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Preliminary assessment of air quality for sulphur dioxide, nitrogen dioxide, nitrogen oxides, particulate matter, and lead in the Netherlands under European Union legislation

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Abstract

The current air quality in the Netherlands for sulphur dioxide, nitrogen dioxide, nitrogen oxides, particulate matter and lead has been assessed in the context of limit values, margins of tolerance and the assessment thresholds used in the first daughter directive for air quality of the European Union. On the basis of the differences in air quality and data on population, numbers and density, three zones and six agglomerations in the Netherlands are defined. Depending on the air quality in relation to the assessment threshold levels in the daughter directive strategies for assessing air quality in the different zones and agglomerations have been defined. Testing for limit values yielded a yearly mean nitrogen dioxide level in many urban areas, which highly exceeded the limit value for this substance. This was also the case for particulate matter concentrations, but to a lesser extent. The monitoring requirements in the daughter directive have been compared with the current station configuration and numbers of different types of stations. Eight new stations will have to be set up for nitrogen dioxide, and 23 for particulate matter under the assumption that only measurements are used to determine the air quality.

Samenvatting

In 1999 is de eerste dochterrichtlijn luchtkwaliteit van de Europese Unie van kracht geworden. De richtlijn betreft zwaveldioxide, stikstofdioxide, stikstofoxiden, fijn stof en lood. Vóór de implementatie van deze wetgeving dienen de lidstaten van de Europese Unie in een Voorlopige Beoordeling de luchtkwaliteit van zwaveldioxide, stikstofdioxide, stikstofoxiden, fijn stof en lood in hun land te beschrijven. De huidige luchtkwaliteit in Nederland voor deze stoffen is beoordeeld in de context van de grenswaarden, de overschrijdingsmarges en de beoordelingsdrempels uit de dochterrichtlijn.

Er zijn in Nederland op basis van de verschillen in luchtkwaliteit drie zones gedefinieerd: *Noord* (met de provincies Groningen, Friesland, Drenthe, Overijssel, Flevoland), *Midden* (Gelderland, Utrecht, Noord-Holland, Zuid-Holland) en *Zuid* (Limburg, Noord-Brabant, Zeeland).

Gegevens over bevolkingsaantallen en dichtheden leiden tot de definitie van zes agglomeraties in Nederland: Amsterdam/Haarlem, Rotterdam/Dordrecht, The Hague/Leiden, Utrecht, Eindhoven en Heerlen/Kerkrade.

Toetsing aan grenswaarden levert op dat de grenswaarde voor het jaargemiddelde voor stikstofdioxide in veel stedelijke gebieden wordt overschreden. In mindere mate geldt dit voor de grenswaarde voor het jaargemiddelde voor fijn stof concentraties. Voor de beoordeling voor de luchtkwaliteit zijn, in afhankelijkheid van de luchtkwaliteit in relatie tot de beoordelingsdrempels uit de dochterrichtlijn, drie vaststellingsstrategiën mogelijk. Regime 1. De concentratie bevindt zich boven de bovenste beoordelingsdrempel: metingen zijn altijd verplicht. Regime 2. De concentratie bevindt zich tussen de onderste en de bovenste beoordelingsdrempel: er dient gebruik te worden gemaakt van metingen eventueel in combinatie met modellen. Regime 3. De concentratie ligt onder de onderste beoordelings-drempel: metingen zijn onder deze omstandigheden niet vereist. De luchtkwaliteit kan beschreven worden met modellen of aan de hand van objectieve ramingen.

Voor de onderscheiden stoffen in de eerste dochterrichtlijn en in de in Nederland gedefinieerde zones en agglomeraties leidt dit tot de volgende uitkomsten:
Zone Noord: fijn stof regime 1, overige stoffen regime 3
Zone Midden: stikstofdioxide en fijn stof regime 1, zwaveldioxide en lood regime 3
Zone Zuid: fijn stof regime 1, stikstofdioxide regime 2, zwaveldioxide en lood regime 3
Agglomeraties Amsterdam/Haarlem, The Hague/Leiden, Utrecht, Eindhoven, Heerlen/Kerkrade: fijn stof en stikstofdioxide regime 1, zwaveldioxide en lood regime 3.
Agglomeratie Rotterdam/Dordrecht: fijn stof en stikstofdioxide regime 1, zwaveldioxide regime 2 en lood regime 3.

Een aantal stedelijke gebieden in de zones vraagt extra aandacht, omdat de concentraties hier duidelijk verhoogd zijn ten opzichte van de regionale achtergrond in de betreffende zone. Deze extra aandacht voor de stedelijke gebieden buiten de agglomeraties wordt ingevuld door modelberekeningen die getoetst worden aan stedelijke metingen in de agglomeraties.

Om te voldoen aan de eisen van de eerste dochterrichtlijn zijn in totaal de volgende minimale aantallen stations nodig als de luchtkwaliteit alleen op basis van metingen zou moeten worden vastgesteld: 8 voor zwaveldioxide, 29 voor stikstofdioxide, 40 voor fijn stof resp. geen voor lood.

In die gevallen dat de concentratie van fijn stof of stikstofdioxide in een zone of agglomeratie boven de bovenste beoordelingsdrempel ligt, moet, van de op grond van het inwoneraantal

vereiste aantal stations, minimaal één station in de stadsachtergrond zijn en moet er minimaal één verkeersgericht station zijn. Voor fijn stof heeft dit betrekking op alle zones en alle agglomeraties. Voor stikstofdioxide geldt dit voor de zone *Midden* en voor alle agglomeraties.

In vergelijking met de huidige stationsconfiguratie en aantallen van de verschillende typen stations betekenen de eisen uit de dochterrichtlijn implementatie van een aantal nieuwe stations. Er moeten 8 nieuwe stations voor stikstofdioxide en 23 voor fijn stof worden ingericht.

Onder de aanname dat alleen metingen worden gebruikt om de luchtkwaliteit vast te stellen zou het aantal meetstations voor fijn stof aanzienlijk uitgebreid moeten worden. Het ruimtelijk beeld van de fijn stof concentraties, zoals dat met rekenmodellen is geconstrueerd, laat echter weinig variatie zien. Het is daarom twijfelachtig of verhoging van het huidige aantal stations een evenredige toename van de informatie over de luchtkwaliteit oplevert.

De hiervoor gegeven aantallen meetstations zijn richtinggevend bij het gebruik van *metingen alleen* om de luchtkwaliteit te beschrijven. Inzet van aanvullend instrumentarium om de luchtkwaliteit te beschrijven, zoals modellen, kan leiden tot een vermindering van het aantal meetstations. Ook kan het gebruik van modellen bijdragen tot een nauwkeuriger beschrijving van de luchtkwaliteit in stedelijke gebieden.

Naast de genoemde aantallen meetstations ten behoeve van de dochterrichtlijn zijn er momenteel meer meetstations operationeel om te voldoen aan andere informatiebehoeften zoals andere internationale verplichtingen, voor de validatie van modellen, de monitoring van trends, het verkrijgen van een compleet ruimtelijk beeld in Nederland en om te voorzien in de mogelijke uitval van stations.

Summary

The first daughter directive on air quality of the European Framework Directive came into force in 1999. This Directive concerned sulphur dioxide, nitrogen dioxide, nitrogen oxides, particulate matter and lead. Before this legislation is implemented, the member states have to describe the air quality in their respective countries in a *Preliminary Assessment of air quality for sulphur dioxide, nitrogen dioxide, nitrogen oxides, particulate matter and lead*. The current air quality in the Netherlands for these components has been assessed in the context of limit values, margins of tolerance and the assessment thresholds used in the daughter directive.

Three zones are defined in the Netherlands on the basis of the differences in air quality; these are the North zone (the provinces of Groningen, Friesland, Drenthe, Overijssel and Flevoland), the Middle zone (the provinces of Gelderland, Utrecht, Noord-Holland and Zuid-Holland) and the South zone (provinces of Limburg, Noord-Brabant and Zeeland).

Data on population, numbers and density, have led to six agglomerations being defined for the Netherlands: Amsterdam/Haarlem, Rotterdam/Dordrecht, The Hague/Leiden, Utrecht, Eindhoven and Heerlen/Kerkrade.

Testing for limit values yielded a yearly mean nitrogen dioxide level in many urban areas, which highly exceeded the limit value for this substance. This was also the case for particulate matter concentrations, but to a lesser extent. Depending on the air quality in relation to the assessment threshold levels in the daughter directive, there are three determinative strategies possible for assessing air quality. Regime 1, where the concentration is found above the upper assessment threshold level: measurements are always obligatory. Regime 2, where the concentration is found between the upper and lower assessment threshold level: measurements have to be used, possibly in combination with models. Regime 3, where the concentration is found below the lower assessment threshold level: measurements are not required under these circumstances. The air quality may in this case be described with models or based on objective estimates.

Testing led to the following results for the substances distinguished in the first daughter directive in the defined Dutch zones and agglomerations:
North zone: particulate matter - regime 1; other substances – regime 3.
Middle zone: nitrogen dioxide and particulate matter – regime 1, sulphur dioxide and lead – regime 3.
South zone: particulate matter - regime 1; nitrogen dioxide – regime 2; sulphur dioxide and lead – regime 3.
Agglomerations: Amsterdam/Haarlem, The Hague/Leiden, Utrecht, Eindhoven and Heerlen/Kerkrade: particulate matter and nitrogen dioxide- regime 1, sulphur dioxide and lead – regime 3.
Rotterdam/Dordrecht: particulate matter and nitrogen dioxide - regime 1, sulphur dioxide – regime 2 and lead – regime 3.

A number of urban areas in the above zones will need extra focus because the concentrations here are clearly increased with respect to the regional background concentrations in the respective zones. The extra attention for urban areas outside the agglomerations will be given in the form of model calculations to be tested using urban measurements in the agglomerations.

To meet the requirements of the first daughter directive the following minimal number of stations are needed if the air quality is to be determined on the basis of measurement: 8 for sulphur dioxide, 29 for nitrogen dioxide, 40 for particulate matter and zero for lead.

In cases where the concentration of particulate matter or nitrogen dioxide is found in a zone or agglomeration exceeding the upper assessment threshold level, minimally one of the required stations has to cover the city background levels and, minimally one station is needed as a traffic station. For particulate matter this is considered for all zones and agglomerations, while for nitrogen dioxide this only applies to the Middle Zone and all agglomerations.

Compared with the current station configuration and numbers of different types of stations, the requirements in the daughter directive will mean implementation of a number of new stations. Eight new stations will have to be set up for nitrogen dioxide, and 23 for particulate matter.

Under the assumption that only measurements are used to determine the air quality, the number of monitoring stations for particulate matter will have to be considerably extended. However, the spatial dispersion of particulate matter, as constructed in mathematical models does not show much variation. Therefore it's doubtful if increasing the number of current stations would provide a proportional increase in the information on air quality.

The above mentioned number of extra monitoring stations serves as a guideline in the use of *measurements only* in describing the air quality. The use of additional instruments, like models, to describe air quality can lead to a decrease in the number of monitoring stations. Also, models can also be used to contribute to a more accurate description of air quality in urban areas.

Besides the number of monitoring stations already mentioned for implementing the daughter directive, there are currently more stations operational for other information needs, such as meeting international obligations, validating models, monitoring trends, making comprehensive spatial maps of the Netherlands and providing for possible station breakdowns.

Contents

1. Introduction

In 1996 the Directive for the assessment and management of air quality (96/62/EG), known in short as the 'Framework Directive', came into force (EU, 1996). In this general directive the European Union has provided a reference framework for assessing and managing outside air. Targets for preventing harmful effects of air pollution on the population and the environment are taken up in this directive, along with a list of 13 air pollutants for which further legislation at the European level will need to be developed. This will be further worked out in the so-called daughter directives.

The first daughter directive, i.e. for sulphur dioxide (SO_2), nitrogen dioxide (NO_2), nitrogen oxides ($NO_x = NO + NO_2$), particulate matter (PM10) and lead (Pb) came into force in 1999. Limit values, alarm threshold values and margins of tolerance have been formulated in this directive. A number of rules and accompanying assessment values are also defined for air quality tests. The daughter directive mentioned will eventually replace former European directives for sulphur dioxide (and suspended particles), nitrogen dioxide and lead. Before the implementation of the directive, the member states are under obligation to provide a general description of the air quality of the respective components in the form of a so-called Preliminary Assessment. In setting up this assessment, use can be made of supporting information, like the report, *Guidance on assessment under the EU Air Quality Directives*[1] compiled by an EU Working Group and the supporting report *Guidance report on preliminary assessment under EC air quality directives* (Van Aalst *et al.*, 1998*).*

The aim of the preliminary assessment is to divide the member state area into so-called zones and agglomerations on the basis of air quality levels. The nature and extent of the required assessment instruments can then be determined for the prescribed zones using different assessment threshold levels.

This report will describe the results of the preliminary assessment of the air quality of sulphur dioxide (and suspended particles), nitrogen dioxide, nitrogen oxides, particulate matter and lead in the Netherlands. Chapter 2 will deal with the instruments for assessing air quality, like the Dutch Air Quality Monitoring Network (LML) and the used models. The testing framework defined in the first daughter directive will also be presented. Chapter 3 describes, in general, the current state of the air quality in terms of sulphur dioxide, nitrogen dioxide, nitrogen oxides, particulate matter and lead in the Netherlands. The focus here will be on air pollution levels in relation to the limit values from the first daughter directive. Measured and modelled air pollution levels will likewise be compared to upper and lower assessment values of the first daughter directive. Zone and agglomeration definitions supported by underlying reasons for these classifications will be presented in this chapter. In Chapter 4 use is made of the division into zones and agglomerations to guide the strategy set out for the assessment of the Dutch air quality. Possible consequences for future monitoring strategies are also discussed. Chapter 5 presents the conclusions in brief.

[1] This report has not been officially published, and is only available as a *final draft*, dated 6 October 2000.

2. Data and Methods

2.1 Measurements

The Dutch National Air Quality Monitoring Network (LML in Dutch) is the infrastructure used to monitor the air quality in the Netherlands. The LML consists of 54 stations, which can be characterised according to site and environmental characteristics (Van Elzakker, 2000):

- *Regional stations:* measurement stations located outside a built-up area and placed so as to avoid the measurements being influenced by local sources. For a number of components (sulphur dioxide, ozone, nitrogen oxides, particulate matter and chemical composition of precipitation), the spatial representativeness has been assumed in such a way as to allow a countrywide picture to be generated when the results of all regional stations are used collectively.
- *City stations*: located in an urban area which has been laid on so that the number of passing vehicles within a radius of 35 m from the station is less than 2750 per 24 hours (Anonymous, 1987; Eerens *et al.,* 1993).
- *Street stations*: located in an urban area which has been laid on so that the number of passing vehicles within a radius of 35 m from the station is at least 10,000 per 24 hours (Anonymous, 1987; Eerens *et al*., 1993).

The actual number of stations for the components named in the first daughter directive are shown in Van Elzakker (2000) (*Table 1*). All monitoring stations are connected to the Computer Information System for Air (RIL), where all monitoring data are stored. When air quality is described with the aid of measurement results in this report, validated data from the RIL database are used.

Table 1. Monitoring sites for sulphur dioxide, nitrogen dioxide, particulate matter and lead in the Dutch National Air Quality Monitoring Network (LML) for 2000 (Van Elzakker, 2000), categorised by the type of station.

Component	Regional	City	Street	**Total**
		number of stations		
Sulphur dioxide (SO_2)	27	5	5	**37**
Nitrogen oxides (NO_x)	26	6	13	**45**
Particulate matter (PM10)	10	4	5	**19**
Lead (Pb)	3	1	-	**4**

2.2 Models

OPS

The Operational Priority Components (OPS) model is an atmospheric-chemical transport model. The model uses data on emissions, chimney heights and possibly the heat content as input, along with meteorological data. The model can calculate time-averaged concentrations and depositions on a national or smaller scale. An extensive description of the model can be found in Van Jaarsveld (1989; 1995). This report documents model calculations made with the OPS model for lead near industrial installations. The uncertainty in the concentrations calculated by the model is 15% for a specific year, and 10% for the long term. Although validation of statements about individual sources has not yet been proven possible, comparisons to the national model show differences smaller than 35% (Van Jaarsveld, 1989).

SIGMA

The so-called post-processor model, SIGMA, assumes a linear relationship between emissions and concentrations or depositions. On a detailed level, emission scenarios of target groups in the Netherlands can be processed by SIGMA to calculate the consequences for the expected concentrations or depositions.

The relationship between emissions and concentrations or depositions is firstly determined for long-term meteorological conditions using the transport model OPS for a 5 x 5 km grid. A large group of source categories for home and abroad have been used as input for the reference year 1995. OPS measurements are very time consuming but have to be calculated only once to establish the relationships between emissions and concentrations or depositions. Subsequently the SIGMA model ensures that concentration fields are calculated very efficiently for a different composition of emission factors and for different target groups[2].

CAR

The acronym CAR stands for Calculation of Air pollution by Road traffic. The model assumes that concentrations at the curbside of a street are composed of: 1) the regional background concentration, 2) the contribution of pollution in the city and 3) the traffic emissions from the street. The regional background is determined from measurements taken through the LML at regional stations. The city contribution is calculated from the virtual diameter from the city and a mean concentration increase (relatively to the regional background per km of buildings). The traffic emissions are calculated from the number and type of traffic per 24 hours, the mean speed and emission factors. The CAR model is calibrated yearly because of influences from meteorological circumstances on concentrations in the street and the dynamics in emission factors. For application of the model on a national scale, a database with information on traffic density and other parameters relevant for emissions on the level of local authorities is used. See Eerens *et al.* (1993) for a detailed description of the model.

2.3 Examination framework

An examination framework for assessing air quality is found in the first daughter directive. A number of limit values are defined (*Table 2*), along with two so-called alert thresholds (*Table 3*), where actual information to the public is required. New in the legislation is a so-called ‘margin of tolerance’. The margin of tolerance is the percentage of the limit value decreasing with time by which this limit value may be exceeded subject to the conditions laid down in the directive (EU, 1996; *Table 4*). The margin of tolerance is somewhat comparable to the Dutch legislation used up to the recent past, called the ‘Exception limit value in loaded traffic situations’.

[2] The model will be described in an RIVM report still to be published by Vissenberg HA, Bloemen HjTHM, Eerens HC, Smeets WLM, Brandes LJ,’ SIGMA - A post processor for air quality assessments’.

Table 2. Limit values according to the first daughter directive (EU, 1999).

Component	Aim[1]	Unity	Limit value	Measuring period	Exceedance
Sulphur dioxide	H	µg SO_2/m^3	350	Hour	Not more than 24× per year
	H	.	125	24 hour	Not more than 3× per year
	E	.	20	Year	Not allowed
	E	.	20	Winter (half yearly)	Not allowed
Nitrogen dioxide	H	µg NO_2/m^3	200	Hour	Not more than 18× per year
	H	.	40	Year	Not allowed
Nitrogen oxides	V	µg NO_x/m^3	30 [2]	Year	Not allowed
Particulate matter (PM10)	H	µg/m³	50	Hour	Not more than 35× per year
	H	.	40	Year	Not allowed
Lead	H	µg Pb/m³	0.5	Year	Not allowed

[1] H: protection of human health.
E: protection of ecosystems.
V: protection of vegetation.
[2] Expressed in µg NO_2/m^3.

Table 3. Alert thresholds according to the first daughter directive (EU, 1999).

Component	Aim[1]	Unity	Limit value	Measuring period	Remark
Sulphur dioxide	H	µg SO_2/m^3	500	Hour	During three successive hours in an area with a surface area of more than 100 km²
Nitrogen dioxide	H	µg NO_2/m^3	400	Hour	During three successive hours in an area with a surface area of more than 100 km²

[1] H: protection of human health.

Table 4. Margins of tolerance of limit values according to the first daughter directive (EU, 1999).

Component	Limit value	Measuring period	Margin of tolerance
Sulphur dioxide	350 µg SO_2/m^3	Hour	43%, decreasing to 0 in 5 years
Nitrogen dioxide	200 µg NO_2/m^3	Hour	50%, decreasing to 0 in 10 years
	40 µg NO_2/m^3	Year	50%, decreasing to 0 in 10 years
Particulate matter (PM10)	50 µg/m³	Hour	50%, decreasing to 0 in 5 years
	40 µg/m³	Year	20%, decreasing to 0 in 5 years
Lead	0.5 µg Pb/m³	Year	100%, decreasing to 0 in 5 (or 10) years [1]

[1] Ten years is valid near specific point sources.

Assessment threshold levels

Under the framework directive and the first daughter directive, the amount of effort required to assess the air quality is dependent on the actual air quality concentrations in relation to how far they are from the limit value. For this purpose, two so-called assessment threshold levels have been defined for each component in the daughter directive: the upper and the lower threshold levels. The corresponding values, which differ per component, are defined as percentages of the limit value of the component concerned. The assessment threshold levels are meant to aid in the air quality assessment strategy. Three different situations can be distinguished (see below and *Figure 1*):

- *The concentration exceeds the upper threshold level*[3] *(regime 1*). Measurements are always obligatory in this situation. If measurements in this case are the only instruments to assess the air quality, a certain minimum number of monitoring stations per zone or agglomeration is required. This minimum is determined by the number of inhabitants or, in the case of the limit value for the protection of ecosystems, the surface area. Furthermore, other instruments besides measurement data are always allowed for the assessment of the air quality. The minimum number of monitoring stations mentioned here as a requirement is then cancelled. However, certain quality criteria are given for the instruments used (Van Aalst *et al.*, 1998).
- *The concentration occurs between the upper and lower assessment threshold levels (regime 2).* Measurements need to be used; if desired, these may be in combination with models. No further requirements are given for the number of measurements and the accuracy of the instruments used.
- *The concentration occurs below the lower assessment threshold (regime 3).* Measurements are not required under these circumstances. The air quality can be assessed with models or with the use of objective estimates.

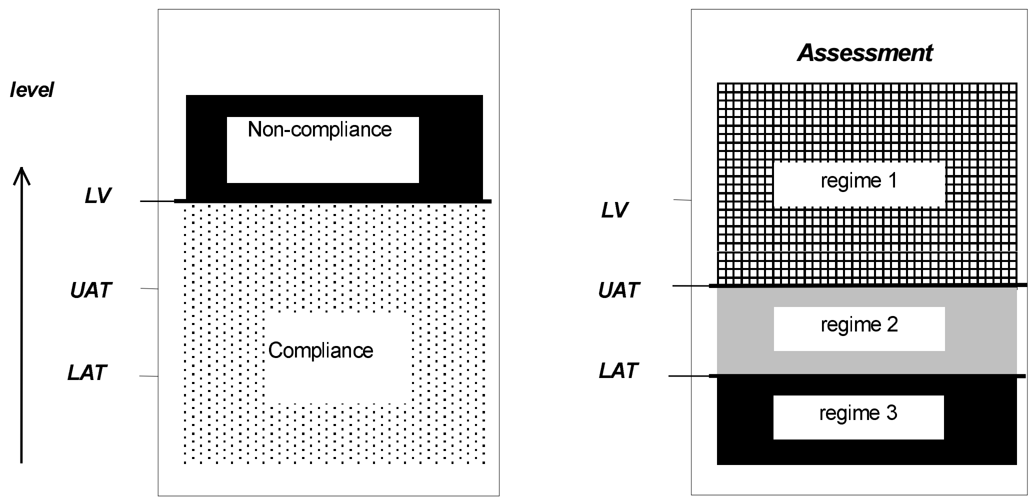

Figure 1. Implication of exceeding the limit value (LV), the upper assessment and lower assessment thresholds (UAT and LAT) for compliance judgement and assessment requirements in a zone (Van Aalst et al., 1999).

It is important to state that exceedance of a limit value in an area does not mean poor air quality in the whole area. When the upper threshold is exceeded, measurements may still comply to European limit values (see also *Figure 1*). Furthermore, an area needs to be characterised as having the *highest* concentration recorded in that area.

The assessment method for an area needs to be determined in relation to the upper and lower threshold levels mentioned in the first daughter directive (*Table 5*).

[3] Included is the situation where the concentration is higher than the limit value.

Table 5. Limit values and related upper and lower assessment threshold levels (EU, 1999).

Component	Nature of the limit value	Unity	Limit value	Upper assessment threshold level	Lower assessment threshold level
Sulphur dioxide	Daily mean Protection of human health	µg SO_2/m³	125	75	50
	Winter half-yearly mean Protection of ecosystems	.	20	12	8
Nitrogen dioxide	Hourly mean Protection of human health	µg NO_2/m³	200	140	100
	Yearly mean Protection of human health	.	40	32	26
Nitrogen oxides	Yearly mean Protection of the vegetation	µg NO_x/m³	30 [1]	24	19,5
Particulate matter	Daily mean Protection of human health	µg/m³	50	30	20
	Yearly mean Protection of human health	.	40	14 [2]	10 [2]
Lead	Yearly mean Protection of human health	µg Pb/m³	0.5	0.35	0.25

[1] Expressed in µg NO_2/m³.
[2] Based on the indicative limit values of January 1, 2010.

Examination of assessment threshold levels, based on concentrations, or otherwise the number of exceedances of a defined value over the last five years, are carried out where sufficient data are available. In this case, an assessment threshold will be deemed to have been exceeded if the total number of exceedances during these five years is more than three times the number of exceedances allowed each year.

Zones and agglomerations

New in the legislation is the introduction of zones and agglomerations. These are areas for which assessment of the air quality needs to be done. The determination of the zones and agglomerations, and the reproduction of the underlying motives, is one of the final goals of the preliminary assessment according to the earlier mentioned supportive report, *Guidance on assessment under the EU Air Quality Directives.* The classification in zones and agglomerations is then used as a tool to realise a description of the air quality for the whole area, with an eye to both the spatial variability and generalisations.

According to the first daughter directive, the definition of a zone is: '*a part of their territory delimited by the member states*'. The definition of an agglomeration is: '*a zone with a population concentration in excess of 250,000 inhabitants or, where the population concentration is 250,000 inhabitants or less, a population density per km^2 which, for the member states, justifies the need for ambient air quality to be assessed and managed'.*

The definitions in the directive are kept general on purpose to give EU member states the possibility to define optimally and for their specific situations how the zones need to be geographically defined and implemented. The zones are required to be defined in such a way that for each location within the territory of a member state, it is simple to unambiguously determine to which zone it belongs. The earlier mentioned guidance report gives some important starting points.

The air quality in a country needs to be described with the aid of these zones and agglomerations. This means in this preliminary assessment that a division of the Netherlands into zones and agglomerations needs to be made. A division, once chosen, together with information on the air quality and the upper and lower assessment strategies, will lead to a determination of the required assessment strategy for the air quality. The scale related to the measurement effort is, as far as the protection of the human health goes, related to the number of inhabitants in a zone or agglomeration (*Table 6*). A different approach is used for the protection of ecosystems and vegetation. The minimum number of measurement locations is one per 20,000 km^2 if the concentration occurs above the upper assessment threshold level. If the concentration is found between the lower and upper assessment threshold level, one station per 40,000 km^2 will be required.

Table 6. Minimum number of monitoring sites using measurements as the only source of information (EU, 1999).

Number of inhabitants in the zone/agglomeration	Concentration above the upper assessment level [1]	Concentration betweeen the upper and the lower assessment level	Concentration below the lower assessment level [2]
x thousands		*number of sites*	
0-250	1	1	-
250-499	2	1	1
500-749	2	1	1
750-999	3	1	1
1000-1499	4	2	1
1500-1999	5	2	1
2000-2749	6	3	2
2750-3749	7	3	2
3750-4749	8	4	2
4750-5999	9	4	2
>6000	10	5	3

[1] For nitrogen dioxide and particulte matter minimal one site in the urban background and one traffic oriented site. Following Dutch terminology a city background site and a street site (see also section 2.1).
[2] I**n agglomerations** only and for nitrogen dioxide and sulphur dioxde only.

3. Results

3.1 Introductory remarks

A combination of measurements and model results will be used here to describe in general the air quality in the Netherlands. Measurements, reproduced as percentiles and means, are given for the year 1999, while for the model results, the reference year is given. Concentrations of components will, as far as possible, be examined for the European limit values in this assessment. However, the defined air quality targets for the daughter directive sometimes deviate from the currently used parameters for describing the air quality in the Netherlands. The air quality will as far as possible be described in this chapter in such a way as to provide insight into the relationship between the air quality in the Netherlands and the targets of the daughter directive. In addition, the different concentration levels in the Netherlands will be tested on a regional scale against the defined upper and lower assessment threshold levels. For this purpose, LML measurements from a time period of five years, i.e.1995-1999 have been used. Examination of the assessment threshold levels will be used in Chapter 4 as a starting point to determine the direction of the assessment strategy for the Dutch air quality.

3.2 Sulphur dioxide

Air quality and concentrations in relation to limit value

An hourly mean limit value of 350 µg SO_2/m^3 for the protection of human health is used in the daughter directive. This hourly value may not be exceeded more than 24 times a year, which roughly coincides with the 99.7th percentile. The LML measurements show that even the maximum hourly concentrations do not exceed the level of 350 µg SO_2/m^3. The second threshold level for the protection of human health is the daily mean of 125 µg SO_2/m^3. This value may not be exceeded more than three times a year, which roughly coincides with the 99.5th percentile. The measurements from the LML show maximum daily mean concentrations of 100 µg/m³ at the most.

The EU standard for the hourly mean (350 µg SO_2/m^3) is, as far as stringency goes, comparable to the current Dutch standard for the 98th percentile (Van Velze *et al.*, 2000). The spatial overview for 1999 is based on interpolated observations (*Figure 2*). The countrywide mean of 98th percentile of daily means was about 9 µg SO_2/m^3 in 1999. The highest levels – closely connected with local industry and the proximity of Belgian sources - were observed in Zeeland. The 98th percentile was slightly increased in several towns due to emissions from industry and traffic.

The countrywide mean 98th percentile of sulfur dioxide has significantly decreased since 1988 due to emission-reduction measures at the most important sources, namely power plants and refineries. The ongoing emission reductions in the Netherlands and the adjacent countries still cause a slightly decreasing trend in the 98th percentile, besides some yearly fluctuations.

For the protection of ecosystems, a limit value of 20 µg SO_2/m^3 for the yearly and winter means is defined. Yearly concentrations for sulphur dioxide are calculated with the model SIGMA (*Figure 3*). SIGMA uses emission factors for source categories from home and abroad as input to calculate the spatial variation for the yearly mean concentration. The calculations refer to the year 1997. The countrywide spatial gradient and the location of local increased concentration levels match the model and measurements well. The highest levels are observed in the Rijnmond area, Zeeland and southwest Brabant-North. This coincides with local industry and the proximity of Belgian sources. Concentrations above the 20 µg SO_2/m^3 are very limited in urban or industrial areas (*Figure 3*), which have a total surface area of less than 100 km^2.

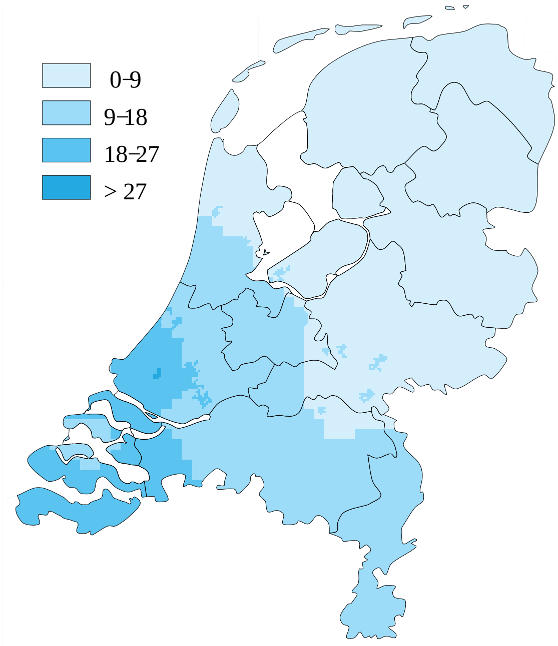

Figure 2. Spatial variation of the 98^{th} *percentile of daily mean sulphur dioxide concentrations on the basis of measurements for 1999. Concentrations in µg* SO_2/m^3.

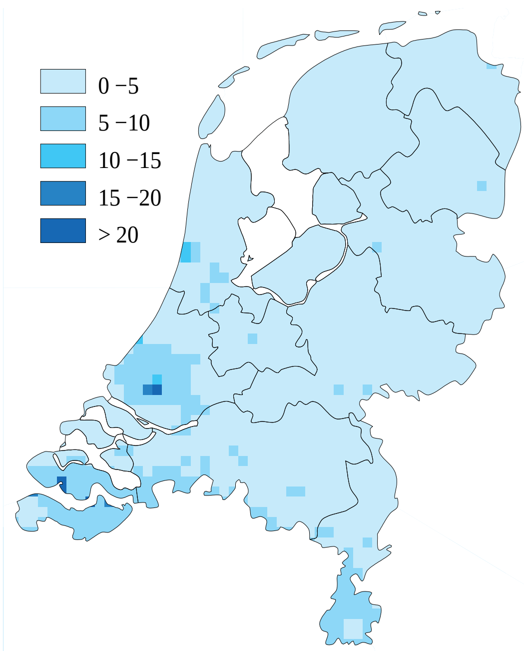

Figure 3. Spatial variation of the yearly mean sulphur dioxide concentrations according to the SIGMA model for 1997. Concentrations in µg SO_2/m^3.

Concentrations in relation to assessment threshold levels

The measurement data on sulphur dioxide for the 1995-1999 period are related to the lower and upper assessment threshold levels of the limit value for the daily mean (50 and 75 µg SO_2/m^3, respectively) and with the lower and upper assessment threshold levels for the limit value for the winter and yearly means (12 and 8 µg SO_2/m^3, respectively). Stations are not distinguished according to type for threshold levels for the protection of health; for assessment threshold levels for the protection of ecosystems and vegetation only data from regional stations are considered.

For sulphur dioxide, lower assessment threshold levels for the daily mean are exceeded at nine regional stations. These stations are situated mainly in the southern half of the Netherlands. Within and near large cities in the Randstad, the lower assessment threshold levels for the daily mean are exceeded nowhere, except for one city station and one street station in Rotterdam in the Rijnmond area. A very limited exceedance of the lower assessment threshold level was observed at a monitoring station in Kerkrade. The lower assessment threshold level has been exceeded ten times in five years, while nine are permitted. Fifteen exceedances of the upper assessment threshold value for sulphur dioxide were observed at a regional station near the Belgian border.

The examination of concentrations in relation to assessment threshold levels for the winter or yearly mean shows a spatial gradient in the Netherlands. The lower assessment threshold level is exceeded nowhere in the northeast of the Netherlands; in the middle of the country the lower assessment threshold level is exceeded at three regional stations, and the upper assessment threshold level at a single regional station, while in the southwest the upper assessment threshold level for sulphur dioxide is exceeded at several stations. This gradient for the winter and yearly means is reproduced qualitatively and quantitatively by the model, SIGMA (*Figure 3*). A more detailed overview of the results of the examination of measurement data is given in Annex B.

3.3 Nitrogen dioxide

Air quality and concentrations in relation to limit values

An hourly mean nitrogen dioxide concentration of 200 µg/m³ is given as one of the limit values for the protection of human health in the daughter directive. This hourly value may not be exceeded more than 18 times a year. A study of Van Velze *et al.* (2000) shows this limit value to be comparable to the current Dutch limit value for the 98th percentile for hourly values (135 µg/m³). As the Dutch limit value is not exceeded, it is not probable that the European limit value of 200 µg/m³ is exceeded.

The countrywide mean 98th percentile for hourly values was 58 µg/m³ in 1999. De 98th percentiles were highest in the Randstad and lowest in the northeast of the country (*Figure 4*).

The yearly mean concentration of nitrogen dioxide was 22 µg/m³, averaged for the Netherlands in 1999. Exceedances of the limit value of 40 µg/m³ occurred in the city background of several large cities like Amsterdam, Rotterdam, The Hague and Utrecht. The yearly mean nitrogen dioxide concentration was also calculated with SIGMA for the year 1997 (*Figure 5*). The rural gradient and the local elevation of concentrations match well with the measurement results from the LML. The mean concentration in the Netherlands in 1997 amounts to 22 µg/m³ according to the model, compared to 24 µg/m³ according to the LML measurements in 1997.

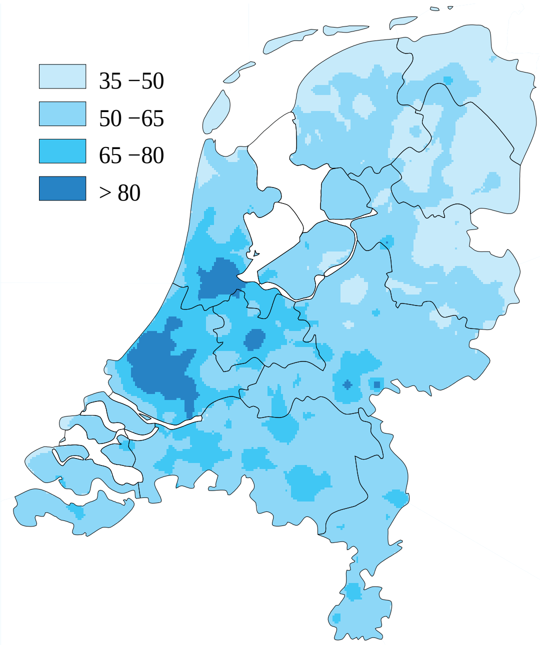

Figure 4. Spatial distribution of the 98th percentile of the hourly mean nitrogen dioxide concentration in 1999 based on measurements. Concentrations in µg NO_2/m³.

Since1989 there has been a decreasing trend of 2% per year in the measured countrywide yearly mean of nitrogen dioxide (*Figure 6*). The decrease was greatest at the beginning of the nineties. Thereafter the decreasing trend continued, with a decrease of 1.4% per year since 1992. Emission-reduction measures in industry, and the energy production and traffic sectors have contributed to the decrease. The decrease at the beginning of the nineties was largely caused by the introduction of the catalytic convertor in road traffic.

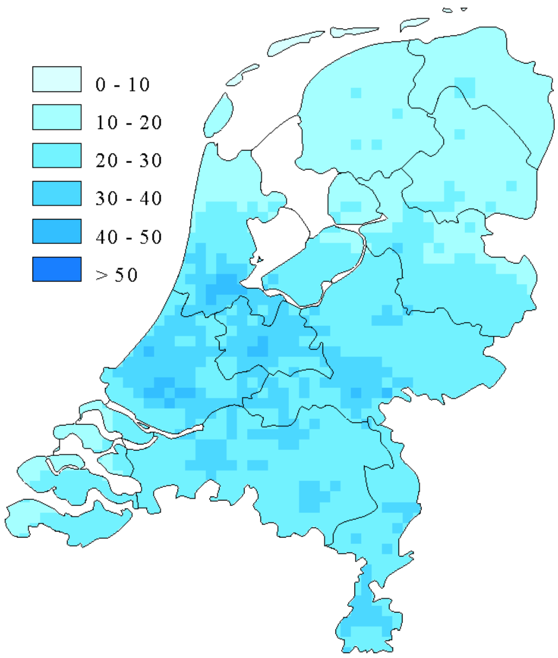

Figure 5. Spatial distribution of the yearly mean nitrogen dioxide concentrations according to the SIGMA model for 1997. Concentrations in µg NO_2/m³.

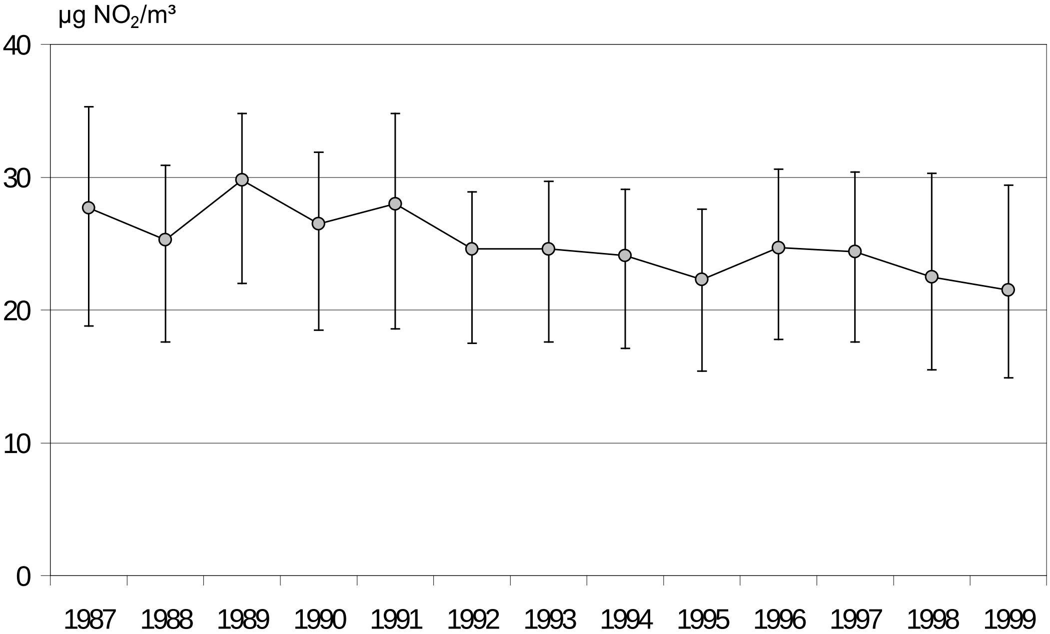

Figure 6. Countrywide mean measured concentration of nitrogen dioxide for 1987-1999. The margin shows the 10th percentile (below) and the 90th percentile (above).

The hourly limit value (200 µg/m³, maximum 18 exceedances per year) was not exceeded in 1999. The yearly limit value (40 µg/m³) was exceeded at most of the city and street stations in 1999.

For the assessment of air quality targets, the measurement data from the LML are used along with models. Calculations by the CAR model show that in 1999 the limit value for the yearly mean was exceeded on 44% of the roads in Dutch cities all over the country. If the temporary margin of tolerance is taken into account (together in total 60 µg NO_2/m³), exceedances would occur along 0.4% of the roads in Dutch cities. Specially cited here are the busy roadways in urban areas. Here, the limit values are also exceeded on a large scale (Van Velze *et al.*, 2000).

Measured levels in relation to assessment threshold levels

Nitrogen dioxide levels were related to assessment threshold levels of limit values for the hourly means (100 and 140 µg NO_2/m³, respectively). The upper assessment threshold level for limit values for the hourly mean were exceeded in the middle of the country and especially, locally, near measurement stations in large cities in the Randstad. No exceedances of the lower assessment threshold level have been observed in the north of the Netherlands. In the south of the country, exceedances of the lower assessment threshold level were observed at two regional stations in the 1995-1999 period.

Examination of measured levels to assessment threshold levels for the limit value for the yearly mean (32 and 26 µg NO_2/m³, respectively) shows the upper assessment threshold level in all large cities in the Randstad to be exceeded. In the north of the Netherlands, however, no exceedance of the lower assessment threshold level was observed. In the south of the Netherlands 4 of the 9 regional stations show an exceedance of the lower assessment threshold level, but not of the upper assessment threshold level. A more detailed overview of the results of this examination is given in Annex B.

3.4 Nitrogen oxides

Air quality and measured levels in relation to limit values

In the daughter directive, a yearly mean of 30 µg NO_x/m^3 is determined as the limit value for the protection of vegetation. The spatial distribution of the mean NO_x concentrations have been calculated for the Netherlands on the basis of measurement results (*Figure 7*).

The limit value for the yearly mean for the protection of the vegetation (30 µg NO_x/m^3) was exceeeded at 31 of the 45 measurement stations in 1999. This exceedance took place especially in large cities in the south and middle of the country. No exceedances occurred in the north of the country.

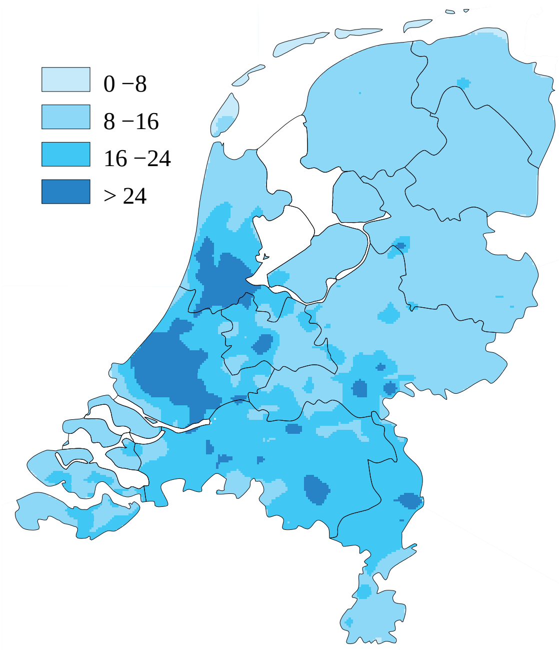

Figure 7. Spatial distribution of the mean nitrogen oxide concentrations based on measurements for 1999. Concentrations in ppb.

Measured levels in relation to assessment threshold levels

Examination for comparison to assessment threshold levels of nitrogen oxides for the protection of vegetation takes place with the limit values for the yearly means. These assessment threshold levels are 24 and 19.5 µg NO_x/m^3, respectively.

The analysis at regional measurement stations yielded exceedances of the upper assessment threshold level for the middle and the south of the country in the 1995-1999 period. In the north of the country 3 of the 8 regional measurement stations showed an exceedance of the upper assessment threshold level for nitrogen oxides. A more detailed overview of these results are given in Appendix B.

3.5 Particulate matter (PM10)

Air quality and examination to limit values

The spatial overview for PM10 concentrations is presented on maps showing the number of days in 1999 in which particulate matter concentrations are exceeding the limit value. The maps are based on interpolated observations taken from regional LML measuring stations. The limit values combined with the margin of tolerance for 2001 (75 µg/m³ for the daily mean) are exceeded for considerably fewer than 35 days in the Netherlands in 1999.

The new limit value for 2005 (50 µg/m³ for the daily mean) is exceeded in a large part of the Netherlands for more than 35 days. A gradient of increasing concentrations of particulate matter can be observed from the north to the south of the country. This is caused by the increasing influence of sources within the Netherlands and elsewhere on the continent. This is also obvious in the number of exceedances of the limit values of 50 µg/m³ for the daily means (*Figure 8*). Based on regional measurements, the countrywide mean number of days showing an exceedance of the limit value of 50 µg/m³ seems to decrease. Next to coincidentally occurring meteorological conditions (such as the severe winters of 1996 and 1997) the emission reduction of acidifying substances and primairy particulate matter which has set in, seems to play a role in the decreasing concentrations of particulate matter (*Figure 9*).

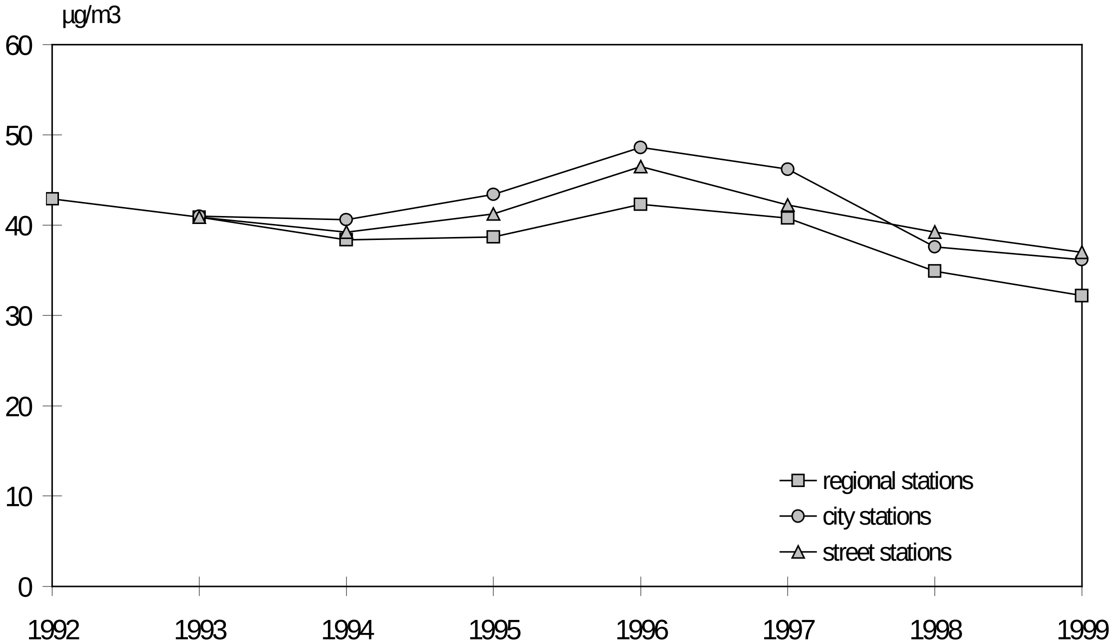

Figure 8. Countrywide mean concentration of particulate matter PM10 for 1992-1999 based on measurements.

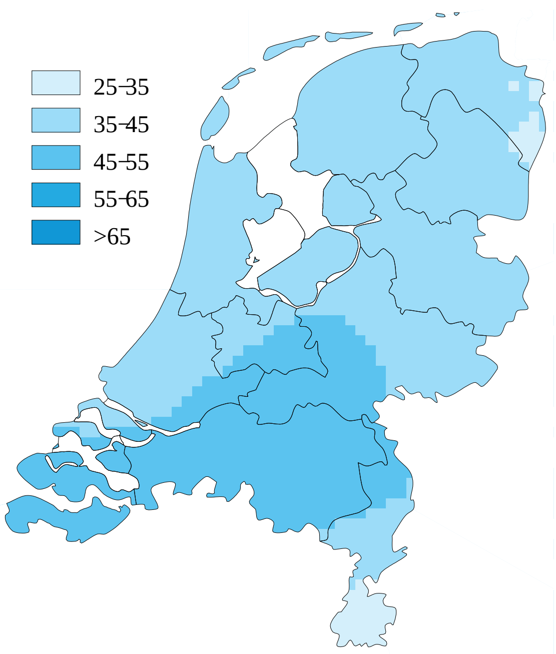

Figure 9. Number of days in which the daily mean concentration of 50 µg/m³ is exceeded based on measurements for 1999.

The limit value of 40 µg/m³ for the yearly mean concentration of particulate matter is still exceeded in a limited number of urban areas in the Netherlands. Averaged over the whole country, the yearly mean concentration of particulate matter amounted to 32 µg/m³ in 1999 (*Figure 10*). This spatial picture is based on LML measurements, where the information from the models was used to interpolate the measurement locations. The concentration increases from the north to the south; this is caused by an increasing influence of sources both in the Netherlands and elsewhere on the continent. Somewhat increased concentrations up to about 10 µg/m³ occur in busy streets in the vicinity of local sources (cities and industrial areas).

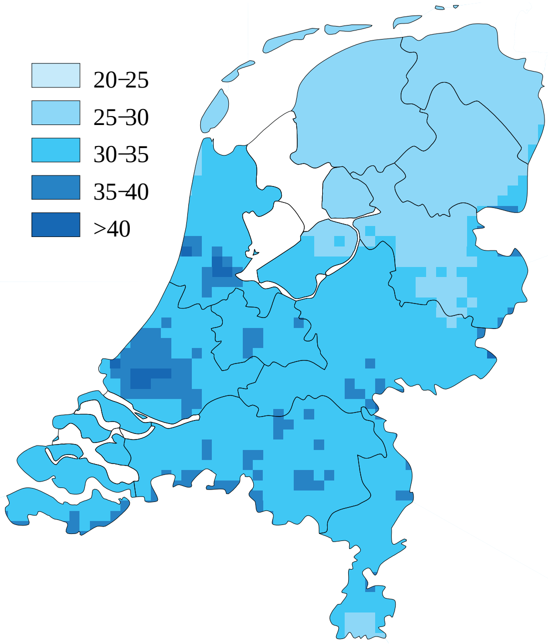

Figure 10. Spatial distribution of the yearly mean particulate matter PM10, based on measurements for 1999; concentrations in µg/m³.

The daily limit value of 50 µg/m³ is on average exceeded 42 times in the Netherlands in 1999. In the long term, only 35 exceedances per year are permitted.

Measured levels in relation to assessment threshold levels
For particulate matter (PM10), examination to assessment threshold levels for limit values takes place against daily and yearly means. The respective assessment threshold levels are 30 and 20 µg/m³ (daily mean) and 14 and 10 µg/m³ (yearly mean). Exceedances of the upper assessment threshold level take place at all the measuring stations. More detailed information of the results of the examination can be found in Annex B.

3.6 Lead

Air quality and the examination to limit values
The yearly mean concentration of lead in the atmosphere in the Netherlands has, since 1984, decreased by more than 92%, up to 0.012 µg/m³ in 1999. After a sharp decline in the eighties, caused by emission reduction measures affecting the target group, traffic, the decrease was reduced in the nineties. This is mainly caused by the universal use of 'clean' petrol.

From way back, strongly increased concentrations of lead caused by traffic were observed in urban areas. Exceedance of the old Dutch limit value of 0.5 µg/m³ took place on a large scale in Dutch cities in the beginning of the eighties (RIVM, 1999). Since 1992, exceedances of the limit value occur no longer, even not in the most loaded traffic situations (*Figure 11*, also see Van Velze, *et. al*., 2000).

Measurement results of air concentrations at regional sites show a decreasing trend and match closer with each other; this may be caused by a decrease in the influence of sources south of the Netherlands. A gradient can be observed in the regional concentrations from the south ('high') to the north ('low'). Yearly mean levels amount to 0.010-0.015 µg/m³ (see *Table 7*).

Table 7. Lead concentrations in air, 1999.

Monitoring site	Location/Type	Concentration
		µg lead/m³
Kollumerwaard	North of Netherlands; regional	0.011
Bilthoven	Middle of Netherlands; regional	0.011
Biest-Houtakker	South of Netherlands; regional	0.014
Vlaardingen	Rijnmond area; streetstation	0.012

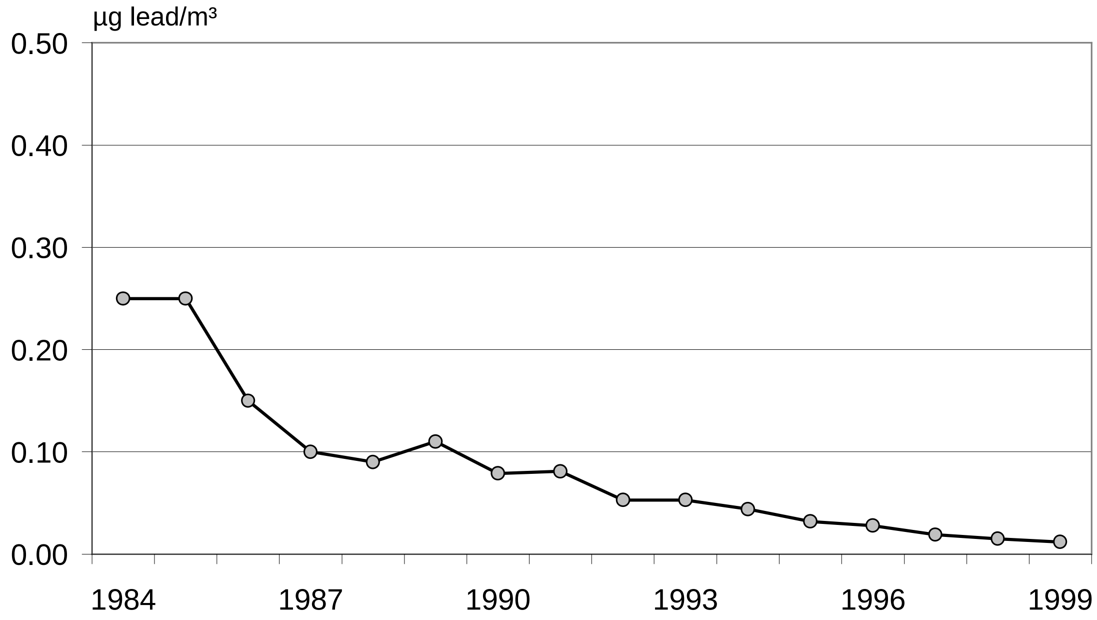

Figure 11. Yearly mean measured lead concentration in air at the urban montioring site of Vlaardingen for 1984-1999.

Industrial sources

A more detailed overview of concentration levels around the most loaded industrial sources can be attained with the aid of data from the Emission Registration on emissions, chimney heights and locations of individual industrial sources (*Table 8*), together with the model OPS. The air quality near 'De Hoogovens' in Beverwijk is not shown in this table; this situation will be described independently.

Table 8. Results of dispersion calculations for industrial sources of lead for 1995 emissions.

Source	Location	C_{max} [1]	d_{max} [2]	C_{gem} [3]
		µg/m³	*m*	*µg/m³*
PLM Glas	Dongen	0.19	35	0.13
Budelco	Budel	0.17	35	0.12
Nedstaal	Alblasserdam	0.15	35	0.12
RMI Holland	Bergen op Zoom	0.04	35	0.06
Nedri Spanstaal	Venlo	0.05	35	0.06

[1] The maximum calculated concentration.
[2] The distance to the source where the maximum concentration is found.
[3] The mean concentration over the model area (1 km²).

Hoogovens

From a more detailed analysis of the situation near industrial sources with the aid of model calculations, it seemed possible to expect higher concentration levels in the vicinity of Hoogovens. During 1999, more recent data on emission characteristics (emissions for 1996, chimney heights and heat content) became available from the Hoogovens for the RIVM project ‘Scanning and scouting air’. The load in the vicinity of the Hoogovens area was re-calculated with these renewed official emission data for lead. The model used an area of 100 km^2, and a gridcell size of 500 x 500 m. The calculated maximum concentration based on the new emission data amounts to about 7.3 µg/m³. This maximum is calculated within the company property boundaries. The mean concentrations over the model area (10 x10 km^2) considered is calculated at 0.34 µg/m³. A concentration of 0.15 µg/m³ was calculated at the monitoring site in Beverwijk. The measurements executed by the RIVM show a local mean concentration of 0.020 µg/m³, which is almost a factor of 10 lower than calculated. Further consultation with the Hoogovens lead to valid re-adjusted emission data becoming available for the 1998/beginning 1999 period[4]. According to this information from the Hoogovens, the lead emissions can be attributed to two emission sources having a chimney height of 150 m (used to be 20 m) and located very close to each other. We are concerned here with fractionally lower emissions than in the emission registration. Once again calculations have been made using these re-adjusted data, also for a model area of 100 km^2 and a grid cell size of 500 x 500 m (*Figure 12*). The result is a maximum calculated concentration of 0.060 µg/m³ at a distance of 1.5 km northeast of the source (just inside of the company terrain boundaries). The mean concentration of the model area concerned (10 x 10 km) is now calculated to be 0.021 µg/m³. To check the results of the calculations, measurements were taken in Beverwijk in 1998/1999 at about 4 km northeast of the company terrain. A concentration of 0.025 µg/m³ was now calculated at the location of this measurement point [5]. If an estimated background contribution of 0.010-0.015 µg/m³ is added, this results in a concentration of 0.035-0.040 µg/m³. This reasonably matches the locally measured concentration of 0.020 µg/m³.

[4] Per July 1999, improvement measures were implemented at the most important source, as a result of which the lead emissions have further decreased by about 70%. Calculations were made using emission data prior to the improvement measures.
[5] The measurements were completed before the implementation of improvement measures. On the basis of the mentioned emission reduction, the contribution of Hoogovens in Beverwijk to the lead concentration will be expected to decrease further to about 0.005-0.010 µg/m³.

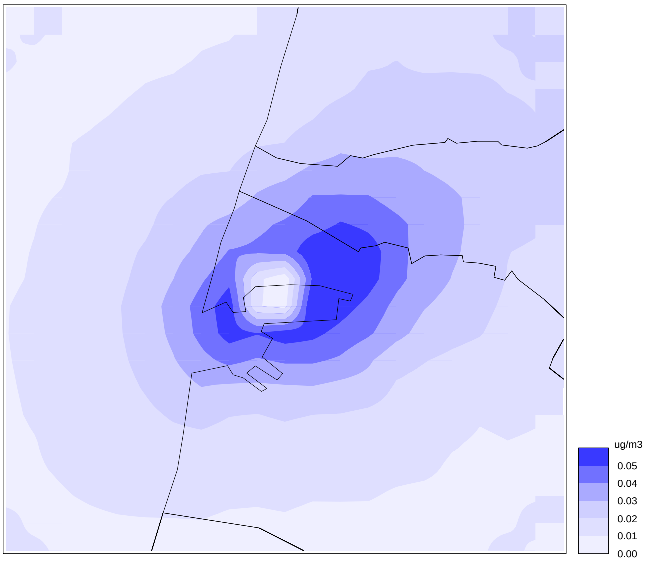

Figure 12. Calculated lead concentrations in air in the vicinity of the Hoogovens. Emission data are valid for 1998/1999 before the implementation of improvement measures. The concentrations mentioned exclude the background contribution; this is estimated at 0.010-0.015 µg/m³ in the modelling area.

Measured levels in relation to assessment threshold levels

For lead, an examination for comparison to the assessment threshold levels for limit values of the yearly mean took place. The assessment threshold levels were 0.35 (upper level) and 0.25 (lower level) µg/m³, respectively. For all the monitoring stations, the concentrations remain below the lower assessment threshold level. More detailed information on the results of the examination are given in Appendix B.

3.7 Zones and agglomerations

In determining the number, and the boundaries of the zones and agglomerations in the Netherlands, the following criteria have been used:

- The borders are taken as the boundaries of areas used by local air quality management authorities. These authorities are responsible for taking measures in case of exceedances in their area.
- Adjoining areas with interrelated air quality should preferably be combined, since only co-ordinated measures will be effective. Dependency in air quality may be the case if there is a substantial impact on local air quality by dispersion in one to another area or if areas have the same source characteristics and/or density.
- Adjoining areas with the same levels of air pollution with respect to the limit values and assessment threshold levels of the EU directives should be combined in one zone. This enhances the possibility of getting a good overall picture of air quality and of the efficiency of reporting by reducing the number of zones.
- Choices are not determined by ‘science’ alone. The definition of zones and agglomerations should be as workable and feasible as possible.

A global view of the air quality in non-urban areas shows the differences in the Netherlands for particulate matter to be small. The levels of sulphur dioxide and nitrogen dioxide, however, show clear differences. For nitrogen dioxide, the levels are the lowest in the north, and highest in the middle. The south of the Netherlands takes a intermediate position (see also section 3.3 and *Figure 5*). For sulphur dioxide, the levels are lowest in the north, and highest in the south. Lead concentrations in air are low over the whole country, and show a weak gradient from the south ('higher') to the north ('lower'). This information is reason enough, along with the above-mentioned criteria, to divide the Netherlands into three zones: North, Middle, and South (*Table 9*, *Figure 13*[6]).

Table 9. Zones in the Netherlands.

No.	Zone	Province	Number of inhabitants[1]
			x thousands
1	North	Groningen, Friesland, Drenthe, Overijssel, Flevoland	3,025
2	Middle	Gelderland, Utrecht, Noord-Holland, Zuid-Holland	4,695
3	South	Limburg, Noord-Brabant, Zeeland	3,190

[1] The inhabitants of agglomerations are not included in the number of inhabitants for the zones; see also *Table 10*.

The basis for arriving at the number and location of agglomerations is the spatial distribution of the population density on a scale of 1x1 km^2. A connected area with a population density above 750 inhabitants per km^2 is nominated as an agglomeration if the total number of inhabitants of the air quality management area comes to more than 250,000. For the Netherlands, this results in six agglomerations (*Table 10, Figure 13*).

Table 10. Agglomerations in the Netherlands (CBS, 2000).

No	City centre	Surrounding municipalities	Number of inhabitants
			x thousands
1	Amsterdam/ Haarlem	Amsterdam, Aalsmeer, Amstelveen, Uithoorn, Ouder Amstel, Diemen, Zaanstad, Heemskerk, Beverwijk, Velsen, Haarlem, Bloemendaal, Zandvoort, Heemstede, Bennebroek, Haarlemmerliede, Spaanwoude and Haarlemmermeer	1,490
2	Rotterdam/ Dordrecht	Rotterdam, Schiedam, Vlaardingen, Maassluis, Rozenburg, Spijkenisse, Albrandswaard, Capelle a/d IJssel, Ridderkerk, Barendrecht, Heerjansdam, Zwijndrecht, Hendrik-ido-Ambacht, Dordrecht, Papendrecht and Sliedrecht	1,250
3	The Hague/ Leiden	The Hague, Monster, 's Gravenzande, Naaldwijk, De Lier, Maasland, Schipluiden, Wateringen, Delft, Rijswijk, Voorburg, Leidschendam, Wassenaar, Voorschoten, Leiden, Oegstgeest, Katwijk, Valkenburg, Rijnsburg and Leiderdorp	1,045
4	Utrecht	Utrecht, Houten, Nieuwegein, IJsselstein, Vleuten-De Meern and Maarssen	415
5	Eindhoven	Eindhoven, Best, Veldhoven, Geldrop, Mierlo, Nuenen and Helmond	410
6	Heerlen/ Kerkrade	Heerlen, Kerkrade, Landgraaf, Brunssum, Voerendaal and Nuth	250

[6] The work presented here is partly based on an unpublished work of H. Eerens and P. Builtjes, 'Assessment of ambient air quality in the Netherlands under the 'EU Framework Directive 1999', Interim report, second draft, TNO/RIVM.

Figure 13. Zones and agglomerations in the Netherlands.

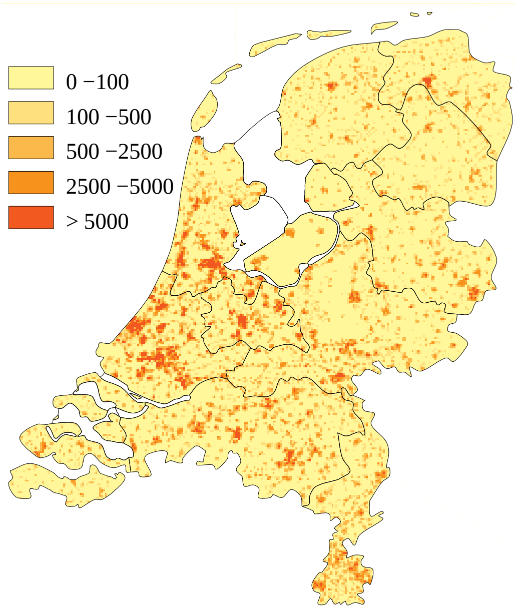

Figure 14. Population density in the Netherlands as number of inhabitants per km^2 (CBS, 2000).

The Netherlands has a high population density with a lot of urban areas in a relatively small surface area. Next to the already defined agglomerations (*Table 10*), there are also other urban areas in the zones (*Figure 14*). This calls for a subtle approach to describing the air quality in the zones. In the first place, an assessment of the air quality in the regional part of the zone; this concerns the largest area. In the second place, the air quality in the urban parts of a zone; the air quality might be assessed lower for some components due to the presence of local sources. Nonetheless, attention should be paid explicitly to these areas, because of the large number of people living in urban locations.

4. Discussion

4.1 Assessment framework

Chapter 3 has supplied data on the quality of sulphur dioxide, nitrogen dioxide, nitrogen oxides, particulate matter and lead in air in the Netherlands. These results can be used as an aid for appointing a regime to the assessment of the air quality in the zones and agglomerations, also mentioned in Chapter 3. However, besides monitoring data[7] and the results of the model calculations, other sources of information may also be used in creating a definition of an assessment regime for a zone or agglomeration. For example, intended policy or emission trends in the Netherlands and abroad, etc. could be considered as well. The regime classification used in this chapter is outlined in 2.3.2. Below is described briefly how it will be used.

- *Regime 1*. The concentration is higher than the upper assessment threshold level, Measurements are always compulsory in this situation.
- *Regime 2*. The concentration is found between the upper and lower assessment threshold levels. Measurements should be used here, possibly in combination with models.
- *Regime 3*. The concentration is lower than the lowest assessment threshold level. Measurements are not required under these circumstances. Air quality may be described with models or objective estimates.

4.2 Sulphur dioxide

In Chapter 3.2 measurements of sulphur dioxide from 1995 – 1999 were tested against the upper and lower assessment thresholds of the limit value for the daily mean. The upper assessment threshold level (75 µg SO_2/m^3, where exceedance is allowed for a maximum of nine days in five years) was found to be exceeded at one station, Sas van Gent (315) in Zeeuws Vlaanderen. This station functioned as a monitor for local industrial sources in the Netherlands and Belgium and should therefore not be seen as a representative regional monitoring station.[8] The monitoring station found in the South zone is therefore not used for assigning an assessment regime to this zone.

The lower threshold level (50 µg SO_2/m^3), where exceedance is allowed for a maximum of nine days in five years) was exceeded at 12 stations (30% of the total number). The extent of the exceedance, both in concentration and number of days was found to be slight (see *also Appendix C, Table C1*). In general, the sulphur dioxide levels in the Netherlands have showed downward trends for the last 15 years (RIVM, 2001). This downward trend is expected to continue into the future (RIVM, 2000; Van Velze *et al.*, 2000). Neither has the threshold level value seen exceedances the last few years. Given the current situation exceedance has since become improbable. In view of this situation and the anticipated further decline in concentrations assessment regime 3 was assigned to all zones.

In the Rotterdam/Dordrecht agglomeration, known as the Rijnmond area, sulphur dioxide levels have increased in relation to the rest of the Netherlands due to the presence of local sources. This was also shown in the greater extent of exceedance of the number of days at the stations in the Rijnmond area.

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[7] See the monitoring stations according to zones and agglomerations in Appendix C.
[8] The monitoring at this location was terminated on 1 January 1999 in accordance with the criteria in the Dutch regulations.

Although the quality of sulphur dioxide in air will improve here in the future as well, the Rotterdam agglomeration has been assigned assessment regime 2, based on the current levels (*Table 11*). In the remaining agglomerations the levels are so low that assessment regime 3 can be assigned.

Table 11. Assessment regimes for sulphur dioxide.

Zone	Regime	Agglomeration	Regime
North	3	Amsterdam/Haarlem	3
Middle	3	The Hague/Leiden	3
South	3	Rotterdam/Dordrecht	2
		Utrecht	3
		Eindhoven	3
		Heerlen/Kerkrade	3

Assessment instruments
Regime 1
Compulsory Monitoring
Regime 2
Monitoring + Modelling
Regime 3
Modelling or Objective Estimates

In section 3.2 the monitoring data for sulphur dioxide between 1995 and 1999 have also been tested against the lower and upper assessment threshold level for the (winter-half) yearly mean limit value for the protection of ecosystems (upper level 12 µg/m³ and lower level 8 µg SO_2/m³). Exceedance of both threshold levels is applicable to largely urban and industrially relevant stations in Rijnmond and a few urban stations situated elsewhere (see *Appendix C, Table C3*). This picture is confirmed by the results of the model calculations for yearly means of sulphur dioxide concentrations (also see section 3.2, *Figure 3*). In the middle and north of the country yearly mean concentrations up to 5 µg SO_2/m³ are calculated for rural areas, Measurements are, for this reason, not compulsory. The concentrations outside urban areas in the southwest and south are between 5 and 10 µg SO_2/m³. The level of sulphur dioxide falls between the upper and lower threshold level in this part of the country. According to the daughter directive, one measurement station per 40,000 km² is applicable here.

4.3 Nitrogen dioxide

In section 3.3 the monitoring data for nitrogen dioxide between 1995 and 1999 have also been tested on the lower and upper assessment threshold level values of the limit value for the hourly mean (100 and 140 µg NO_2/m³, respectively, with a maximum of 54 exceedances in five years). The upper threshold level is exceeded at about a dozen street stations (see *Appendix C, Table C3*). All the stations are situated within the defined agglomerations except for two. These two, Breukelen[9] and Apeldoorn-Loolaan (where the upper threshold level is exceeded), are situated in the Middle zone. Because of the specific locations of these stations, the monitoring results cannot be considered characteristic as for this zone on the whole. The lower threshold level is exceeded at all 19 urban stations and in addition at 8 regional stations in the Middle and South zones. The modelling results presented in section 3.3 show, in addition to the measurement results, clearly increased levels in all the urban areas in the Netherlands and along the major traffic arteries.

The North zone, where the levels are, relatively speaking, the lowest, an assessment regime of 3 is assigned. Extra attention though will be needed for a number of urban areas in this zone, like Almere, Groningen and Zwolle (compare *Figures 4* and *14*). The Middle and South zones are assigned regime 2; here too special attention will be needed for a number of urban areas, like Apeldoorn, Arnhem, Nijmegen, Ede/Wageningen and the area north of the

[9] Situated on the roadway

Amsterdam agglomeration (Middle) and Breda, Den Bosch, Sittard, Tilburg and Venlo (South).

All agglomerations are assigned regime 1. The monitoring results largely form the reason for this; the resulting picture is confirmed and further elaborated in the results of the model calculations. The agglomeration of Heerlen/Kerkrade is also assigned regime 1. This is completely based on model results, since the monitoring results for the Wijnandsrade – located in this agglomeration – are not considered representative for the highest concentrations in the agglomeration.

In section 4.4 a test was also carried out on the lower- and upper threshold level values of the limit value of the yearly mean (32 and 26 µg NO_2/m³, respectively). The monitoring results show that the lower threshold level is exceeded in the Middle and South zones, even though slightly (see *Appendix C, Table C4*). No exceedance has occurred in the North zone. Model calculations show an exceedance of the limit value in the Middle zone in the area outside the cities spread over an area of about 500 km² (Van Velze *et al.*, 2000). On the basis of these considerations the Middle zone is assigned a regime of 1, South a regime of 2 and North a regime of 3 (see *Table 12*).

Just as in the previous sections, a number of urban areas in these zones need special attention, since the concentrations here have clearly increased in relation to the regional background in the respective zone. We are concerned with such urban areas as Almere, Groningen and Zwolle in the North zone, Apeldoorn, Arnhem, Nijmegen, Ede/Wageningen and the areas north of the agglomerations of Amsterdam in the Middle zone, and cities as Breda, Den Bosch, Sittard, Tilburg and Venlo in the South zone. This extra attention for the urban areas outside the agglomerations will take the form of model calculations that will be tested against urban measurements in the agglomerations (see also Eerens *et al.*, 1993; RIVM, 2001).

The upper assessment threshold level is exceeded at all the city stations. In most cases even concentrations exceeding the limit value are found. This finding is confirmed by the model results, implying that in comparable situations where monitoring is not going on, increased levels of the same order of magnitude can be expected. Although the nitrogen concentrations are expected to drop in the coming years (Van Velze *et al.*, 2000), the agglomerations have for now been assigned assessment regime 1 (*Table 13*). By comparison, the regime based on yearly means is 'stricter' on a number of points than the hourly-mean-based regime. For this reason the regime employing yearly means will be used for nitrogen dioxide.

Table 12. Assessment regimes for sulphur dioxide.

Zone	Regime	Agglomeration	Regime
North	3	Amsterdam/Haarlem	1
Middle	1	The Hague/Leiden	1
South	2	Rotterdam/Dordrecht	1
		Utrecht	1
		Eindhoven	1
		Heerlen/Kerkrade	1

Assessment instruments
Regime 1
Compulsory Monitoring
Regime 2
Monitoring + Modelling
Regime 3
Modelling or Objective Estimates

4.4 Nitrogen oxides

Testing for nitrogen oxides is carried out on assessment thresholds for the limit values of yearly means so as to protect the vegetation. The assessment threshold levels are 24 and 19.5 µg NO_x/m³, respectively. The upper threshold level was exceeded at all the regional stations in the south and middle parts of the country and in all the agglomerations. In the north the upper threshold level was exceeded at 3 of the 8 regional stations. The lower threshold level was exceeded at 6 of the 8 regional stations. Based on the measurement results for the regional stations, one station per 20,000 km^2 needs to be set up for ecosystems; this means two stations for the whole of the country. These stations can be chosen from the station sets as determined for nitrogen dioxide (see also section 4.3). Extra consideration should be given here to the strategic monitoring requirements for station locations as laid down in the daughter directive.

4.5 Particulate matter (PM10)

In section 3.5 the first test on particulate matter (PM10) is carried out on the assessment threshold level for the limit value of the daily mean. Threshold levels are 30 and 20 µg/m³ and exceedance may not take place more than 21 times in five years. Considerable exceedance of the upper assessment threshold level takes place at all stations in the agglomerations and the zones (see *Appendix C, Table C6*). This is why all zones and agglomerations fall under assessment regime 1.

A second test is carried out on assessment threshold levels for the yearly mean. The threshold levels are 14 and 10 µg/m³, respectively. These threshold values are very strict, as they are based on indicative limit values meant for 2010, being a yearly mean of 20 µg/m³. The upper threshold level is exceeded substantially at all monitoring stations (see *Appendix C, Table C7*). All zones and agglomerations fall under assessment regime 1.

Monitoring PM2.5 has to date not been implemented in the Netherlands. Such measurements will be made compulsory under the first daughter directive, forcing the installation of five monitoring stations for PM2.5, so as to create a representative picture of the PM2.5 levels in the Netherlands. These monitoring stations will be combined with the existing monitoring stations for PM10.

4.6 Lead

Testing for lead takes place on assessment thresholds for the limit values of yearly means. Assessment threshold levels come to 0.35 and 0.25 µg/m³. The concentrations remain under the lower assessment level for all stations (see *Appendix C, Table C8*). The extensive analysis of the situation around industrial installations (see section 3.6) demonstrates that concentrations there too are found below the lower assessment threshold level. Assessment regime 3 is allocated to all the zones and agglomerations.

4.7 Consequences for the LML

The division into zones and agglomerations has been derived in the preceding sections. Using the information from these sections, an overview of the regime division for all components can be made (*Table 13*). The number of monitoring stations needed can be determined, along with the criteria for the number of monitoring stations in relation to the assessment regime according to the daughter directive (*Table 14*)[10]. Here it is assumed in the first place that the air quality will be assessed using measurements as the only source of information.

The Amsterdam/Haarlem agglomeration, with a population of slightly less than 1.5 million will therefore be assigned four monitoring stations for nitrogen dioxide; five stations would

[10] See also *Table 6* in section 2.3.

have been compulsory for agglomerations of more than 1.5 million. The demographic developments of the past few years do not give reason to suppose that the population in this agglomeration will rise above 1.5 million on the short term. The population of the Heerlen/Kerkrade agglomeration is 250,000. Here a higher class has been chosen on the basis of the demographic developments, which will mean two instead of one station (for nitrogen dioxide).

Table 13. Assessment regimes in zones and agglomerations.

Agglomeration / zone	Sulphur dioxide	Nitrogen dioxide	Particulate matter (PM10)	Lead
Agglomeration				
Amsterdam/Haarlem	3	1	1	3
The Hague/Leiden	3	1	1	3
Rotterdam/Dordrecht	2	1	1	3
Utrecht	3	1	1	3
Eindhoven	3	1	1	3
Heerlen/Kerkrade	3	1	1	3
Zone				
North	3	3	1	3
Middle	3	1	1	3
South	3	2	1	3

Table 14. Number of monitoring stations using measurements as the only source of information.

Agglomeration / zone	Sulphur dioxide	Nitrogen dioxide	Particulate matter (PM10)	Lead
	Number of stations			
Agglomeration				
Amsterdam/Haarlem	1	4	4	
The Hague/Leiden	1	4	4	
Rotterdam/Dordrecht	2	4	4	
Utrecht	1	2	2	
Eindhoven	1	2	2	
Heerlen/Kerkrade	1	2	2	
Zone				
North	0	0	7	
Middle	1	8	8	
South	0	3	7	
Total	**8**	**29**	**40**	**0**

On the basis of number of stations required for the number of inhabitants, minimally one station will have to record city background levels and minimally one will have to focus on traffic[11] for the cases where the concentration of particulate matter or nitrogen dioxide in one zone or agglomeration is found above the upper assessment threshold level. This applies to all zones and agglomerations for particulate matter. For nitrogen dioxide this applies to the Middle zone and all agglomerations.

[11] Following the usual station categories, this will be a street station.

The current station set will therefore have to be extended according to the following scheme (see also *Appendix D*):

- the North zone gets 6 more stations for particulate matter, including one street station and one city station.
- the Middle zone gets 2 more stations for particulate matter, including one city station, and one city station for nitrogen dioxide.
- the South zone gets four more stations for particulate matter, including one street station and one city station.

Besides the current stations in the agglomerations, the following changes will take place:

- Amsterdam/Haarlem: one station for nitrogen dioxide and three stations for particulate matter, including one street station for the latter.
- The Hague/Leiden: three stations for nitrogen dioxide, including one street station, plus three stations for particulate matter, also including one street station.
- Rotterdam/Dordrecht: one station for particulate matter.
- Utrecht: one city station for particulate matter.
- Eindhoven: one city station for particulate matter and one city station for nitrogen dioxide.
- Heerlen/Kerkrade: one city and one street station for particulate matter, and one city and one street station for nitrogen dioxide.

Compiling the above information brings the number of new stations needed to 8 for nitrogen dioxide and 23 for particulate matter.

It is observed here is that when only measurements are used to determine air quality, the number of monitoring stations for particulate matter should be largely extended. However, in the spatial representation of particulate matter concentrations, as constructed in calculation models (*Figure 10*), there is little variation. Therefore it is doubtful if increasing the current number of stations will mean a proportional increase in the information on the air quality.

Nevertheless, the given number of monitoring stations (*Table 14*) serves as an indication when using only measurements to describe the air quality. In this sense they can be considered as minimum numbers. Member states are free to set up more than this number of monitoring stations.

Adding additional instruments, like models, to describe air quality can, however, lead to a reduction in the given number of monitoring stations. The use of models can also contribute to a more accurate description of air quality in urban areas.

Finally, it should be noted that the Dutch National Air Quality Network is not only an instrument in the framework of legislation and regulations, but also provides for other information needs, like international obligations, validation of models, monitoring of trends, and spatial views (see Buijsman, 1995). Monitoring sites will, in the future too, be necessary to fulfil these purposes[12].

[12] This will be worked out in an RIVM report still to be published within the project ‘Monitoring Air’.

5. Conclusions

The current air quality in the Netherlands for the substances, sulphur dioxide, nitrogen dioxide, nitrogen oxides, particulate matter and lead, is assessed in the context of the limit values, the margins of tolerance and the assessment threshold levels in the first European Union daughter directive on air quality.

Three zones were defined in the Netherlands on the basis of the differences in air quality; these were the North (the provinces of Groningen, Friesland, Drenthe, Overijssel and Flevoland), Middle (the provinces of Gelderland, Utrecht, Noord-Holland and Zuid-Holland) and South (provinces of Limburg, Noord-Brabant and Zeeland) zones.

Data on population, numbers and density, have been used to define six agglomerations: Amsterdam/Haarlem, Rotterdam/Dordrecht, The Hague/Leiden, Utrecht, Eindhoven and Heerlen/Kerkrade.

Testing for limit values yielded a yearly mean nitrogen dioxide in many urban areas highly exceeding the limit value for this substance. This was also the case for particulate matter concentrations, but to a lesser extent. Depending on the air quality in relation to the assessment threshold levels in the daughter directive, there were three determination strategies (regimes) possible for assessing air quality; these differed in the extent to which measurement and models were used. Regime 1, where the concentration is found above the highest/upper assessment threshold level; regime 2, where the concentration is found between the upper and lower assessment threshold levels and regime 3, where the concentration is found below the lower assessment threshold level. The following results were obtained for the components distinguished in the first daughter directive and in the zones and agglomerations described in the Netherlands.

Zones:
North: particulate matter - regime 1; other substances – regime 3
Middle: nitrogen dioxide and particulate matter – regime 1, sulphur dioxide and lead – regime 3
South: particulate matter - regime 1; nitrogen dioxide – regime 2; sulphur dioxide and lead – regime 3

Agglomerations:
Amsterdam/Haarlem, The Hague/Leiden, Utrecht, Eindhoven and Heerlen/Kerkrade: particulate matter and nitrogen dioxide - regime 1, and sulphur dioxide and lead – regime 3.
Rotterdam/Dordrecht: particulate matter and nitrogen dioxide - regime 1, sulphur dioxide – regime 2, and lead – regime 3.

There needs to be more focus on a number of urban areas in the above zones because the concentrations here were clearly increased with respect to the regional background concentrations in the respective zones. This involves cities like Almere, Groningen, and Zwolle in the North zone, Apeldoorn, Arnhem, Nijmegen, Ede/Wageningen and the area north of the agglomeration Amsterdam in the Middle zone, and cities like Breda, Den Bosch, Sittard, Tilburg and Venlo in the South zone. Extra focus on urban areas outside agglomerations will be achieved through model calculations to be validated with urban measurements within the agglomerations.

To meet the requirements of the first daughter directive the following minimal number of stations are needed if the air quality is to be determined on the basis of measurement: 8 for sulphur dioxide, 29 for nitrogen dioxide, 40 for particulate matter and zero for lead.

In cases where the concentration of particulate matter or nitrogen dioxide was found in a zone or agglomeration to exceed the upper assessment threshold level, a minimum of one station should be a city background station and a minimum of one should be a traffic station. These minimal recommendations for stations are based on the number of stations required for a certain number of inhabitants and applies to all zones and agglomerations when considering particulate matter. For nitrogen dioxide this only applies to the Middle zone and all agglomerations.

Assuming that all the measurements are used to determine air quality, the number of monitoring stations for particulate matter will have to be extended. The spatial distribution of particulate matter concentrations, as constructed with calculation models show, however, little variation. Therefore it is doubtful if increasing the current number of stations will provide a proportional increase in the information on air quality.

Nevertheless, the given number of monitoring stations serves as an indication when using *measurements only* to describe air quality. Adding more instruments, like models, to describe air quality can, however, lead to a reduction in the given number of monitoring stations. The use of models can also contribute to a more accurate description of air quality in urban areas.

Besides the stated number of monitoring stations running, there are currently more monitoring stations operational for realising such activities as meeting international obligations, validation of models, and monitoring trends, along with being able to obtain comprehensive spatial maps of air pollution concentrations in the Netherlands, and provide for possible station breakdown.

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Appendix A Mailing list

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Appendix B Measurement methods in the LML

Several operational characteristics for each monitoring system are presented below using information from Van Elzakker (2000).

Determination of sulphur dioxide

Type	: automatic analyser
Measuring instrument	: Thermo Electron 43W
Measuring principle	: ultraviolet fluorescence
Measuring range	: 0-2000 µg SO_2/m^3
Detection limit	: 3 µg SO_2/m^3
Time period	: 1 hour
Remark	: method is in compliance with ISO/FDIS 10498 Air – Determination of sulphur dioxide – UV-fluorescence[13]

Determination of nitrogen oxides

Type	: automatic analyser
Measuring instrument	: Thermo Electron 42W
Measuring principle	: chemoluminescence
Measuring range (NO)	: 0-1248 / 2496* / 6242# µg NO/m³
Measuring range (NO_2)	: 0-1915 / 3830* / 9574# µg NO_2/m^3 [* stations: 236, 237, 238, 404, 418, 441, 518, 520, 636, 638, 640, 641, 727, 728, 729; # stations: 433, 637, 639]
Detection limit	: 1 µg NO_2/m^3
Time period	: 1 hour
Remark	: Method is in compliance with ISO 7996: 1985 Air – Determination of mass concentration of nitrogen oxides – chemoluminescence

Determination of PM10

Type	: automatic analyser
Measuring instrument	: FAG FH 62I-N with Andersen 236B PM10-inlet configuration; inlet tube heated (set point 50º C)
Measuring principle	: attenuation of β-radiation
Measuring range	: 0-1000 µg/m³
Detection limit	: 10 µg/m³
Time period	: 1 hour
Remark 1	: Research has shown this method in comparison to the reference method to systematically underestimate the particle mass concentration. The PM10 monitoring data from LML are therefore multiplied by a correction factor of 1.33 to provide an average correction for this underestimation.
Remark 2	: Method is in compliance with prEN 12341 Air Quality – Field test procedure to demonstrate equivalence of sampling methods for the PM10 fraction of particulate matter.

[13] Guideline is in preparation.

Sampling of aerosols and the determination of lead

Type	: active sampler
Sampling instrument	: medium volume sampler, RIVM fabricate
Sampling	: continuously
Filter	: Whatman nr. 42
Flow	: 5.9 l/min
Analysis	: off-line; inductively coupled plasma/mass spectrometry
Detection limit	: 0.5 ng/m^3
Time period	: 1 day
Remark	: analysis of 50% of the sampling material (every other day)

Sampling of precipitation and the determination lead

Type	: active sampler
Sampling instrument	: ECN, wet-only, polythene funnel (400 cm^2) and collection bottle (5 l)
Sampling period	: 2 weeks
Analysis	: off-line; inductively coupled plasma/mass spectrometry
Detection limit	: 0.001 µmol/l
Time period	: 4 weeks

Appendix C Review of measurement results related to threshold levels

Table C1. Sulphur dioxide (SO_2), exceedance of threshold values for daily averaged concentrations. Compliance variable: Number of days with a daily averaged concentration above concentrations given should be no more than nine days in five years. Exceedance of a threshold value is shown in bold.

Measuring site	Type	Upper threshold (75 µg SO_2/m^3)	Lower threshold (50 µg SO_2/m^3)
		Number of days	
107-Posterholt	Regional	3	**14**
131-Vredepeel	Regional	2	9
133-Wijnandsrade	Regional	1	**10**
227-Budel	Regional	3	**10**
230-Biest-Houtakker	Regional	0	2
232-Volkel	Regional	1	4
234-Putte	Regional [1]	4	**19**
235-Huijbergen	Regional	2	**10**
237-Eindhoven-Noordbrabantlaan	Street	0	0
301-Zierikzee	Regional	0	2
315-Sas van Gent	Regional [1]	**15**	**64**
318-Philippine	Regional	1	9
404-The Hague	City background	0	3
411-Schipluiden	Regional	0	5
415-Maassluis	Regional [1]	2	**25**
416-Vlaardingen-Lyceumlaan	City background	4	**48**
418-Rotterdam	City background	0	9
433-Vlaardingen-Floreslaan	Street	5	**50**
437-Westmaas	Regional	0	1
444-De Zilk	Regional	0	1
518-Amsterdam-Cabeliaustraat	City background	0	1
520-Amsterdam-Florapark	City background	0	1
538-Wieringerwerf	Regional	0	0
620-Cabauw	Regional	0	1
627-Bilthoven	Regional	0	3
631-Biddinghuizen	Regional	0	0
633-Zegveld	Regional	0	1
638-Utrecht-Vleutenseweg	Street	0	2
641-Breukelen	Street	0	1
722-Eibergen	Regional	0	**10**
724-Wageningen	Regional	1	**12**
729-Apeldoorn-Arnhemseweg	Street	0	7
733-Loenen	Regional	0	5
807-Hellendoorn	Regional	0	**10**
818-Barsbeek	Regional	0	2
913-Sappemeer	Regional	0	0
918-Balk	Regional	0	0
928-Witteveen	Regional	0	4
934-Kollumerwaard	Regional	0	0

[1] Monitoring site is primarily ‘industrial’.

Table C2. Sulphur dioxide (SO_2), exceedance of threshold values for (winter half) yearly averages. Compliance variable: (winter half) yearly average above the value given. Exceedance of threshold value is shown in bold.

Measuring site	Type	**Yaer** Upper threshold (12 µg /m³)	**Year** Lower threshold (8 µg /m³)	**Winter** Upper threshold (12 µg /m³)	**Winter** Lower threshold (8 µg /m³)
		Concentration in µg SO_2/m^3			
107-Posterholt	Regional	8	8	8	8
131-Vredepeel	Regional	6	6	6	6
133-Wijnandsrade	Regional	6	6	6	6
227-Budel	Regional	8	8	8	8
230-Biest-Houtakker	Regional	6	6	6	6
232-Volkel	Regional	5	5	5	5
234-Putte	Regional [1]	**17**	**17**	**17**	**17**
235-Huijbergen	Regional	12	**12**	12	**12**
237-Eindhoven	Street	7	7	7	7
301-Zierikzee	Regional	8	8	8	8
315-Sas van Gent	Regional [1]	**22**	**22**	**22**	**22**
318-Philippine	Regional	9	**9**	10	**10**
404-The Hague	City background	10	**10**	11	**11**
411-Schipluiden	Regional	12	**12**	12	**12**
415-Maassluis	Regional [1]	**15**	**15**	**16**	**16**
416-Vlaardingen-Lyceumln	City background	**20**	**20**	**21**	**21**
418-Rotterdam	City background	**13**	**13**	**14**	**14**
433-Vlaardingen-Floreslaan	Street	**20**	**20**	**21**	**21**
437-Westmaas	Regional	7	7	7	7
444-De Zilk	Regional	7	7	7	7
518-Amsterdam-Cabeliaustr	City background	9	**9**	8	8
520-Amsterdam-Florapark	City background	10	**10**	9	**9**
538-Wieringerwerf	Regional	4	4	5	5
620-Cabauw	Regional	5	5	6	6
627-Bilthoven	Regional	6	6	6	6
631-Biddinghuizen	Regional	4	4	4	4
633-Zegveld	Regional	6	6	6	6
638-Utrecht-Vleutenseweg	Street	9	**9**	9	**9**
641-Breukelen	Street	8	8	9	**9**
722-Eibergen	Regional	5	5	5	5
724-Wageningen	Regional	6	6	6	6
729-Apeldoorn-Arnhemsew	Street	6	6	6	6
733-Loenen	Regional	5	5	5	5
807-Hellendoorn	Regional	5	5	5	5
818-Barsbeek	Regional	4	4	4	4
913-Sappemeer	Regional	3	3	3	3
918-Balk	Regional	4	4	4	4
928-Witteveen	Regional	4	4	4	4
934-Kollumerwaard	Regional	3	3	3	3

[1] Measurement site is primarily 'industrial'.

Table C3. Nitrogen dioxide (NO_2), exceedance of threshold values for hour averaged values. Compliance variable: Number of hours with an hourly averaged concentration above the value given should be no more than 54 in five years. Exceedance of threshold value is shown in bold.

Measuring site	Type	Upper threshold (140 µg NO_2/m^3)	Lower threshold (100 µg NO_2/m^3)
		Number	*of hours*
107-Posterholt	Regional	0	28
131-Vredepeel	Regional	26	**124**
133-Wijnandsrade	Regional	3	20
227-Budel	Regional	1	25
230-Biest-Houtakker	Regional	2	42
232-Volkel	Regional	0	29
235-Huijbergen	Regional	3	**56**
236-Eindhoven-Genovevalaan	Street	**61**	**676**
237-Eindhoven-Noordbrabantlaan	Street	**62**	**559**
238-Eindhoven-Piuslaan	Street	**136**	**995**
301-Zierikzee	Regional	0	22
318-Philippine	Regional	1	27
404-The Hague	City background	31	**512**
411-Schipluiden	Regional	6	**240**
418-Rotterdam	City background	33	**444**
433-Vlaardingen-Floreslaan	Street	**69**	**548**
437-Westmaas	Regional	5	**59**
441-Dordrecht	City background	22	**227**
444-De Zilk	Regional	1	**167**
518-Amsterdam-Cabeliaustraat	City background	44	**475**
520-Amsterdam-Florapark	City background	7	**340**
537-Haarlem	Street	**85**	**925**
538-Wieringerwerf	Regional	3	23
620-Cabauw	Regional	0	**92**
627-Bilthoven	Regional	15	**70**
631-Biddinghuizen	Regional	1	7
633-Zegveld	Regional	0	29
636-Utrecht-de Jongweg	Street	18	**515**
637-Utrecht-Wittevrouwenstraat	Street	**595**	**4311**
638-Utrecht-Vleutenseweg	Street	**83**	**1063**
639-Utrecht-Erzeijstraat	Street	**129**	**967**
640-Utrecht-Universiteitsbibliotheek	City background	11	**314**
641-Breukelen	Street	**77**	**792**
722-Eibergen	Regional	0	10
724-Wageningen	Regional	6	**114**
727-Apeldoorn-Loolaan	Street	10	**152**
728-Apeldoorn-Stationsstraat	Street	**51**	**500**
729-Apeldoorn-Arnhemseweg	Street	19	**276**
733-Loenen	Regional	2	**66**
807-Hellendoorn	Regional	4	24
818-Barsbeek	Regional	0	16
913-Sappemeer	Regional	16	25
918-Balk	Regional	0	4
928-Witteveen	Regional	0	5
934-Kollumerwaard	Regional	0	6

Table C4. Nitrogen dioxide (NO_2), exceedance of threshold values for year averaged values. Compliance variable: year average above value given. Exceedance of threshold value is shown in bold

Measuring site	Type	Upper threshold (32 µg NO_2/m³)	Lower threshold (26 µg NO_2/m³)
		Concentration	*in µg NO_2/m³*
107-Posterholt	Regional	28	**28**
131-Vredepeel	Regional	27	**27**
133-Wijnandsrade	Regional	26	26
227-Budel	Regional	25	25
230-Biest-Houtakker	Regional	27	**27**
232-Volkel	Regional	26	26
235-Huijbergen	Regional	27	**27**
236-Eindhoven-Genovevalaan	Street	**47**	**47**
237-Eindhoven-Noordbrabantlaan	Street	**47**	**47**
238-Eindhoven-Piuslaan	Street	**52**	**52**
301-Zierikzee	Regional	22	22
318-Philippine	Regional	23	23
404-The Hague	City background	**39**	**39**
411-Schipluiden	Regional	**36**	**36**
418-Rotterdam	City background	**45**	**45**
433-Vlaardingen-Floreslaan	Street	**46**	**46**
437-Westmaas	Regional	29	**29**
441-Dordrecht	City background	**39**	**39**
444-De Zilk	Regional	26	26
518-Amsterdam-Cabeliaustraat	City background	**42**	**42**
520-Amsterdam-Florapark	City background	**41**	**41**
537-Haarlem	Street	**52**	**52**
538-Wieringerwerf	Regional	18	18
620-Cabauw	Regional	28	**28**
627-Bilthoven	Regional	32	**32**
631-Biddinghuizen	Regional	19	19
633-Zegveld	Regional	26	26
636-Utrecht-de Jongweg	Street	**44**	**44**
637-Utrecht-Wittevrouwenstraat	Street	**63**	**63**
638-Utrecht-Vleutenseweg	Street	**54**	**54**
639-Utrecht-Erzeijstraat	Street	**51**	**51**
640-Utrecht-Universiteitsbibliotheek	City background	**41**	**41**
641-Breukelen	Street	**44**	**44**
722-Eibergen	Regional	21	21
724-Wageningen	Regional	29	**29**
727-Apeldoorn-Loolaan	Street	**37**	**37**
728-Apeldoorn-Stationsstraat	Street	**45**	**45**
729-Apeldoorn-Arnhemseweg	Street	**37**	**37**
733-Loenen	Regional	24	24
807-Hellendoorn	Regional	20	20
818-Barsbeek	Regional	19	19
913-Sappemeer	Regional	17	17
918-Balk	Regional	16	16
928-Witteveen	Regional	16	16
934-Kollumerwaard	Regional	13	13

Table C5. Nitrogen oxides (NO_x), exceedance of threshold values for yearly averaged concentrations. Compliance variable: yearly average above value given. Exceedance of threshold value is shown in bold (reference period 1994-1999); exceedance of limit value is shown in bold/underlined (reference year 1999).

Measuring site	Type	Upper threshold (24 µg NO_x/m^3)	Lower threshold (19.5 µg NO_x/m^3)	**Limit value** (30 µg NO_x/m^3)
		Concentration in µg NO_x/m^3 [1]		
107-Posterholt	Regional	**46**	**46**	**38**
131-Vredepeel	Regional	**40**	**40**	**33**
133-Wijnandsrade	Regional	**41**	**41**	**33**
227-Budel	Regional	**39**	**39**	**33**
230-Biest-Houtakker	Regional	**41**	**41**	**34**
232-Volkel	Regional	**38**	**38**	**33**
235-Huijbergen	Regional	**39**	**39**	**31**
236-Eindhoven-Genovevalaan	Street	**130**	**130**	**109**
237-Eindhoven-Noordbrabantlaan	Street	**137**	**137**	**117**
238-Eindhoven-Piuslaan	Street	**177**	**177**	**151**
301-Zierikzee	Regional	**30**	**30**	25
318-Philippine	Regional	**33**	**33**	27
404-The Hague	City background	**70**	**70**	**63**
411-Schipluiden	Regional	**61**	**61**	**56**
418-Rotterdam	City background	**81**	**81**	**73**
433-Vlaardingen-Floreslaan	Street	**111**	**111**	**101**
437-Westmaas	Regional	**45**	**45**	**36**
441-Dordrecht	City background	**70**	**70**	**61**
444-De Zilk	Regional	**39**	**39**	25
518-Amsterdam-Cabeliaustraat	City background	**91**	**91**	**82**
520-Amsterdam-Florapark	City background	**75**	**75**	**69**
537-Haarlem	Street	**137**	**137**	**126**
538-Wieringerwerf	Regional	**26**	**26**	19
620-Cabauw	Regional	**44**	**44**	**36**
627-Bilthoven	Regional	**52**	**52**	**61**
631-Biddinghuizen	Regional	**26**	**26**	23
633-Zegveld	Regional	**43**	**43**	**33**
636-Utrecht-de Jongweg	Street	**120**	**120**	**100**
637-Utrecht-Wittevrouwenstraat	Street	**252**	**252**	**218**
638-Utrecht-Vleutenseweg	Street	**137**	**137**	**115**
639-Utrecht-Erzeijstraat	Street	**145**	**145**	**124**
640-Utrecht-Universiteitsbibliotheek	City background	**68**	**68**	**56**
641-Breukelen	Street	**163**	**163**	**149**
722-Eibergen	Regional	**29**	**29**	23
724-Wageningen	Regional	**45**	**45**	**34**
727-Apeldoorn-Loolaan	Street	**89**	**89**	**71**
728-Apeldoorn-Stationsstraat	Street	**108**	**108**	**92**
729-Apeldoorn-Arnhemseweg	Street	**95**	**95**	**69**
733-Loenen	Regional	**34**	**34**	27
807-Hellendoorn	Regional	**28**	**28**	23
818-Barsbeek	Regional	**25**	**25**	19
913-Sappemeer	Regional	22	**22**	19
918-Balk	Regional	22	**22**	19
928-Witteveen	Regional	22	**22**	17
934-Kollumerwaard	Regional	17	17	15

[1] In µg NO_2/m^3

Table C6. Particulate matter (PM10), exceedance of threshold values for daily averaged concentrations. Compliance variable: Number of days with a daily averaged concentration above value given should be no more 21 in five years. Exceedance of threshold value is shown in bold.

Measuring site	Type	Upper threshold (30 µg/m³)	Lower threshold (20 µg/m³)
		Number	*of days*
131-Vredepeel	Regional	**1011**	**1524**
133-Wijnandsrade	Regional	**921**	**1434**
230-Biest-Houtakker	Regional	**1111**	**1539**
236-Eindhoven-Genovevalaan	Street	**1165**	**1674**
318-Philippine	Regional	**1042**	**1519**
404-The Hague	City background	**1249**	**1706**
418-Rotterdam	City background	**1206**	**1704**
433-Vlaardingen-Floreslaan	Street	**1152**	**1611**
437-Westmaas	Regional	**931**	**1482**
441-Dordrecht	City background	**968**	**1588**
444-De Zilk	Regional	**906**	**1491**
520-Amsterdam-Florapark	City background	**1032**	**1518**
538-Wieringerwerf	Regional	**775**	**1382**
639-Utrecht-Erzeijstraat	Street	**1205**	**1621**
641-Breukelen	Street	**1116**	**1588**
722-Eibergen	Regional	**874**	**1334**
724-Wageningen	Regional	**999**	**1477**
728-Apeldoorn-Stationsstraat	Street	**1083**	**1615**
928-Witteveen	Regional	**632**	**1137**

Table C7. Particulate matter (PM10), exceedance of threshold values for yearly averaged concentrations. Compliance variable: Yearly average concentration above value given. Exceedance of threshold value is shown in bold (reference period 1994-1999); exceedance of limit value is shown in bold/underlined (reference year 1999).

Measuring site	Type	Upper threshold (14 µg/m³)	Lower threshold (10 µg/m³)	**Limit value** (40+20 µg/m³)
			Concentration	*µg/m³*
131-Vredepeel	Regional	**39**	**39**	**35**
133-Wijnandsrade	Regional	**36**	**36**	**29**
230-Biest-Houtakker	Regional	**43**	**43**	**37**
236-Eindhoven-Genovevalaan	Street	**42**	**42**	**36**
318-Philippine	Regional	**42**	**42**	**33**
404-The Hague	City background	**42**	**42**	**<u>43</u>**
418-Rotterdam	City background	**43**	**43**	**38**
433-Vlaardingen-Floreslaan	Street	**42**	**42**	**36**
437-Westmaas	Regional	**39**	**39**	**35**
441-Dordrecht	City background	**37**	**37**	**32**
444-De Zilk	Regional	**36**	**36**	**30**
520-Amsterdam-Florapark	City background	**40**	**40**	**35**
538-Wieringerwerf	Regional	**35**	**35**	**33**
639-Utrecht-Erzeijstraat	Street	**45**	**45**	**37**
641-Breukelen	Street	**42**	**42**	**40**
722-Eibergen	Regional	**37**	**37**	**29**
724-Wageningen	Regional	**39**	**39**	**34**
728-Apeldoorn-Stationsstraat	Street	**40**	**40**	**34**
928-Witteveen	Regional	**31**	**31**	**27**

Table C8. Lead in air; exceedance of threshold values for yearly averaged concentrations. Compliance variable: Yearly average concentration above value given. Exceedance of threshold value is shown in bold

Measuring site	Type	Upper threshold (0.35 µg/m³)	Lower threshold (0.25 µg/m³)
		Concentration	*µg lead per m³*
230-Biest-Houtakker	Regional	0.02	0.02
433-Vlaardingen-Floreslaan	Street	0.02	0.02
627-Bilthoven	Regional	0.02	0.02
934-Kollumerwaard	Regional	0.01	0.01

Appendix D Measurement sites in zones and agglomerations

The table below shows operational measurement sites in the Dutch National Air Quality Monitoring Network broken down into zones and agglomerations. Measurement results of these sites have been used to review air quality in the zones and the agglomerations.

Table D1. Measurement sites of the Dutch National Air Quality Monitoring Network in zones and agglomerations

Agglomeration/ Measuring site	Type	Sulphur dioxide (SO_2)	Nitrogen dioxide (NO_2) [1]	Particulate matter (PM10)	Lead
Agglomeration Amsterdam					
518-Amsterdam-Cabeliaustraat	City background	•	•		
520-Amsterdam-Florapark	City background	•	•	•	
537-Haarlem	Street		•		
Agglomeration The Hague					
404-The Hague	City background	•	•	•	
Agglomeration Rotterdam					
411-Schipluiden	Regional	•	•		
415-Maassluis	Regional [2]	•			
416-Vlaardingen-Lyceumlaan	City background	•			
418-Rotterdam	City background	•	•	•	
433-Vlaardingen-Floreslaan	Street	•	•	•	•
441-Dordrecht	City background		•	•	
Agglomeration Utrecht					
636-Utrecht-de Jongweg	Street		•		
637-Utrecht-Wittevrouwenstraat	Street		•		
638-Utrecht-Vleutenseweg	Street	•	•		
639-Utrecht-Erzeijstraat	Street		•	•	
640-Utrecht-Universiteitsbibliotheek	City background		•		
Agglomeration Eindhoven					
236-Eindhoven-Genovevalaan	Street		•	•	
237-Eindhoven-Noordbrabantlaan	Street	•	•		
238-Eindhoven-Piuslaan	Street		•		
Agglomeration Kerkrade					
133-Wijnandsrade	Regional	•	•	•	

[1] Also for nitrogen oxides (NO_x)
[2] This montioring site is primarily ‘industrial’.

Table D1 continued

Zone/ Measuring site	Type	Sulphur dioxide (SO_2)	Nitrogen dioxide (NO_2) [1]	Particulate matter (PM10)	Lead
Zone North					
631-Biddinghuizen	Regional	•	•		
807-Hellendoorn	Regional	•	•		
818-Barsbeek	Regional	•	•		
913-Sappemeer	Regional	•	•		
918-Balk	Regional	•	•		
928-Witteveen	Regional	•	•	•	
934-Kollumerwaard	Regional	•	•		•
Zone Middle					
437-Westmaas	Regional	•	•	•	
444-De Zilk	Regional	•	•	•	
538-Wieringerwerf	Regional	•	•	•	
620-Cabauw	Regional	•	•		
627-Bilthoven	Regional	•	•		•
633-Zegveld	Regional	•	•		
641-Breukelen	Street	•	•	•	
722-Eibergen	Regional	•	•	•	
724-Wageningen	Regional	•	•	•	
727-Apeldoorn-Loolaan	Street		•		
728-Apeldoorn-Stationsstraat	Street		•	•	
729-Apeldoorn-Arnhemseweg	Street	•	•		
733-Loenen	Regional	•	•		
Zone South					
107-Posterholt	Regional	•	•		
131-Vredepeel	Regional	•	•	•	
227-Budel	Regional	•	•		•
230-Biest-Houtakker	Regional	•	•	•	•
232-Volkel	Regional	•	•		
235-Huijbergen	Regional	•	•		
301-Zierikzee	Regional	•	•		
318-Philippine	Regional	•	•	•	

[1] Also for nitrogen oxides (NO_x)