National Environmental Research Institute
University of Aarhus · Denmark

NERI Technical Report No. 681, 2008

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Annual Summary for 2007

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Kåre Kemp
Thomas Ellermann
Jørgen Brandt
Jesper Christensen
Matthias Ketzel
Steen Solvang Jensen

Data sheet

Series title and no.: NERI Technical Report No. 681

Title: The Danish Air Quality Monitoring Programme
Subtitle: Annual Summary for 2007

Authors: Kåre Kemp, Thomas Ellermann, Jørgen Brandt, Jesper Christensen, Matthias Ketzel & Steen Solvang Jensen
Department: Department of Atmospheric Environment

Publisher: National Environmental Research Institute ©
University of Aarhus - Denmark
URL: http://www.neri.dk

Year of publication: July 2008
Referees: Peter Wåhlin

Technical support: Axel Egeløv, Lone Grundahl, Henrik Skov, Bjarne Jensen, Christina F. Emborg, Henrik W. Madsen, Birgit Thomsen, Jane Søfting, Lizzi Stausgaard, Hans P. Ahleson, Hans Nielsen, Mary-Ann Chrillesen, Tom Rasmussen

Financial support: Ministry of the Environment and Municipalities of Copenhagen, Aalborg, Aarhus and Odense.

Please cite as: Kemp, K., Ellermann, T., Brandt, J., Christensen, J., Ketzel, M. & Jensen, S.S., 2008: The Danish Air Quality Monitoring Programme. Annual Summary for 2007. National Environmental Research Institute, University of Aarhus. 47 pp. -NERI Technical Report No. 681. The report is available in electronic format (pdf) at NERI's website http://www.dmu.dk/Pub/FR681.pdf

Abstract: The air quality in Danish cities has been monitored continuously since 1982 within the Danish Air Quality Monitoring (LMP) network. The aim has been to follow the concentration levels of toxic pollutants in the urban atmosphere and to provide the necessary knowledge to assess the trends, to perform source apportionment, and to evaluate the chemical reactions and the dispersion of the pollutants in the atmosphere. In 2007 the air quality was measured in four Danish cities and at two background sites. Model calculations were also carried out to supplement the measurements. At several stations NO_2 and PM_{10} were found in concentrations above EU limit values, which the Member States have to comply with in 2005 and 2010. The concentrations for most pollutants have been strongly decreasing since 1982, however, only a slight decrease has been observed for NO_2 and O_3.

Keywords: Atmospheric pollution, urban pollution, nitrogen compounds, ozone, sulphur compounds, heavy metals, volatile organic pollutants, dispersion models

Layout: Majbritt Pedersen-Ulrich

ISBN: 978-87-7073-058-7
ISSN (electronic): 1600-0048

Number of pages: 47

Internet version: The report is available in electronic format (pdf) at NERI's website http://www.dmu.dk/Pub/FR681.pdf

Contents

Summary and Conclusion

The Danish Air Quality Monitoring Programme (LMP IV) has been revised and is still under revision in accordance with the EU Frame-work Directive and the four daughter directives of SO_2, NO_x/NO_2, PM_{10}, lead, benzene, CO, ozone, arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons. The data sets for year 2007 are almost complete for most stations. The monitoring programme consists of 11 stations.

The concentrations were in 2007 almost the same or slightly lower as in 2006. Changes may mainly be due to meteorological conditions. Two exceedances of the limit value occurred for PM_{10}, while 1 exceedance of the limit value + plus margin of tolerance were measured for NO_2.

The limit value + the margin of tolerance for the annual average of NO_2 (46 µg/m^3 in 2007) was exceeded in Copenhagen at the street station on H.C. Andersens Boulevard. The limit value (to be complied with in 2010) of the annual average of NO_2, was in 2007 exceeded at two street stations in Copenhagen. The NO_2 concentrations seem to have been almost constant during the last ten years. Model calculations at selected streets in Copenhagen and Aalborg showed that the limit value + margin of tolerance was exceeded on several streets in central Copenhagen and Aalborg.

The ozone level was in 2007 slightly lower than in 2006 at all rural and urban background stations but no clear trend is observed. The decrease in 2007 may be ascribed to the "rainy" summer of 2007. The information threshold at 180 µg/m^3 was not exceeded. The target values were not exceeded, but the long-term objectives for both the max 8 hours on 120 µg/m^3 and the AOT40 on 6000 µg/m^3·h were exceeded at several non-traffic stations. The O_3 pollution in Denmark is to a large extent caused by long distance transport of pollutants from other European countries.

The limit value for the 35th highest daily average value for PM_{10} (50 µg/m^3) was in 2007 exceeded at 2 stations. The limit value for the annual average (40 µg/m^3) was not exceeded (the margin of tolerance is = 0 from 2005). Emission in other European countries contributes significantly to the PM_{10} levels in Denmark.

The SO_2 and lead levels have been decreasing for more than two decades and are far below the limit values. The limit values for benzene and CO are not exceeded and the levels have been decreasing for the last decade.

Measurements of the concentrations of particle bound PAH were started up in June 2007 at H.C. Andersens Boulevard, Copenhagen. The average concentration of benzo[a]pyrene was 0,32 ng/m^3 for the second ½ year of 2007 and it is therefore unlikely that the target value for benzo[a] pyrene (1 ng/m^3) was exceeded in 2007.

Actual data, quarterly reports, annual and multi-annual summaries are available at the website of NERI
(http://www.dmu.dk/-International/Air).

Danish summary - Dansk resumé

Rapporten præsenterer resultaterne fra overvågningsprogrammet for luftkvalitet i danske byer (LMP IV) for 2007. Formålet med programmet er at fastlægge koncentrationer af skadelige stoffer i luften i danske byer, følge udviklingen af koncentrationerne og vurdere kilderne til de enkelte stoffer. Målingerne bruges til at vurdere effekten af allerede gennemførte tiltag og beregne virkningen af mulige fremtidige tiltag. Desuden tjener resultaterne som videnbasis for en række videnskabelige undersøgelser, fx vurdering af små partiklers effekt på sundheden.

Der er fastsat grænse- og målværdier for flere af de målte stoffer. Grænseværdierne skal overholdes fra 2005 eller 2010. Frem til da er det dog tilladt at overskride disse grænseværdier indenfor en fastsat tolerancemargin, som løbende reduceres. En detaljeret beskrivelse af gældende mål- og grænseværdier og deres gennemførelse findes i en bekendtgørelse fra Miljøministeriet (Miljøministeriet 2007). Bekendtgørelsen er baseret på EU-direktiverne (EC 1996, 1999, 2000, 2003 og 2005). En revision af luftrammedirektivet og de tre første datterdirektiver er blevet vedtaget i 2008 og det nye direktiv vil blive implementeret i 2008 og 2009. En af de væsentligste ændringer i det nye direktiv er, at der stilles krav om målinger af de fine partikler ($PM_{2,5}$), og at der er blevet indført grænseværdi for $PM_{2,5}$.

De væsentligste konklusioner fra overvågningsprogrammet i 2007 er følgende:

- Generelt var niveauerne i 2007 på samme eller lidt lavere niveau end i 2006. Ændringer kan for en stor del skyldes meteorologiske forhold, bl.a. den ”dårlige” sommer i 2007.
- Indholdet af kvælstofdioxid (NO_2) overskred i 2007 grænseværdierne, som skal overholdes fra 2010 på to målestationer (de to gadestationer i København). Grænseværdien + tilladte margin (i 2007: 46 µg/m^3) blev i 2007 overskredet på H.C. Andersens Boulevard i København. Ligeledes viste modelberegninger at grænseværdi + tilladte margin var overskredet på et stort antal gadestrækninger i centrum af København og på tre gadestrækninger i Aalborg.
- Indholdet af partikler mindre end 10 µm (PM_{10}) overskrider grænseværdierne som skal overholdes fra 2005 på 2 gadestationer (København og Odense).
- Der er ikke fastsat egentlige grænseværdier for ozon (O_3), men kun "målværdier" og ”langsigtede mål” (hensigtsværdier). De langsigtede mål blev overskredet på flere bybaggrunds- og landstationer.
- De øvrige målte stoffer findes i koncentrationer under grænseværdierne, og for flere stoffer (fx svovldioxid og bly) er indholdet faldet kraftigt siden målingernes start.
- Målinger af partikelbundet PAH blev startet op i juni 2007 på H.C. Andersens Boulevard, København. Middelværdien for benz[a]pyren var 0,32 ng/m^3 og det er derfor sikkert, at målværdien på 1 ng/m^3 ikke blev overskredet i 2007.

1 Introduction

The fourth Danish Air Quality Monitoring Programme (LMP) was started in 2000. The programme comprises an urban monitoring network with stations in the four largest Danish cities (fig. 2.1). The results are used for assessment of the air pollution in urban areas. The programme is carried out in a co-operation between the National Environmental Research Institute (NERI), the Danish Environmental Protection Agency, the Municipalities of Copenhagen, Århus, Aalborg and Odense. NERI is responsible for the practical programme. The results are currently published in quarterly reports in Danish and they are summarised in annual reports in English with a Danish summary (e.g. last years report Kemp et al. 2007). The network, which was organized by the Environmental Protection Agency of the Municipality in Copenhagen, is now formally a part of the LMP program, as a result the infrastructure reform in Denmark. Measurements are continued unchanged. Statistical parameters and actual data are accessible at the website: http://www.dmu.dk/-International/Air. Selected actual data are also available at tele-text, Danish National Television. Moreover, this report presents results from model calculation of air quality in Denmark carried out as supplement to the measurements in LMP.

Two national air quality monitoring networks are in operation in Denmark. Beside the LMP programme, a network in rural areas (the Danish Background Monitoring Program) was established in 1978 (fig. 2.1). NERI runs both programmes. At present gas and aerosol measurements are performed at six stations, and various ions are determined in precipitation collected at 9 sites.

The present Danish limit values are identical with the limit values laid down in the EU directives. The EU legislation consists of the framework directive (EC 1996), giving general rules for network design and limit value strategies, and a number of daughter directives giving limit values, target values, alert thresholds, reference methods and monitoring strategies for specific pollutants. The limit values are close to the recommendations (WHO, 2000) based on the known health effects of the pollutants. The limit values must in most cases be attained in 2005 or 2010. Until then a so-called margin of tolerance are added to the limit values. The margin of tolerance is gradually reduced to zero at the date of compliance. Daughter Directives for NO_2, SO_2, particulate matter (PM_{10}) and Pb (EC, 1999), CO and benzene (EC, 2000), O_3 (EC, 2002) and Cr, As, Cd, Hg and PAH (EC, 2005) are adopted. In the following chapters the results from measurements and model calculations are compared to limit and threshold values. Please refer to the Directives for a detailed description of the exact definitions of the limit values, margin of tolerance, target values and alert thresholds.

A new directive has recently been finalised. this directive merges the framework directive and the first three daughter directives into a single streamlined and updated directive. One of the major changes in the new directive is that the new directive includes $PM_{2.5}$. The new directive will be implemented in 2008 and 2009.

2 Measurements and model calculations

The measuring strategy is in short to place one or more pairs of stations in each city. One of the stations is located close (at the sidewalk) to a street lane with a high traffic density. The other is located within a few hundred meters from the street station, and is representative for the urban background pollution; it is not influenced by a single or a few streets or other nearby sources. In most cases the background stations are placed on rooftops. In addition, two rural stations monitor the pollution outside city areas. Further information about the program and results is found at the website: http://www.dmu.dk/International/Air.

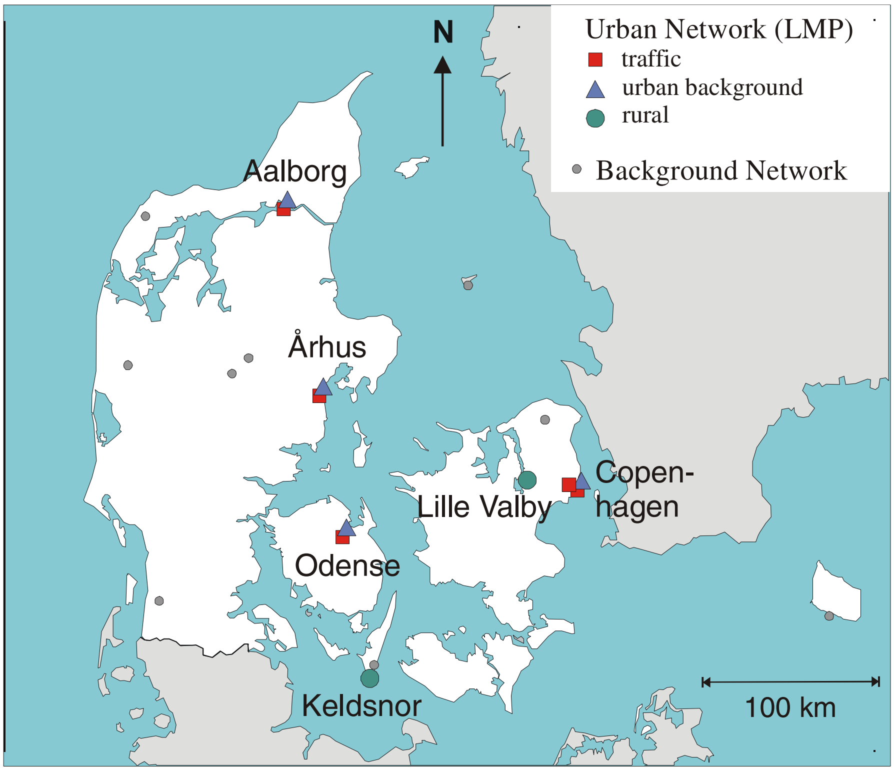

Figure 2-1 Monitoring stations in the two nation-wide air quality networks.

Table 2-1 Stations in the LMP network included in this report for 2007

Name	Street/location	Type	Remarks
Copenhagen/1257	Jagtvej	Street	
Copenhagen/1259	H.C. Ørsted Institute	Urban background	
Copenhagen/1103	H.C. Andersens Boulevard	Street	$PM_{2.5}$ 24 hour measurements startet 2007
Århus/6153	Banegårdsgade	Street	
Århus/6159	Valdemarsgade	Urban Background	
Odense/9155	Albanigade	Street	
Odense/9159	Town hall in Odense	Urban background	
Aalborg/8151	Vesterbro	Street	
Aalborg/8158	Østerbro	Urban background	
Lille Valby/2090	-	Rural	
Keldsnor/9055	-	Rural	

The following compounds were measured:

- NO, NO_x including the derived compound NO_2 (NO_2=NO_x-NO) and PM_{10} were measured at all stations. PM_{10} was measured by means of β-absorption.
- $PM_{2.5}$ was measured by means of β-absorption at Copenhagen 1103.
- Elements (heavy metals) in PM_{10} were measured at Copenhagen/1103, Copenhagen/1257, Copenhagen/1259, Århus/6153, Århus/6159 and Lille Valby/2090. .
- PM_{10} was measured at Copenhagen/1103, -/1257 and -/1259 by means of TEOM.
- $PM_{2.5}$ was measured at Copenhagen/1103, -/1259 and Lille Valby/2090 by means of TEOM.
- O_3 was measured at all urban background and rural stations, Copenhagen/1257 and Copenhagen/1103
- CO was measured at all street stations, the urban background station, Copenhagen/1259 and the rural site Lille Valby /2090.
- Benzene and Toluene were measured at Copenhagen/1103 and Copenhagen/1257
- PAH were measured at Copenhagen/1103.
- SO_2 was measured at Aalborg/8151 and at Copenhagen/1103. The main purpose was to monitor episodic high concentrations.
- The meteorological parameters - temperature, wind speed and direction, relative humidity and global radiation - were measured at all urban background stations.

The pollutants are described in the appendix 1.

Measurements of gasses (NO, NOx, NO2, O3, CO, SO2, benzene and toluene) and PM_{10} and $PM_{2,5}$ using TEOM were recorded as ½-hour averages. PM10 and PM2.5 using beta measurements, elements in the particles and PAH were measured as 24 hour averages.

Short descriptions of the measured pollutants are given in the appendix 1. The actually applied measurement methods are listed at the website: http://www.dmu.dk/International/Air.

In LMP the measurements at fixed measurement stations are supplemented with model calculations using the Thor modelling system. This is an integrated model system, capable of performing model calculations at regional scale over urban background scale and down to individual street canyons in cities – on both sides of the streets (thor.dmu.dk). At present the system includes global meteorological data from National Centres for Environmental Prediction, United States, which is used as input for the four dimensional data assimilation (FDDA) in the meteorological model MM5v3 (Grell et al., 1995). The meteorological data from MM5v3 is used to drive the air pollution models, including the Danish Eulerian Hemispheric Model, DEHM , the Urban Background Model, UBM (Berkowicz, 2000b) and the Operational Street Pollution Model, OSPM (Berkowicz 2000a). DEHM is providing air pollution input data for UBM which again is providing air pollution input data to OSPM. Further details about the system can be found in Brandt et al. (2001 and 2003).

Model calculations of air quality on national scale is carried out using DEHM, which is an Eulerian model where emissions, transport, chemical reactions, physical transformations, and depositions of air pollutants are calculated in a three dimensional net of grid cells covering the northern hemisphere. The transport of air pollutants is calculated on the basis of meteorological data from a weather forecast model and takes place in and out of the individual grid cells in both horizontal and vertical directions. The calculations of air quality in Denmark are carried out with a geographical resolution of 16.67 km x 16.67 km in the horizontal plane. In the vertical direction the model is divided into 20 layers covering the lowest 15 km of the atmosphere. Of these the lowest layers are relatively thin (60 m) while the upper layers are relatively thick (2000 m). The model includes a comprehensive chemical scheme for calculation of the chemical reactions in the bottom part of the atmosphere. The model calculations for 2007 are carried out using meteorological data from the meteorological model MM5v3 (Grell et al., 1995). The emission inventories used in DEHM have a geographical resolution on 16.67 km x 16.67 km for Europe and are based on Danish national emission inventories for the year 2005 made by NERI (www.dmu.dk) and international emission inventories for the year 2005 collected and distributed by EMEP (www.emep.int).

The Urban Background Model, UBM, calculates the urban background air pollution based on emission inventories with a spatial resolution of 1 km x 1 km and based on input data from DEHM concerning the regional background. UBM is suitable for calculations of urban background concentrations when the dominating source is the road traffic. The model includes a simple scheme for calculation of the dispersion and transport of the air pollutants and a simple chemical model accounting for oxidation of nitrogen monoxide by ozone based on an assumption of photochemical equilibrium on the time scale of the pollution transport across the city area. The model is described in detail in Berkowicz (2000b).

Finally, the street canyon model OSPM (www.ospm.dmu.dk) is used to calculate the air pollution at 2 m height at the side walks of selected streets. Meteorological data from the meteorological model MM5 and air pollution concentrations from UBM are used as input to the model. The model includes emissions from traffic, simple chemical reactions describing the reactions of air pollutants in the street canyons and the dispersion of the air pollution in the street canyon (due to meteorological conditions and the moving traffic).

The traffic emission data used for the calculations with UBM and OSPM is based on NERI's traffic database with traffic volumes on all road links in Denmark for the year 2005 together with emission factors from the latest version of the COPERT IV model applied for 2007 conditions. The input data for the OSPM model on traffic volume and street configurations are generated using the AirGIS system (Jensen et al., 2001; http://airgis.dmu.dk).

The model calculations for 2007 for Copenhagen have been updated considerably since the reporting for 2006. This year full model calculations using DEHM, UBM, and OSPM were used to determine the air quality in 138 streets with meteorological and emission data as input data to the three models. Last year the calculations for Copenhagen were based solely on calculations for the street canyons based on input from the urban background measurement station in Copenhagen.

It was the intention to use the same model system for the calculations for 32 streets in Aalborg. However, the implementation of the model system for Aalborg took longer time than expected and the full model calculations could therefore not bee carried out for this annual reporting. In stead the calculations for Aalborg were based on calculations with OSPM based on input data from the urban background measurement station.

3 Nitrogen oxides

3.1 Yearly Statistics

Table 3-1 Nitrogen dioxide (NO_2) in 2007. All parameters are calculated with hourly averages.

Unit: µg/m^3	Number	Average	Median	98. percentile	19. highest
Traffic:					
Copenhagen/1257	8230	41	37	104	139
Copenhagen/1103	8125	52*)	49	116	158
Århus/6153	8518	40	36	99	140
Odense/9155	8756	32	23	101	133
Aalborg/8151	8674	34	28	98	128
Urban Background:					
Copenhagen/1259	8421	19	16	55	74
Århus/6159	8456	19	15	56	74
Odense/9159	8349	17	14	51	74
Aalborg/8158	7350	16	12	55	78
Rural:					
Lille Valby/2090	8454	9	7	34	53
Keldsnor/9055	8326	9	6	37	55
Limit values/limit value + margin of tolerance for 2007	>7884	40/46			200/230

*) Limit value + margin of tolerance exceeded.

Table 3-2 Nitrogen oxides (NO_x=NO+NO_2) 2007. All parameters are calculated with hourly averages.

Unit: µg/m^3 (as NO_2)	Number	Average	Median	98. percentile	19. highest
Traffic:					
Copenhagen/1257	8230	87	65	289	468
Copenhagen/1103	8125	115	98	329	519
Århus/6153	8518	91	68	322	498
Odense/9155	8757	69	39	321	565
Aalborg/8151	8674	95	63	375	622
Urban Background:					
Copenhagen/1259	8421	25	19	82	142
Århus/6159	8456	27	17	120	223
Odense/9159	8350	22	16	88	205
Aalborg/8158	7350	23	12	97	308
Rural:					
Lille Valby/2090	8455	11	8	46	107
Keldsnor/9055	8327	11	7	46	122

The limit values are based on EU Council Directive 1999/30/1999 (EC 1999) and implemented through a national Statutory Order from the Ministry of Environment (Miljøministeriet 2007).

3.2 Episodes

Table 3-3 Episodic results for Nitrogen dioxide (NO_2) in 2007. All parameters are calculated with hourly averages.

Unit: µg/m³	**Max. 3 hours**	**Date**	**Hour**	**Max. hour**	**Date**	**Hour**
Traffic:						
Copenhagen/1257	161	071215	23-24	206	071216	2-3
Copenhagen/1103	193	071216	1-2	199	070402	6-7
Århus/6153	146	070414	1-2	194	070413	7-8
Odense/9155	168	071023	6-7	202	071023	7-8
Aalborg/8151	148	070608	10-11	150	070608	10-11
Urban Background:						
Copenhagen/1259	82	070402	6-7	100	070427	7-8
Århus/6159	87	070401	19-20	102	070401	20-21
Odense/9159	90	070401	21-22	108	070401	22-23
Aalborg/8158	90	071023	23: 7	123	071023	8-9
Rural:						
Lille Valby/2090	58	070207	20-21	73	070402	7-8
Keldsnor/9055	55	071223	3-4	81	070620	1-2
Alert threshold	400	-		-	-	

Table 3-4 Episodic results for Nitrogen oxides ($NOx=NO+NO_2$) 2007. All parameters are calculated with hourly averages.

Unit: µg/m³ (as NO_2)	**Max. 3 hours**	**Date**	**Hour**	**Max. hour**	**Date**	**Hour**
Traffic:						
Copenhagen/1257	283	071215	22-23	778	071215	23-24
Copenhagen/1103	345	071216	1-2	882	070402	6-7
Århus/6153	253	070424	5-6	891	071025	6-7
Odense/9155	498	071023	6-7	1179	071023	7-8
Aalborg/8151	356	071025	8-9	878	071023	8-9
Urban Background:						
Copenhagen/1259	77	070424	5-6	206	071216	1-2
Århus/6159	136	071023	7-8	330	071023	9-10
Odense/9159	132	071215	22-23	380	071022	21-22
Aalborg/8158	336	071023	7-8	898	071023	8-9
Rural:						
Lille Valby/2090	66	071223	13-14	134	071223	14-15
Keldsnor/9055	74	071223	2-3	151	071223	5-6

The Alert threshold for maximum 3 hours concentration of NO_2 is given in EU Council Directive (EC, 1999) and implemented through a national Statutory Order from the Ministry of Environment (Miljøministeriet 2007).

The "Max 3. hour" values are defined and calculated in the following way: First find the lowest one hour value for all consecutive three-hours periods. Second find the highest of these lowest one hour values which is defined as the "Max 3. hours" values, which is listed in table 3-3 and 3-4.

3.3 Trends

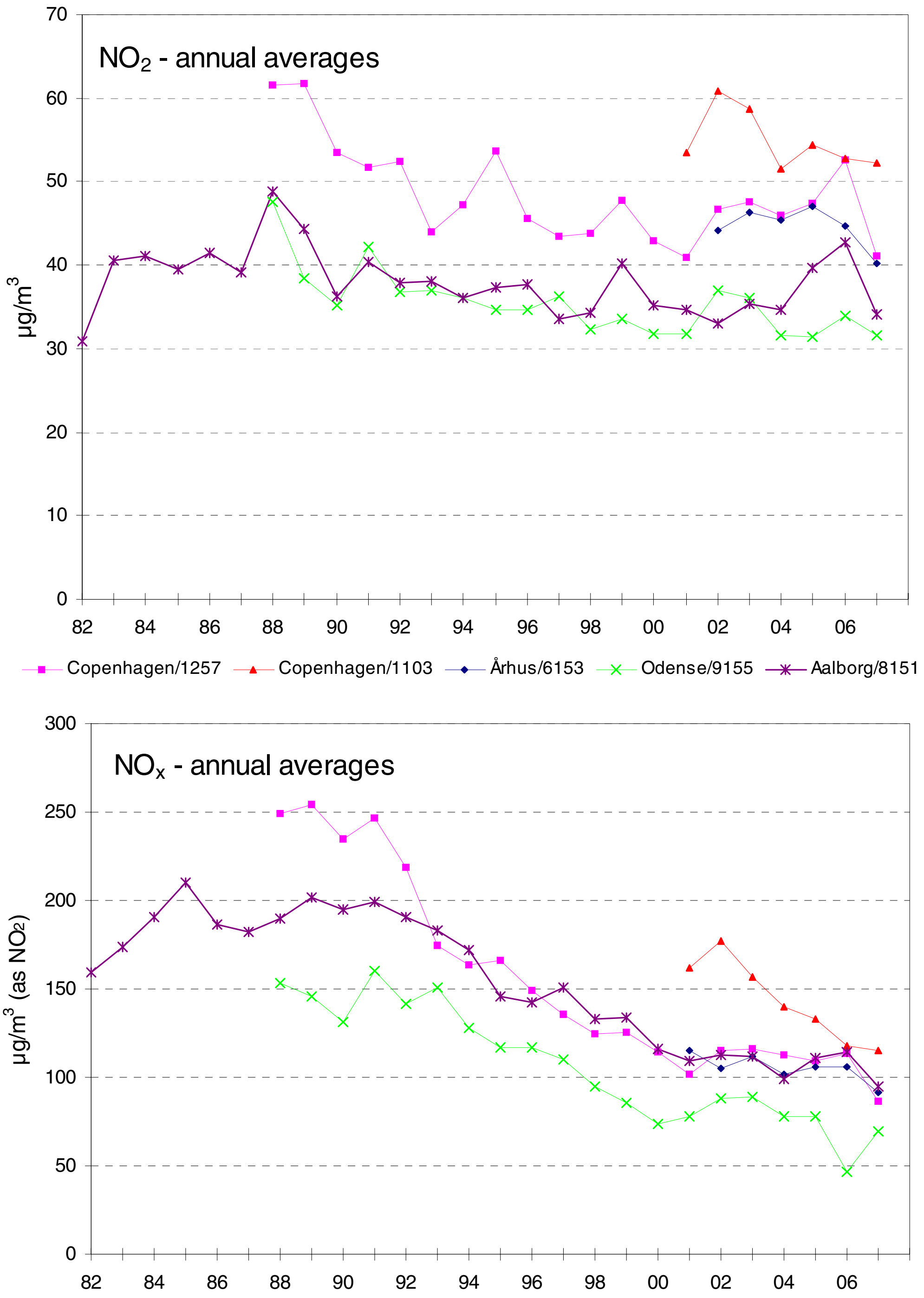

Figure 3-1 The graphs show the time series for the annual average values measured at street stations. Previous results from Copenhagen/1103 can be found at the homepage of Copenhagen Environmental Protection Agency (www.Miljoe.kk.dk)

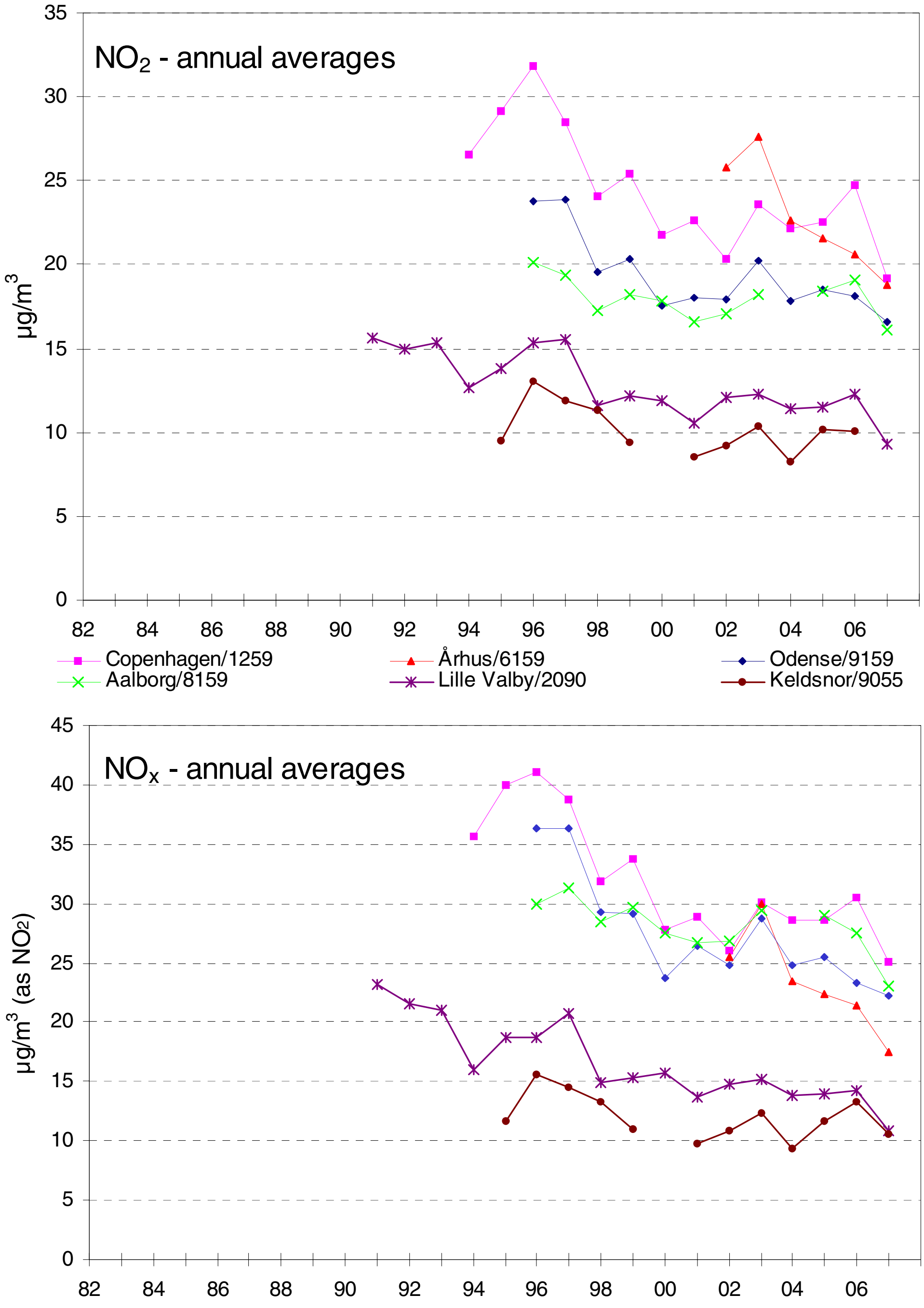

Figure 3-2 The graphs show the time series for the annual average values measured at urban background and rural stations.

3.4 Results from model calculations

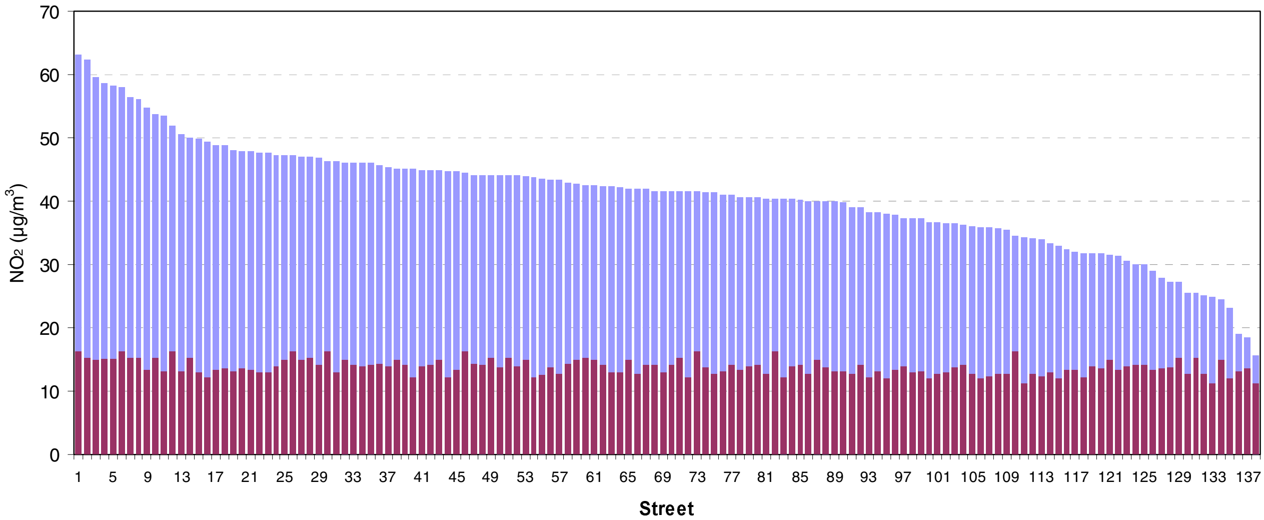

Figure 3-3 Annual mean concentrations of NO_2 for 2007 for 138 streets in Copenhagen. The contribution from traffic in the street canyons is calculated with the street canyon model OSPM. The urban background (dark red colour) is obtained from calculations with the urban background model UBM with input data from the regional scale model DEHM. The value for a street is for the kerb side with the highest annual mean concentration. The names of the streets can be seen in table 3.4.

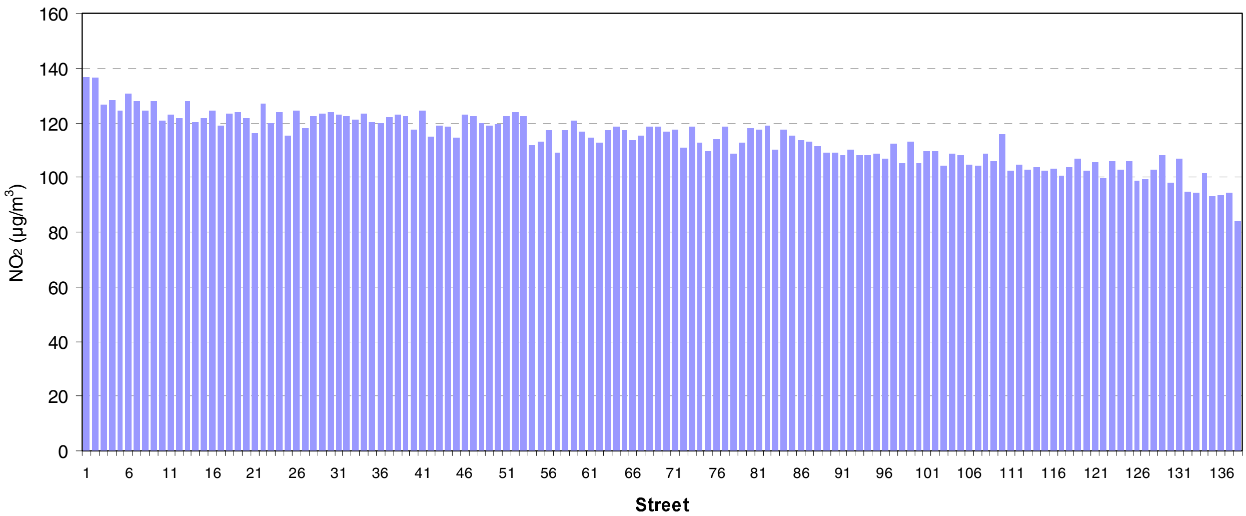

Figure 3-4 The 19th highest concentration of NO_2 in 2007 for 138 streets in Copenhagen. The contribution from traffic in the street canyons is calculated with the street canyon model OSPM. The urban background is obtained from calculations with the urban background model UBM with input data from the regional scale model DEHM. The value for a street is for the kerb side with the highest annual mean concentration. The streets are sorted as in figure 3.3. The names of the streets can be seen in table 3.4.

Table 3-4 Number and names for the streets shown in figure 3.3, 3.4 and 3.5. The numbers in parenthesis refer to different segments of streets with more than one calculation point.

Number	Street	Number	Street	Number	Street
1	H C Andersens Boulevard(3)	47	Torvegade	93	Frederikssundsvej(7)
2	Nørre Søgade	48	Vesterbrogade(2)	94	Jyllingevej(2)
3	Ågade	49	Gothersgade(1)	95	Frederiksborgvej(1)
4	Lyngbyvej(2)	50	Nørrebrogade	96	Frederikssundsvej(6)
5	Lyngbyvej(3)	51	Rosenørns Alle	97	Alhambravej
6	H C Andersens Boulevard(2)	52	Gammel Kongevej(2)	98	Slotsherrensvej(2)
7	Åboulevard(3)	53	Nordre Fasanvej(3)	99	Istedgade
8	Gyldenløvesgade	54	Gammel Køge Landevej(1)	100	Ålholmvej(2)
9	Tuborgvej(3)	55	Folehaven(1)	101	Strandvejen(3)
10	Åboulevard(1)	56	Folke Bernadottes Allé	102	Amager Boulevard
11	Sydhavnsgade	57	Grøndals Parkvej	103	Hareskovvej
12	H C Andersens Boulevard(1)	58	Holmens Kanal	104	Godthåbsvej(2)
13	Nordre Fasanvej(2)	59	Jagtvej(4)	105	Peter Bangs Vej(1)
14	Åboulevard(2)	60	Nørre Voldgade(1)	106	Vigerslevvej(2)
15	Sallingvej(2)	61	Tagensvej(4)	107	Frederiksborgvej(2)
16	Frederikssundsvej(8)	62	Tagensvej(2)	108	Roskildevej(2)
17	Tomsgårdsvej(1)	63	Amagerbrogade(2)	109	Folehaven(2)
18	Østerbrogade(3)	64	Søndre Fasanvej(2)	110	Tietgensgade
19	Nordre Fasanvej(1)	65	Jagtvej(2)	111	Amagerbrogade(3)
20	Østerbrogade(4)	66	Østerbrogade(2)	112	Strandvejen(2)
21	Frederikssundsvej(3)	67	Vesterbrogade(1)	113	Slotsherrensvej(1)
22	Toftegårds Allé(2)	68	Falkoner Alle(1)	114	Bellahøjvej
23	Jyllingevej(1)	69	Toftegårds Allé(1)	115	Vigerslevvej(1)
24	Vesterbrogade(3)	70	Bülowsvej(2)	116	Frederikssundsvej(4)
25	Borups Alle	71	Nørre Farimagsgade	117	Tuborgvej(2)
26	Stormgade	72	Englandsvej(1)	118	Røde Mellemvej(1)
27	Jagtvej(1)	73	Bernstorffsgade(1)	119	Godthåbsvej(3)
28	H.C. Ørsteds Vej(1)	74	Øster Voldgade(1)	120	Ålholmvej(1)
29	Rolighedsvej	75	Strandvejen(1)	121	Hulgårdsvej(1)
30	Bernstorffsgade(2)	76	Smallegade	122	Hulgårdsvej(2)
31	Amagerfælledvej	77	Mimersgade	123	Hillerødgade(4)
32	Øster Søgade	78	Tomsgårdsvej(2)	124	Godthåbsvej(1)
33	Frederikssundsvej(1)	79	Hillerødgade(3)	125	Hillerødgade(1)
34	Nordre Fasanvej(5)	80	Falkoner Alle(3)	126	Tuborgvej(1)
35	Vester Farimagsgade	81	Søndre Fasanvej(1)	127	Kalvebod Brygge
36	Bredgade	82	Hammerichsgade	128	Tagensvej(5)
37	H.C. Ørsteds Vej(2)	83	Frederikssundsvej(2)	129	Øster Voldgade(2)
38	Nordre Fasanvej(4)	84	Vesterfælledvej	130	Roskildevej(1)
39	Falkoner Alle(2)	85	Bülowsvej(1)	131	Nørre Voldgade(2)
40	Frederikssundsvej(5)	86	Peter Bangs Vej(2)	132	Gammel Køge Landevej(2)
41	Gammel Kongevej(1)	87	Jagtvej(3)	133	Røde Mellemvej(2)
42	Sallingvej(1)	88	Dag Hammarskjølds Allé	134	Fredensgade
43	Tagensvej(3)	89	Tagensvej(1)	135	Englandsvej(2)
44	Amagerbrogade(1)	90	P Knudsens Gade(1)	136	Vigerslev Allé
45	Østerbrogade(1)	91	P Knudsens Gade(2)	137	Artillerivej
46	Vester Voldgade	92	Rebildvej	138	Strandvænget(2)

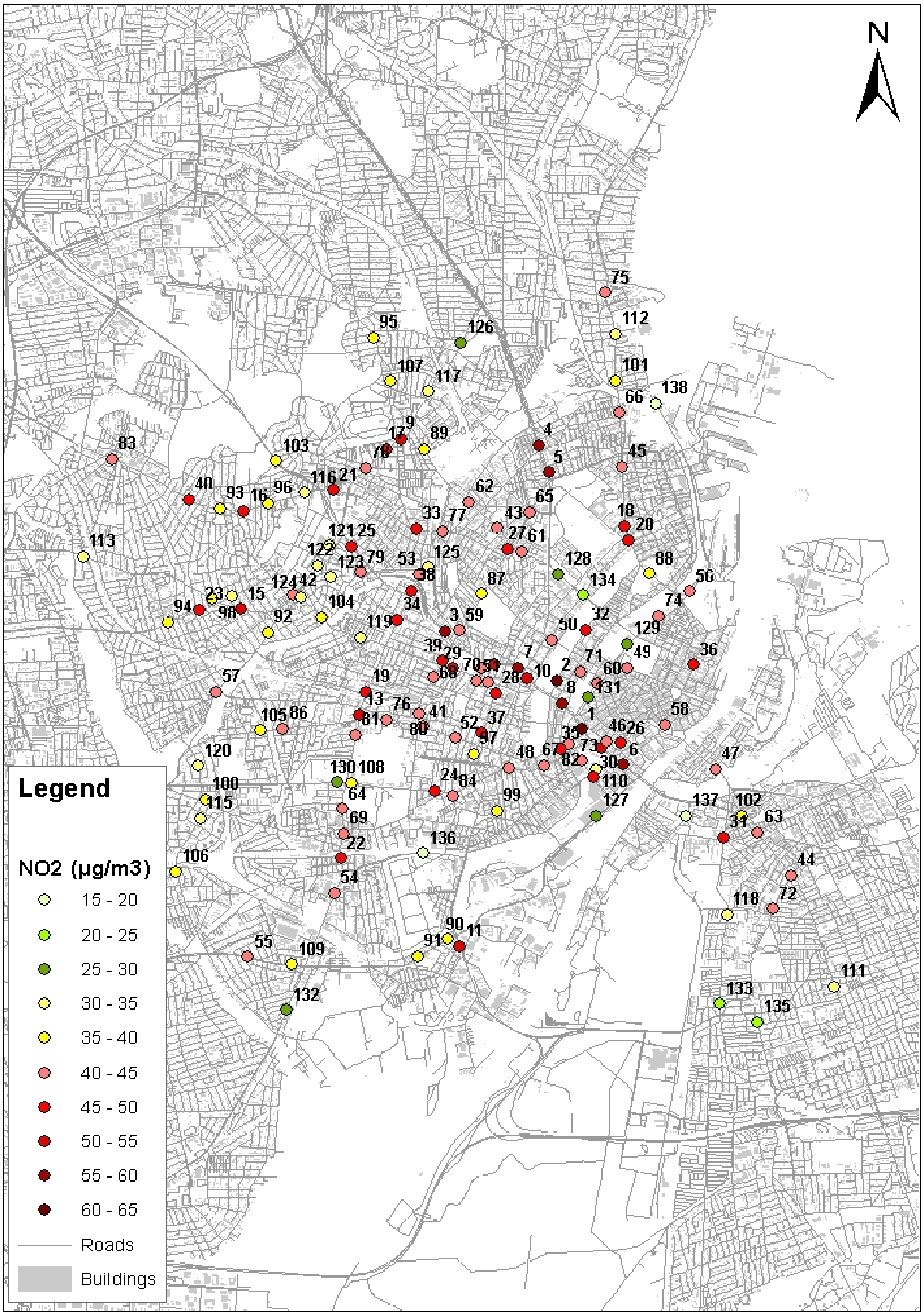

Figure 3-5 Map showing the locations of the selected streets in Copenhagen and the annual mean concentrations of NO_2 for 2007. The contribution from traffic in the street canyons is calculated with the street canyon model OSPM. The urban background is obtained from calculations with the urban background model UBM with input data from the regional scale model DEHM. The value for a street is for the kerb side with the highest annual mean concentration. The numbers for the streets are the same as in figure 3.3. The numbers indicate the ranking of the NO_2 concentrations with number one for the street with the highest NO_2 concentration. The names and numbers for the streets are shown in table 3.4.

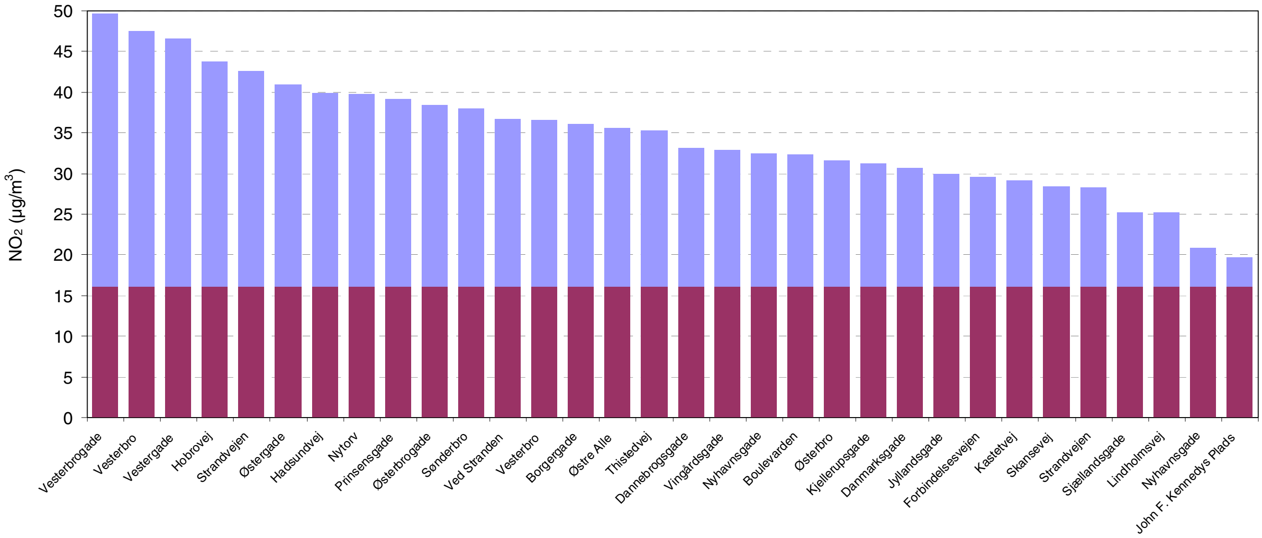

Figure 3-6 Annual mean concentrations of NO_2 for 2007 for 32 streets in Aalborg. The contribution from traffic in the street canyons is calculated with the street canyon model OSPM. The urban background (dark red colour) is obtained from the measurements at the urban background measurement station at Østerbro. The value for a street is for the kerb side with the highest annual mean concentration.

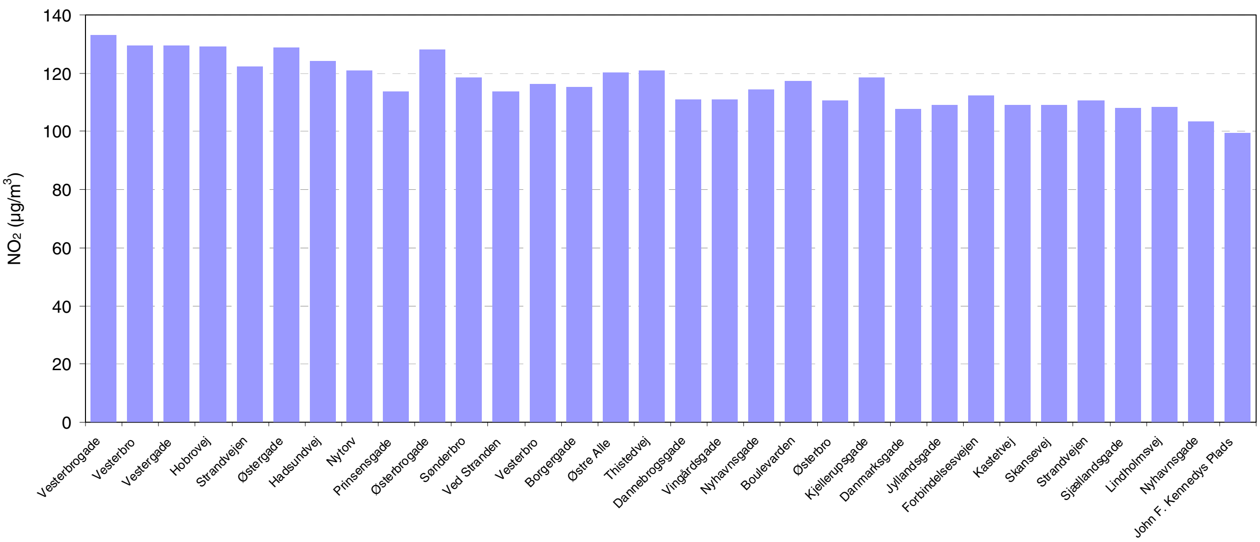

Figure 3-7 The 19th highest concentration of NO_2 in 2007 for 32 streets in Aalborg. The contribution from traffic in the street canyons is calculated with the street canyon model OSPM. The urban background is obtained from the measurements at the urban background measurement station at Østerbro. The value for a street is for the kerb side with the highest annual mean concentration. The streets are sorted as in figure 3.6.

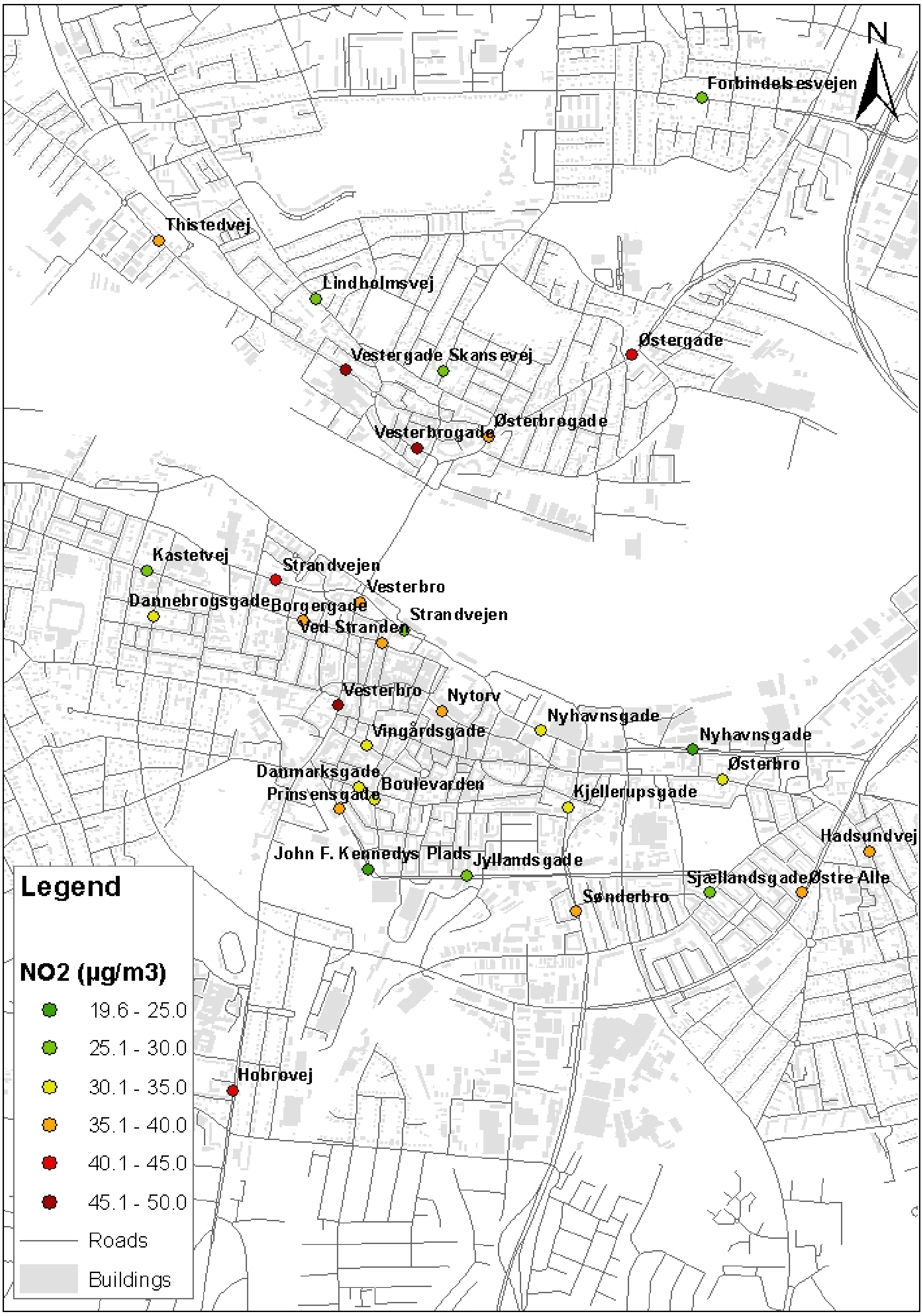

Figure 3-8 Map showing the location of the selected streets in Aalborg and the annual mean concentrations of NO_2 for 2007. The contribution from traffic in the street canyons is calculated with the street canyon model OSPM. The urban background is obtained from calculations with the urban background model UBM with input data from the regional scale model DEHM. The value for a street is for the kerb side with the highest annual mean concentration.

In 2007 the limit value plus margin of tolerance for protection of human health is 46 µg/m^3 for the annual mean concentration and 230 µg/m^3 for the 19th highest concentration of NO_2. The limit values are based on EU Council Directive 1999/30/1999 (EC 1999) and implemented through a national Statutory Order from the Ministry of Environment (Miljøministeriet 2007).

The results from the model calculations for Copenhagen for 2007 show that the limit value plus margin of tolerance for the annual mean concentration was exceeded in 35 of the 138 selected streets in Copenhagen (figure 3.3). The limit value plus margin of tolerance for the 19th highest concentration is not exceeded at any of the selected streets (figure 3.4).

For Aalborg the model calculations show that the limit value plus margin of tolerance for the annual mean concentration was exceeded in 3 of the 32 selected streets in 2007 (figure 3.5). The limit value plus margin of tolerance for the 19th highest concentration is not exceeded at any of the selected streets (figure 3.6).

The streets with exceedances of the limit value plus margin of tolerance all have a daily traffic intensity of more than 13.000 vehicles per day. However, it is not only the traffic intensity which determines the concentration of NO_2. Also the width of the street, the height of the surrounding buildings and the composition of vehicles has large impact on the concentration of NO_2 in the streets.

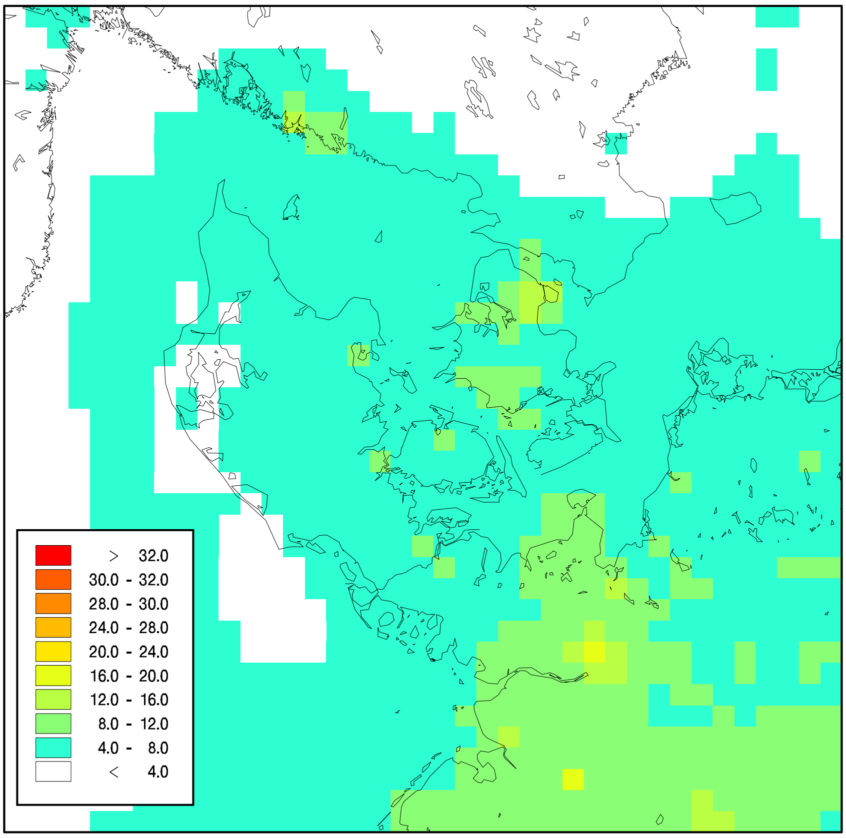

Figure 3-7 Annual mean concentrations of NO_x for 2007 calculated with DEHM given as µg/m^3, when all NO_x is calculated as NO_2. The figure shows the average concentrations for the 16,67 x 16,67 km grit cells used in the model.

The limit value for protection of ecosystems is 30 µg/m^3 NO_x calculated as NO_2 for the calendar year. The limit value is based on EU Council Directive (EC, 1999) and implemented through a national Statutory Order from the Ministry of Environment (Miljøministeriet 2007). The results from the model calculations show (figure 3.7) that the annual mean concentrations of NO_x were below the limit value in 2007.

4 Ozone

4.1 Annual statistics

Table 4-1 *Ozone* (O_3) 2007. All parameters are calculated with one-hour average values. The eight hour values are calculated as a moving average based on hourly measurements. For the "26. highest 8 hour" value is used the highest daily 8 hour average values calculated as described in the EU Directive 2002/3/EC.

Unit: µg/m^3	Number of results	Average	Median	Max. 8 hours	26. highest 8 hour	Max. 1 hour	AOT40 µg/m^3.h
Urban Background:							
Copenhagen/1259	8612	54	54	134	98	141	5570
Århus/6159	8456	45	47	114	54	126	2671
Odense/9159	8073	54	54	133	100	159	6917
Aalborg/8158	8610	52	55	118	78	124	2808
Rural							
Lille Valby/2090	8456	57	58	137	106	149	9081
Keldsnor/9055	8662	59	60	123	80	141	5535
Traffic							
Copenhagen/1257	8267	39	38	113	77	124	261
Copenhagen/1103	8201	33	32	94	70	112	153
Target value	>7884	-	-	-	120	-	18 000
Long term objective	>7884	-	-	120	-	-	6 000

The target values and long term objectives are given in the EU Council Directive (EC, 2002) and implemented through a national Statutory Order from the Ministry of Environment (Miljøministeriet 2007).

Number of information to the public due to exceedance of the information threshold (180 µg/m^3) in 2007: 0.

Number of information to the public due to exceedance of the alert threshold (240 µg/m^3) in 2007: 0.

4.2 Trends

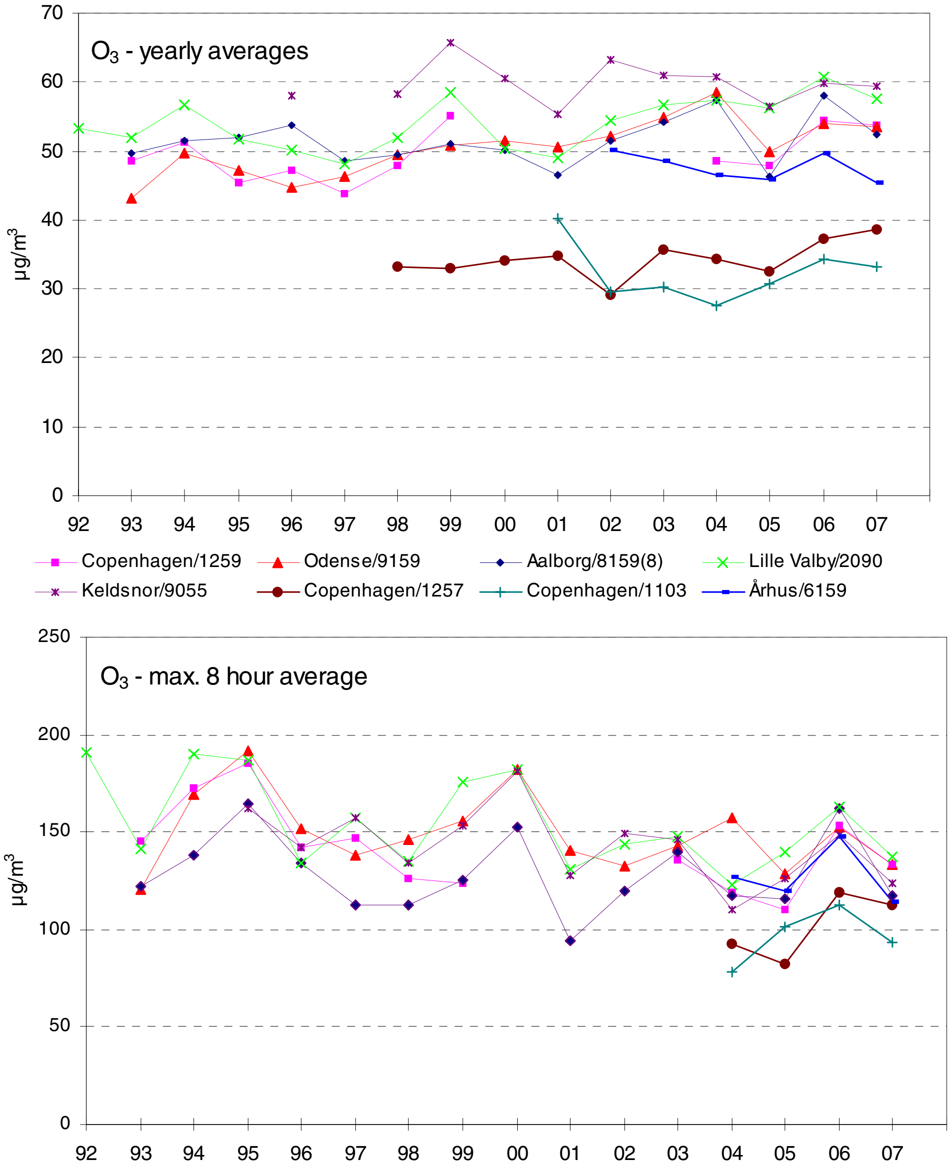

Figure 4-1 Annual average values and the max. 8 hour average value. The latter is calculated as hourly 8 hour running averages according to the provisions in the EU Council Directive (EC, 2002). Previous results from Copenhagen/1103 can be found at the Website of the Copenhagen Environmental Protection Agency (www. Miljoe.kk.dk).

4.3 Results from model calculations

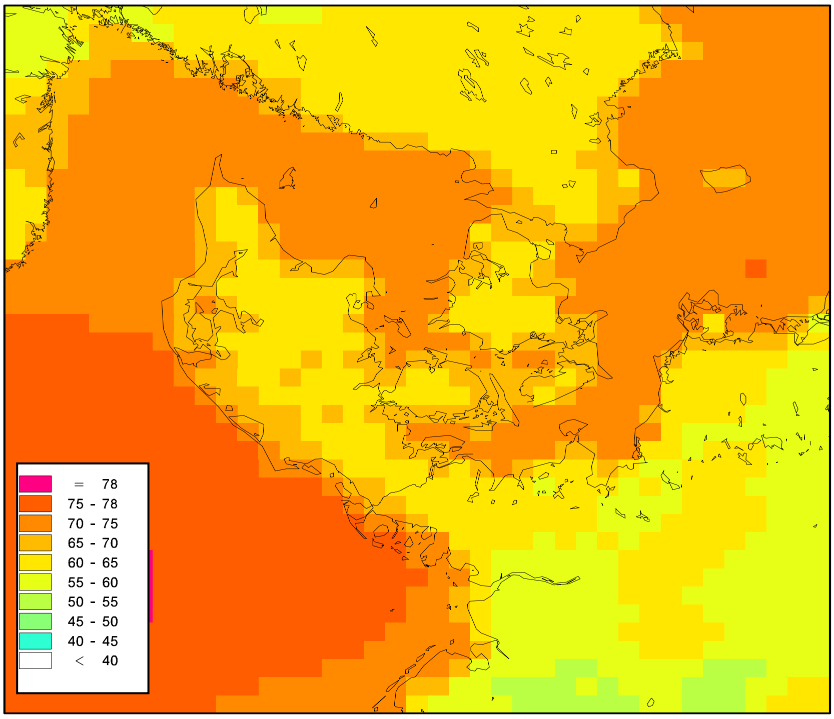

Figure 4-2 Annual mean concentrations of O_3 ($\mu g/m^3$) for 2007 calculated using DEHM. The figure shows the average concentrations for the 16,67 x 16,67 km grit cells used in the model.

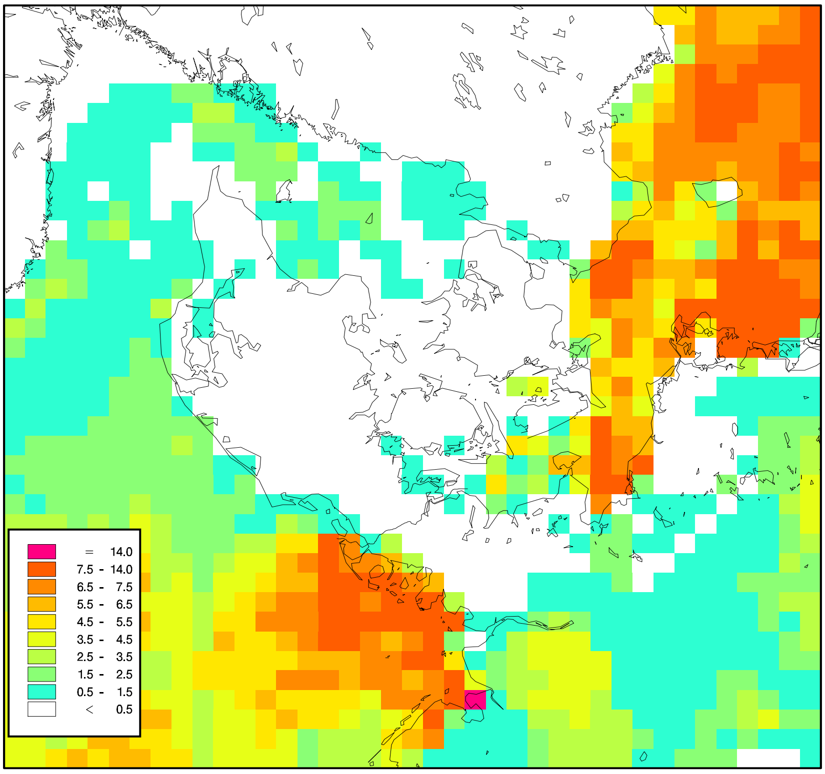

Figure 4-3 Number of exceedances of 120 $\mu g/m^3$ for 8-hour running mean concentrations of ozone in 2007. The calculations were carried out using DEHM.

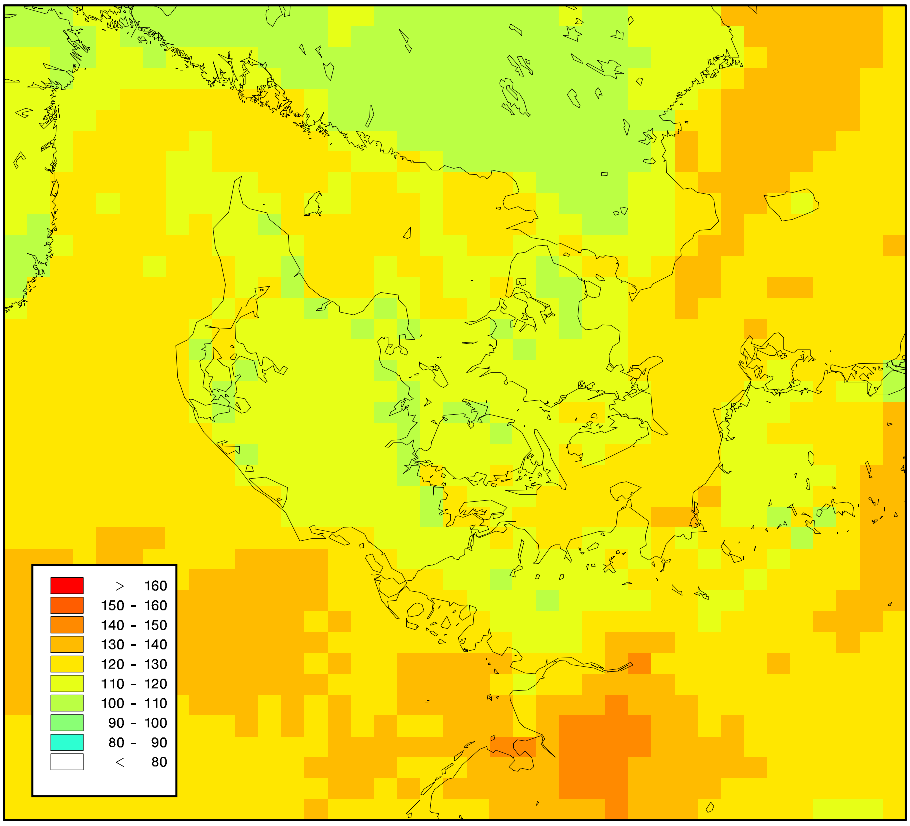

Figure 4-4 Maximum 8 hour running mean concentration (µg/m^3) of ozone in 2007 calculated using DEHM

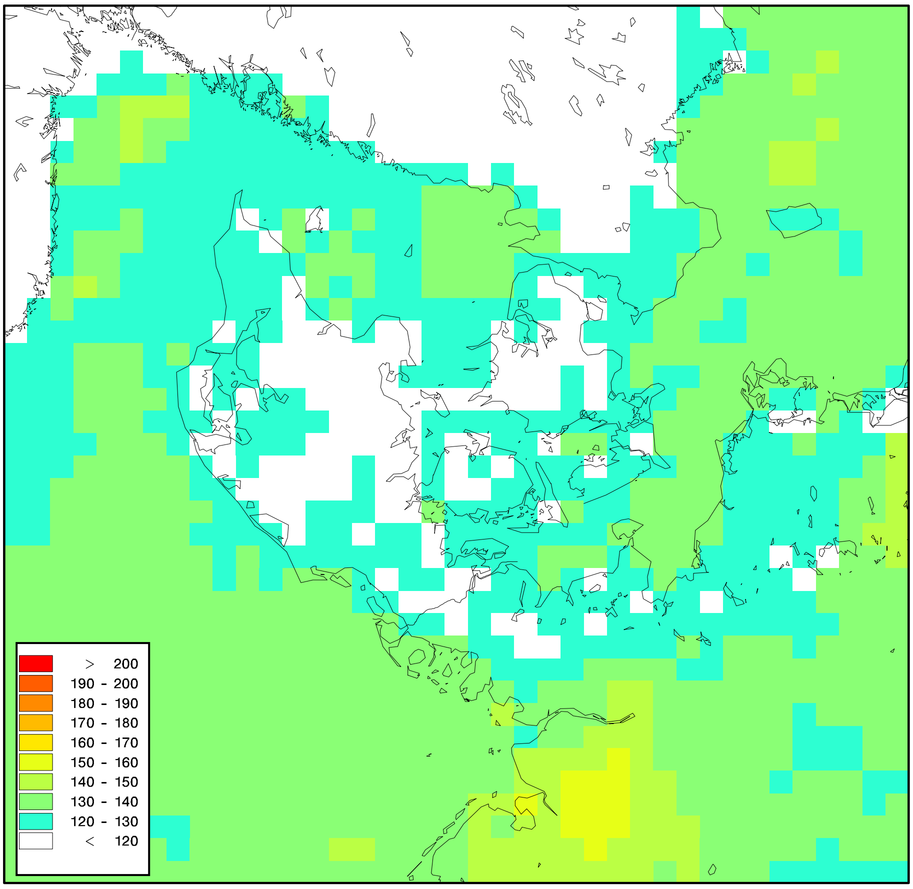

Figure 4-5 Maximum one hour mean concentration of ozone (µg/m3) in 2007 calculated using DEHM

The target value for protection of human health is that the running 8 hour mean concentration of ozone must not exceed 120 µg/m³ more than 25 times a calendar year. The long term objectives are that the running 8 hour mean concentration of ozone must not exceed 120 µg/m³. The target value and long term objective are given in the EU Council Directive (EC, 2002) and implemented through a national Statutory Order from the Ministry of Environment (Miljøministeriet 2007). Results from the model calculations show that the target value was not exceeded (figure 4.3). However, the long term objective was exceeded at several places in Denmark; mainly in the coastal areas (figure 4.4).

According to the directive (EC, 2002) the public has to be informed if the one hour mean concentration exceed the information threshold of 180 µg/m³. Based on measurements this threshold was not exceeded in 2007. The model calculations show also that the one hour mean concentration did not exceed 180 µg/m³ in 2007. However, the model results are 10-20% lower than the measurements. The reason for this discrepancy is most likely that the model does not include emissions from wild fires. Large wild fires are known to increase episodic ozone concentrations. Work has been initiated to include emissions from wild fires in the model. Inclusion of emissions of wild fires in the model calculations may also increase the area where the long term objective for ozone was exceeded in 2006.

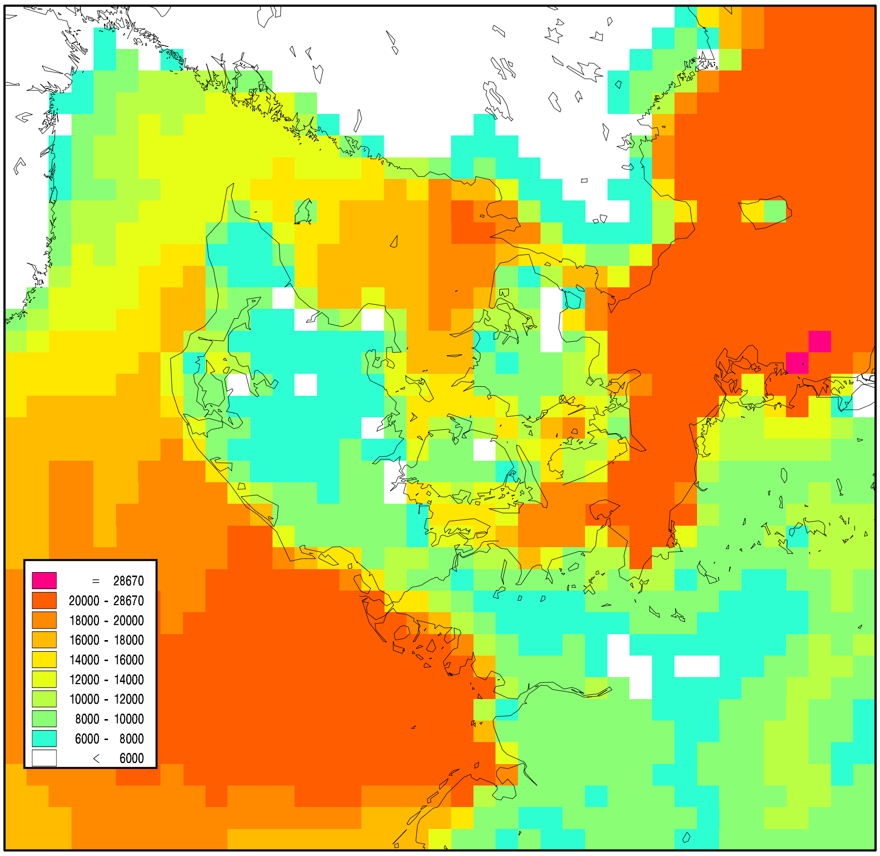

Figure 4-6 AOT40 (µg/m³·h) calculated for 2007 using DEHM.

AOT40 (in units of µg/m^3·h) is the sum of the hourly difference between values above 80 µg/m^3 (=40 ppbv) and 80 µg/m^3 measured during the time from 8:00 to 20:00 in the period from May to July. The target values and long term objectives for protection of vegetation is 18000 and 6000 µg/m^3·h, respectively. The target values and long term objectives are given in the EU Council Directive (EC, 2002) and implemented through a national Statutory Order from the Ministry of Environment (Miljøministeriet 2007). The results from the model calculations using DEHM (figure 4.6) show that AOT40 was below the target value except for a very few coastal places. However, the long term objective was exceeded for more than half of the country.

5 Carbon monoxide

5.1 Annual statistics

Table 5-1 Annual statistics for carbon monoxide (CO) in 2007. All parameters are calculated with hourly average. The 8-hour values are calculated as a moving average based on hourly results.

Unit: µg/m³	Number	Average	Median	98-percentile	99.9-percentile	Max. 8-hours	Max hour
Traffic:							
Copenhagen/1257	8623	556	473	1514	2628	2460	3226
Copenhagen/1103	8161	530	466	1332	2013	1874	2514
Århus/6153	6865	372	326	920	1659	1463	2110
Odense/9155	7685	463	324	1572	3709	3661	4734
Aalborg/8151	7972	540	442	1504	2443	2062	3018
Urban Background:							
Copenhagen/1259	7749	287	270	568	1077	1020	1552
Rural							
Lille Valby/2090	7972	251	237	508	1008	1040	1133
Limit value	-	-	-	-	-	10 000	-
Guideline values	-	-	-	-	-	10 000	30 000

The limit value is based on EU Council Directive (EC, 2000) and implemented through a national Statutory Order from the Ministry of Environment (Miljøministeriet 2007).

The guideline values are proposed in WHO, 2000. (Air Quality Guidelines for Europe, Second Edition, WHO Regional Publications, European Series, No. 91, Copenhagen 2000).

5.2 Trends

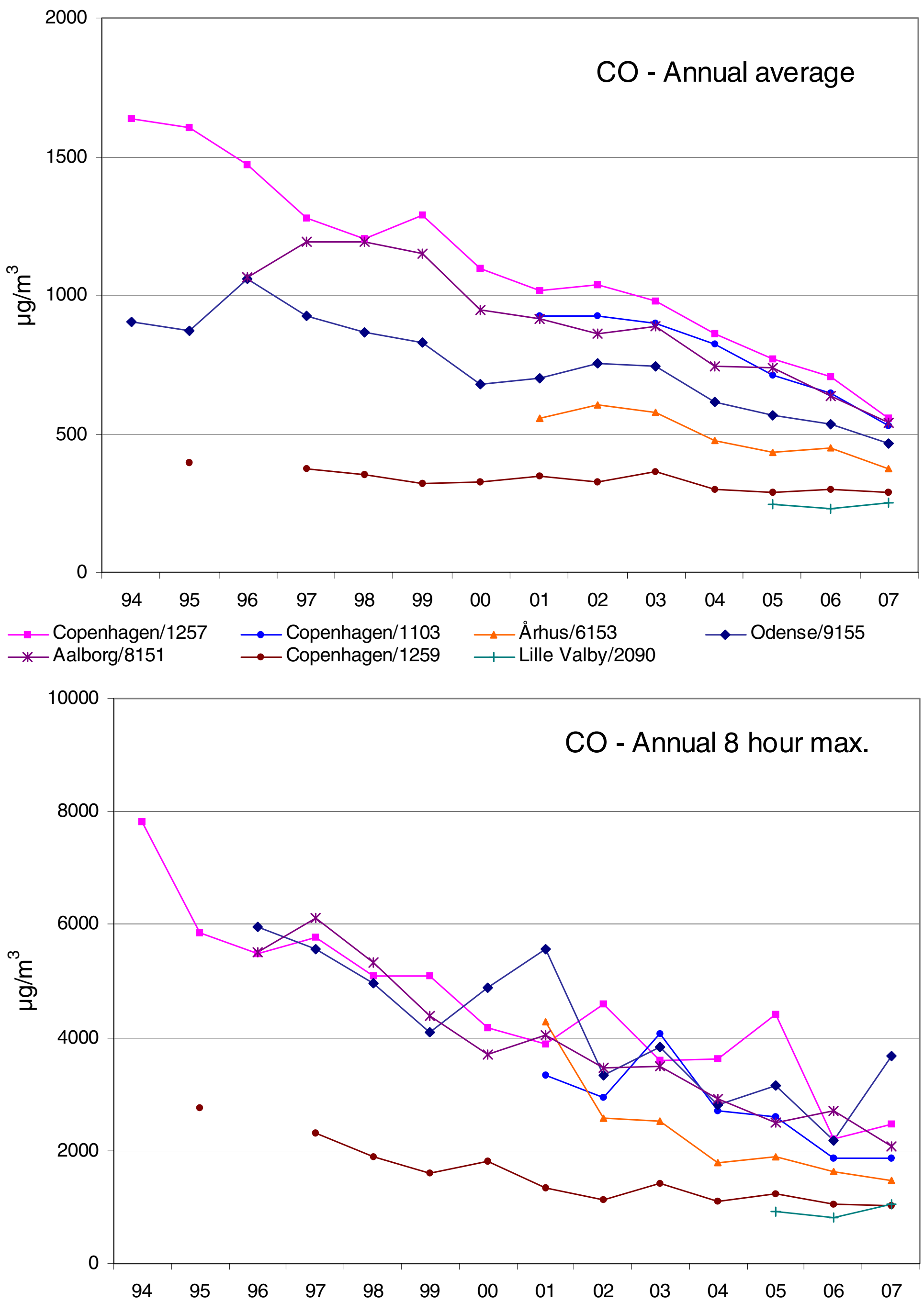

Figure 5-1 Annual average values and highest 8-hour value calculated based on an hourly moving average. Previous results from Copenhagen/1103 can be found at the website of the Copenhagen Environmental Protection Agency (www.Miljoe.kk.dk).

6 Benzene and Toluene

6.1 Annual statistics

Table 6-1 Annual statistics for Benzene in 2007. All values are calculated as 1 hour averages. The 8 hours values are calculated as a moving average of hourly averages. The life time risk level is defined as the concentration that through a lifelong exposure is estimated to give an increase in risk of 1:10^5 for developing cancer.

Unit: µg/m^3	Number of results	Average	Max. 8 hours	Max. 1 hour
Copenhagen/1257	7560	2.0	12	16
Limit value	>7784	5	-	-
Life time risk level at 1:10^5		1.7		

The limit value is based on EU Council Directive (EC, 2000) and implemented through a national Statutory Order from the Ministry of Environment (Miljøministeriet 2007).

Table 6-2 Annual statistics for Toluene in 2007. The max. 7 days is calculated as the highest value for a moving 7 days average based on daily averages (WHO, 2000).

Unit: µg/m^3	Number of results	Average	Max. 7 days	Max. 1 hour
Copenhagen/1257	7447	7.6	14	102
Guideline value	-	-	260	-

The guideline and lifetime risk level are established by WHO (WHO, 2000).

6.2 Trends

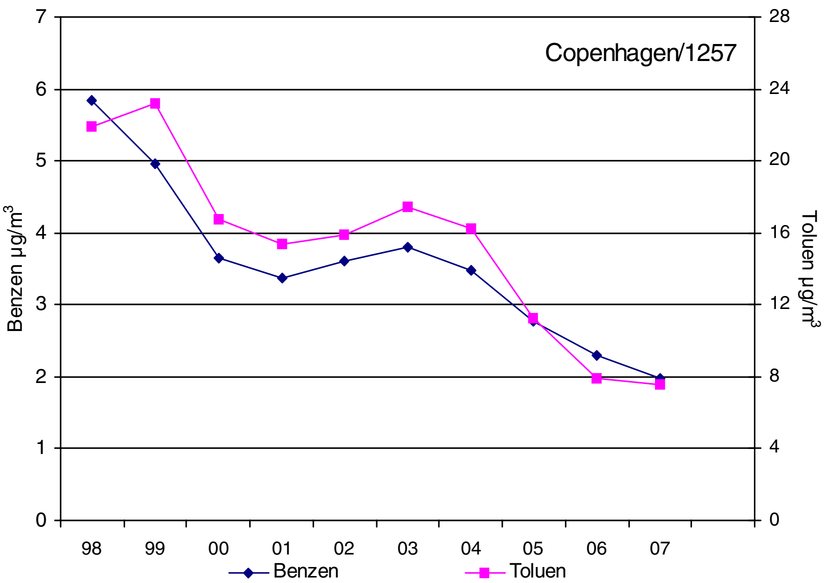

Figure 6-1 Annual average for benzene and toluene measured at Copenhagen/1257.

7 Particles (TSP, PM_{10} and $PM_{2.5}$)

7.1 PM measurements

The limit values are based on the EU Council Directive (EC, 1999) and implemented through a national Statutory Order from the Ministry of Environment (Miljøministeriet 2007).

The SM200 sampler manufactured by OPSIS, Sweden, has been used in Denmark to measure PM_{10} in accordance with the EU Directive (EC, 1999). The sampler provides the possibility for sampling PM_{10}, which later can be used for weighing and chemical analysis. Moreover, the PM_{10} is determined immediately after exposure by means of absorption of β-rays in the particles. This option provides the possibility of presenting "on-line" results.

Recent results (Harrison, 2006) indicate that the β-ray results from the SM200 sampler comply better with the reference method for PM_{10} given in the Directive, than the results from weighing of the filters. For this reason we have decided from 2006 and onwards to report results from the β-method. Previoulsy, results from weighing of the filters were reported.

The results from the two methods differ slightly. From 2002 to 2005, where comprehensive data sets are available, it is shown that the β-method in average yields results that are 1.08 times the weighing for the yearly average and 1.09 times the weighing for the 39th highest concentration.

In 2007 measurements of $PM_{2.5}$ was started at one station (Copenhagen/1103).

In the trend graphs (fig. 7.1 and 7.2) a slight increase is expected due to the change of method.

7.2 Annual statistics

At all stations PM_{10} was collected continuously on filters in 24 hours intervals for subsequent β-absorption measurement shortly after exposure(table 7-1) and later chemical analysis in the laboratory. Additionally PM_{10} is measured at the stations Copenhagen/1103 and /1259 using a TEOM (Tapered-element oscillating microbalance) instrument. The TEOM measurements are performed with a time resolution of 30 minutes (table 7-3). During sampling the particles are heated to 50°C. At that temperature some of the volatile compounds may evaporate (mainly secondary aerosols). The loss will depend of the actual composition of the aerosols. The European Commission has accepted that TEOM measurements can be used in relation to EU limit values if the measured values are multiplied with a factor 1.3. However, the correction factor depends on the specific measurement site and measurements of PM10 using TEOM and a correction factor of 1.3 may therefore have high uncertainty.

$PM_{2.5}$ was measured with the SM200 sampler at one station (table 7-2), while the TEOM method is used at Copenhagen1103/1257/1259 and LilleValby/2090 (table 7-4).

Table 7-1 Annual statistics for PM_{10} in 2007. All parameters are calculated as daily averages.

Unit µg/m^3	Number of results	Average	36.highest result	90 percentile	95 percentile	8.highest result	Max. day
Traffic							
Copenhagen/1257	325	30	47	50	58	68	86
Copenhagen/1103	292	38	58*)	62	71	76	101
Århus/6153	318	27	39	41	53	56	76
Odense/9155	317	35	57*)	59	69	79	92
Aalborg/8151	266	33	44	49	63	68	266
Urban background							
Copenhagen/1259	341	24	39	39	47	54	71
Århus/6159	265	25	36	41	48	56	84
Aalborg/8158	310	27	40	42	51	58	179
Rural							
Lille Valby/2090	244	24	37	45	55	59	80
Keldsnor/9055	347	24	39	40	48	60	99
Limit values (2005)	>329	40	50				

***)** Limit value exceeded.

Table 7-2 Annual statistics for $PM_{2.5}$ in 2007. All parameters are calculated as daily averages. The limit values shall be met in 2015.

Unit µg/m^3	Number of results	Average	36.highest result	90 percentile	95 percentile	8.highest result	Max. day
Traffic							
Copenhagen/1103	226	23	32	36	44	45	67
Proposed limit value 2015(2020)	>329	25(20)					

Table 7-3 Annual statistics for PM_{10} measured in 2007 using TEOM. The values are calculated based on daily averages.

Unit µg/m^3	Number of results	Average	36.highest result	90 percentile	Average × 1.3	36. highest × 1.3
Traffic						
Copenhagen/1103	136	30	-	-	38	-
Urban background						
Copenhagen/1259	357	15	23	23	19	29
Limit values	>329	-	-	-	40	50

Table 7-4 Annual statistics for $PM_{2.5}$ measured in 2007 using TEOM. The values are calculated based on daily averages.

Unit µg/m^3	Number of results	Average	36.highest result	90 percentile
Traffic				
Copenhagen/1257	42	-	-	-
Copenhagen/1103	327	14	24	24
Urban Background				
Copenhagen/1259	358	10	16	17
Rural				
Lille Valby/2090	332	9	15	16

7.3 Trends

Up till 2000 the particulate matter was measured as Total Suspended Particulate matter (TSP) corresponding to particles with a diameter up to around 25 µm. The exact cut-off depended strongly on the wind velocity. From 2001 PM_{10} measurements are started at all stations except Copenhagen/1103 where the TSP measurements were continued to the end of 2005. The TSP is on the average 30-80% higher than PM_{10} at the street stations, while the difference is less at urban background and rural sites.

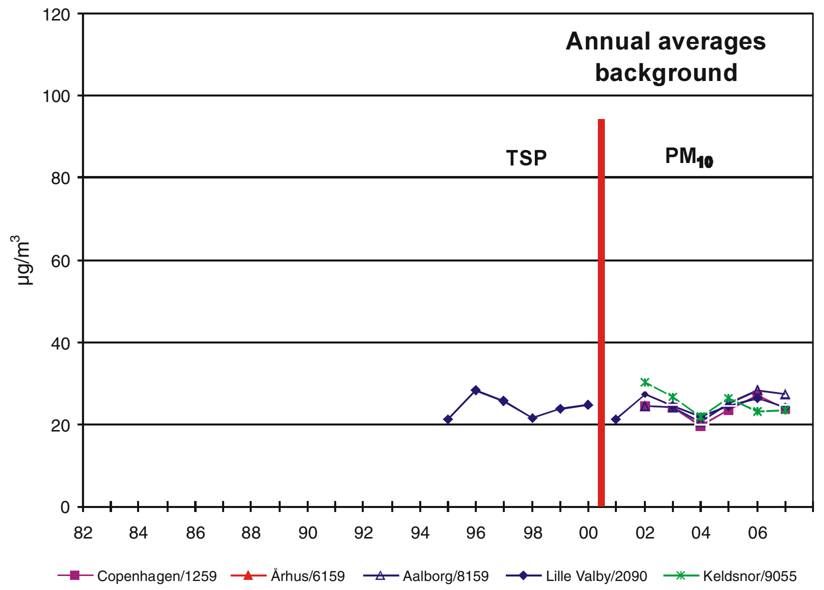

Figure 7-2 Annual averages for TSP and PM_{10} measured at urban background and rural stations. The change from gravimetric determination to use of β-measurements from 2006 gives rise to a 5-10% increase from 2005 to 2006.

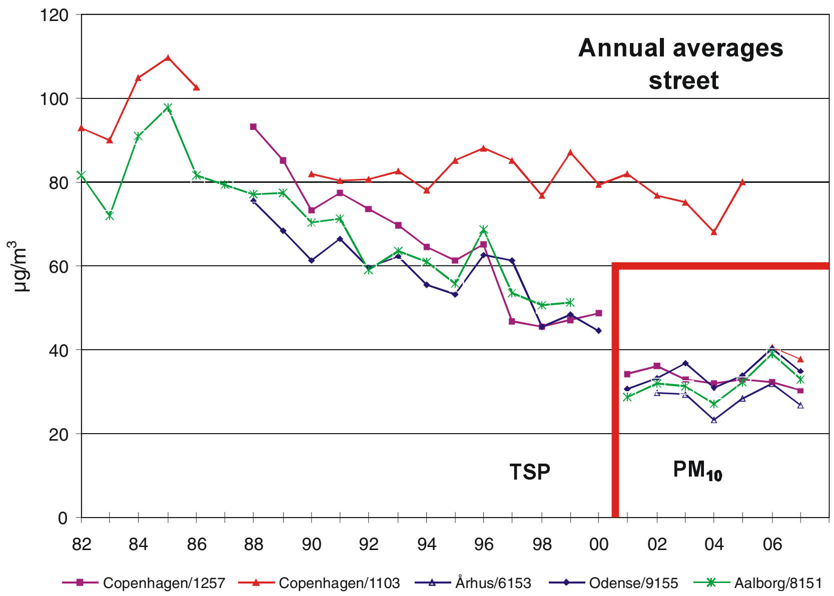

Figure 7-1 Annual averages for TSP and PM10 measured at street stations. Results from 2000 and earlier are for TSP, while later results are for PM10 – except for Copenhagen/1103, where TSP measurements were continued to the end of 2005. The PM10 results are shown in the area in the bottom right of the plot area. The change from gravimetric determination to use of β-measurements from 2006 gives rise to a 5-10% increase from 2005 to 2006

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8 Heavy Metals

8.1 Annual statistics

Table 8-1 Annual statistics for Vanadium (V), Chromium (Cr), Manganese (Mn), Nickel (Ni), Cupper (Cu), Zink (Zn), Arsenic (As), Selenium (Se), Cadmium (Cd) and Lead (Pb) measured in PM_{10} dust during 2007 The lifetime risk level is defined as the concentration that through a lifelong exposure is estimated to give an excess risk of $1:10^5$ for developing cancer. The filters are occasionally contaminated with Cr, Ni, Cu and Zn. The outliers for these elements are excluded before calculation of averages. At urban background and rural stations the contamination with Cr still contributes with a significant amount to the average values.

Unit: ng/m^3	V	Cr	Mn	Ni	Cu	Zn	As	Se	Cd	Pb
PM10, Traffic										
Copenhagen/1257	4.7	5.7	12.0	3.7	52.0	33.1	0.5	0.4	< 1.9	5.7
Copenhagen/1103	6.1	12.4	41.6	4.2	85.7	68.1	0.6	0.4	< 2.0	7.9
Århus/6153	4.3	3.3	8.3	3.6	29.7	25.1	0.6	0.3	< 1.8	4.6
Århus/6159	3.7	< 0.1	4.5	3.0	7.0	15.9	0.5	0.3	< 2.9	3.9
PM10, Urban background										
Copenhagen/1259	3.4	< 0.2	4.0	1.7	3.7	14.5	0.5	0.4	< 2.1	3.9
PM10, Rural										
Lille Valby/2090	4.5	< 0.1	5.7	2.6	9.6	17.3	0.4	0.4	< 2.3	4.3
PM2.5, Traffic										
Copenhagen/1103	3.6	2.0	6.8	1.8	14.4	18.0	0.3	0.2	< 2.3	3.3
Target (limit) Values - EEC				20			6		5	(500)
Guideline value (WHO) *)	1000		150						5	
Life time risk level at $1:10^5$ (WHO) *)				25			6.6			

*) Target values for Ni, As and Cd are implemented through EU Council Directive 2004/107/EC (EC, 2005). A limit value for Pb is found in EU Council Directive 1999/30/EC (EC, 1999). The guidelines and life time risk for the carcinogenic metals are established by WHO (WHO, 2000).

8.2 Trends

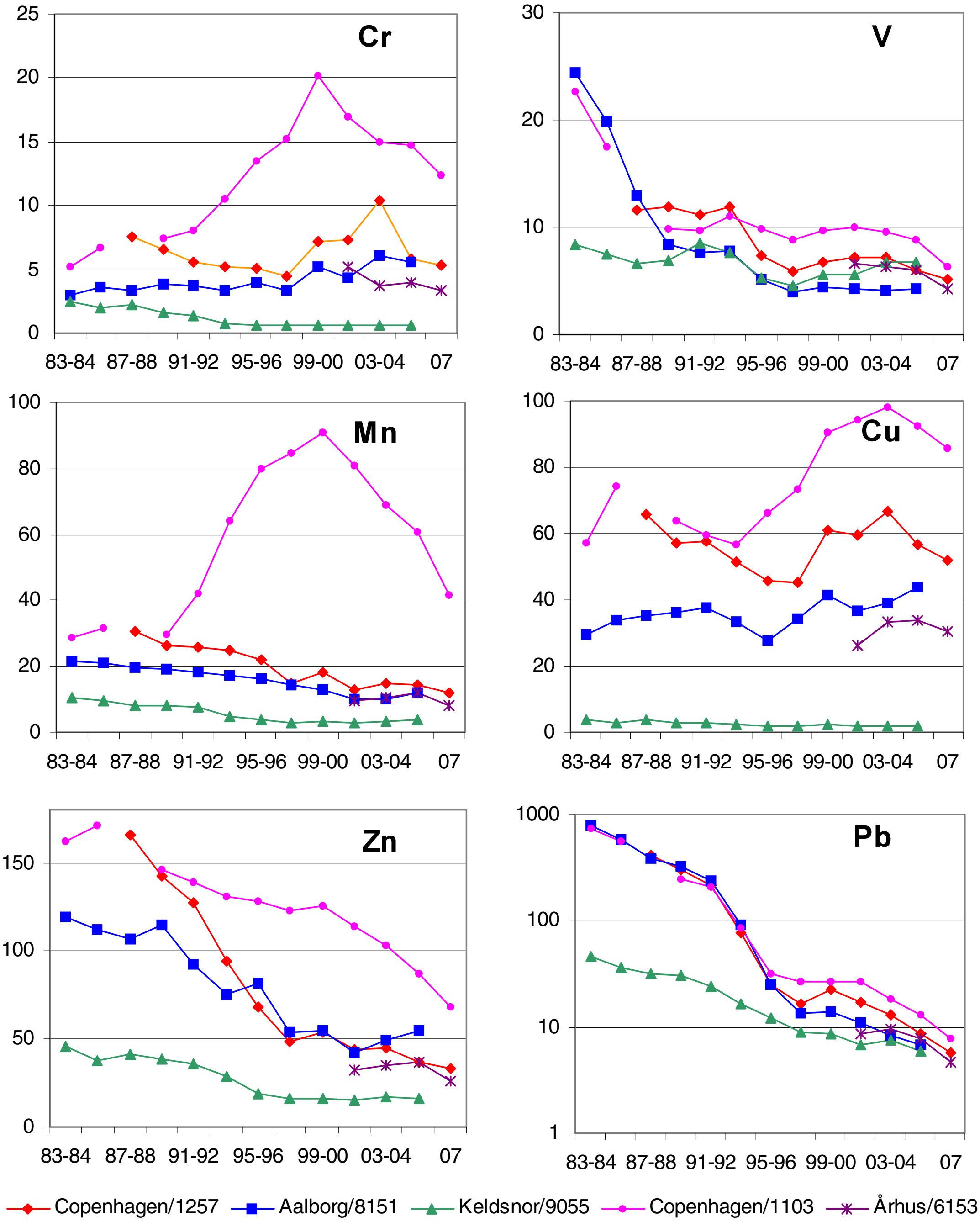

Figure 8-1 Biannual averages from selected stations for some heavy metals in particulate matter. Until 2000 in TSP and later in PM_{10} – except for Copenhagen/1103 where PM_{10} replaced TSP from the beginning of 2006. The heavy metals are usually found in fine particles, which make the TSP and the PM_{10} values comparable. The remarkable increase in the concentrations of especially Mn and to some extent Cr at Copenhagen/1103 may be caused by the use of slag from steel production for filling material in the bitumen at H. C. Andersens Boulevard. The increase in Cu (especially at Copenhagen/1103), which to a large extend comes from brake pads, reflects the increase in traffic volume. y-axis units are ng/m^3. (Note that the scale for Pb is logarithmic.)

9 Sulphur Compounds

9.1 Annual statistics

Table 9-1 Annual statistics for SO_2 in 2007. All parameters are calculated based on hourly averages. The detection limit for the monitors is a few µg/m^3, which makes the average and median values encumbered with high relative uncertainties.

Unit: µg/m3	Number of results	Average year	Average winter	Median	98-percentile	Max. Hour	4. highest day
Traffic							
Copenhagen/1103	8064	3.3	4.0	2.8	11.5	75	9
Aalborg/8151	8629	2.6	3.1	2.0	10.0	26	8
Limit values	>7884	20	20			350	125

The limit values are based on EU Council Directive (EC, 1999) and implemented through a national Statutory Order from the Ministry of Environment (Miljøministeriet 2007).

Table 9-2 Annual averages for particulate sulphur (S) measured in PM_{10} in 2007. The sulphur containing particles are mainly present in sub-micron particles, which make the TSP and PM_{10} results comparable. Measurements are daily averages.

Unit: µg(S)/m3	Number of results	Average
Traffic		
Copenhagen/1257	349	0.71
Copenhagen/1103	335	0.80
Århus/6153	361	0.71
Urban background		
Copenhagen/1259	316	0.63
Århus/6159	319	0.52
Rural		
Lille Valby/2090	365	0.68

9.2 Trends

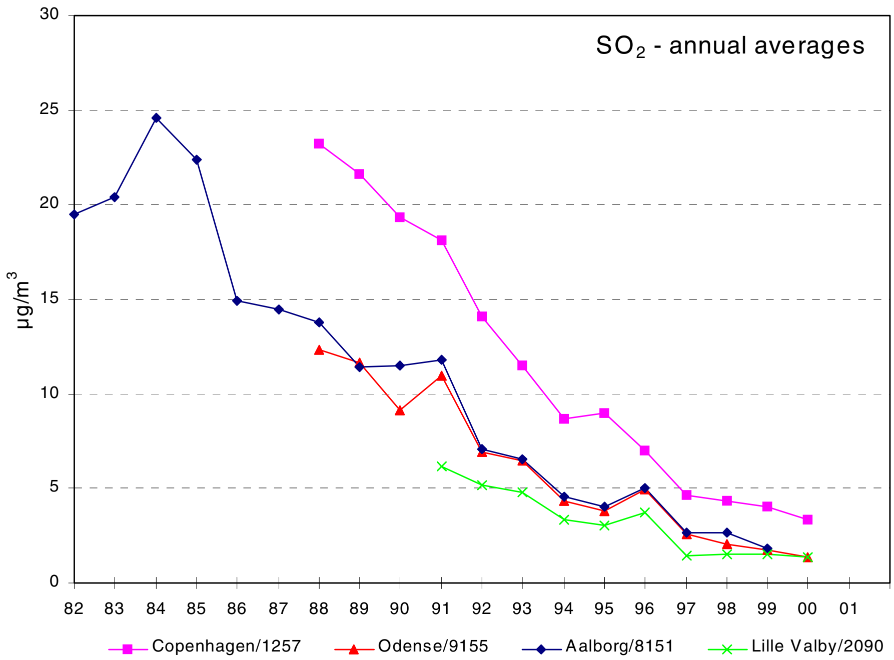

Figure 9-1 Annual averages for SO_2. The results are obtained using KOH impregnated filters for collection of SO_2. These measurements ceased in 2000 because the concentrations had become far below the limit and guideline values. Due to the low concentrations the trend curve is not continued after 2000. The aim with the measurements is to monitor episodic results.

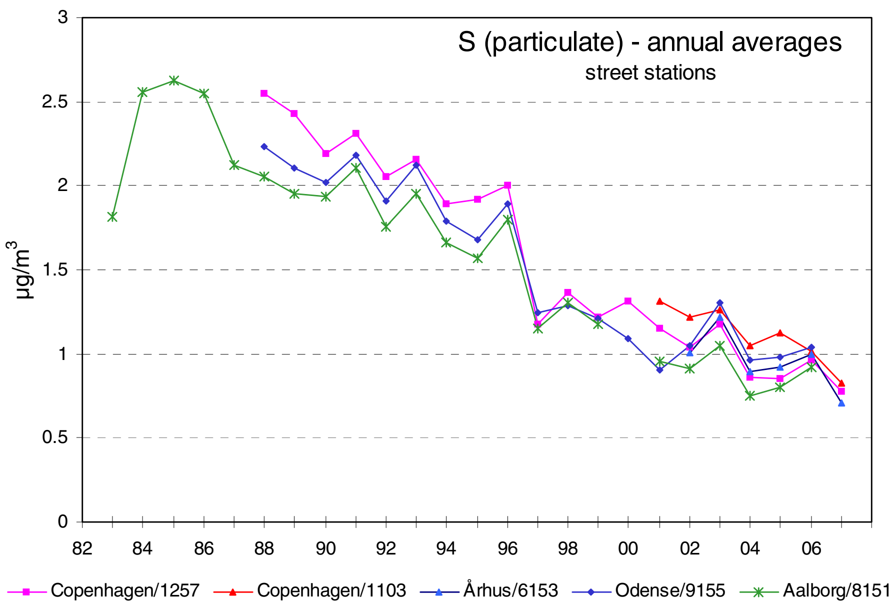

Figure 9-2 Annual averages for particulate sulphur at street stations. The particulate sulphur from 2000 and earlier is determined in TSP, and the 2001 results and later are for PM_{10} – except for Copenhagen/1103, where TSP measurements are continued. The sulphur containing particles are mainly present in sub-micron particles, which makes the TSP and PM_{10} results comparable.

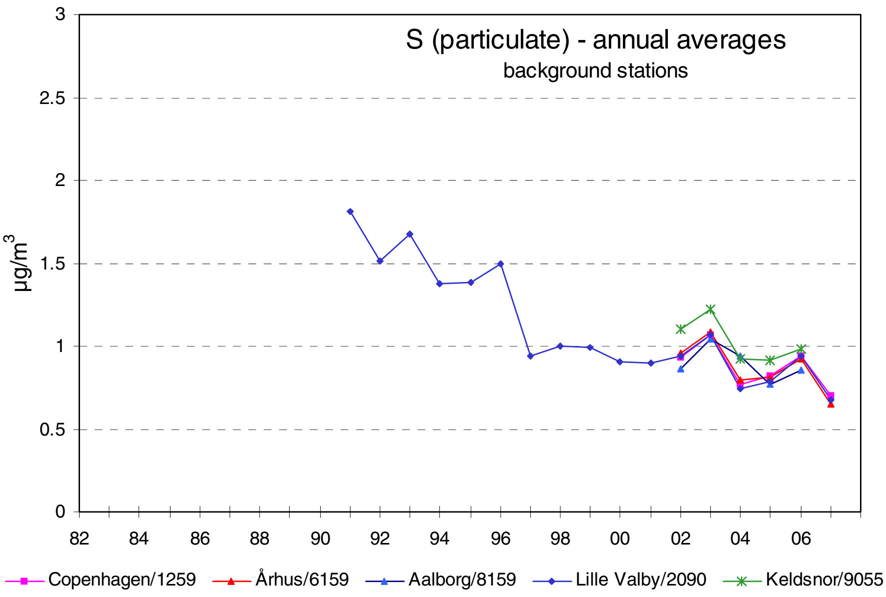

Figure 9-3 Annual averages for particulate sulphur at urban background and rural stations. The particulate sulphur from 2000 and earlier is determined in TSP and the 2001 results and later are in PM_{10}. The sulphur containing particles are mainly present in submicron particles, which makes the TSP and PM_{10} results comparable.

9.3 Results from model calculations

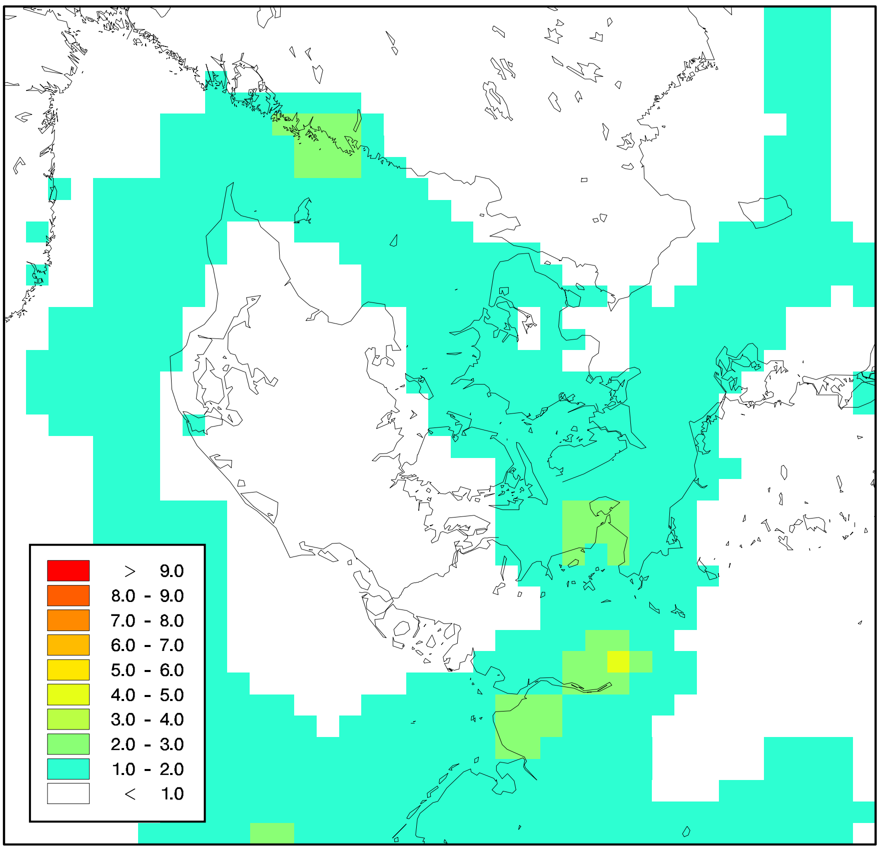

Figure 9-4 Annual mean concentrations of SO_2 (µg/m^3) for 2007 calculated with DEHM. The figure shows the average concentrations for the 16,67 x 16,67 km grit cells used in the model. The higher concentrations calculated for the inner Danish waters are due to emissions from ships.

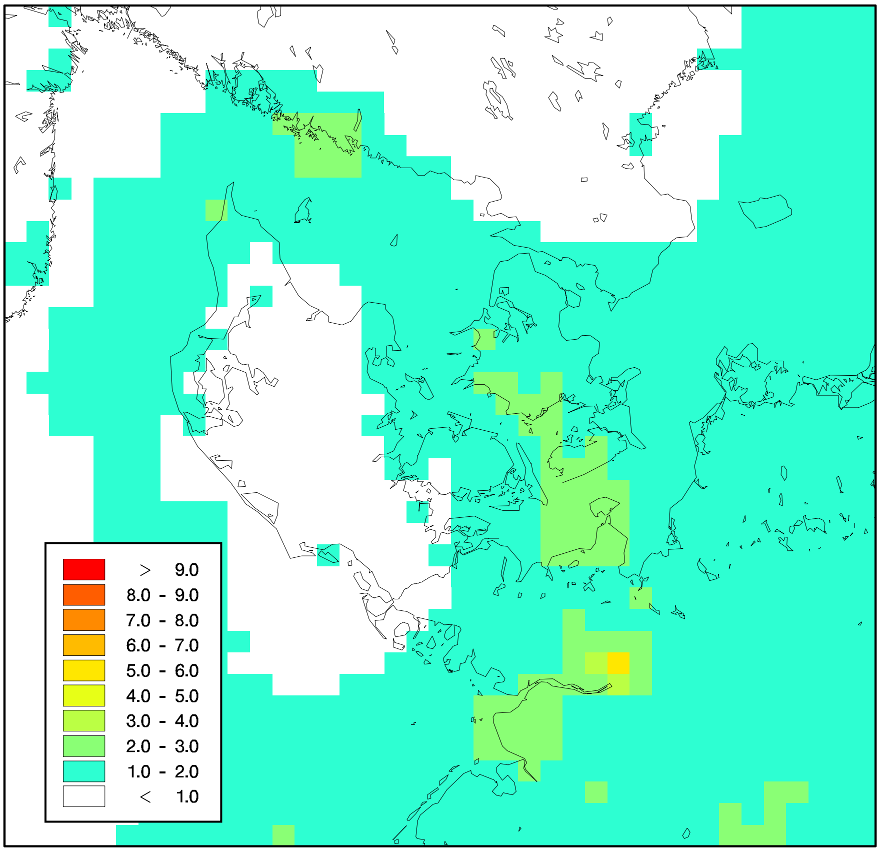

Figure 9-5. Winter mean concentrations of SO_2 (µg/m^3) for 2007 calculated with DEHM. The figure shows the average concentrations for the 16,67 x 16,67 km grit cells used in the model. The high concentrations calculated for the inner Danish waters are due to emissions from ships.

The limit value for protection of ecosystems is 20 µg/m^3 SO_2 calculated both for the calendar year and winter period (1 October to 31 March). The limit value is based on EU Council Directive (EC, 1999) and implemented through a national Statutory Order from the Ministry of Environment (Miljøministeriet 2007). The results from the model calculations using DEHM show that the annual and winter mean concentrations of SO_2 in 2007 (figure 9.4 and 9.5) are below the limit value.

10 Polyaromatic Hydrocarbons (PAHs)

Following the Directive 2004/107/EC of the European Parliament (EC, 20005), measurement of atmospheric concentrations of benzo[a]pyrene and other particle bound PAHs have been introduced in the Danish Air Quality Monitoring Programme (LMP) starting from June 2007. The target value for benzo[a]pyrene in ambient air is set to 1 ng/m^3 averaged over a calendar year. Benzo[a]pyrene is used as a marker for the carcinogenicity of PAHs.

10.1 Sampling and analysis

Particulate matter (PM10 fraction) is collected at the urban station of H.C. Andersen Boulevard (1103) in Copenhagen by high volume sampling (HVS) at a flow rate of 0.5 m^3 min^{-1} over a period of 24 hours, for an average total volume of 700 m^3.

The filters are kept frozen until analysis. A quarter of a filter is extracted by Accelerated Solvent Extraction (ASE) with a mixture of dichloromethane/hexane (50:50, v/v). Before extraction, the filters are spiked with deuterium-labelled PAH. Clean up of the extracts is performed on line in the extraction cell by adding activated silica.

Analysis of the extracts is carried out by gas chromatography-mass spectrometry (GC-MS). Concentrations of individual PAH in samples are corrected for recovery of a deuterium-labelled PAH standard with the closest molecular weight. A total of 18 PAHs are analyzed in the method.

10.2 Results

The available data do not cover a whole year, as the measurement of PAHs started at the end of June 2007. However, the seasonal variations are well represented, since at least three seasons are included in the sampling period.

The average concentration of benzo[a]pyrene measured in Copenhagen was 0.32 ng/m^3 in the period June-December 2007. The concentration of 1 ng/m^3 was exceeded only eight times, all in November and December. The minimum, maximum and average monthly concentrations of benzo[a]pyrene in the period June-December 2007 are summarized in Table 10.1.

The average concentrations of the other five PAH listed as relevant in the EU Directive were the following: benzo[a]anthracene, 0.34 ng/m^3; benzo[b]fluoranthene, 0.45 ng/m^3; benzo[j+k]fluoranthenes, 0.37 ng/m^3; indeno[1,2,3-cd]pyrene, 0.31 ng/m^3; dibenzo[a,h]anthracene 0.10 ng/m^3. The monthly average concentrations of the 18 analyzed PAH are summarized in Appendix 2.

The seasonal trends in PAH concentrations are summarized in Figure 10.1. As expected, the atmospheric concentrations are low during summer months, while concentrations increase in winter months due to higher emissions and less photochemical degradation of the compounds. Only minor deviations from these average concentrations are expected when data from the whole year will be available in 2008. Moreover, although the measurements only cover the second half of 2007 it is safe to conclude that the target value for benzo[a]pyrene on 1 ng/m^3 was not exceeded in 2007.

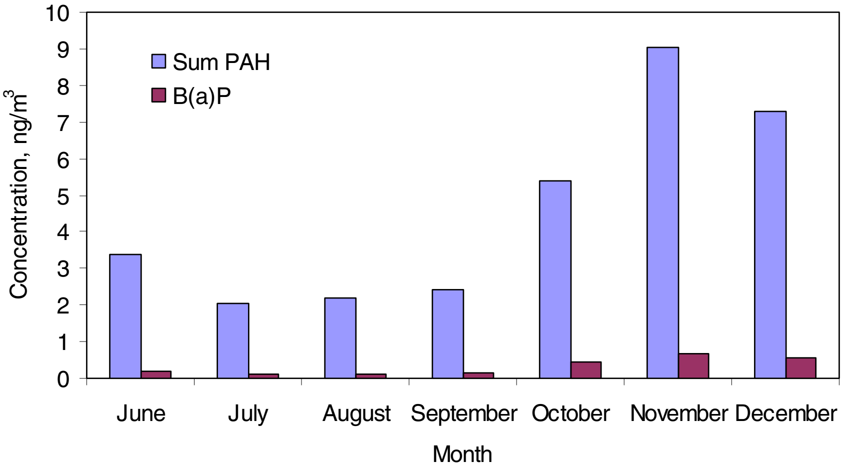

Figure 10-1 Monthly average concentrations of benzo[a]pyrene (B(a)P) and the sum of the analysed PAH.

Table 10-1 Minimum, maximum and average monthly concentrations (ng/m3) of benzo[a]pyrene during the period June-December 2007.

Month	Minimum conc.	Maximum conc.	Average conc.
June	0.07	0.43	0.18
July	0.03	0.54	0.11
August	0.04	0.34	0.10
September	0.07	0.42	0.14
October	0.23	0.88	0.44
November	0.16	2.04	0.65
December	0.17	1.77	0.55

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Appendix 1

Pollutants measured in the LMP Network

NO and partly NO_2 are formed by combustion at high temperatures. The main sources are power plants and traffic. At the street stations the traffic is the main source. The application of catalytic converter in the exhaust reduces the emission considerably. NO is relatively harmless, but NO_2 can cause respiratory problems.

Most of the NO_2 in the urban atmosphere is produced by oxidation of nitrogen monoxide (NO) by ozone (O_3). The reaction will take place immediately, if sufficient O_3 is present. O_3 is often the limiting component for a complete oxidation in the street canyons, but practically all NO is oxidised at the urban background and rural stations. Within a few hours the NO_2 is further oxidised to nitrate and/or nitric acid, which may cause acid precipitation and eutrofication. NO_2 is a toxic gas, which may cause respiratory problems. There are limit values for the allowed concentration of NO_2 in the atmosphere.

O_3 is formed by photochemical reactions (i.e. by the influence of sunlight) between nitrogen oxides and volatile organic compounds (VOC's). The VOC's can be of natural and anthropogenic origin. The major part of the O_3 measured in Denmark originates from sources outside the country. Usually the highest concentrations are found at rural and urban background sites. O_3 is removed by NO at street level. O_3 is a toxic gas, which may cause respiratory problems and damage on crops and forests. There are so-called target values for the concentration of O_3 in the atmosphere.

The main source of CO in urban air is petrol-fuelled cars. The CO is formed due to incomplete combustion. The application of catalytic converter in the exhaust reduces the emission considerably. CO is only slowly removed from the atmosphere. CO is a toxic gas that may prevent the uptake of oxygen in the blood. There are limit values for the allowed concentration of CO in the atmosphere.

Benzene is present in petrol. It may also be formed in engines due to incomplete combustion. Since 1994 the benzene content in petrol has been reduced by up to a factor of 5. The concentration in the atmosphere has been reduced correspondingly. Benzene is a carcinogenic gas. There is a limit value for the average content in the atmosphere.

Many different VOC's are present in the air. Several of these are emitted by incomplete combustion in e.g. engines and wood burning stoves. Several of the VOC's are carcinogenic. A "target value" is implemented through an EU Council Directive in 2004 for Benzo(a)-pyrene as indicator for PAH (Polycyclic Aromatic Hydrocarbones). Of the VOC's only benzene, toluene and xylenes are measured routinely in LMP IV at present.

The main sources for PM_{10} and $PM_{2.5}$ are resuspended dust and combustion. PM are also due to chemical reactions in the atmosphere e.g. oxidation of nitrogen dioxide, sulphur dioxide and VOC. The submicron particles, which are formed by combustion and chemical reactions in the atmosphere, are suspected to be the most harmful for the health. There are still a lack of knowledge about the connection between health effects and particle size. Limit values for the PM_{10} concentration in the atmosphere are implemented at present. The limit values are under revision and will include $PM_{2.5}$. The limit values will be currently reviewed when better knowledge about the adverse health effects of fine particles influence on health is obtained.

PM_{10} and $PM_{2.5}$ is measured using two different methods in the LMP program:

- The particles are collected on filters in 24^h intervals. The mass on the filters is determined by measurements of β-absorption in the dust. This method is considered to be equivalent to the reference method (EN 12341:1999 and EN14907:2005).
- The particles are collected on a "tapered oscillating microbalance" (TEOM) and heated to 50°C. During heating volatile compounds may evaporate. The loss will be most pronounced for "secondary aerosols" containing ammoniumnitrate.

There are a number of different HM's in the atmosphere. They are emitted from e.g. coal and oil fired power plants, waste incinerators and industries. HM's may also be emitted from traffic due to wear on engines, tires and brake pads. Several HM's are toxic even in low concentrations and a few also carcinogenic. A limit value is implemented for lead. Target values are values are implemented for arsenic, cadmium, nickel and mercury. WHO has proposed guideline values for the toxic non-carcinogenic and estimated life time risks for the carcinogenic HM's.

Sulphur dioxide (SO_2) is formed by burning of fossil fuel and biomass. The SO_2 is oxidised in the atmosphere to particulate sulphuric acid and sulphate. The conversion time depends strongly on the temperature and humidity in the air. It is typically of the order of one day. Sulphuric acid contributes to "acid rain" and the deposition of sulphate causes damage to sensitive ecosystems. During the last 20 years the reduction of sulphur in fossil fuel and improved flue gas cleaning has reduced the concentration of SO_2 with one order of magnitude. SO_2 may cause respiratory problems. There are limit values for the allowed concentration of SO_2 in the atmosphere.

Appendix 2

PAH concentrations

Average monthly concentrations (ng/m^3) of the 18 PAH during the period June-December 2007.

Compound	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Fluorene	0.02	0.02	0.01	0.02	0.03	0.03	0.05	0.03
Dibenzothiophene	0.01	0.01	0.01	0.02	0.01	0.02	0.03	0.02
Phenanthrene	0.15	0.13	0.15	0.13	0.30	0.52	0.23	0.24
Anthracene	0.03	0.03	0.03	0.02	0.04	0.08	0.06	0.04
2-Methylphenanthrene	0.06	0.06	0.08	0.05	0.12	0.15	0.09	0.09
3,6-Dimethylphenanthrene	0.02	0.03	0.03	0.02	0.04	0.04	0.05	0.03
Fluoranthene	0.28	0.21	0.23	0.24	0.55	0.98	0.49	0.44
Pyrene	0.37	0.28	0.32	0.33	0.74	1.05	0.53	0.53
Benzo[a]anthracene	0.15	0.11	0.13	0.14	0.36	0.73	0.60	0.34
Chrysene + Tryphenylene	0.27	0.21	0.25	0.28	0.64	1.32	1.20	0.63
Benzo[b]fluoranthene	0.48	0.18	0.16	0.20	0.60	0.78	0.79	0.45
Benzo[k+j]fluoranthene	0.42	0.15	0.13	0.17	0.56	0.67	0.60	0.37
Benzo[e]pyrene	0.33	0.14	0.13	0.15	0.40	0.60	0.62	0.34
Benzo[a]pyrene	0.18	0.11	0.10	0.14	0.42	0.65	0.55	0.32
Perylene	0.07	0.03	0.03	0.02	0.09	0.16	0.17	0.08
Indeno[1,2,3 cd]pyrene	0.20	0.13	0.14	0.22	0.54	0.52	0.44	0.31
Dibenzo[a,h]anthracene	0.05	0.04	0.03	0.03	0.13	0.19	0.17	0.09
Benzo[ghi]perylene	0.33	0.20	0.23	0.31	0.65	0.74	0.65	0.44

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PO Box 358
DK-4000 Roskilde
Denmark
Tel: +45 4630 1200
Fax: +45 4630 1114

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National Environmental Research Institute
Vejlsøvej 25
PO Box 314
DK-8600 Silkeborg
Denmark
Tel: +45 8920 1400
Fax: +45 8920 1414

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Department of Freshwater Ecology

National Environmental Research Institute
Grenåvej 14, Kalø
DK-8410 Rønde
Denmark
Tel: +45 8920 1700
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The air quality in Danish cities has been monitored continuously since 1982 within the Danish Air Quality Monitoring (LMP) network. The aim has been to follow the concentration levels of toxic pollutants in the urban atmosphere and to provide the necessary knowledge to assess the trends, to perform source apportionment, and to evaluate the chemical reactions and the dispersion of the pollutants in the atmosphere. In 2007 the air quality was measured in four Danish cities and at two background sites. Model calculations were also carried out to supplement the measurements. At several stations NO_2 and PM_{10} were found in concentrations above EU limit values, which the Member States have to comply with in 2005 and 2010. The concentrations for most pollutants have been strongly decreasing since 1982, however, only a slight decrease has been observed for NO_2 and O_3.

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978-87-7073-058-7
ISSN 1600-0048