_2

5.2 PM_{10}

In Figures 8 and 9 the results of the PCA analysis performed with PM_{10} data are shown. At a few stations the PM_{10} measurements in 2010 were performed in fewer than six months: 442 (Dordrecht-Bamendaweg), 487 (DCMR, Pleinweg-Pleinweg), 488 (DCMR, Rotterdam-Zwartewaalstraat), 490 (DCMR, Maasboulevard-Maasboulevard), 565 (PNH, Oude Meer), 572 (PNH, Staalstraat) and 573 (PNH, Reijndersweg); these stations were left out in this analysis.

The analysis using PM_{10} data does not show distinct clusters of street and Urban Background stations (Figure 7). This 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.

Results:

- There is a good correspondence between the yearly average concentration of PM_{10} measured at Berghaven by the RIVM and the yearly average concentration measured by DCMR (station 432 versus station 496): both stations have comparable PC-1 scores in Figure 7. However this figure shows a discrepancy between the diurnal variations (different PC-2 scores) as can be confirmed by Figure 11a. The difference is highest in the morning. The same phenomenon (same yearly average, different diurnal variations) was observed at Overtoom/Vondelpark (station 14 versus station 543). These differences might be caused by differences in the measurement methods. The LML–method is susceptible to relative humidity.
- The score plots show that PM_{10} concentration measured at station 230 (Biest Houtakker-Biestsestraat) is comparable to PM_{10} concentration measured at other stations in this area (236 and 237). In earlier analysis when data of 2007 were used, a distinction was found for station 230 (Nguyen et al., 2009). However in 2010 the difference between 230 (Biest Houtakker-Biestsestraat) and other stations in this area became much smaller (Appendix 7).
- The score plot of diurnal variation (Figures 7) shows high PC-2 scores of stations 319 (Nieudorp-Coudorp) en 482 (Markweg,Botlek). Combining with the loadings plot (Figure 8) suggests that the PM_{10} concentration at these stations is high at midday; this is indeed confirmed by the diurnal variation at these stations (Figure 9b). The PCA analysis of wind roses (Figures 10 and 11) does not show an extreme effect of the wind rose at these stations.
- The analysis of wind roses (Figure 10 and 11) shows that PM_{10} the concentration at station 553 (PNH, Wijk aan Zee) and at station 551 (PNH, IJmuiden) is attributed to the activity in IJmond (the PM_{10} concentration at station 553 is high when the wind is from the South and the concentration at station 551 is high when the wind is from the North).
- Figure 10 shows a cluster of five LML stations in Heerlen/Maastricht with high PC-2 scores. Combining with the loadings plot (Figure 11) suggests that the PM_{10} concentrations at these stations are high when the wind is north- easterly. This is indeed shown by the wind roses in Figure 12. Because these stations are located south-westerly of the Ruhr area, the contribution might come from the Ruhr area. Stations in the North Limburg and eastern part of Noord-Brabant are also project positive on

PC-2 although less pronounced. This might be due to another orientation to major sources for example in the Ruhr area. Note that such PCA observations are primarily suited to formulate hypotheses on sources. To prove the influence of sources one needs more deterministic models like OPS or LOTUS EUROS which is beyond the scope of this study.

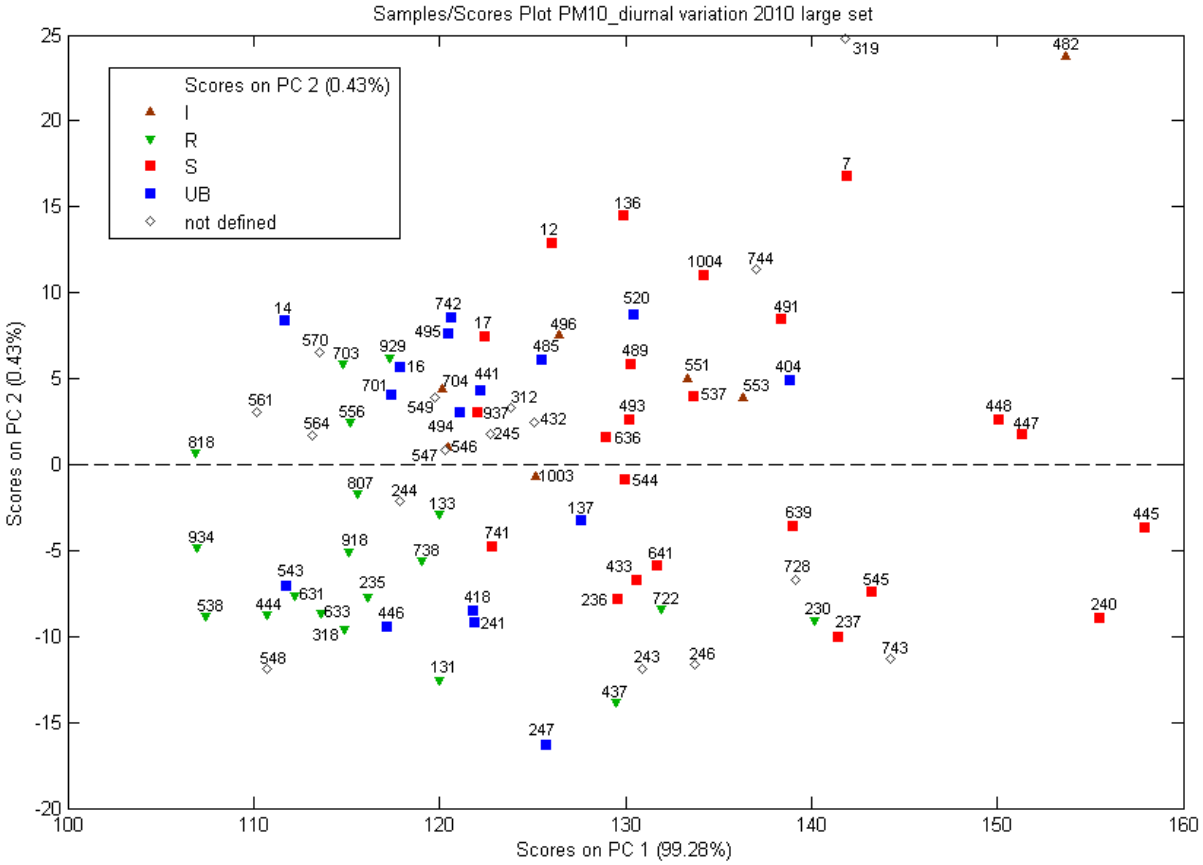


Figure 7 Score plot for the first two PCs for diurnal variation of PM_{10}
Note that 14 and 543 are different measurements at the same location (Overtoom/Vondelpark); 432 and 496 are different measurements at Berghaven. 448 and 493 are also measurements at the same location (Bentinckplein in Rotterdam), but the data are not comparable because of low data coverage in 2010 (75-80%) by both measurements.

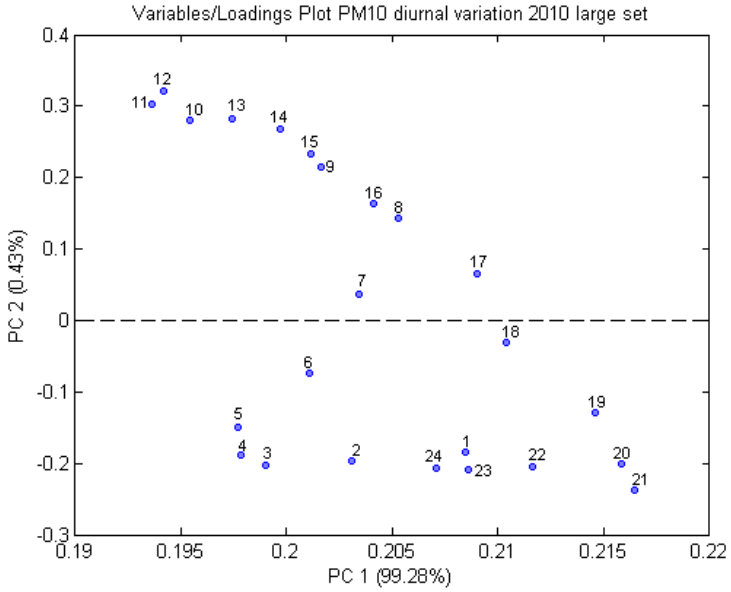
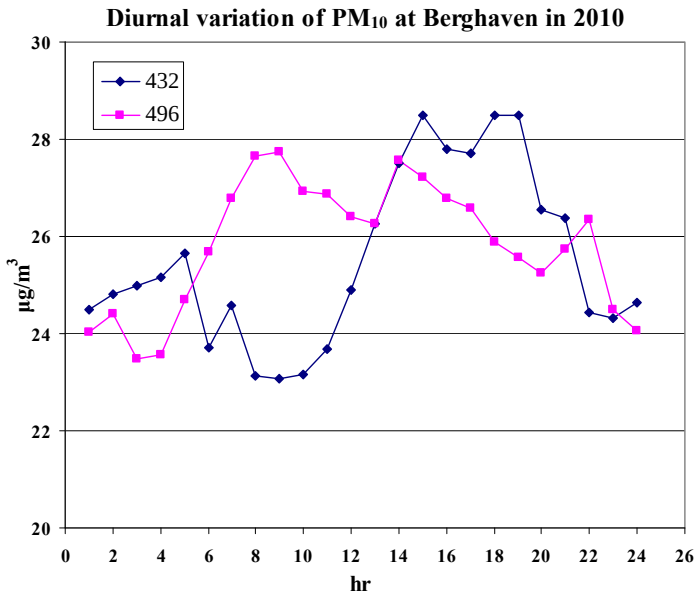
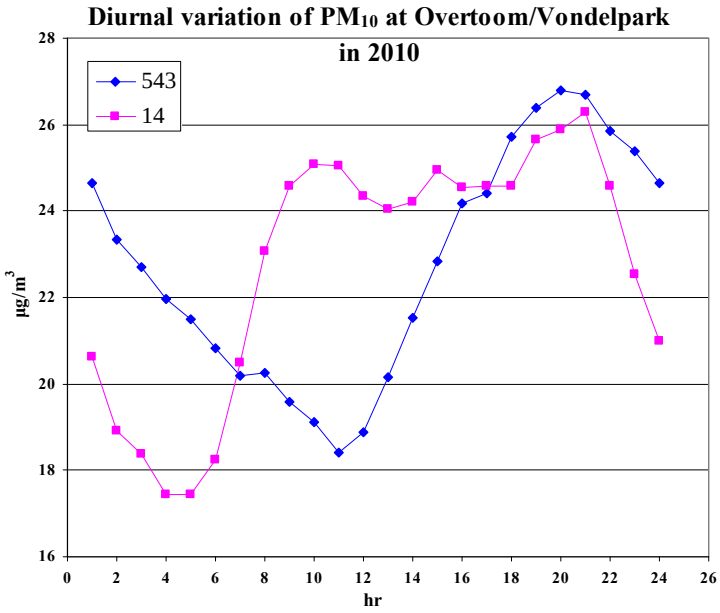


Figure 8 Loadings plots for diurnal variation of PM_{10}





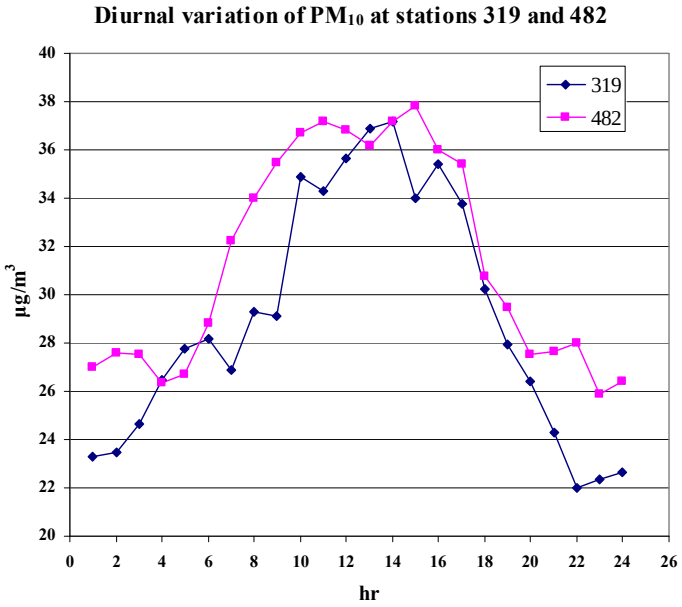


Figure 9 : Diurnal variation at some typical stations
Figure 9a (Top and middle) Differences in diurnal variation of PM_{10} measured at Berghaven and Overtoom
Figure 9b (Bottom) diurnal variation at 319 and 482 shows high PM_{10} concentrations at these stations at midday

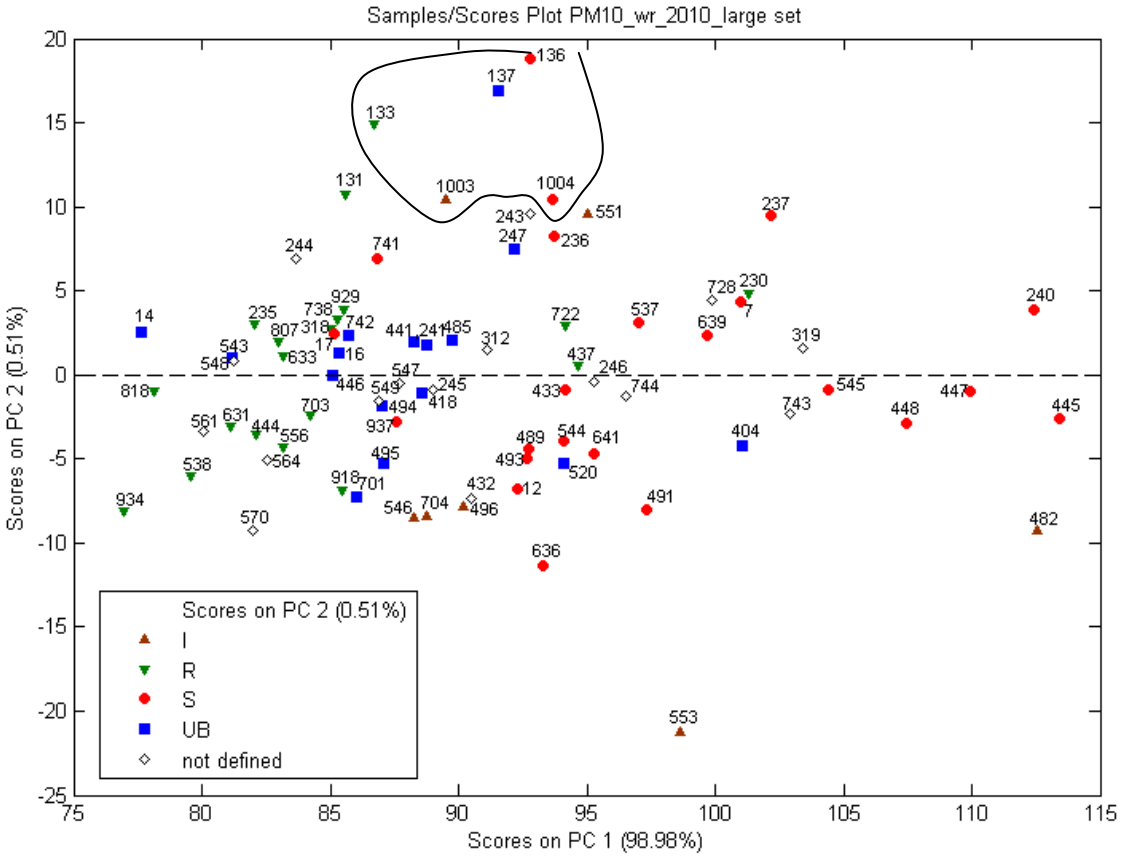


Figure 10 Score plot for the first two PCs for wind roses of PM_{10}

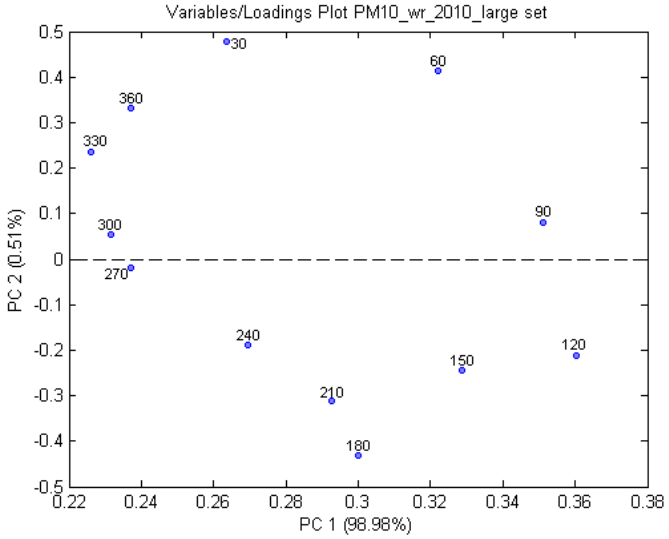


Figure 11 Loadings plots for wind roses of PM_{10}

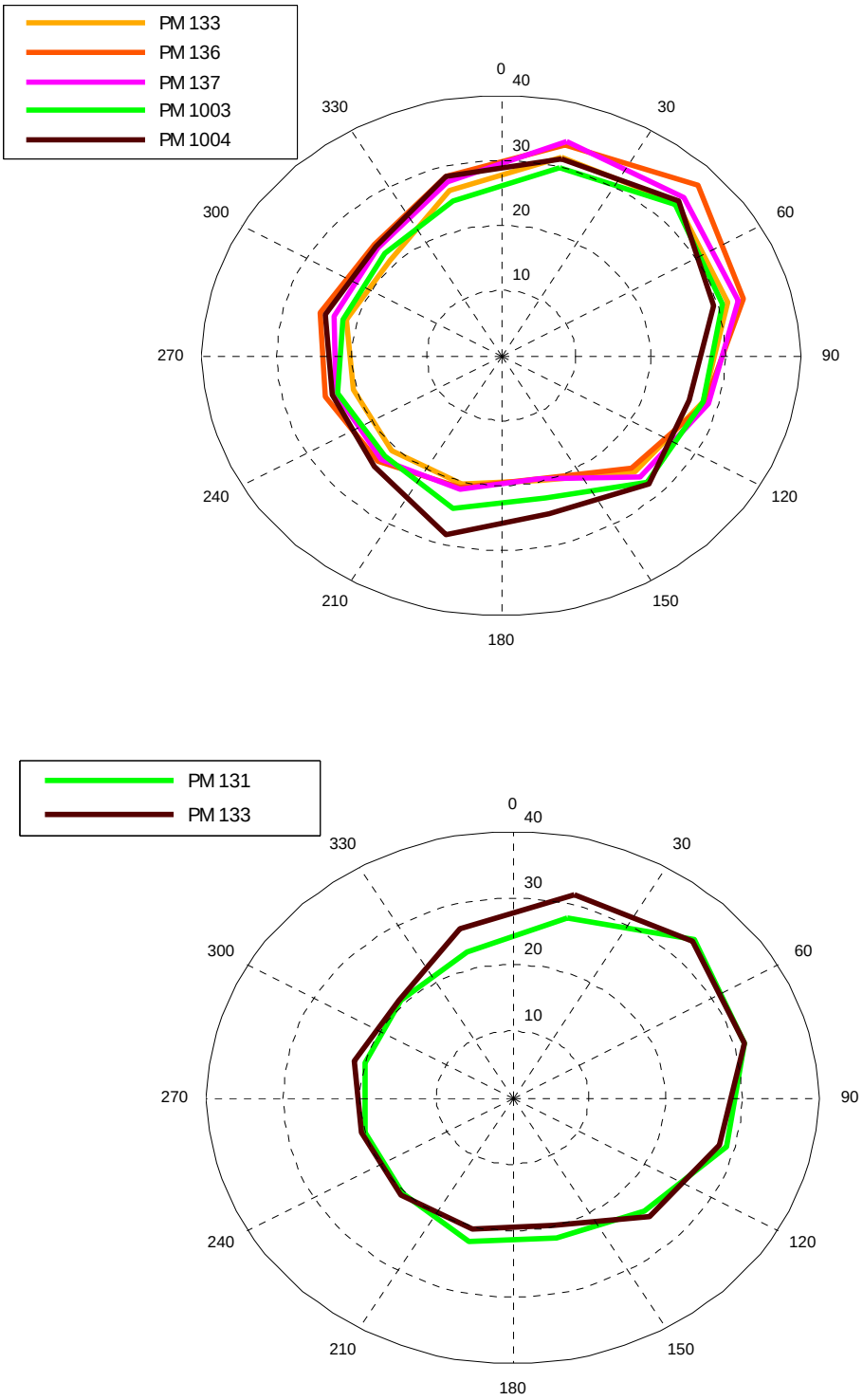


Figure 12 (Top) Wind roses of PM_{10} at five LML stations in and near Heerlen (Bottom) Wind rose at Vredepeel versus wind rose at station 133 (Wijnadsrade,Opfergelstraat), a rural station near Heerlen

6 Screenings results obtained with measurements in monitoring networks of RIVM, GGD Amsterdam and DCMR

These PCA analyses were performed with a smaller data set. Only stations of RIVM, GGD Amsterdam and DCMR were used and stations without classification ('not defined'-stations) were not included.
Apart from NO_2 and PM_{10} we also performed analyses with NO, CO, NH_3, SO_2 and with two combinations of traffic related components (NO&NO_2 and NO&NO_2&CO).

6.1 NO_2

Figure 13 shows the results of the analysis performed with diurnal variations of NO_2. These plots show distinct clusters stations and have the same pattern as the plots obtained with the large data set.

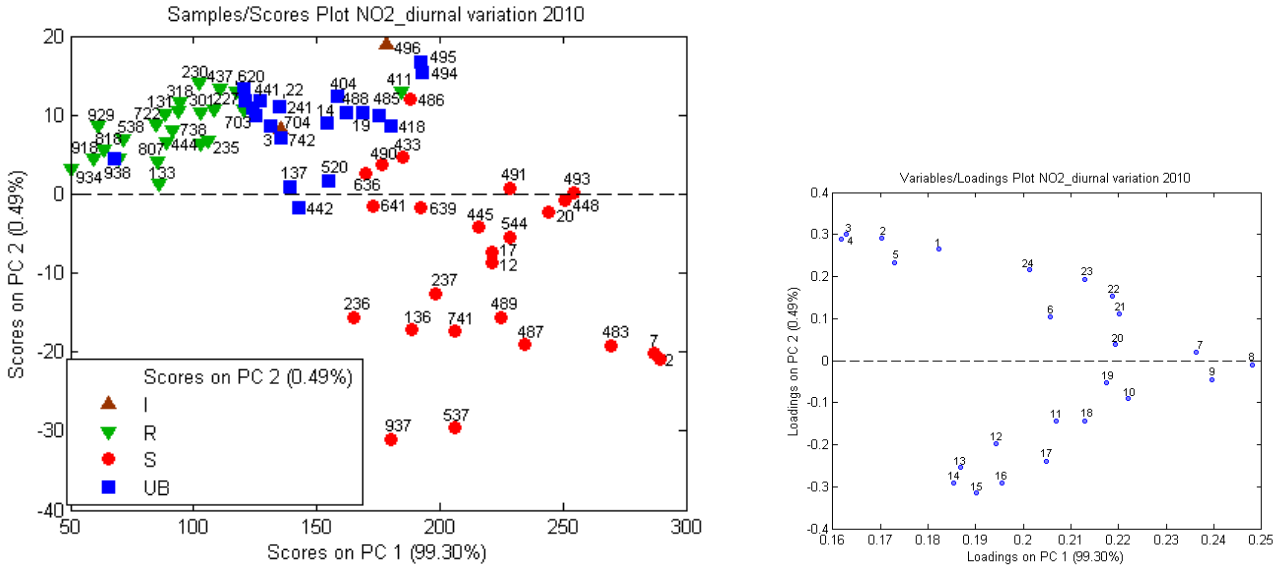


Figure 13 (Left) Score plot for the first two PCs for diurnal variation of NO_2(Right) Loadings plot
The score plot shows distinct clusters of stations.

6.2 NO

Also for NO there are clear distinct clusters of stations (Figure 14). The distinction between street and background stations is more pronounced for NO than for NO_2.

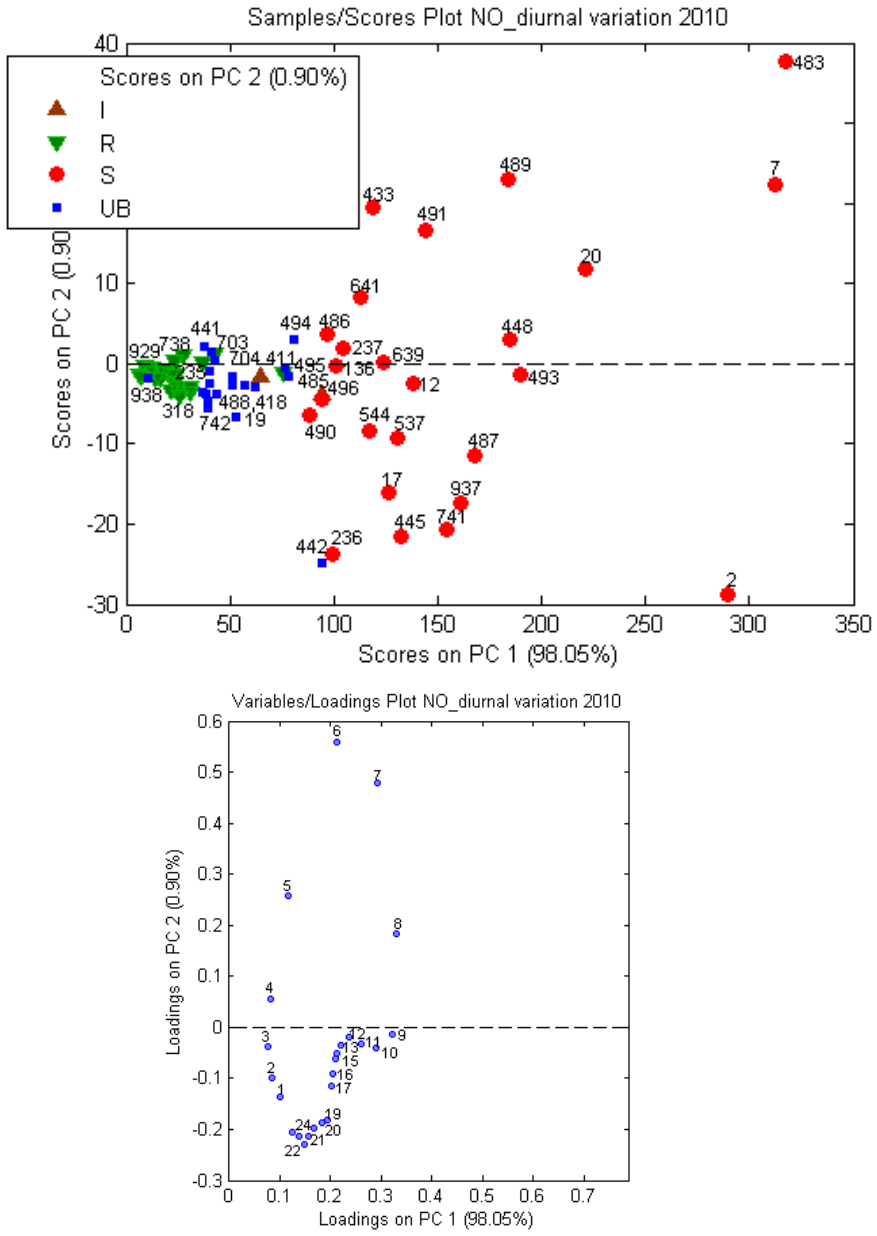


Figure 14 (Top) Score plot for the first two PCs for diurnal variation of NO (Bottom) Loadings plot
The score plot shows distinct clusters of stations. Note that station 442 (Dordrecht-Bamendaweg) has only data from December.

Results of PCA analysis performed with diurnal variation of NO:

- Like in the analysis with NO_2, distinctions of stations 938 (Groningen–Nijensteinheerd) and 411 (Schipluiden-Groeneveld) are also shown by the analysis of NO.
- The score plot (Figure 14) shows good correspondence between station 493 (DCMR, Statenweg) and station 448 (Rotterdam-Bentinckplein), but the correspondence in the NO_2 measurement (Figure 13) is slightly better as can be shown in Figure 15a).
- The score plot (Figure 14) shows that, compared to other Street stations, NO concentration at stations 2 (GGD Amsterdam, Haarlemmerweg), 7 (GGD Amsterdam, Einsteinweg (A10)) and 483 (DCMR, Botlek(A15), Botlektunnel) is substantially higher.
- Combining the score plot and the loadings plot in Figure 14 suggests that NO concentration at station 483 (DCMR, Botlek(A15), Botlektunnel) and station 7 (GGD Amsterdam, Einsteinweg (A10)) is relatively high in the morning (these stations have positive PC-2 score) while the concentration at station-2 (GGD Amsterdam, Haarlemmerweg) is relatively high in the evening and during the night (negative PC-2 score). Figure 15 indeed shows this pattern.

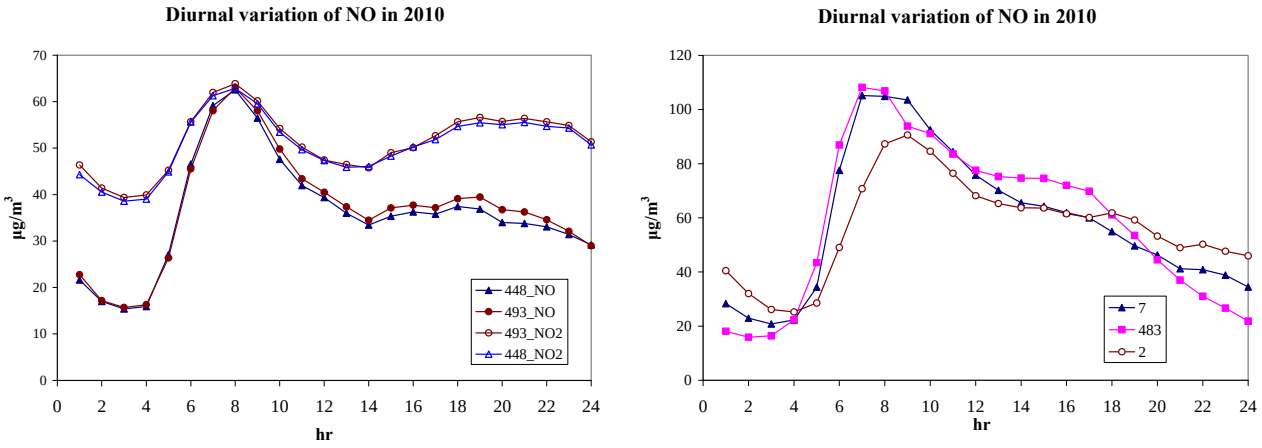


Figure 15
Figure 15a (Left) NO and NO_2 measurements at 448 (Rotterdam-Bentinckplein) and 493 (DCMR, Statenweg)
Figure 15b (Right) Diurnal variation of NO at station 7 (GGD Amsterdam, Einsteinweg (A10)), 483 (DCMR, Botlek(A15), Botlektunnel) and at station 2 (GGD Amsterdam, Haarlemmerweg)

6.3 PM_{10}

Figure 16 shows results of the analysis performed with diurnal variations of PM_{10}. Like in the analysis with a large data set there are no distinct clusters of street and Urban Background stations. The analysis with a small data set gives the same results as the analysis performed with the large data set

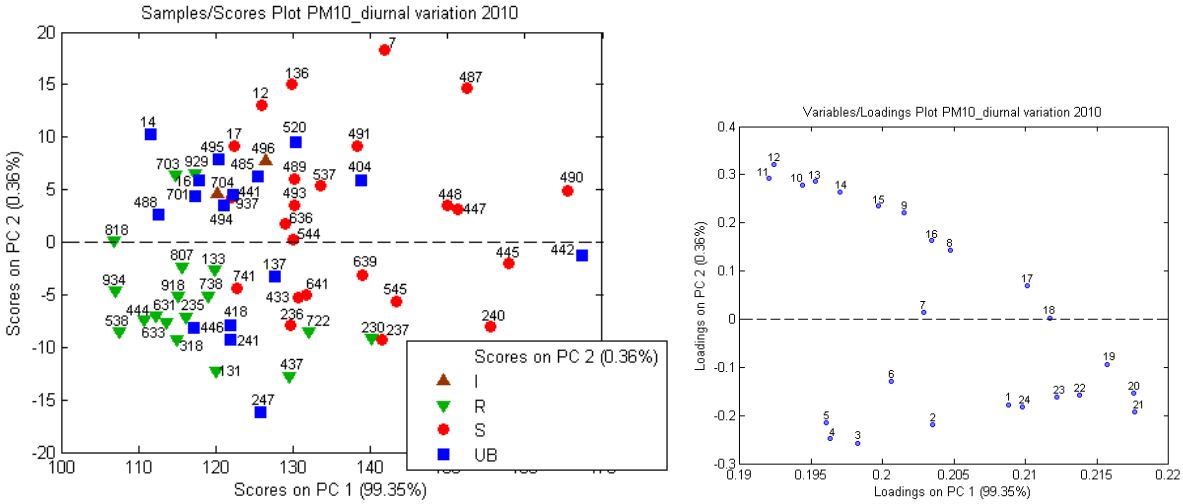


Figure 16 (Left) Score plot for the first two PCs for diurnal variation of PM_{10} (Right) Loadings plot
The score plot does not show distinct clusters of stations. Note that station 442 (Dordrecht-Bamendaweg) only has data from December 2010. Stations 487 (DCMR,Pleinweg-Pleinweg) and 488 (DCMR,Rotterdam-Zwartewaalstraat) have data from 1 September 2010; station 490 (DCMR,Maasboulevard-Maasboulevard) has data from 28 September 2010.

6.4 CO

The analysis with CO shows clear distinct clusters of rural, Urban Background and Street stations (Figure 17), however with some distinctions. Most remarkable observations are:

- This analysis also shows distinction of the Urban Background station 938 (Groningen-Nijensteinheerd), as already observed with NO and NO_2.
- The distinction of station 411 (Schipluiden-Groeneveld) is not observed with CO.
- Figure 17 shows distinction of station 641 (Breukelen-Highway (A2)) and 491 (DCMR, Overschie-Oost Sidelinge (A13)). Both these stations are located in remote area nearby a highway. Station 490 (DCMR, Maasboulevard-Maasboulevard) differs too but the results might be not representative because this station has only data from 20 July 2010.
- Combining the score plot and the loadings plot in Figure 17 suggests that average CO concentrations at stations 7 (GGD Amsterdam, Einsteinweg (A10)) and 236 (Eindhoven-Genovevalaan) are comparable but these stations have different diurnal variations. CO concentration at station 7 is high during the night while CO concentration at station 236 is high in the afternoon. Figure 18 confirms this pattern.

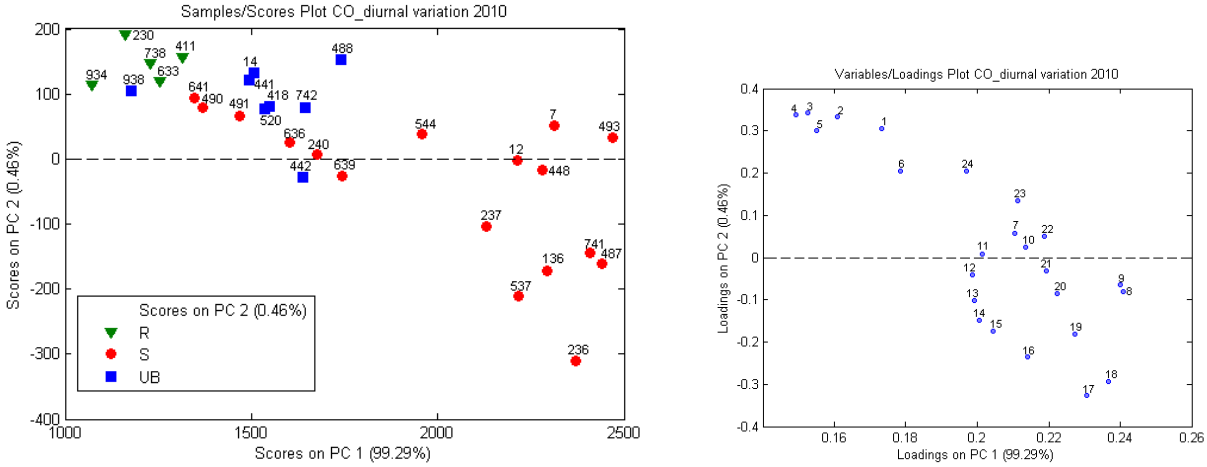


Figure 17 (Left) Score plot for the first two PCs for diurnal variation of CO (Right) Loadings plot
The score plot shows distinct clusters of stations. Note that station 442 (Dordrecht-Bamendaweg) has only data from December 2010 and station 490 (DCMR,Maasboulevard-Maasboulevard) has only data from 20 July 2010.

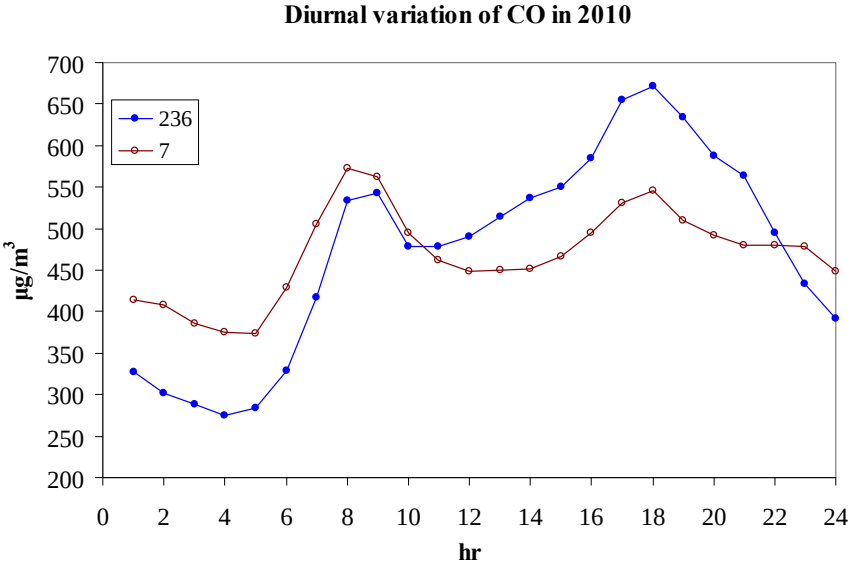


Figure 18 Diurnal variation of CO at some typical stations

6.5 O_3

The analysis of O_3 shows distinct clusters of rural and Street stations while Urban Background stations are mixed (Figure 19).
For O_3 measurements, stations 133 (Wijnandsrade-Opfergeltstraat), 411 (Schipluiden-Groeneveld), 441 (Dordrecht-Frisostraat), 520 (Amsterdam-Florapark) and 938 (Groningen–Nijensteinheerd) are classified as Suburban station. Suburban stations are located in the suburbs of major cities. These stations are important because many inhabitants can be exposed to O_3 concentrations that are higher than those found in city centres. Unfortunately

three of these stations (411, 441 and 520) had quite low data coverage in 2010, ranging from 58 to 81%.

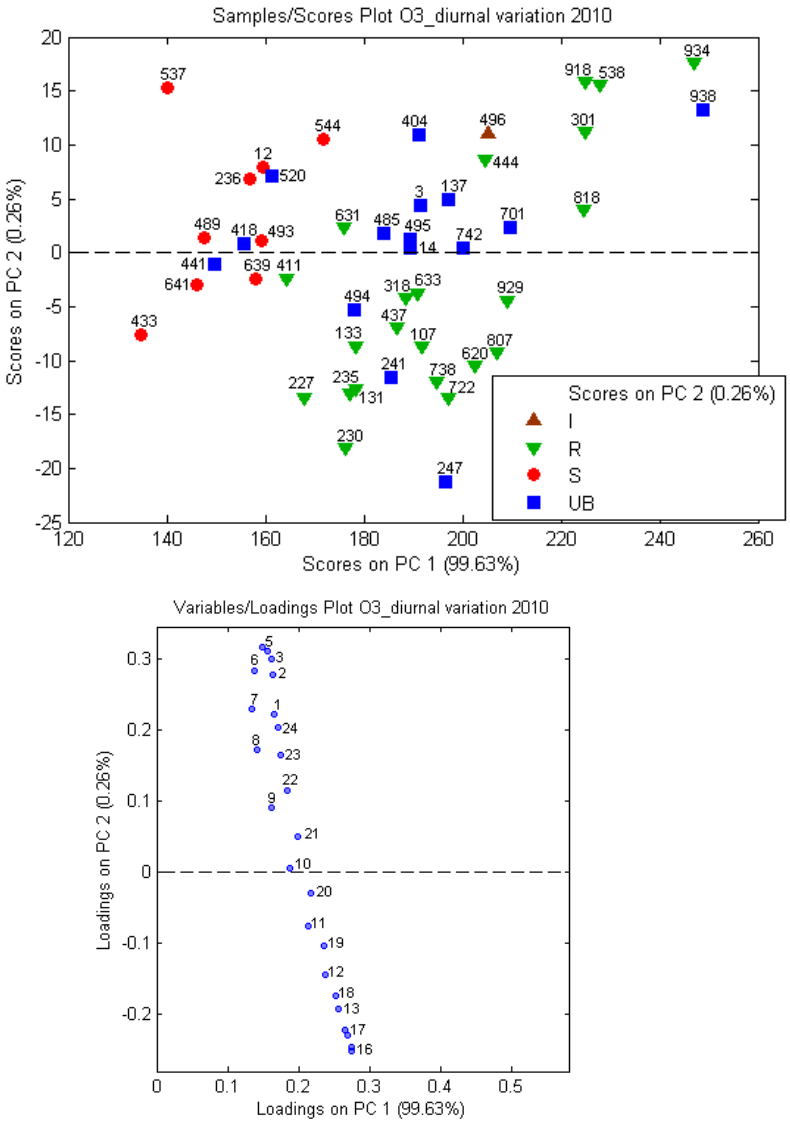


Figure 19 (Top) Score plot for the first two PCs for diurnal variation of O_3 (Bottom) Loadings plot
Note that station 247(Veldhoven-Europalaan) has data from 11 June 2010, station 631 (Biddinghuizen-Hoekwantweg) has data up to 2 October 2010

Results:

- There are clear clusters of rural and Street stations. Urban background stations are mixed.
- Urban Background station 938 (Groningen–Nijensteinheerd) resembles a rural station.
- Stations 441 (Dordrecht-Frisostraat) and 520 (Amsterdam-Florapark) are classified as Suburban station for O_3. The PCA analysis (Figure 19) shows that these stations do not resemble suburban stations. Despite of low data coverage in 2010, the conclusions are the same as in earlier

analyses (Nguyen et al.,2009). Based on the PCA analysis, station 404 (Den Haag-Rebecquestraat) and station 3 (GGD Amsterdam, Nieuwendammerdijk) seem to be appropriate stations to monitor suburban concentrations in these areas.

- The loadings plot in Figure 19 shows that stations with a negative PC-2 score have an O_3 peak in the afternoon (12:00-18:00). Stations with the most negative PC-2 score are all located in the south-eastern part of the Netherlands. Compared to stations 131 and 133 (south-eastern Netherlands), station 934 (located in the northern part of the Netherlands) has a higher annual concentration of O_3, but stations 131 and 230 have more peak concentrations (Figure 20)
- An earlier analysis performed with data in 2007(Nguyen et al.,2009) shows differences between station 137 (Heerlen-Deken Nicolayestraat) and other Urban Background stations (the concentration at 137 was substantially higher). This station is located close to a building. It was not clear whether the difference at station 137 was caused by its locations. Data in 2010 do not show any difference between stations 137 and other Urban Background stations (Figure 19). Figure 21 shows that the concentration at this station has decreased substantially between 2006 and 2009 while such a decrease did not occur at other stations in that area. The reason is not clear.

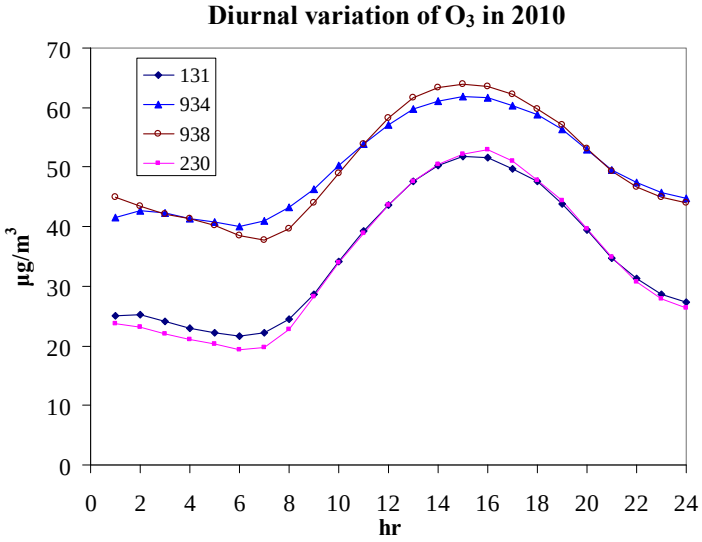


Figure 20 Diurnal variation of O_3 at 934 (Kollumerwaard,Rural), 938 (Groningen, Urban Background)in the north of the Nethelands and at 131 (Vredepeel,Rural) and 230 (Biest Houtakker,Rural) in the south-eastern part of the Netherlands Annual concentration of O_3 is lower in the south- eastern part of the Netherlands but there are more O_3 peaks.

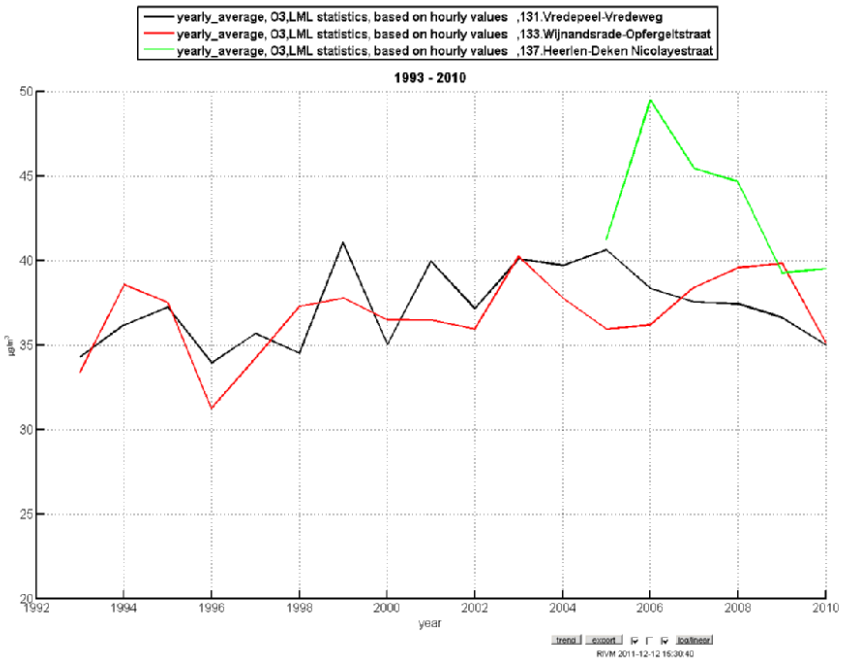


Figure 21 Annual concentration of O_3 at some typical stations in the south-eastern part of the Netherlands

6.6 SO_2

6.6.1 Diurnal variation

The PCA analysis of SO_2 does not show a distinct cluster of Street stations (Figure 22), which is in line with the fact that SO_2 is not a traffic-related pollutant. Stations with higher annual concentrations have a higher PC-1 score. These stations are all located in Rijnmond. Combining of the loadings plot and the score plot in Figure 22 suggests that stations with negative PC-2 have high concentrations of SO_2 during the day (10:00-19:00), while stations with a positive PC-2 score have high concentrations of SO_2 in the early morning and at night. This pattern of diurnal variation is indeed confirmed by Figure 23.

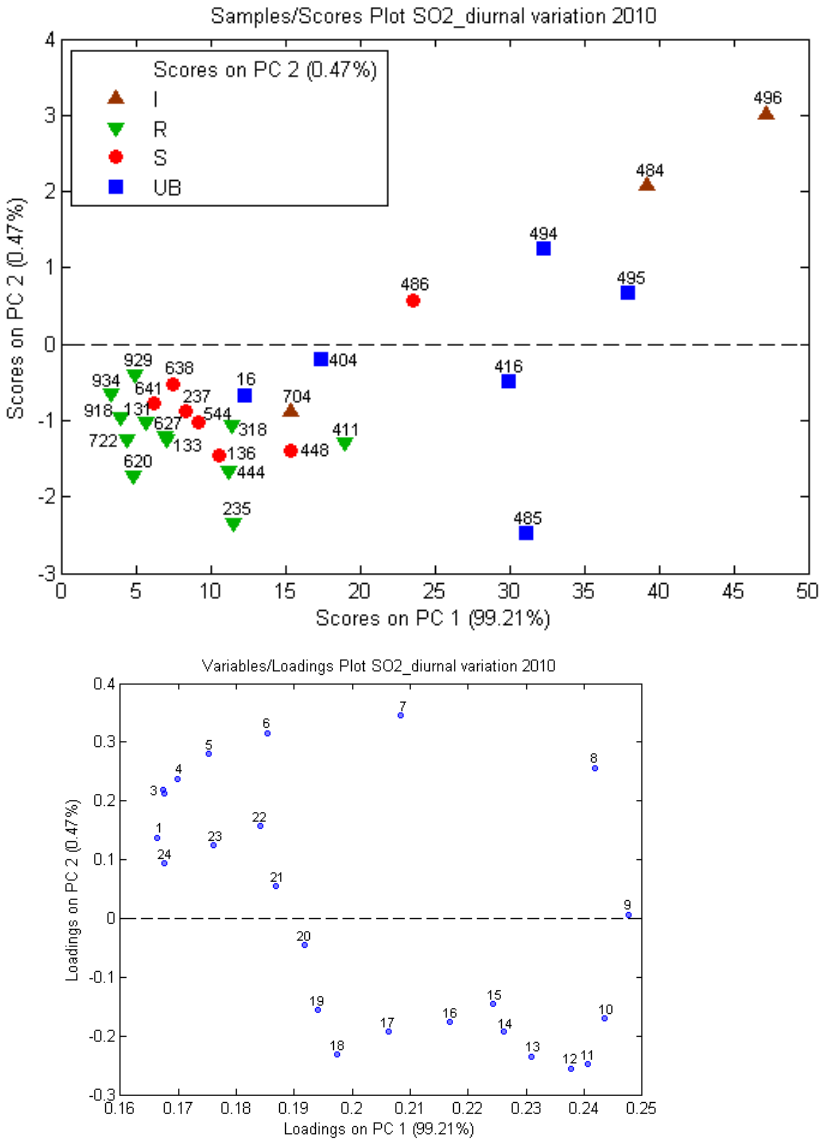


Figure 22(Top) Score plot for the first two PCs for diurnal variation of SO_2 (Bottom) Loadings plot.

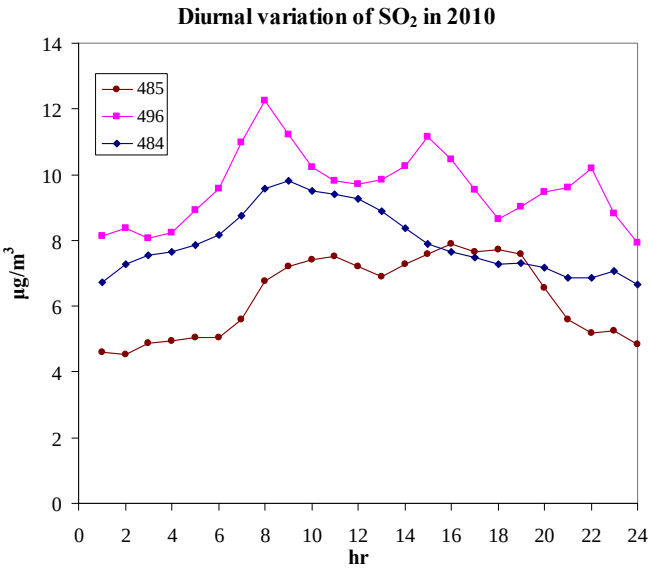


Figure 23 Diurnal variation of SO_2 at 485 (DCMR,Hoogvliet-Leemkuil), 496 (DCMR,Berghaven-Berghaven) and 484 (DCMR,Botlek-Oude Maasweg) SO_2 concentration at 485 is relatively high between 10:00 and 19:00.

6.6.2 *Wind roses analyses*

Figure 24 shows the PCA analysis of SO_2 wind roses. Combining of the loadings plot and the score plot in Figure 33 suggests that a station with positive PC-2 score, for example station 485 (DCMR,Hoogvliet-Leemkuil), has high SO_2 concentrations when the wind is northerly. Stations with negative PC-2 score, for example station 416 (Vlaardingen-Lyceumlaan) or station 496 (DCMR,Berghaven-Berghaven), have high SO_2 concentrations when the wind is southerly. Figure 25 indeed confirms these patterns which are in agreement with the location of these stations relatively to the harbour (Appendix 6).

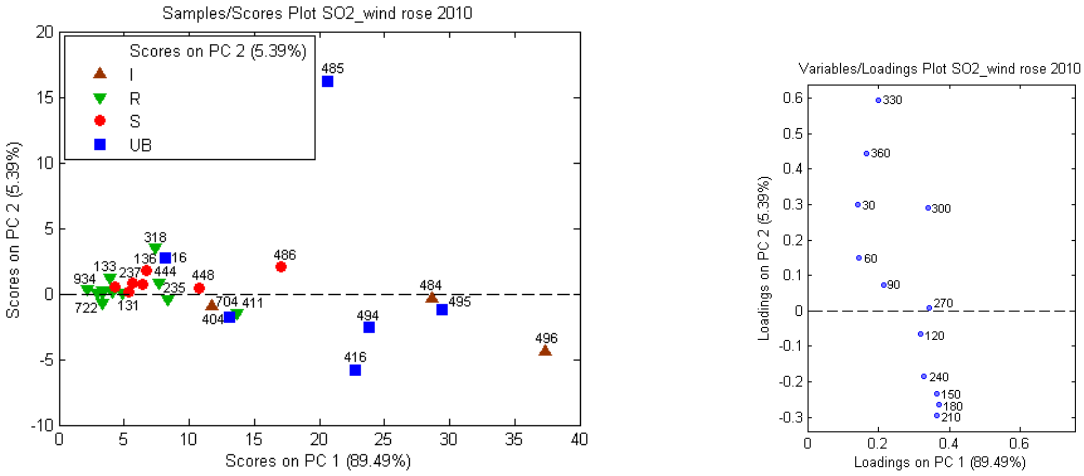


Figure 24 (Left) Score plot for the first two PCs for SO_2 wind roses (Right) Loadings plot

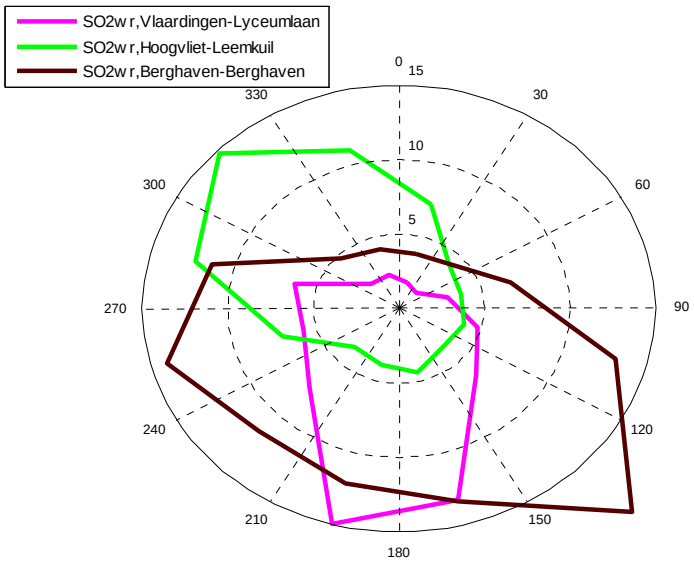


Figure 25 SO_2 wind rose of 416 (Vlaardingen-Lyceumlaan),485 (DCMR, Hoogvliet-Leemkuil) and 496 (DCMR,Berghaven-Berghaven)
SO_2 concentration at Hoogvliet is high when the wind is north westerly. At Vlaardingen-Lyceumlaan and Berghaven the SO_2 concentration is high when the wind is southerly.

6.7 Pollutants from traffic

6.7.1 Combination of NO_2 and NO

The combination of NO_2 and NO shows distinct clusters of stations with differences of stations 411 and 938 as already being observed in individual analyses of NO_2 and NO (Figure 26). The loadings plot shows NO_2 concentrations are higher than NO concentration (NO_2 has higher loadings on the PC-1 score). The score plot (Figure 26) shows clear difference between stations 2 (GGD Amsterdam, Haarlemmerweg), 7 (GGD Amsterdam, Einsteinweg) and 483 (DCMR, Botlek(A15), Botlektunnel) and other Street stations. These stations have much higher PC-2 scores. Because NO has a positive loading on the PC-2 score (Figure 26) we can conclude that the distinctions of stations 2, 7, and 483 are due to differences of the NO concentrations.

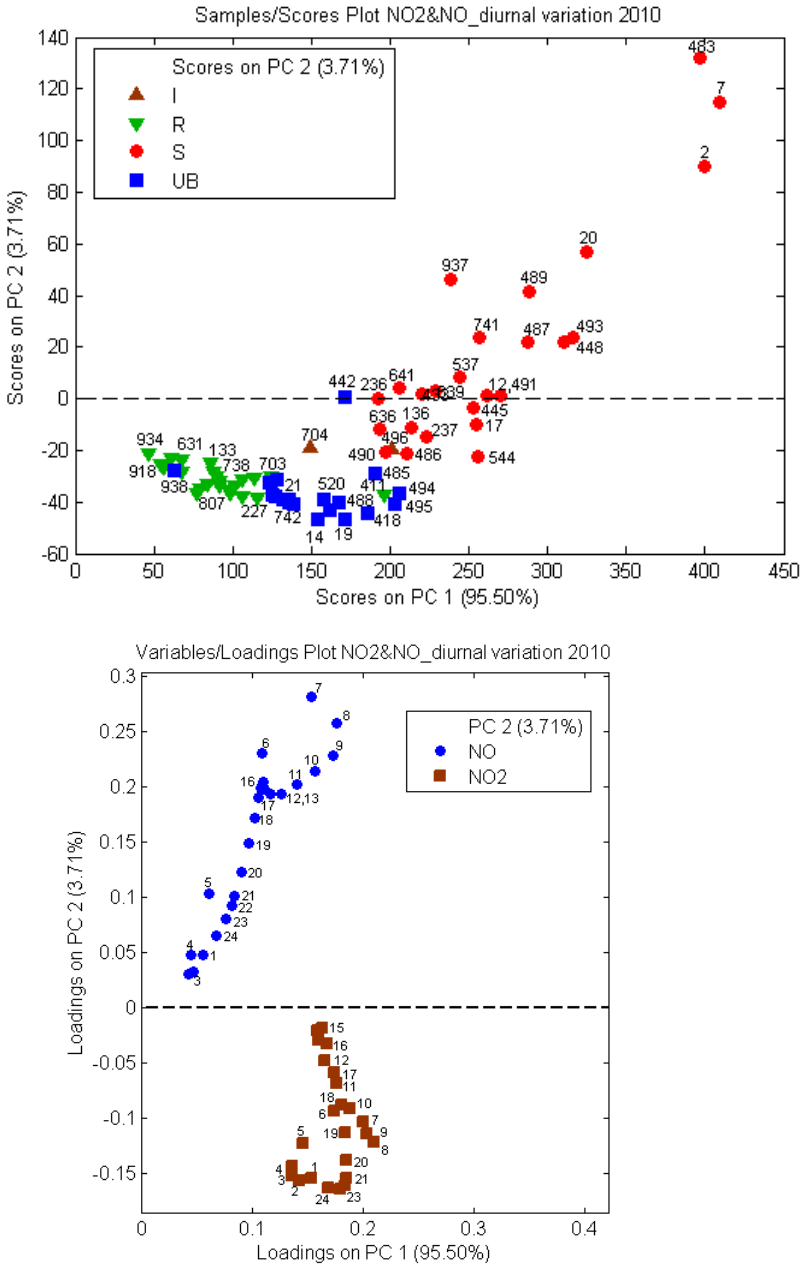


Figure 26 (Left) Score plot for the first two PCs for the combined diurnal variation of NO_2 and NO
(Right) Loadings plot
Note that station 442 (Dordrecht-Bamendaweg) only has data from December 2010; station 490 (DCMR, Maasboulevard-Maasboulevard) has data from 20 July 2010.

6.7.2 *Combination of NO, NO_2 and CO*

This analysis shows clear clusters of stations. Apart from the distinction of stations 411 and 938, this analysis shows obvious difference of station 7 (GGD Amsterdam, Einsteinweg). This station has much higher PC-2 score than other Street stations. Because the plot is very dominated by station 7, analysis was also performed without this station (Figure 28). From the loading plots in Figure 28 we can conclude that the NO_x emission at station 7 is relatively high

and the CO emission is relatively low. This is indeed shown by Figure 29. Figure 28 shows Street stations in Brabant have negative PC-2 score, indicating relatively more CO in this area. As an example, in Figure 29 the diurnal variations of CO and NO concentration measured at a Street station in Noord-Brabant, in Amsterdam and in Rijnmond are shown.

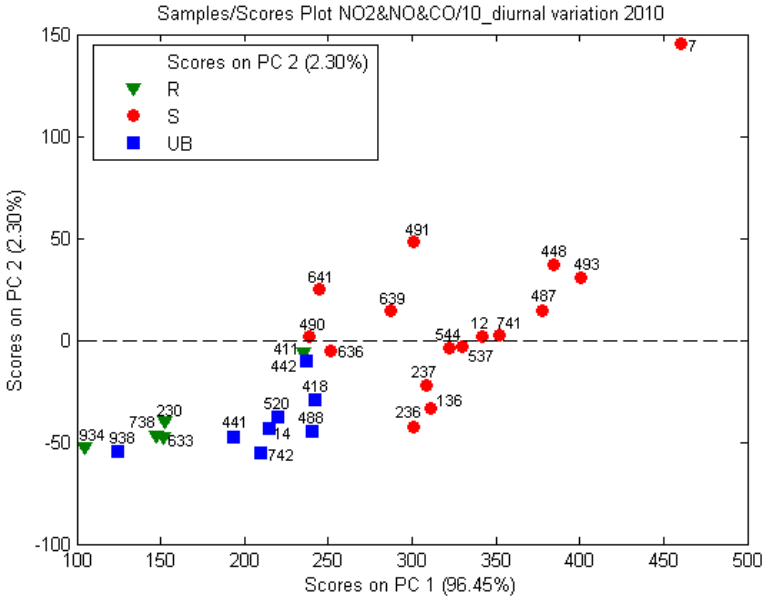


Figure 27 (Left) Score plot for the first two PCs for the combined diurnal variation of NO_2 , NO and CO
(Right) Loadings plot

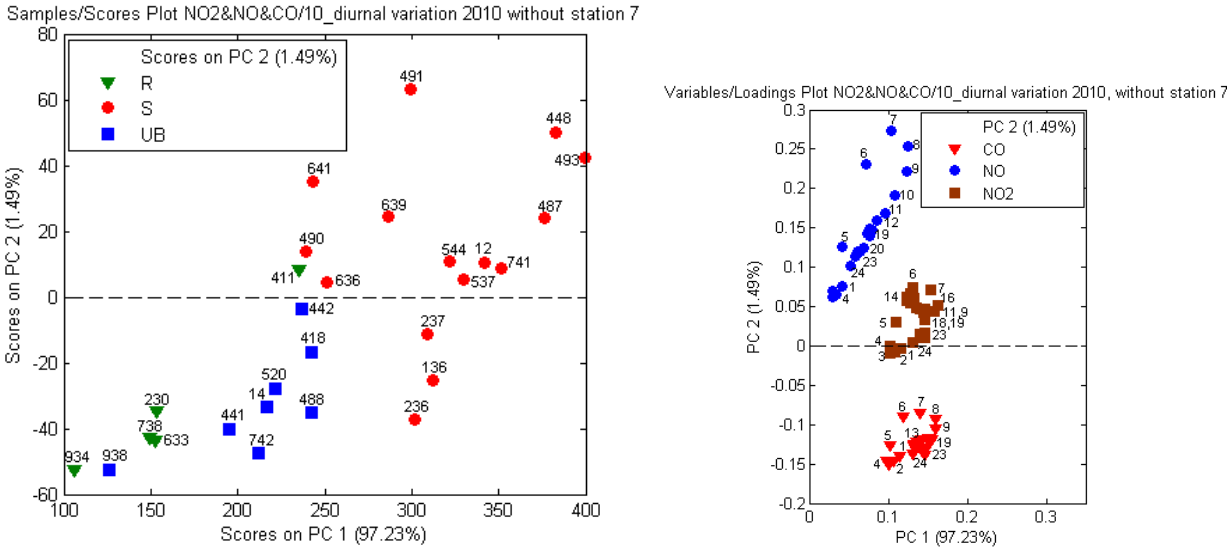


Figure 28 (Left) Score plot for the first two PCs for the combined diurnal variation of NO_2 , NO and CO, without station 7.(Right) Loadings plot

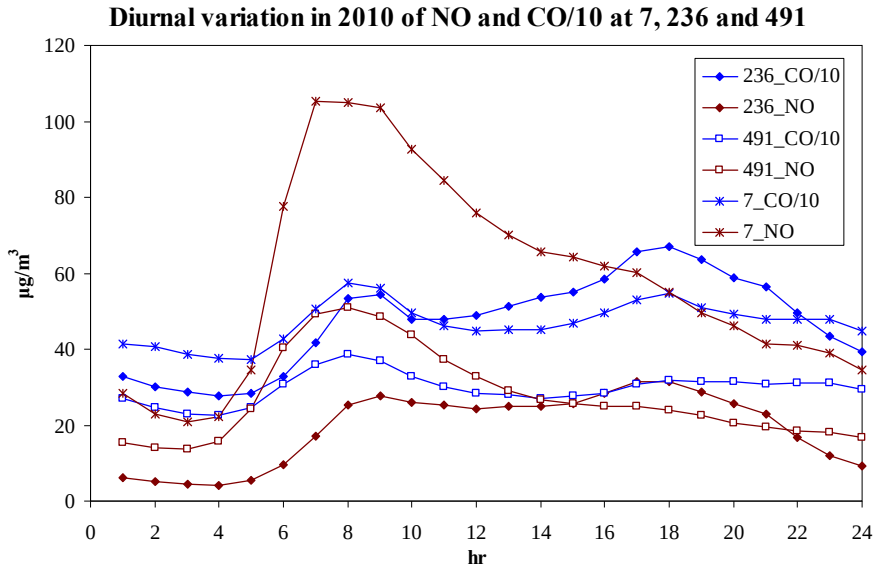


Figure 29 Diurnal variation of NO and CO/10 at stations 7 (GGD Amsterdam, Einsteinweg), 491(DCMR, Overschie-Oost Sidelinge) and 236 (Eindhoven-Genovevalaan)
At station 236 the CO concentration is relatively higher than at a station in Amsterdam and in Rijnmond.

6.8 Agriculture-related pollutant (NH_3)

Stations with NH_3 measurements are all Rural stations. Stations with high annual concentrations of NH_3 have high PC-1 score (Figure 30). Combining the score plot and the loadings plot in Figure 30 suggests that the NH_3 concentration at 131 (Vredepeel-Vredeweg) and 738 (Wekerom-Riemterdijk) is relatively high during the night (these stations have negative PC-2 score) while the concentration at other stations is relatively high during the day (positive PC-2 score). This pattern is indeed confirmed by Figure 31. The concentration profile of stations 131 and 738 are typical for 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.

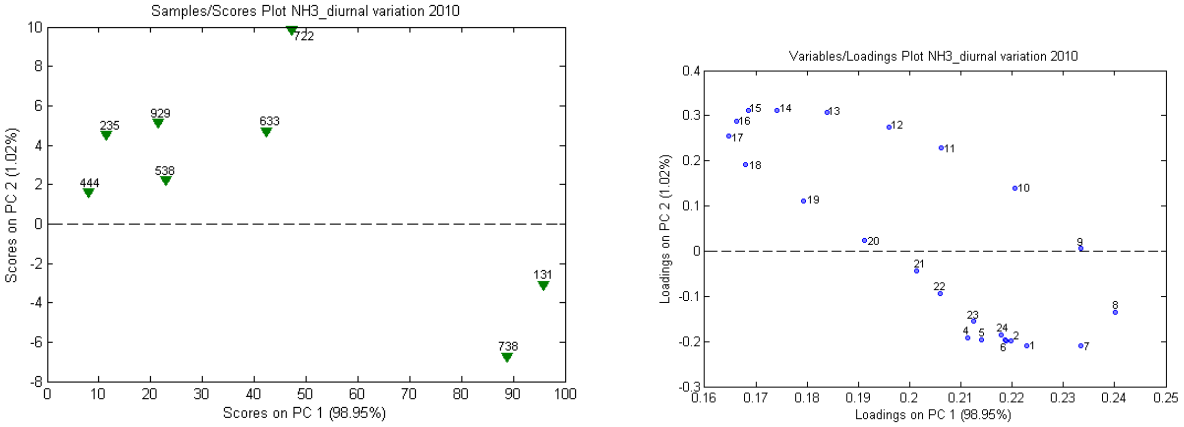


Figure 30 (Left) Score plot for the first two PCs for diurnal variation of NH_3(Right) Loadings plot

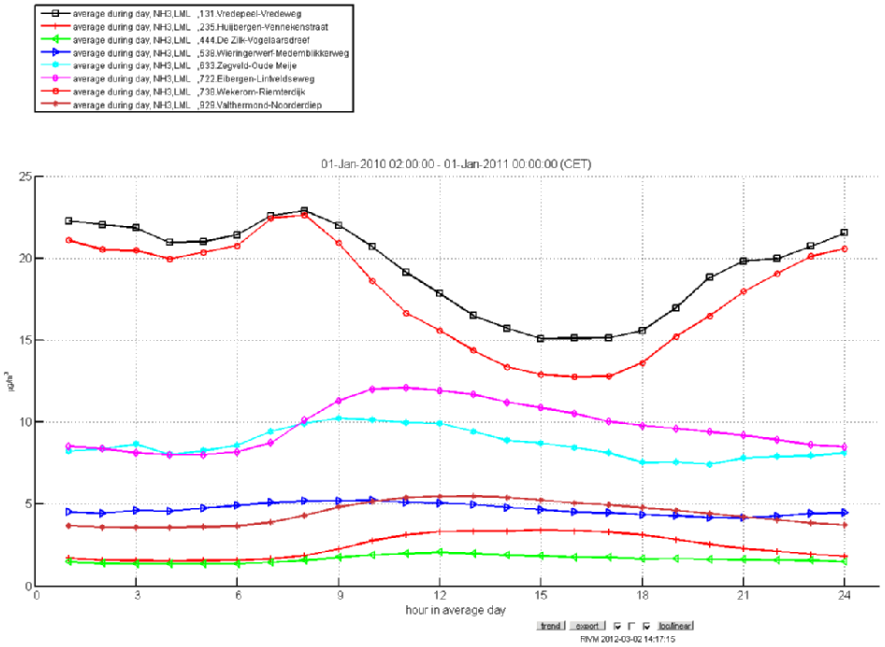


Figure 31 Diurnal variation of NH_3 in 2010 at LML stations

7 Results of the PCA analysis

This analysis shows that there is a good distinction between Rural stations and other stations. The distinction between the Urban Background and the Street stations is clear for traffic related pollutants (e.g. NO, NO_2, CO). For other pollutants (PM, SO_2), as can be expected, there is no clear distinction between these stations. A few stations are distinct from their own groups. By means of other techniques (wind rose analyses, photographs etc.) most of these observations can be explained. An overview of these observations is given below:

Table 2 Overview of PCA results

Station Nr.	Type	Remarkable observation	Observed with components	Possible cause of observed distinction
2 (GGD Amsterdam-Haarlemmerweg)	S	Distinct from other stations	NO	Very close to road
7 (GGD Amsterdam-Einsteinweg)	S	Distinct from other stations	NO	Located very close to a highway
131(Vredepeel-Vredeweg)&738 (Wekerom-Riemterdijk)	R	Distinct from other stations	NH_3	Diurnal variation shows hotspots of NH_3
411 (Schipluiden-Groeneveld)	R	Distinct from other Rural stations	NO,NO_2	Contribution of inland activities
416 (Vlaardingen-Lyceumlaan)	UB	Distinct from other UB stations	SO_2	Contribution from Pernis/Rotterdam harbour
441 (Dordrecht-Frisostraat)	Sub-urban for O_3	More like UB	O_3	
448 (Rotterdam-Bentinckplein)	S	Distinct from other Street stations	SO_2	Contribution from Pernis/Rotterdam harbour
483 (DCMR, Botlek (A15))	S	Distinct from other Street stations	NO	Located on a highway
485 (DCMR, Hoogvliet-Leemkuil)	UB	Distinct from other UB stations	SO_2	Contribution from Pernis/Rotterdam harbour
486 (DCMR,Pernis-Soetermanweg)	S	Distinct from other Street stations	NO_2, SO_2	There is no local traffic, influenced by highway at 600m distance. Contribution from Pernis/Rotterdam harbor
491 (DCMR, Overschie-Oost Sidelinge)	S	Distinct from other Street stations	CO	Located on a highway
494 (DCMR, Schiedam)&495(DCMR, Maasluis-Kwartellaan)	UB	Distinct from other UB stations	SO_2	Contribution from Pernis/Rotterdam harbour
520 (Amsterdam-Florapark)	Sub-urban for O_3	More like UB	O_3	
565 (PNH,Oude Meer)	R	Distinct from other Rural stations	NO_2	Results might be not representative due to short measurements period
641 (Breukelen-Highway)	S	Distinct from other Street stations	CO	Located on a highway
938 (Groningen-Nijensteinheerd)	UB	More like a Rural station	NO,NO_2,CO, O_3	Located in the suburbs of Groningen
999 (Ossendrecht,Noord-Brabant)	R	Distinct from other Rural stations	NO_2	Contribution from Antwerp

This study shows that generally, all monitoring stations represent the current classification well. Also for NH_3 (all of them are Rural stations) no irregularity has been observed.

This study shows that some stations differ from other stations with the same classification. These stations are:

- Station 938 (Groningen-Nijensteinheerd), which is located in the suburbs of Groningen, is classified as Urban Background station (Suburban for ozone). The PCA performed in this study shows that, for all components, this station resembles Rural stations. This is presumably due to the combination of a suburban location in a clean environment. The result shows that precautions are necessary in comparing this station with other stations. On the other hand the results from this station are presumably quite representative for the air quality in the northern cities.
- Station 411 (Schipluiden-Groeneveld) is classified as Rural station but resembles an urban environment. This is very much due to the density of greenhouses and other influences of the Rijnmond area.
- Although stations 441(Dordrecht-Frisostraat) and 520 (Amsterdam-Florapark) are currently classified as Suburban station for ozone, the PCA analysis shows that these stations do not differ from other Urban Background stations. Based on this analysis, station 404 (Den Haag-Rebecquestraat) and station 3 (GGD Amsterdam, Nieuwendammerdijk) seem to be appropriate Suburban stations for O_3 in these areas.

8 Discussion

8.1 How consistent is this evaluation

This evaluation has been performed with data of LML, GGD Amsterdam, DCMR, province of Noord-Brabant and province of Limburg. Stations of GGD Amsterdam and DCMR are mostly Urban Background or Street stations. Because a relatively large number of Street stations were used in this analysis, some of which are located near a highway, any difference between a Highway station and a normal Street station would be better revealed. Compared to earlier analysis the use of a larger database in this analysis is therefore an advantage.
Local variation at measurement stations might influence the result of the analysis. For example the character of station 641 (Breukelen-Highway) has been changed after the highway A2 was broadened and the PM_{10} hotspot at station 230 (Biest Houtakker- Biestsestraat) seems to have disappeared in 2010. Consequently some observations in the past were not confirmed in this evaluation. Therefore, it is recommended to review the conclusions regularly with new data.

8.2 Classifications

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 ozone. 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) also has the class Suburban Background 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.
The nature of a station depends also on the wind direction. For example, stations of DCMR which are located northerly of the river (e.g. stations 494 and 495) have contribution of the harbour and the port-industrial area when the wind is from the south while the northerly wind comes from a relatively open area.
In some cases it is not simple to classify a station. For example station 486 (DCMR, Pernis-Soetermanweg) is classified as a Street station. There is no direct traffic near this station but it is influenced by the highway at 600 m distance. Due to industrial activities in a port-industrial area this station is classified as Urban Industry in AIRBASE.
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-Vredeweg) is clearly influenced by NH_3 hotspot and the stations in the Rijnmond 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 Table 2 (chapter 7). For Street stations of the LML air quality monitoring network, a more detailed description of the street and the effect of their geometry on the CAR results can be found in

RIVM report on the CAR-II model (Wesseling et al., 2007). For stations of the GGD and DCMR, relevant remarks can be found in Table 2.

8.3 Representativeness

In practice it is not easy to investigate whether a station is representative or not. The criteria on macro and micro siting listed in Annex III of the Directive are only global guidelines. Some measurement stations of GGD Amsterdam have a sampling height of more than 4 m but it does not mean that these stations are not representative.
An earlier study (Nguyen et al.,2009) did not show observable effect of vegetation on the concentration measured at stations 722 and 520. There is also no indication that station 16 (GGD Amsterdam,Westerpark) is not representative because of trees near the sampling point (Figure 8.1, Appendix 8). However, it is recommended to prune vegetation near measurement stations regularly.

Earlier study also recommended to replace station 137 (Heerlen-Deken Nicolayestraat), which is located close to a building, to a more suitable place in this area when this station has to be renewed. The same recommendation holds for station 17 (GGD Amsterdam, Stadhouderskade) as this station is located close to the junction Westeinde-Stadhouderskade and the minimal distance of 25 m is not fulfilled.

With respect to Street stations it is relevant to emphasize that locations of measurement stations are not necessary the same as monitoring locations in the National Air Quality Cooperation Programme (NSL). At some measurement stations along highways there is no monitoring location in the NSL and some measurement stations are closer to the road than locations in the NSL. Consequently in some areas, concentration in the NSL might be lower than the limit value while measurements can still show exceedances.

9 Conclusions and recommendations

This evaluation has resulted in several observations, and an overview of these is given in Table 3. Most of these observations are only informative in nature. This table also shows whether a station is suitable for the production of the concentration map (GCN). This table also shows whether the concentration at a monitoring station can be calculated by the 'Standaard rekenmethode' (SRM) and if these locations are included in the National Air Quality Cooperation Programme (NSL).

Stations which are suitable for the GCN maps:
The following stations are currently not used in the production of the GCN map but seem to be suitable: 488 (DCMR, Rotterdam-Zwartewaalstraat), 556 (PNH, de Rijp), 246 (Fijnaart-Zwingelspaansedijk) and 549 (Laren-Jagerspad). Station 549 is currently a 'not defined'-station. Station 441 (Dordrecht-Frisostraat) seems suitable too but measurements at this station were stopped in November 2010.

Issues required more attention:

- The location of station 137 (Heerlen-Deken Nicolayestraat) 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 cannot 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.
- The location of station 17 (GGD Amsterdam, Stadhouderskade) is not optimal (too close to a junction). If this station has to be renewed the new monitoring station should preferably be placed at a more suitable location on this street.
- Measurements of DCMR, GGD and RIVM give comparable yearly average PM_{10} concentration at Berghaven and Overtoom, the difference between diurnal variation at station 496 (DCMR, Berghaven) and station 432 (Hoek van Holland-Berghaven) and between stations 14 (GGD Amsterdam, Vondelpark) and 543 (Amsterdam-Overtoom) is very likely due to the PM_{10} measurement method of the RIVM. The difference is not relevant for limit values that are based on yearly or daily averages but might influence other analysis.
- Classification:
  Compared to the AIRBASE classification the Dutch classification is a simple one. The PCA analysis shows that in some cases the more detailed AIRBASE classification is more representative. This aspect is relevant and should be taken into account when the data of measurements are interpreted.
    - Station 938 (Groningen-Nijensteinheerd), which is located in the suburbs of Groningen, is classified as Urban Background station (Suburban for ozone) but it would be better classified as a Rural station (Suburban for O_3).
    - Stations 441(Dordrecht-Frisostraat) and 520 (Amsterdam-Florapark) are currently classified as Suburban station 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. Based on the PCA analysis, station 404 (Den Haag-Rebecquestraat) and station 3 (GGD Amsterdam, Nieuwendammerdijk) seem to be appropriate stations to monitor suburban concentrations in these areas.
    - The classification Industry or Urban is more suitable for station 486 (DCMR, Pernis-Soetermanweg).
    - For stations along a highway in remote areas (for example station 641) the classification Rural Traffic is more representative than the classification Street. Generally, measurements at stations along a highway should not be compared to a normal Street station.
- Completion of documentation:
    - RIVM: update of the Google maps application of LML stations is recommended.
    - DCMR: the current map with locations of measurement stations should be supplemented with photographs of the surrounding areas.

Table 3 Overview of observations
X means that the station has less than 50% data in 2010. A black Y means that the station is currently used in the production of the GCN map. A blue Y means that the station is suitable for the production of the GCN map.

Rural	Nr.	SO_2	PM10	NH_3	CO	O_3	NO	NO_2	Netherlands NL-simple	Netherlands Ozone	AIRBASE R/U/SU	AIRBASE T/I/B	AIRBASE Ozone	Micro obs	Screening results	Suitable for GCN
Posterholt-Vlodropperweg	107					x	x	x	Rural		R	B	R			Y
Vredepeel-Vredeweg	131	x	x	x		x	x	x	Rural		R	B	R	Farm	Diurnal variation shows NH_3 hotspots	Y
Wijnandsrade-Opfergeltstraat*	133	x	x			x	x	x	Rural	Suburb	SU	B	SU			Y
Budel-Toom	227					x	x	x	Rural		R	B	R			Y
Biest Houtakker-Biestsestraat	230		x		x	x	x	x	Rural		R	B	R			Y
Huijbergen-Vennekenstraat	235	x	x	x		x	x	x	Rural		R	B	R			Y
Zierikzee-Lange Slikweg	301					x	x	x	Rural		R	B	R			Y
Philippine-Stelleweg	318	x	x			x	x	x	Rural		R	B	R			Y
Schipluiden-Groeneveld*	411	x			x	x	x	x	Rural	Suburb	SU	B	SU		Windrose shows inland activities	Y
Westmaas-Groeneweg	437		x			x	x	x	Rural		R	B	R			Y
De Zilk-Vogelaarsdreef	444	x	x	x		x	x	x	Rural		R	B	R			Y
Wieringerwerf-Medemblikkerweg	538		x	x		x	x	x	Rural		R	B	R			Y
PNH, de Rijp	556		x						Rural							Y
PNH, Oude Meer	565		x					x	Rural						Results might be not representative due to short measurement period.	
Cabauw-Zijdeweg	620	x				x	x	x	Rural		R	B	R			Y
Bilthoven-Van Leeuwenhoeklaan	627	x							Rural		SU	B				
Biddinghuizen-Hoekwantweg	631		x			x	x	x	Rural		R	B	R			Y
Zegveld-Oude Meije	633		x	x	x	x	x	x	Rural		R	B	R			Y
HAMSAmsterdam-Spaarnwoude	703		x				x	x			R					Y
Eibergen-Lintveldseweg	722	x	x	x		x	x	x	Rural		R	B	R	Surrounded by trees		Y
Wekerom-Riemterdijk	738		x	x	x	x	x	x	Rural		R	B	R		Diurnal variation shows NH_3 hotspots	Y
Hellendoorn-Luttenbergerweg	807		x			x	x	x	Rural		R	B	R			Y
Barsbeek-De Veenen	818		x			x	x	x	Rural		R	B	R			Y
Balk-Trophornsterweg	918	x	x			x	x	x	Rural		R	B	R			Y
Valthermond-Noorderdiep	929	x	x	x		x	x	x	Rural		R	B	R			Y
Kollumerwaard-Hooge Zuidwal	934	x	x		x	x	x	x	Rural		R	B	R			Y
Prov. Noord-Brabant, Ossendrecht	999							x	Rural						Contribution from Antwerp	

Agricultural hotspot
Harbor/Industrial
Differs from other stations
Looks like rural
Looks like UB
Looks like street

Urban Background	Nr.	SO_2	PM10	NH_3	CO	O_3	NO	NO_2	Netherlands NL-simple	Netherlands Ozone	AIRBASE R/U/SU	AIRBASE T/I/B	AIRBASE Ozone	Micro obs	Screening results	Suitable for GCN
GGD Amsterdam, Nieuwendammerdijk	3					x	x	x	UB		U	B				Y
GGD Amsterdam, Vondelpark	14		x		x	x	x	x	UB		U	B				Y
GGD Amsterdam, Westerpark	16	x	x						UB		U	B		Trees nearby (see photo 8.1 in app. 8)		Y
GGD Amsterdam, Oude Schans	19						x	x	UB		U	B				Y
GGD Amsterdam, Kantershof	21						x	x	UB		U	B				Y
GGD Amsterdam, Sportpark Ook Meer	22						x	x	UB		U	B				Y
Heerlen-Deken Nicolayestraat	137		x			x	x	x	UB		U	B	U	close to building		Y
Breda-Bastenakenstraat	241		x			x	x	x	UB		SU	B				Y
Veldhoven-Europalaan	247		x			x	x	x								Y
Den Haag-Rebecquestraat	404	x	x			x	x	x	UB		U	B	U			Y
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		close to a large tree	Contribution from Rotterdam harbour	Y
Dordrecht-Frisostraat*	441		x		x	x	x	x	UB	Suburb	U	B	U		Ozone: UB instead of Suburb?	Y
Den Haag-Bleriotlaan	446		x						UB		SU	B				Y
DCMR, Hoogvliet-Leemkuil	485	x	x			x	x	x	UB		U	I		Hybrid Urban Background / Industry	Contribution from Pernis/Rotterdam harbour	Y
DCMR, Rotterdam-Zwartewaalstraat	488		x		x		x	x	UB		U	B				Y
DCMR, Schiedam-Alphons Ariensstraat	494	x	x			x	x	x	UB		U	B			Contribution from Pernis/Rotterdam harbour	Y
DCMR, Maassluis-Kwartellaan	495	x	x			x	x	x	UB		U	I		Hybrid Urban Background/Industry/shipping	Contribution from Pernis/Rotterdam harbour	
Amsterdam-Florapark*	520		x		x	x	x	x	UB	Suburb	U	B	U	Surrounded by trees	Ozone: UB instead of Suburb?	Y
Amsterdam - Overtoom	543		x					x								Y (same as 14)
ZNSTD,Zaandam	701		x			x	x	x	UB		U	B				Y
Nijmegen-De Ruyterstraat	742				x	x	x	x	UB		U	B	U			Y
Groningen-Nijensteinheerd*	938				x	x	x	x	UB	Suburb	SU	B			Locates in the sub urban of Groningen. Rural instead of UB?	Y

*) Sub urban for ozone

Agricultural hotspot
Harbor/Industrial
Differs from other stations
Looks like rural
Looks like UB
Looks like street

Street	Nr.	SO_2	PM10	NH_3	CO	O_3	NO	NO_2	Netherlands NL-simple	Netherlands Ozone	AIRBASE R/U/SU	AIRBASE T/I/B	AIRBASE Ozone	Micro obs	Screening results	Suitable for SRM	NSL monitoring location nearby	
GGD A'dam, Haarlemmerweg	2						x	x	Street		U	T		Very close to road (<2.5 m). Inlet via underground, see photo 8.2 in app. 8		No, distance to axis might be < 4m	Y	
GGD Amsterdam, Einsteinweg	7		x		x		x	x	Street		U	T		Highway with buildings at both sides. Close to road. See photo. 8.3 in app. 8		Outside the scope of SRM2	N	
GGD A'dam, Van Diemenstraat	12		x		x	x	x	x	Street		U	T				Y	Y	
GGD A'dam, Stadhouderskade	17		x				x	x	Street		U	T		Sampling height at >5 m, 15 m from junction with Westeinde		N	Y	
GGD A'dam, Jan van Galenstraat	20						x	x	Street		U	T		near bus stop (100 buses/day)		No, due to effect of busses	Y	further away from the road
Heerlen-Looierstraat	136	x	x		x		x	x	Street		U	T		Building and trees on short distance of inlet (<5m)		Y	Y	further away from the road
Eindhoven-Genovevalaan	236		x		x	x	x	x	Street		U	T	U			Y	Y	further away from the road
Eindhoven-Noordbrabantlaan	237	x	x		x		x	x	Street		U	T				Y	Y	further away from the road
Breda-Tilburgseweg	240		x		x				Street		SU	T				Y	Y	further away from the road
Vlaardingen-Floreslaan	433		x			x	x	x	Street		U	T	U			No, effect of hedge?	N	
Den Haag-Amsterdamse Veerkade	445		x				x	x	Street		U	T				Y	Y	
Leiden-Willem de Zwijgerlaan	447		x						Street		U	T	U	Building and trees on short distance of inlet (<5m). This station is located at the corner of a high building		No, due to corner of building	Y	
Rotterdam-Bentinckplein	448	x	x		x		x	x	Street		U	T				Y	Y	further away from the road
DCMR, Botlek(A15)-Botlektunnel	483						x	x	Street			I		Hybrid Highway/Industry		Y(SRM2)	N	
DCMR, Pernis-Soetemanweg	486	x					x	x	Street		U	I		Hybrid Highway/Industry/shipping	Contribution from Pernis/Rotterdam harbour	Y	Y	
DCMR, Pleinweg-Pleinweg	487		x		x		x	x	Street		U	T				Theoretical:Y (see note)	Y	further away from the road
DCMR, Ridderkerk-Hogeweg	489		x			x	x	x	Street			T		Highway		Y(SRM2)	Y	
DCMR, Maasboulevard	490		x		x		x	x	Street			T		Traffic / inland shaipping (WR South)		Y	N	
DCMR, Overschie-Oost-Sidelinge	491		x		x		x	x	Street			T		Highway&road parallel		Y	Y	
DCMR, Statenweg-Statenweg	493		x		x	x	x	x	Street			T				Y	Y	further away from the road
Haarlem-Amsterdamsevaart	537		x		x	x	x	x	Street		U	T				Y	Y	
Amsterdam-Bernhardplein	544	x	x		x	x	x	x	Street		U	T	U	Trees <10m (western)		N	Y, along the road nearby	
Amsterdam-A10 west	545		x						Street		U	T		Highway		Theoretical: Y; however: too complex situation	N	
Utrecht-de Jongweg	636		x		x		x	x	Street		U	T	U			Y	Y	
Utrecht-Vleutenseweg	638	x							Street		U	T				Y	Y	
Utrecht-Erzeijstraat	639		x		x	x	x	x	Street		U	T	U			Y	Y	further away from the road
Breukelen-Highway	641	x	x		x	x	x	x	Street		R	T	R	Highway in remote area	Highway. Rural Traffic instead of Street?	Y(SRM2)	Y	
Nijmegen-Graafseweg	741		x		x		x	x	Street		U	T		Keizer Karel junction		Y	Y	further away from the road
Groningen-Europaweg	937		x				x	x	Street		U	T	U	Stands on a slope		Y	Y	further away from the road
Prov. Limburg, Maastricht A2	1004		x					x	Street					50km/hr section on a highway with buildings		Y	Y,closer to road	
Prov. Limburg, Roermond	1005							x	Street					Located at the rim of the road		Y	Y	further away from the road

Agricultural hotspot
Harbor/Industrial
Differs from other stations
Looks like rural
Looks like UB
Looks like street

note: at this location (487) there is a main road and a parallel road. In NSL the intensity of the parallel road is incorporated in the main road

	Nr.	SO_2	PM10	NH_3	CO	O_3	NO	NO_2	Netherlands NL-simple	Netherlands Ozone	AIRBASE R/U/SU	AIRBASE T/I/B	AIRBASE Ozone	Micro obs	Screening results	Suitable for GCN	Suitable for SRM	NSL locations nearby
Industry																		
DCMR, Botlek-Oude Maasweg	484	x										I		Hybrid Industrie/shipping	Contribution from Pernis/Rotterdam harbour		n.a.	N
DCMR, Berghaven-Berghaven	496	x	x			x	x	x				I		Hybrid Rural/Industry+shipping	Contribution from Rotterdam harbour		n.a.	Y
DCMR, Markweg-Markweg	482		x					x				I					n.a.	N
PNH, Hemkade	546		x					x			U	I		3 m from water			n.a.	N
PNH, IJmuiden	551		x					x										
PNH, Wijk aan Zee	553		x					x			U	T					n.a.	N
PNH, Staalstraat	572		x														Y	Y
PNH, Reijndersweg	573		x														n.a.	N
PNH, Hoogtij	704	x	x				x	x				I		3 m from water			n.a.	N
Prov. Limburg, Buggenum	1001							x									n.a.	N
Prov. Limburg, Geleen-Vouershof	1002							x									n.a.	N
Prov. Limburg, Geleen-Asterstraat	1003		x					x									n.a.	N
Not defined																		
De Rips-Blaarpeelweg	243		x								R	B					n.a.	N
De Rips-Klotterpeellaan	244		x								R	B					n.a.	N
Moerdijk-Julianastraat	245		x					x			R	B		Highways at 1-3 km			n.a.	N
Fijnaart-Zwingelspaansedijk	246		x					x			R	B		Highways at 1-3 km		Y	n.a.	N
Axel - Zaaidijk	312		x								R	B					n.a.	N
Nieuwdorp-Coudorp	319		x														n.a.	N
Hoek van Holland-Berghaven	432		x								U	I					n.a.	N
Hilversum-Geradtsweg	547		x					x			U	T					N(between 2 driving lanes)	Y
Bussum - Ceintuurbaan	548		x					x			U	T					Y	Y
Laren-Jagerspad	549		x					x			U	T				Y	n.a.	N
PNH, Badhoevedorp	561		x					x						30 m from local and 80 m from N-road, 0.5 and 1 km from 2 highways			N (behind a building)	Y (closer to road)
PNH, Hoofddorp	564		x					x						500 m from take off strip, 300 m from aircraft taxi lane			N	N
PNH, Beverwijk-West	570		x														n.a.	N
Apeldoorn - Stationstraat	728		x								U	T					Y	Y
Kootwijkerbroek - Drieenhuizerweg	743		x														N (behind a building)	Y
Barneveld - Scherpenzeelseweg	744		x														N (behind a building)	Y(closer to road)

Agricultural hotspot
Harbor/Industrial
Differs from other stations
Looks like rural
Looks like UB
Looks like street

n.a. : the station does not locate along a (NSL)road

References

De Jonge, D. (2012). Metadata meetstation in beheer bij de GGD Amsterdam 2012, report GGD/LO 12-1129.

EU(2008) Directive 2008/50/EC of the European Parliament and of the council of 21 May 2008 on ambient air quality and cleaner air for Europe.

Mooibroek, D., Berhout, J.P.J., Hoogerbrugge, R. (2012).Jaaroverzicht luchtkwaliteit 2011. RIVM report 680704020.

Provincie Noord-Brabant. Onderzoek naar de luchtkwaliteit aan de Burgemeester voetenstraat in Ossendrecht. Report 2010-0002-L-O, 2011.

Wesseling, J.P., Mooibroek, D., Van Pul, W.A.J.(2007).Een vergelijking tussen met CAR II versie 5.0 berekende concentraties en metingen van het LML RIVM report 680600003.

Google Maps application http://www.onsite360.nl/projecten/rivm/startpagina/ (January 2013)

http://www.luchtmetingen.amsterdam.nl (January 2013)
http://www.luchtmetingen.noord-holland.nl (January 2013)

http://www.dcmr.nl/luchtkwaliteit/index.htm (January 2013)

http://www.nsl-monitoring.nl (January 2013)

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 m 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, and planning requirements.

Macro scale

On a 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:

- 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);
- 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 km2. **A Member State may provide for a sampling point to be sited at a smaller 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 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 fewer 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*: $f_j = \frac{1}{N}\sum_{i=1}^{N} h_{ij} = \frac{N_j}{N}$,

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*: $f_j^c = \frac{1}{N}\sum_{i=1}^{N} h_{ij}\, c_i$

f_j^w : value of weighed concentration rose for sector

j: $f_j^w = \frac{1}{f_j} f_j^c = \frac{1}{f_j}\frac{1}{N}\sum_{i=1}^{N} h_{ij}\, c_i = \frac{1}{N_j}\sum_{i=1}^{N} h_{ij}\, c_i$

Appendix 3 NO_2 wind rose at station Ossendrecht in Noord-Brabant and the location of this station

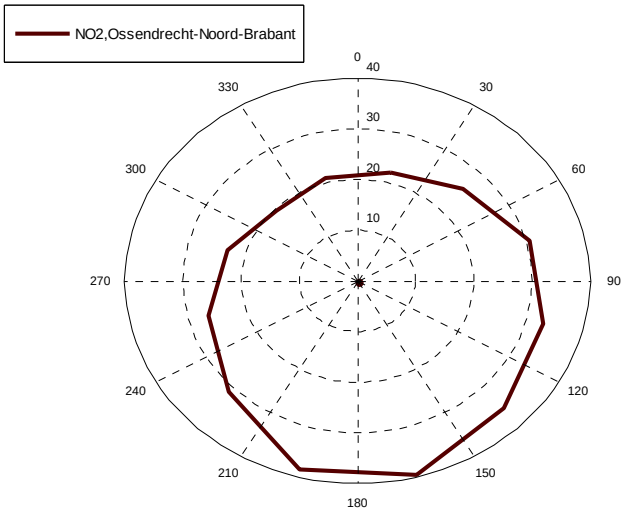


Figure 3.1 NO_2 wind rose at station Ossendrecht in Noord-Brabant

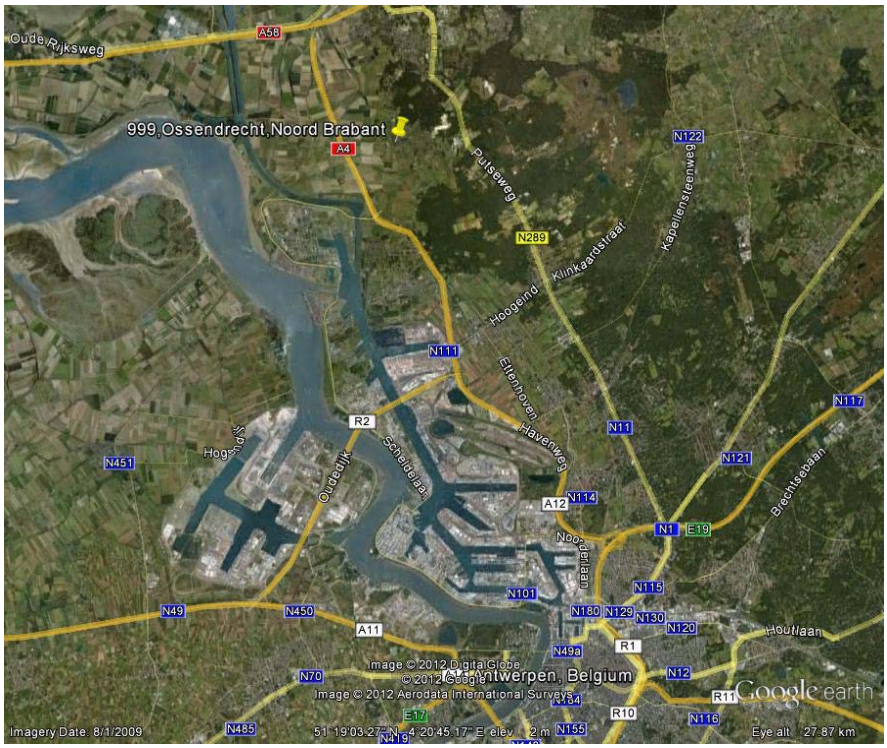
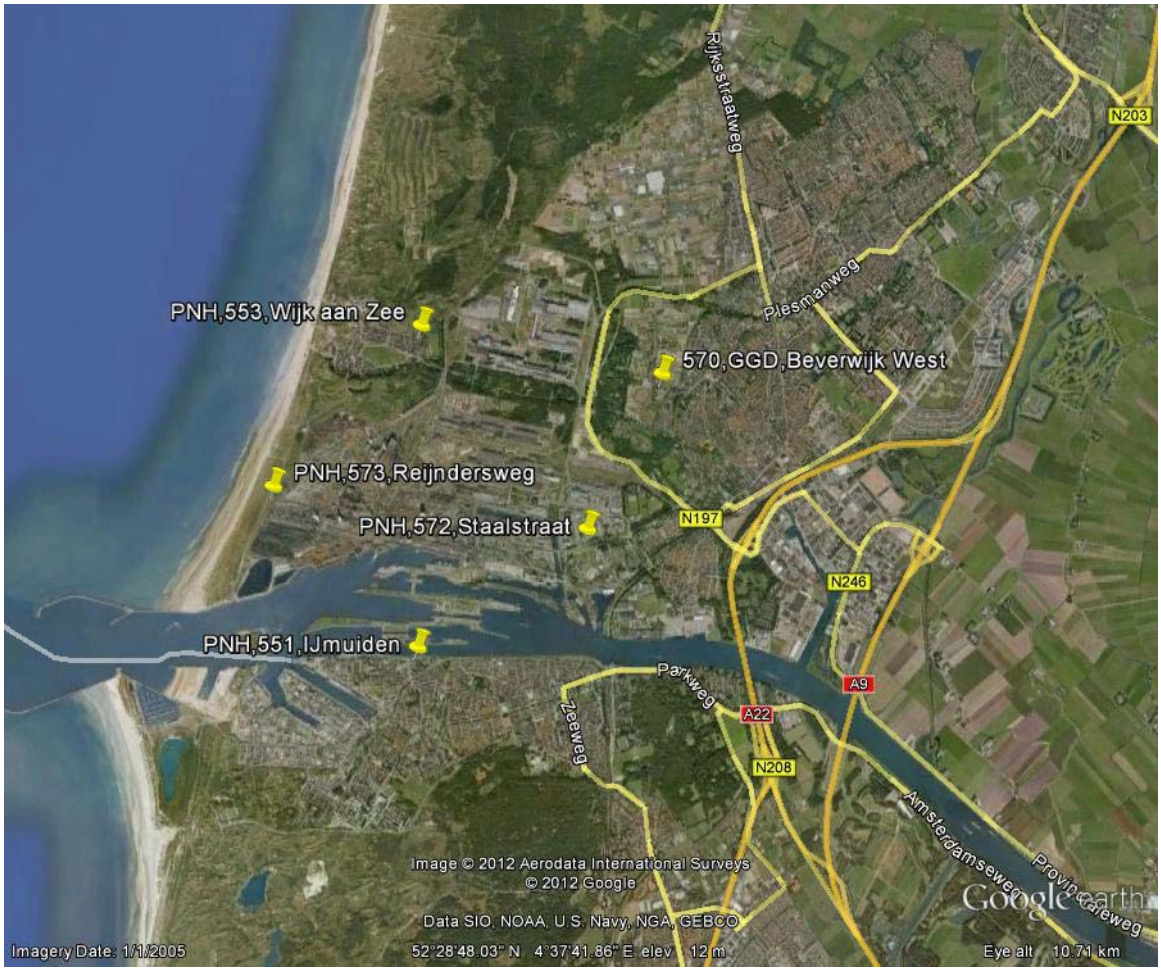


Figure 3.2 Location of station Ossendrecht in Noord-Brabant

Appendix 4 Locations of measurement stations in the industrial area IJmond (Noord-Holland)



Appendix 5 Location of some typical stations

Figure 5.1 Location of 549 (Laren,Jagerspad)

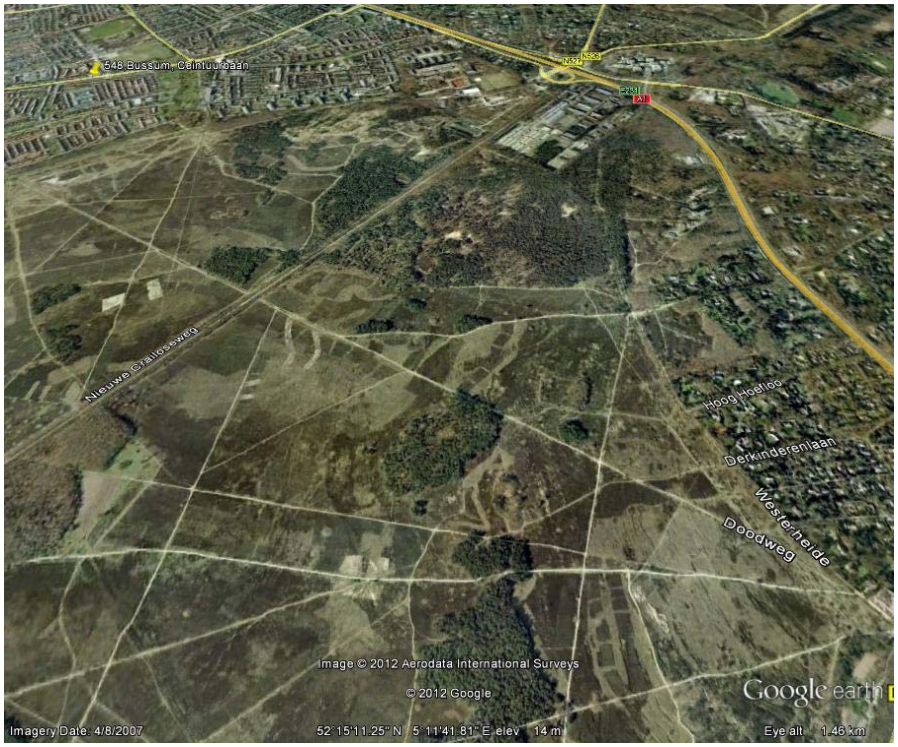


Figure 5.2 Location of 548 (Bussum-Ceintuurbaan, yellow drawing pin)

Figure 5.3 Location of 245 (Moerdijk-Julianastraat) and 246 (Fijnaart-Zwingelspaansedijk)

Appendix 6 Locations and wind roses of measurement stations in Rijnmond

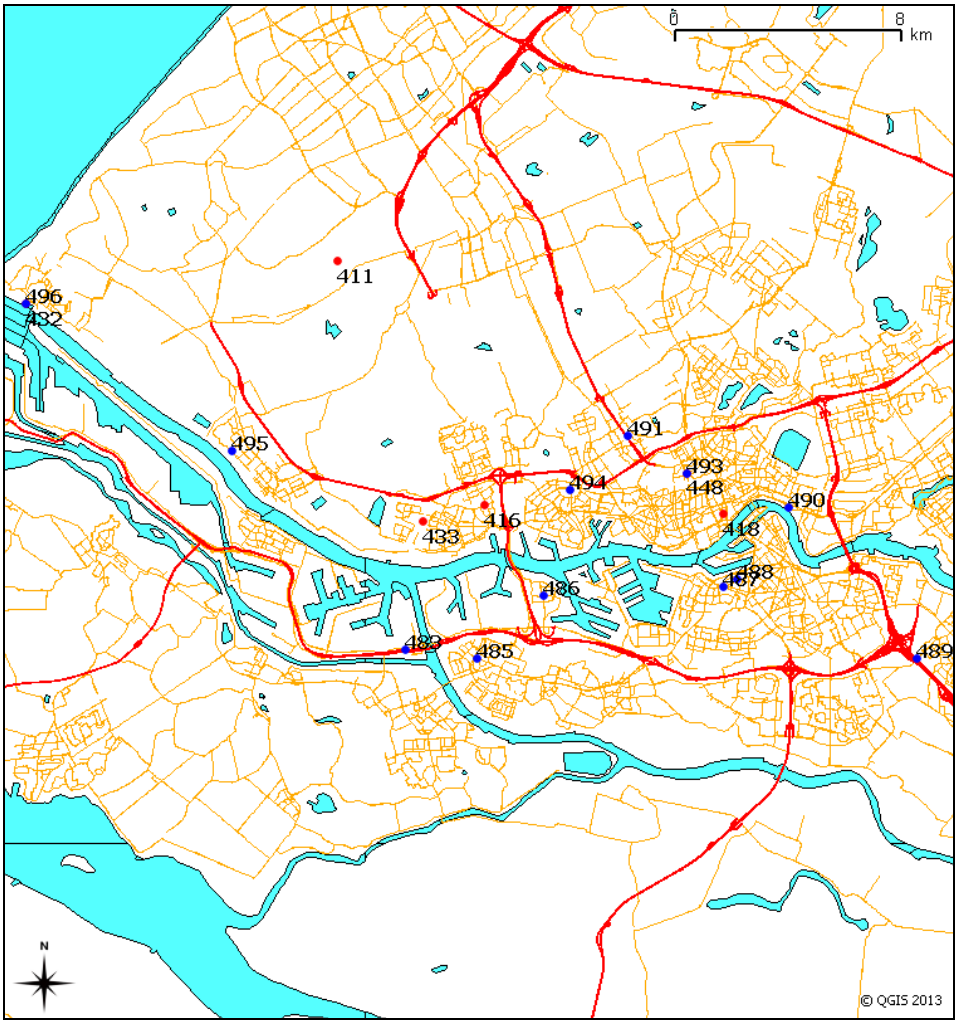


Figure 6.1 Locations of measurement stations in Rijnmond. Red: LML, blue: Rijnmond-stations

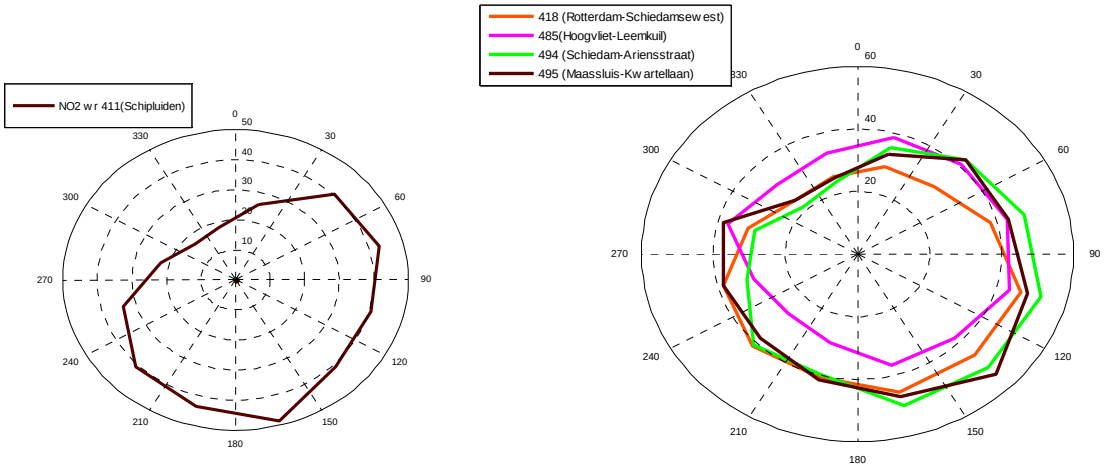
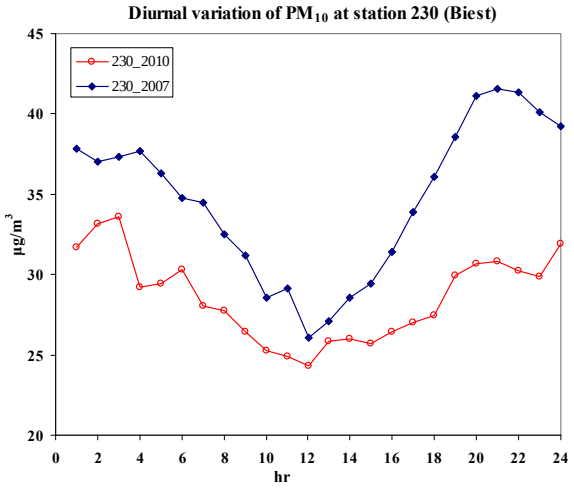
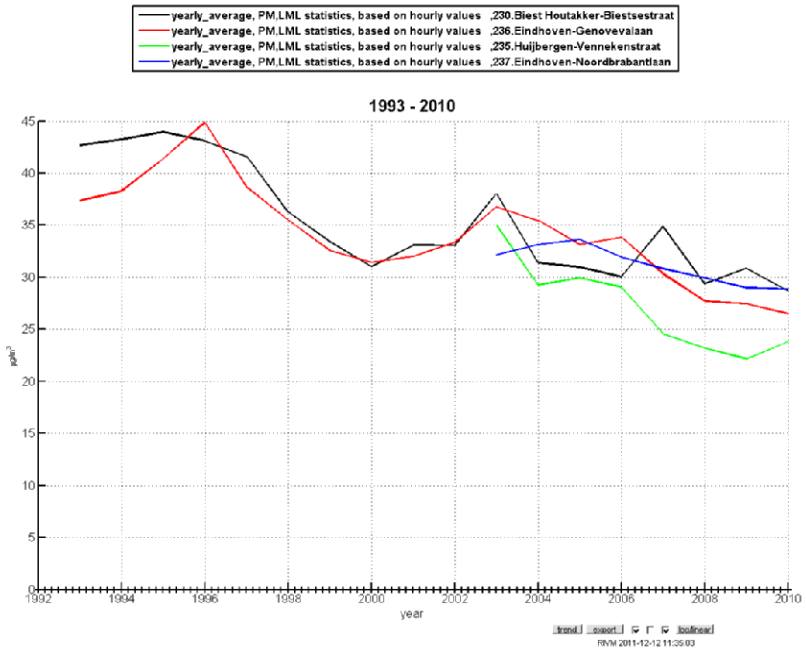


Figure 6.2 NO_2 wind roses of measurement stations in Rijnmond

Appendix 7 Diurnal variation of PM_{10} at station 230 (Biest) and some other stations in Noord-Brabant





Appendix 8 Photographs of deviating measurement stations in Amsterdam

016 WESTERPARK

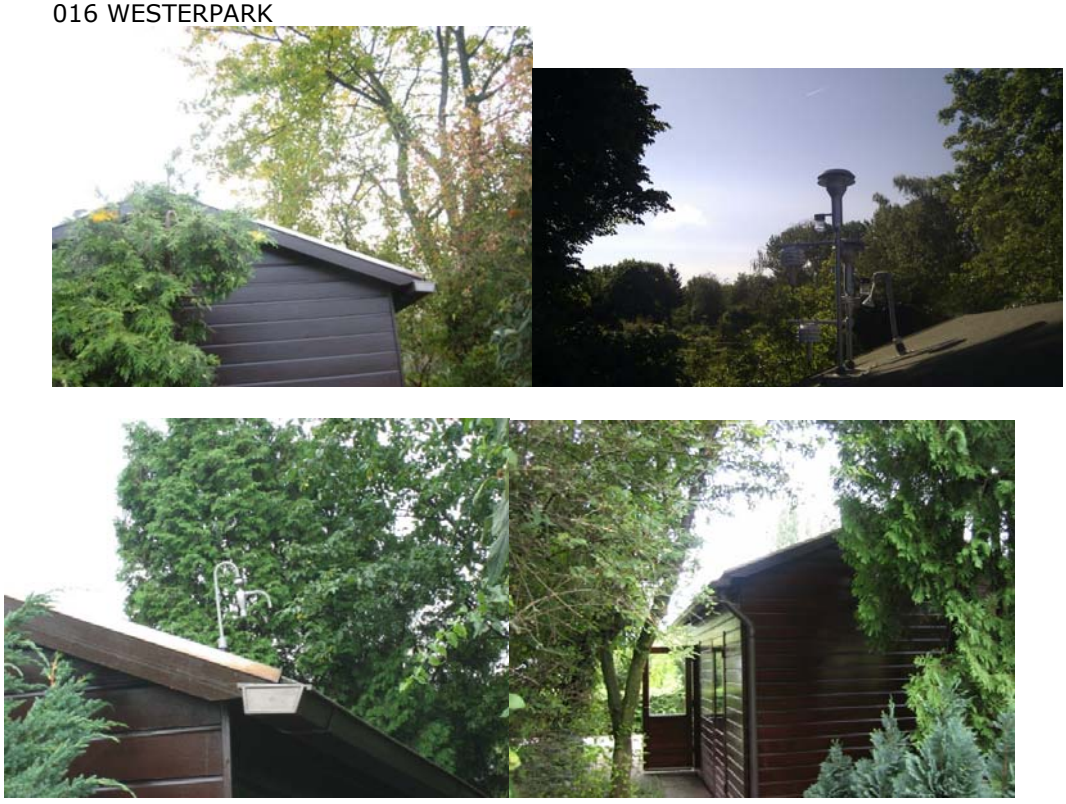


Photo 8.1 Trees near station 16 (GGD Amsterdam,Westerpark)

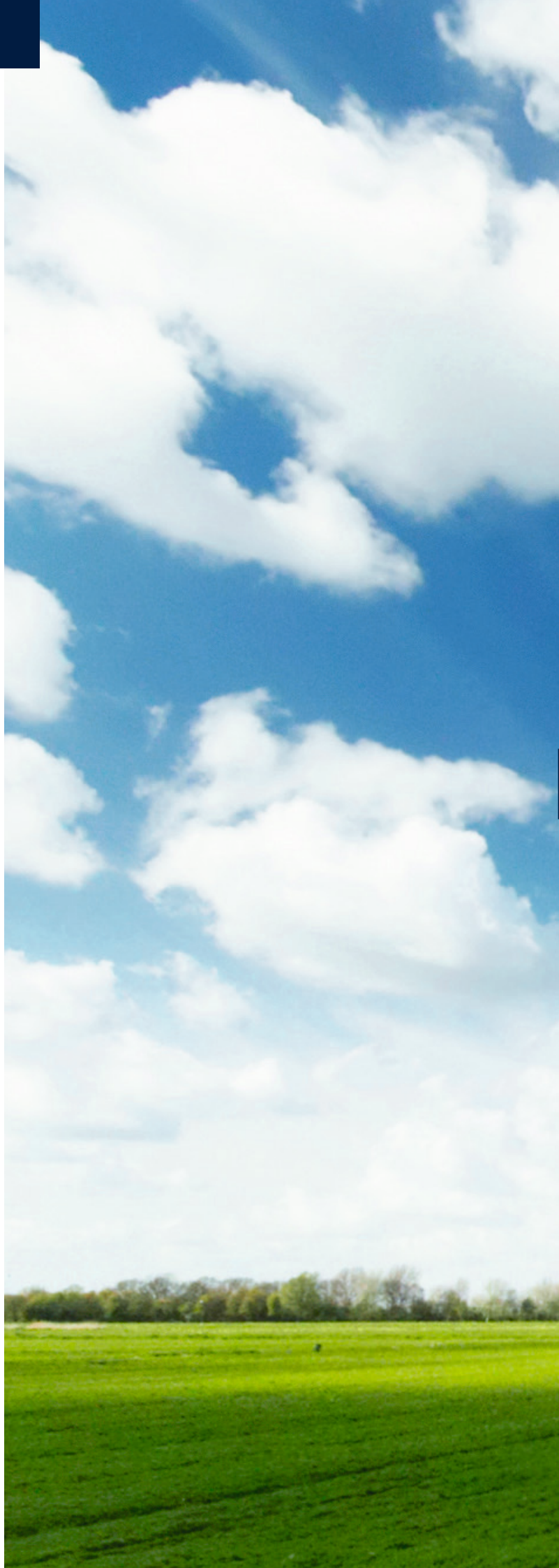
002 HAARLEMMERWEG

Photo 8.2 Inlet via underground of station 2 (GGD Amsterdam, Haarlemmerweg)
The height of the inlet is within the criteria (1.5-4 m) but the location is very close to the road (<2.5 m).

Photo 8.3 Station 2 (GGD Amsterdam, Einsteinweg)
This station is located close to a highway with buildings at both sides.

P.L. Nguyen | G. Stefess | D. de Jonge | A. Snijder | P.M.J.A. Hermans | S. van Loon | R. Hoogerbrugge

RIVM report 680704021/2012



This is a publication of:

GGD Amsterdam

DCMR milieudienst Rijnmond

Provincie Noord-Brabant

provincie limburg

National Institute for Public Health and the Environment

P.O. Box 1 | 3720 BA Bilthoven
The Netherlands
www.rivm.nl

June 2013

004801