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Air Quality Monitoring Programme

Annual Summary for 2004

NERI Technical Report No. 544

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Data sheet

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Abstract: The air quality in Danish cities has been monitored continuously since 1982 within the Danish Air Quality (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 2004 the air quality was measured in four Danish cities and at two background sites. NO_2 and PM_{10} were at several stations found in concentrations above EU limit values, which the Member States have to comply with in 2005 and 2010. While the concentrations for most other pollutants have been strongly decreasing since 1982, only a slight decrease has been observed for NO_2. The measurement has been supplemented with dispersion models for a number of streets in Copenhagen and Aalborg.

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Summary and Conclusion

The Danish Air Quality Monitoring Programme (LMP IV) has been revised and is still under revision in accordance with the Framework 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 2004 are almost complete for most stations. The monitoring programme consists of 10 stations. Also results from one station under the Municipality of Copenhagen are included in this report.

NO_2

The limit value + the margin of tolerance for the annual average of NO_2 (52 µg/m^3 in 2004) was touched, but not exceeded. The limit value (to be complied with in 2010) of the annual average of NO_2 was in 2004 exceeded at three street stations. The NO_2 concentrations seem to have been stabilised during the last five years after several years of decrease.

O_3

The ozone level was in 2004 - more or less - the same at all rural and urban background stations and no clear trend is observed. The information threshold of 180 µg/m^3 was not exceeded. The target values were not exceeded, but the long-term objectives of max 8 hours on 120 µg/m^3 were exceeded at all urban background and rural stations. The long term objective for AOT40 at 6000 µg/m^3 *hours were exceeded in a few cases. The O_3 pollution in Denmark is to a large extent caused by emissions in other European countries.

PM_{10}

The limit value + margin of tolerance for the 35th highest daily average value for PM_{10} (55 µg/m^3 for 2004) was exceeded at one station. The limit value itself at 50 µg/m^3 to be complied with in 2005, was in 2004 exceeded at 2 out of 5 street stations. At all stations the indicative limits values for PM_{10}, supposed to be met in 2010, (annual average value at 20 µg/m^3 and 50 µg/m^3 not to be exceeded more than 7 times per year) were exceeded at almost all stations (including the rural station Keldsnor/9055). Emission in other European countries contributes significantly to the PM_{10} levels in Denmark.

SO_2, CO and benzene

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.

The concentrations were in 2004 in general lower than in 2003 – probably mainly due to meteorological conditions. One exceedance of the limit value + margin of tolerance occurred for the PM_{10} limit not to be exceeded more than 35 times a calendar year.

Dispersion models

A supplementary assessment of the air quality has been carried out using NERI's air quality models in the agglomerations Copenhagen and Aalborg. The assessment was performed for NO_x/NO_2, CO and O_3 in urban background and in selected streets, 138 streets in Copenhagen and 10 streets in Aalborg. Modelling was also performed for

PM_{10}/$PM_{2.5}$ in Copenhagen. The model results give an overview of the air pollution over the urban areas and in many streets.

The modelling data of annual averages at urban background show good agreement with measurement data from the corresponding monitoring stations for the gaseous pollutants in Copenhagen as well as in Aalborg, within $\pm$ 15%. The PM_{10} model results, which only were available for Copenhagen, are more uncertain, mainly due to uncertain emission factors. The modelling results for the streets are also in acceptable agreement with the available measurement data.

The model results for 3-5 streets in Copenhagen show 10-50% higher concentrations than measured at the most polluted street station (H.C. Andersens Boulevard). Direct comparison between measurements and model results in streets in Aalborg is not possible, because model calculations were not made for the location of the measurement station (Vesterbro at Limfjordsbroen). The model results show that most of the streets in Aalborg are less polluted than at the measurement location, and no locations show significantly higher pollution.

Actual data, quarterly reports, annual and multi-annual summaries are available at the WebPages of NERI (luft.dmu.dk).

1 Introduction

LMP IV

The fourth Danish Air Quality Monitoring Programme (LMP IV) was started in 2000. The programme comprises an urban monitoring network with stations in the four largest Danish cities, *Figure 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 Environmental Protection Agency of the Municipality in Copenhagen, the Municipality of Århus, the County of Funen (for the city of Odense) and the Municipality of Aalborg. 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. This report includes results from the LMP network and a local network in Greater Copenhagen organised by the Environmental Protection Agency of the Municipality in Copenhagen. Statistical parameters and actual data are accessible at the Web address: luft.dmu.dk. Selected actual data are also available at tele-text, Danish National Television.

The reports from the LMP programme have been based only on results from the measuring locations. Calculations with the OSPM (Operational Street Pollution Model) dispersion model and the THOR model system (which also includes the OSPM model) are now included in the programme in order to evaluate to what extent the measured values are representative for a larger area or similar locations.

Other air quality networks in Denmark

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, *Figure 2-1*. NERI runs this programme. At present gas and aerosol measurements are performed at six stations, and various ions are determined in precipitation collected at 10 sites. The Environmental Protection Agency of the Municipality in Copenhagen is responsible for a network in the central part of Copenhagen (www. miljoe.kk.dk). A number of pollutants are measured at two sites. One of the sites (H.C. Andersens Boulevard) is operated by NERI and is under the same quality control/quality assurance as the other measurement stations in LMP IV. The other station is equiped with a DOAS (Differential optical Adsorption Spectrometry). Further measurements are carried out in the counties of Århus (http://www.aaa.dk/aaa/index/serviceomraader/nm/nm-industri_affald_jord_luft/nm-mfs-luft.htm and Funen (www.fyns-amt.dk/wm108516/).

New limit values implemented by the EU Commission

The present Danish limit values are identical with the limit values laid down in the EU directives. The new 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) and O_3 (EC, 2002) are adopted. Most recently a daughter Directive for Cr, As, Cd, Hg and PAH (EC, 2005) have been adopted. In the following chapters the measured results are compared to the limit 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.

2 Measurements

Station locations

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 stations monitor the pollution outside the city areas. Further information about the program and results is found at the Web address: LUFT.DMU.DK.

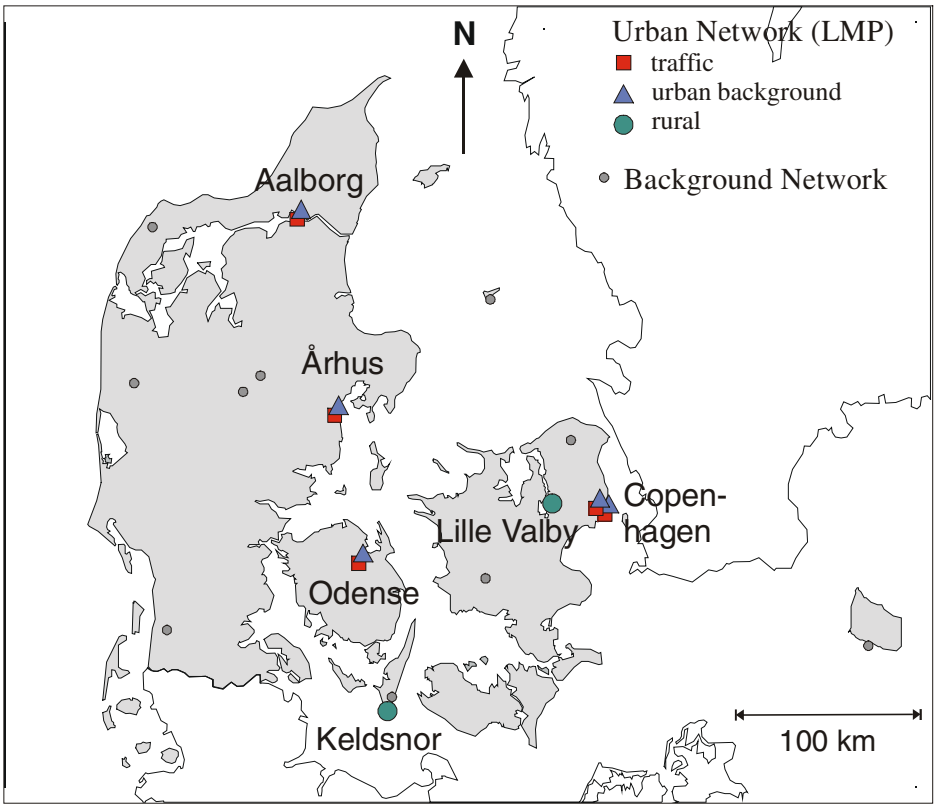

Figure 2-1 Monitoring stations in the two nation-wide air quality networks (including the stations in the Copenhagen network).

Table 2-1 Stations in the LMP IV network and the Copenhagen network included in this report for 2004.

Name	Street/location	Type	Remarks
Copenhagen/1257	Jagtvej	Street	
Copenhagen/1259	H.C. Ørsted Institute	Urban background	
Copenhagen/1103	H.C. Andersens Boulevard	Street	Copenhagen Municipality
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	Started October 2004. Results are not reported for 2004 due to the short period.
Aalborg/8159	Dept. for Envir. and Urban Affairs	Urban background	Stopped July 2004. Replaced by 8158.
Lille Valby/2090	-	Rural	
Keldsnor/9055	-	Rural	

Compounds measured

The following compounds were measured:

- NO, NO_x (including NO_2=NO_x-NO), PM_{10} and elements (heavy metals) in PM_{10} were measured at all stations (TSP is measured in stead of PM_{10} at Copenhagen/1103). PM_{10} was measured gravimetrically.
- PM_{10} was measured at Copenhagen/1103, -/1257 and -/1259 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 and the urban background station, Copenhagen/1259
- Benzene and Toluene were measured at Copenhagen/1257
- SO_2 was measured at Aalborg/8151 and at Copenhagen/1103. The main purpose was to monitor episodic high concentration.
- 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.

Averaging time

Apart from gravimetric measurements of PM_{10} and TSP all parameters were recorded as ½-hour averages. PM_{10}, TSP and elements in the particles were measured as 24 hour averages. At the three stations in Copenhagen also ½-hour averages of PM_{10} were recorded using TEOM.

Other information

Short descriptions of the measured pollutants are given in the appendix. The actually applied measurement methods are listed at the Web address: LUFT.DMU.DK

3 Nitrogen oxides

3.1 Yearly Statistics

Table 3-1 Nitrogen dioxide (NO_2) 2004. All parameters are calculated with hourly averages.

Unit: µg/m^3	Number	Average	Median	98. percentile	19. highest
Traffic:					
Copenhagen/1257	8606	46	44	104	130
Copenhagen/1103	7823	52	49	107	142
Århus/6153	8223	45	43	101	129
Odense/9155	8665	32	26	89	118
Aalborg/8151	8285	35	30	90	116
Urban Background:					
Copenhagen/1259	8411	22	19	60	81
Århus/6159	8721	23	19	66	91
Odense/9159	8336	18	15	53	67
Aalborg/8159	4300	-	-	-	-
Rural:					
Lille Valby/2090	8505	11	9	40	54
Keldsnor/9055	6448	8	6	30	48
Limit values/limit value + margin of tolerance for 2004	>7884	40/52			200/360

Table 3-2 Nitrogen oxides (NO_x=NO+NO_2) 2004. All parameters are calculated with hourly averages.

Unit: µg/m^3 (as NO_2)	Number	Average	Median	98. percentile	19. highest
Traffic:					
Copenhagen/1257	8606	113	89	365	567
Copenhagen/1103	7823	139	112	422	690
Århus/6153	8371	102	79	324	636
Odense/9155	8665	78	44	349	589
Aalborg/8151	8690	99	67	364	590
Urban Background:					
Copenhagen/1259	8414	29	22	99	190
Århus/6159	8721	34	23	148	396
Odense/9159	8346	25	18	91	238
Aalborg/8159	4300	-	-	-	-
Rural:					
Lille Valby/2090	8506	14	10	57	117
Keldsnor/9055	6449	9	7	35	65

The limit values are based on EU Council Directive 1999/30/1999 (EC 1999) and implemented through a national Regulation from the Ministry of Environment (Miljøministeriet 2003A).

3.2 Episodes

Table 3-3 Episodic results for Nitrogen dioxide (NO_2) 2004. All parameters are calculated with hourly averages.

Unit: µg/m^3	Max. 3 hours	Date:hour	Max. hour	Date:hour
Traffic:				
Copenhagen/1257	168	040904: 0	185	040904: 2
Århus/6153	164	040411: 1	188	041108: 7
Copenhagen/1103	128	040510:19	195	040115: 8
Odense/9155	122	040510:13	142	040416: 7
Aalborg/8151	116	041220: 6	162	040810: 6
Urban Background:				
Copenhagen/1259	85	040330:21	93	040330:22
Århus/6159	100	040130: 8	156	040115: 9
Odense/9159	68	041109: 7	79	040129: 8
Aalborg/8159	107	040115: 5	133	040115: 6
Rural:				
Lille Valby/2090	54	041126: 6	66	040416: 7
Keldsnor/9055	58	040505: 7	77	040503:19
Alert threshold	400	-	-	-

Table 3-4 Episodic results for Nitrogen oxides (NO_x=NO+NO_2) 2004. All parameters are calculated with hourly averages.

Unit: µg/m^3 (as NO_2)	Max. 3 hours	Date:hour	Max. hour	Date:hour
Traffic:				
Copenhagen/1257	750	041108: 7	1382	041108: 7
Copenhagen/1103	1182	041108: 6	1467	041108: 7
Århus/6153	640	040127: 7	1159	040115: 8
Odense/9155	701	041109: 7	1199	041001: 7
Aalborg/8151	640	040115: 8	725	041109:15
Urban Background:				
Copenhagen/1259	216	041117: 8	360	040413: 6
Århus/6159	497	040127: 8	1091	040115: 9
Odense/9159	259	040127: 7	392	041001: 7
Aalborg/8159	511	040115: 6	694	040115: 9
Rural:				
Lille Valby/2090	119	040115:16	235	041220:11
Keldsnor/9055	75	040421:10	88	040905: 8

The Alert threshold is given in EU Council Directive (EC, 1999) and implemented through a national Regulation from the Ministry of Environment (Miljøministeriet 2003A).

With reference to the definition of the alert threshold, the lowest one-hour values are calculated for all consecutive three-hour periods. The highest of these one-hour values are listed in the table in the column "Max. 3 hour". The alert threshold is expected never to be exceeded in Denmark.

3.3 Trends

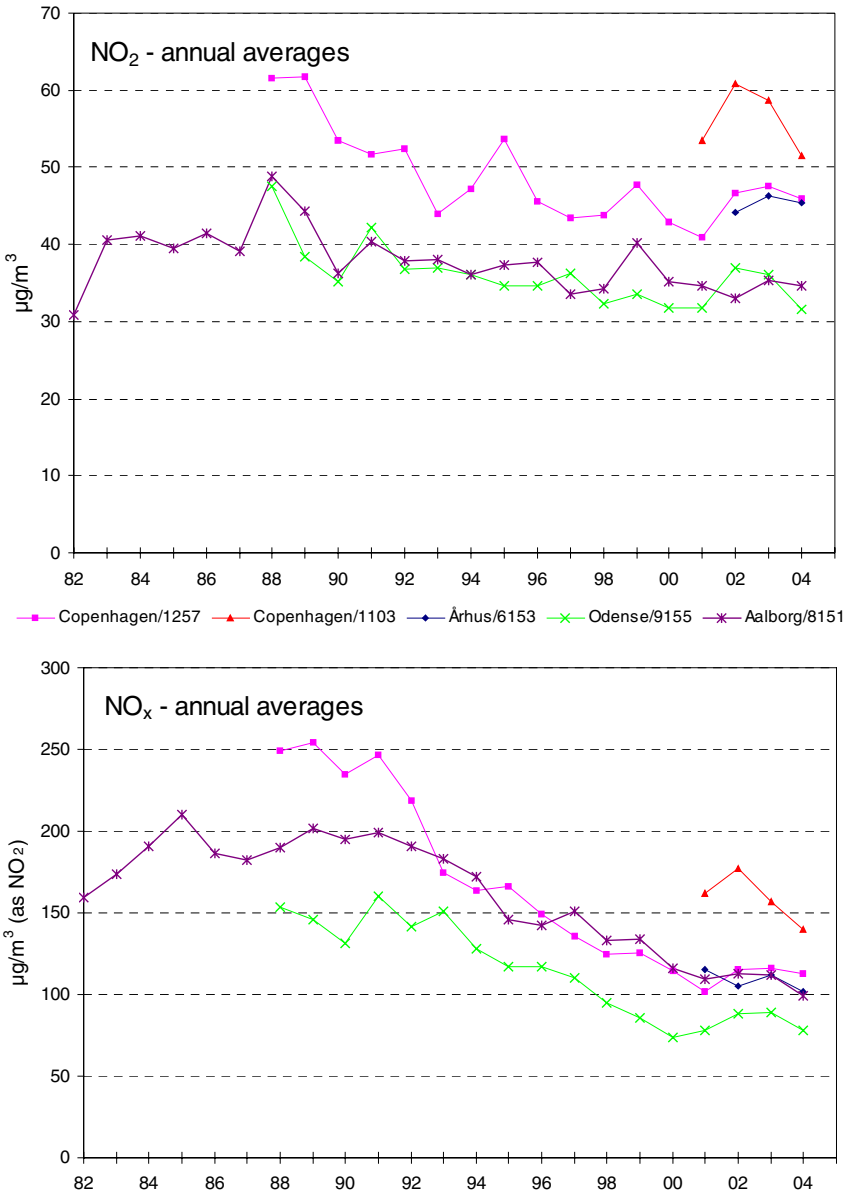

Figure 3-1 The graphs show the time series for the annual average values measured at street stations. Previous results from Copenhagen/1103 can be found at the WebPages of the Copenhagen Environmental Protection Agency (www. Miljoe.kk.dk).

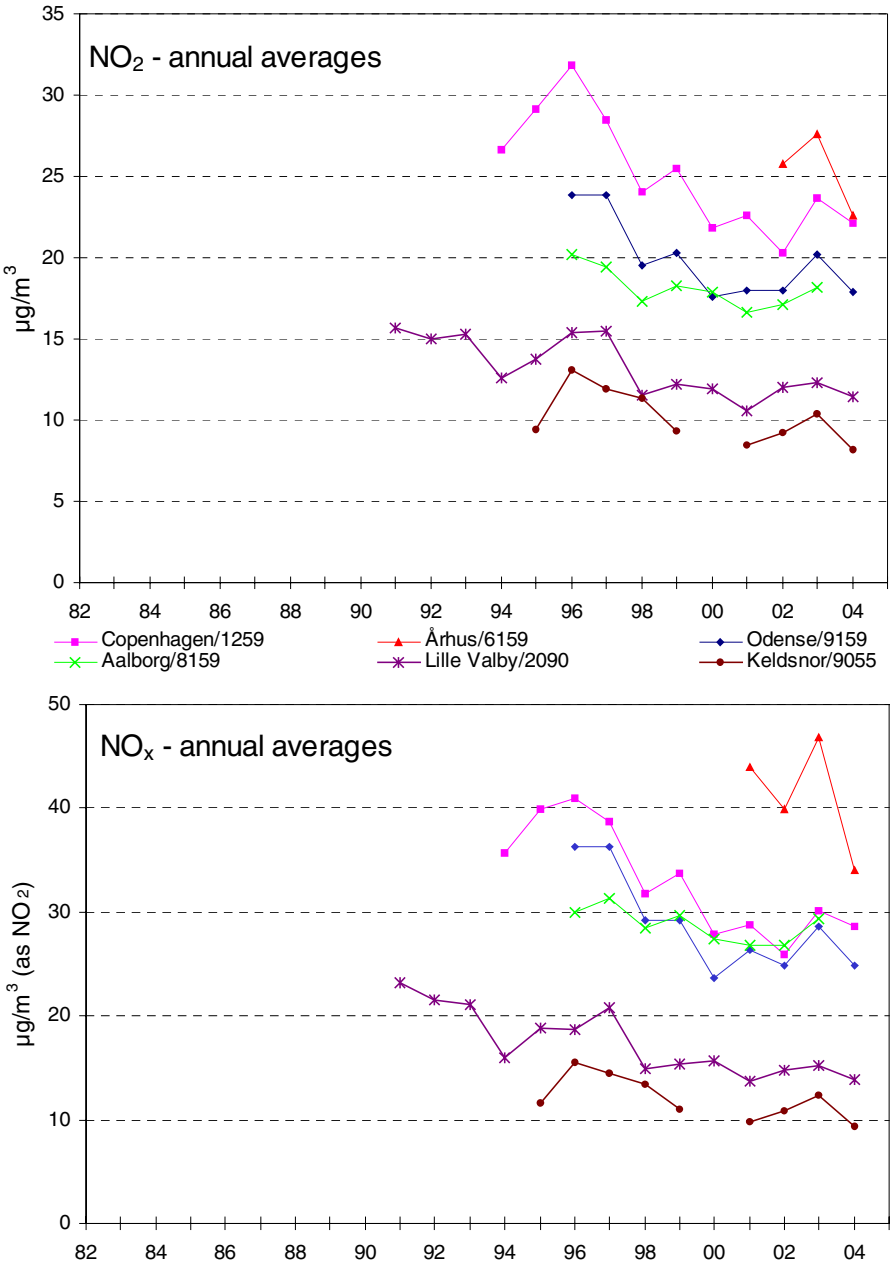

Figure 3-2 The graphs show the time series for the annual average values measured at urban background and rural stations.

4 Ozone

4.1 Annual statistics

Table 4-1 Ozone (O_3) 2004. 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	7821	49	49	119	89	127	1702
Århus/6159	8481	47	49	127	89	133	2207
Odense/9159	8399	59	60	157	108	167	8133
Aalborg/8159	4304	-	-	-	-	-	-
Rural							
Lille Valby/2090	8501	58	59	123	101	136	6520
Keldsnor/9055	6452	61	62	110	90	118	1865
Traffic							
Copenhagen/1257	8607	34	33	92	74	103	300
Copenhagen/1103	7618	28	26	79	61	95	1
Target value	>7884	-	-	-	120	-	18 000
Long term objective	>7884	-	-	120	-	-	6 000

The target values and long time objectives are given in the EU Council Directive (EC, 2002) and implemented through a national Regulation from the Ministry of Environment (Miljøministeriet 2003B).

Number of information to the public due to exceedance of the information threshold (180 µg/m^3) in 2004: 0.

Number of information to the public due to exceedance of the alert threshold (240 µg/m^3) in 2004: 0.

4.2 Trends

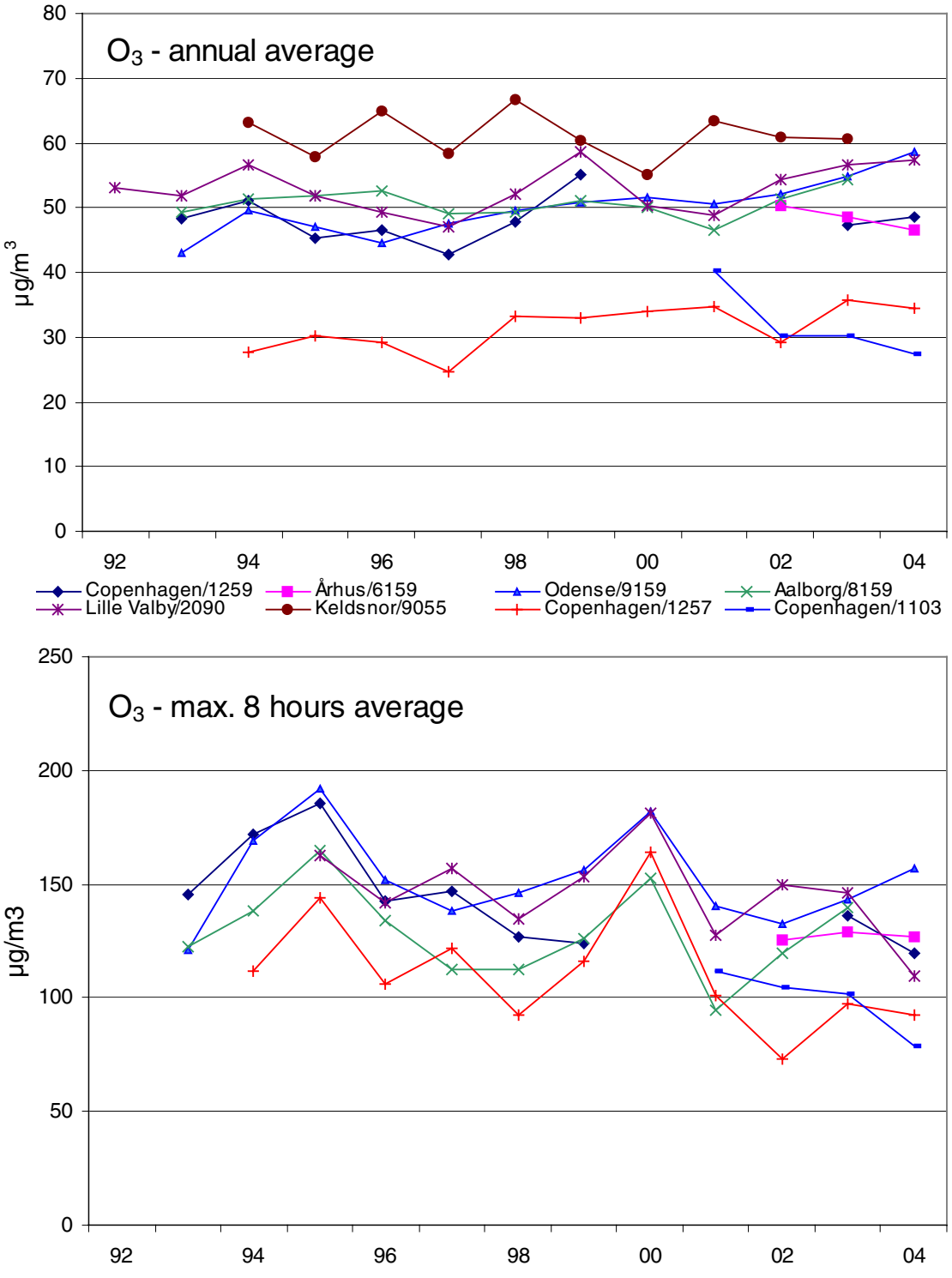

Figure 4-1 Annual average values and the max. 8 hour average value. The latter is calculated as hourly moving 8 hour averages according to the provisions in the EU Council Directive (EC, 2002). Previous results from Copenhagen/1103 can be found at the WebPages of the Copenhagen Environmental Protection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

5 Carbon monoxide

5.1 Annual statistics

Table 5-1 Annual statistics for carbon monoxide (CO) 2004. All parameters are calculated with hourly average. The 8-hour values are calculated as a moving average based on hourly results.

Unit: µg/m^3	Number	Average	Median	98-percentile	99.9-percentile	Max. 8-hours	Max hour
Traffic:							
Copenhagen/1257	8598	858	729	2417	4688	3624	8297
Copenhagen/1103	7889	823	724	2106	4057	2713	5376
Århus/6153	8554	477	404	1266	2340	1780	3086
Odense/9155	8664	614	448	2058	3703	2816	5884
Aalborg/8151	8700	744	582	2152	3660	2916	4449
Urban Background:							
Copenhagen/1259	8527	300	272	661	1473	1106	2140
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 Regulation from the Ministry of Environment (Miljøministeriet 2003B).

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

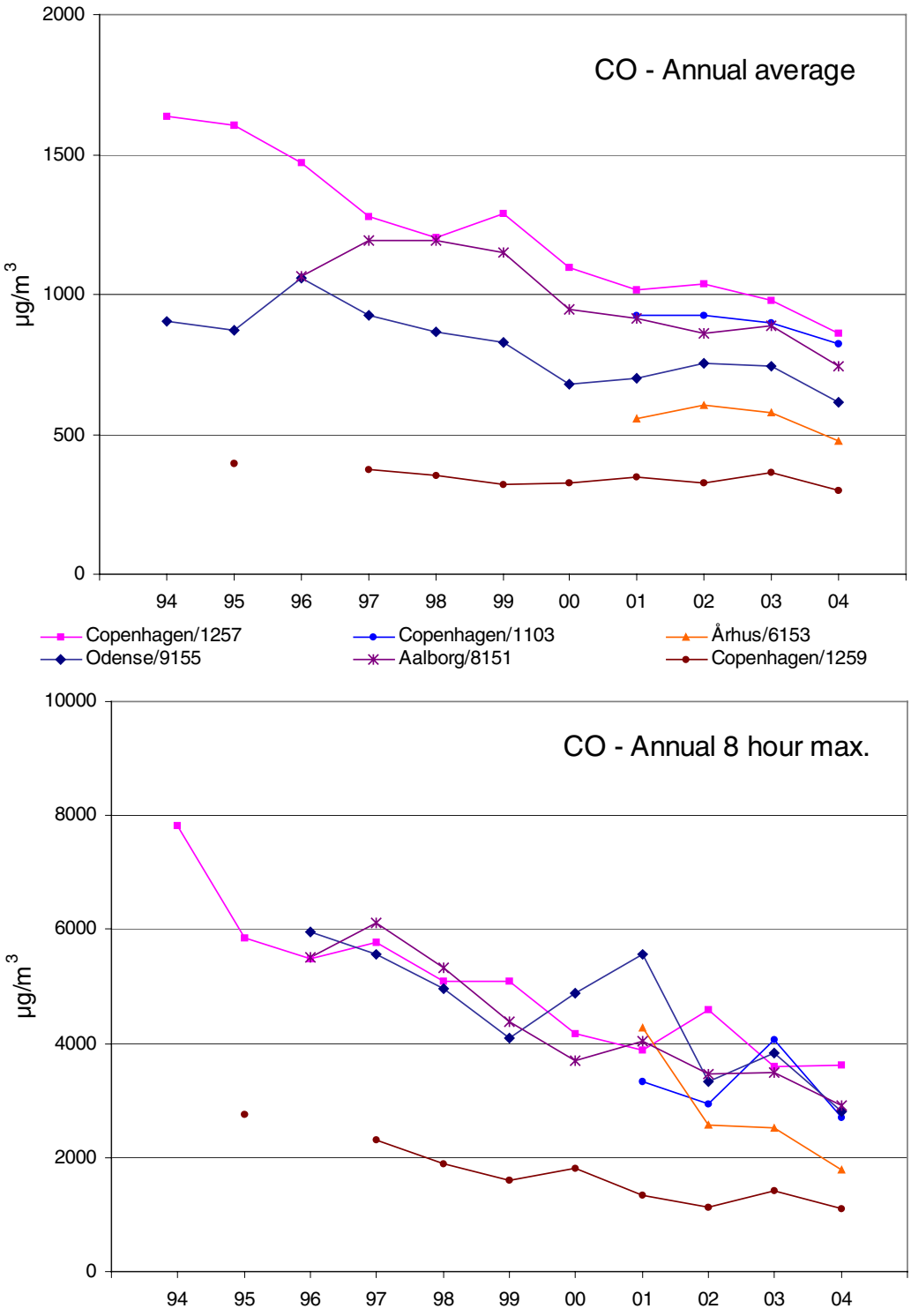

Figure 5-1 Annual average values and highest 8-hour value calculated based on an hourly moving average. Previous results from Copenhagen/1103 can be found at the WebPages of the Copenhagen Environmental Protection Agency (www. Miljoe.kk.dk).

6 Benzene and Toluene

6.1 Annual statistics

Table 6-1 Annual statistics for Benzene 2004. 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 excess risk of $1:10^5$ for developing cancer.

Unit: µg/m^3	Number of results	Average	Max. 8 hours	Max. 1 hour
Copenhagen/1257	6715	3.5	16	36
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 Regulation from the Ministry of Environment (Miljøministeriet 2003B).

Table 6-2 Annual statistics for Toluene 2004. 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	6700	16.1	58	96
Guideline value	-	-	260	-

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

7 Particles (TSP, PM_{10})

7.1 Annual statistics

The limit values are based on the EU Council Directive (EC, 1999) and implemented through a national Regulation from the Ministry of Environment (Miljøministeriet 2003A). However, it is widely recognised that the present knowledge is insufficient for definition of the limit values. It is therefore stipulated that the indicative limit values (to be met in 2010) will be reviewed.

At all stations (except Copenhagen/1103) PM_{10} is collected continuously on filters in 24 hours intervals for later gravimetric determination of the mass. These measurements are considered to be equivalent to the reference methods in the Directive (EC, 1999). Additionally PM_{10} is measured at the stations in Copenhagen using a TEOM (Tapered-element oscillating microbalance) instrument. The TEOM measurements are performed with a time resolution of 30 minutes. During sampling the particles are heated to 50 ^{0}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 (see box on next page).

The limit values are implemented through EU Council Directive (EC, 1999) and a national Regulation from the Ministry of Environment (Miljøministeriet 2003A).

At some stations there are too few measurements for a valid comparison with the limit values. In these cases the 90-percentile will give a better impression of the compliance with the limit value that must not be exceeded more than 35 times every year.

Estimated PM10 at H.C. Andersens Boulevard, 2004

PM_{10} is measured as 24h averages with a gravimetric method (with SM200 monitor) that is equivalent with the EU reference method at two sites in Copenhagen

- Copenhagen/1257 (JGTV), at kerbside in a street canyon (Jagtvej)
- Copenhagen/1259 (HCOE), an urban background station on the roof of the H.C. Oersted Institute

PM10 is also measured with half-hour time resolution with TEOM monitors at JGTV, HCOE, and Copenhagen/1103 (HCAB) at H.C. Andersens Boulevard. The TEOM monitors do not measure PM_{10} correct, because the high collecting temperature (50 ^{0}C) results in losses of volatile material from the collecting filter. A comparison of PM10 and 24h averages of TEOM_PM10 at JGTV and HCOE has shown that the losses are the same at the two sites taking the uncertainties of the measurements into account. The losses are 8-9 μgm^{-3} in average on an annual basis. The average PM10/TEOM_PM10 ratio is approximately 1.4 at JGTV, and 1.7 (in 2003) at HCOE. The EU commission has accepted that TEOM_PM10 can be used with a correction factor 1.3 as substitute for PM_{10} measurements according to the EU reference method.

Table: Using the assumption that the PM losses with the TEOM monitor are the same at HCAB as at JGTV and HCOE it is possible to make a correction of the 24h TEOM_PM10 average at HCAB on days when measurements of the PM loss at JGTV or HCOE are available. The result of this correction for 2004 is shown in table below, where also is shown the result using the correction factor 1.3.

	TEOM_ PM10	PM10_loss (JGTV and/or HCOE)	TEOM_PM10 corrected for losses	TEOM_PM10*1.3
Average value	31.6	8.3	39.8	41.1
Number of 24h values	305	358	302	305
90% percentile	46.9	16.6	59.6	61.0
36th highest value	45.4	16.6	56.8	59.0

Unit: μgm^{-3}

We can conclude that the factor 1.3 gives corrected values that are not far from the values corrected for losses, so the factor appears to be nearly OK for HCAB, while it is definitely too small for JGTV and HCOE. Under all circumstances we consider the values corrected for losses to be the most reliable estimates of PM10 at HCAB. According to this is the limit value for the annual average not exceeded (39.8 μgm^{-3} in comparison with 41.6 μgm^{-3} for 2004). The number of measurements is smaller than the required 90% of days in the year, so the 90% percentile seems to be more adequate than the 36th highest value. This value clearly exceeds the limit value (59.6 μgm^{-3} in comparison with 55 μgm^{-3} for 2004).

Table 7-1 Annual statistics for PM_{10} 2004. All parameters are calculated as daily averages. The limit values shall be met at 2005. The indicative limit values are valid from 2010. They will, however, be reviewed before that.

Unit µg/m^3	Number of results	Average	36.highest result	90 percentile	95 percentile	8.highest result	Max. day
Traffic							
Copenhagen/1257	341	32	48	50	57	64	80
Århus/6153	289	23	33	37	45	51	89
Odense/9155	336	31	51	52	62	76	252
Aalborg/8151	307	27	41	42	49	58	71
Urban background							
Copenhagen/1259	346	19	32	32	37	40	53
Århus/6159	262	21	33	36	41	48	91
Odense/9159	142	27	-	-	-	-	-
Aalborg/8159	151	21	-	-	-	-	-
Rural							
Lille Valby/2090	341	22	36	37	44	53	81
Keldsnor/9055	250	22	33	36	46	49	56
Limit values (2005) /limit value + margin of tolerance 2004	>329	40/41.2	50/55	-	-		
Limit values (2010) (indicative)		20		-	-	50	-

Table 7-2 Annual statistics for TSP (Total Suspended Particles) 2004. 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/1103	322	70	110	111	123	142	186

Table 7-3 Annual statistics for PM_{10} measured 2004 using TEOM. The values are calculated based on daily averages. Please refer to the text box.

Unit µg/m^3	Number of results	Average	36.highest result	90 percentile	Average ×1.3	36. highest ×1.3
Traffic						
Copenhagen/1257	336	23.4	35.0	35.3	30.4	45.5
Copenhagen/1103	305	31.6	45.4	46.9	41.1	59.0
Urban background						
Copenhagen/1259	317	15.9	23.4	23.8	20.7	30.4
Limit values /limit value (2005) + margin of tolerance 2004	>329	-	-	-	40/41.6	50/55

7.2 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 however strongly on the wind velocity. From 2001 PM_{10} measurement was started at all stations except Copenhagen/1103 where the TSP sampling was continued. 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.

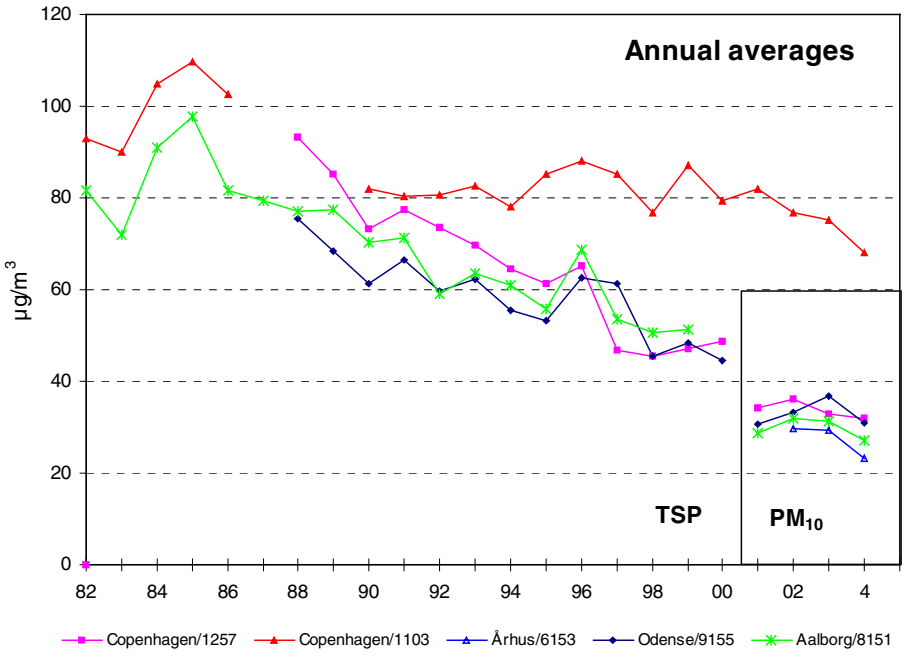

Figure 7-1 Annual averages for TSP and PM_{10} measured at street stations. Results from 2000 and earlier are for TSP, while later results are for PM_{10} - except for Copenhagen/1103, where TSP measurements are continued. The PM_{10} results are shown in the area in the bottom left of the plot area.

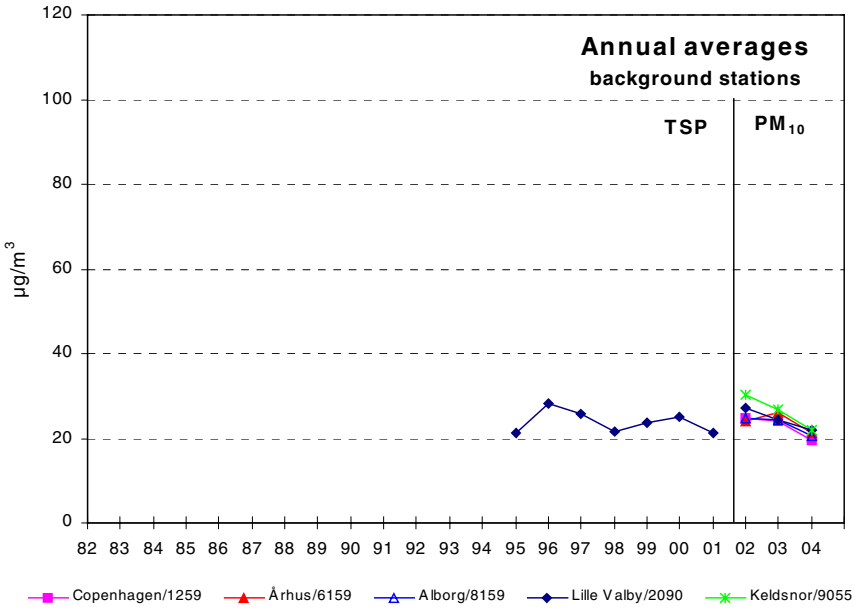

Figure 7-2 Annual averages for TSP and PM_{10} measured at urban background and rural stations.

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} during 2004. The lifetime risk level is defined as the concentration that through a lifelong exposure is estimated to give a excess risk of $1:10^5$ for developing cancer. The filters are occasionally contaminated with Cr, Ni, Cu and Zn. The out-layers for these elements are excluded before average calculation. 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
Traffic										
Copenhagen/1257	6.8	13.4	15.9	4.5	63.8	41.5	0.5	0.4	< 1.3	10.7
Copenhagen/1103 +)	9.2	15.3	71.9	4.7	96.2	98.7	0.6	0.3	< 0.7	16.0
Århus/6153	5.6	3.6	10.0	5.1	31.4	29.9	0.6	0.4	< 2.4	7.6
Odense/9155	4.5	4.5	16.9	2.6	40.8	51.6	0.7	0.5	< 1.4	11.3
Aalborg/8151	3.6	5.6	9.5	2.5	38.1	50.1	0.5	0.4	< 1.3	6.8
Urban background										
Copenhagen/1259	6.0	3.1	5.8	3.2	9.7	18.8	0.5	0.4	< 1.3	6.4
Århus/6159	4.3	1.6	7.4	3.8	10.0	20.0	0.7	0.4	< 1.3	6.7
Odense/9159	-	-	-	-	-	-	-	-	-	-
Aalborg/8159	-	-	-	-	-	-	-	-	-	-
Rural										
Lille Valby/2090	3.9	1.6	4.7	2.2	4.0	16.0	0.8	0.4	< 1.3	5.2
Keldsnor/9055	6.3	< 1.1	2.7	2.6	4.0	17.8	0.4	0.6	< 1.3	5.8
Target/limit values *)				20			6		5	500
Guideline value (WHO) *)	1000		150						5	
Life time risk level at $1:10^5$ (WHO) *)				25			6.6			

+) Measured in TSP (Total Suspended Particulate matter). Most of the heavy elements are present in particles. The heavy metals are primarily found in fine particles. The TSP and PM_{10} results are in most cases comparable because the heavy metals primarily are found in fine particles.

*) 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

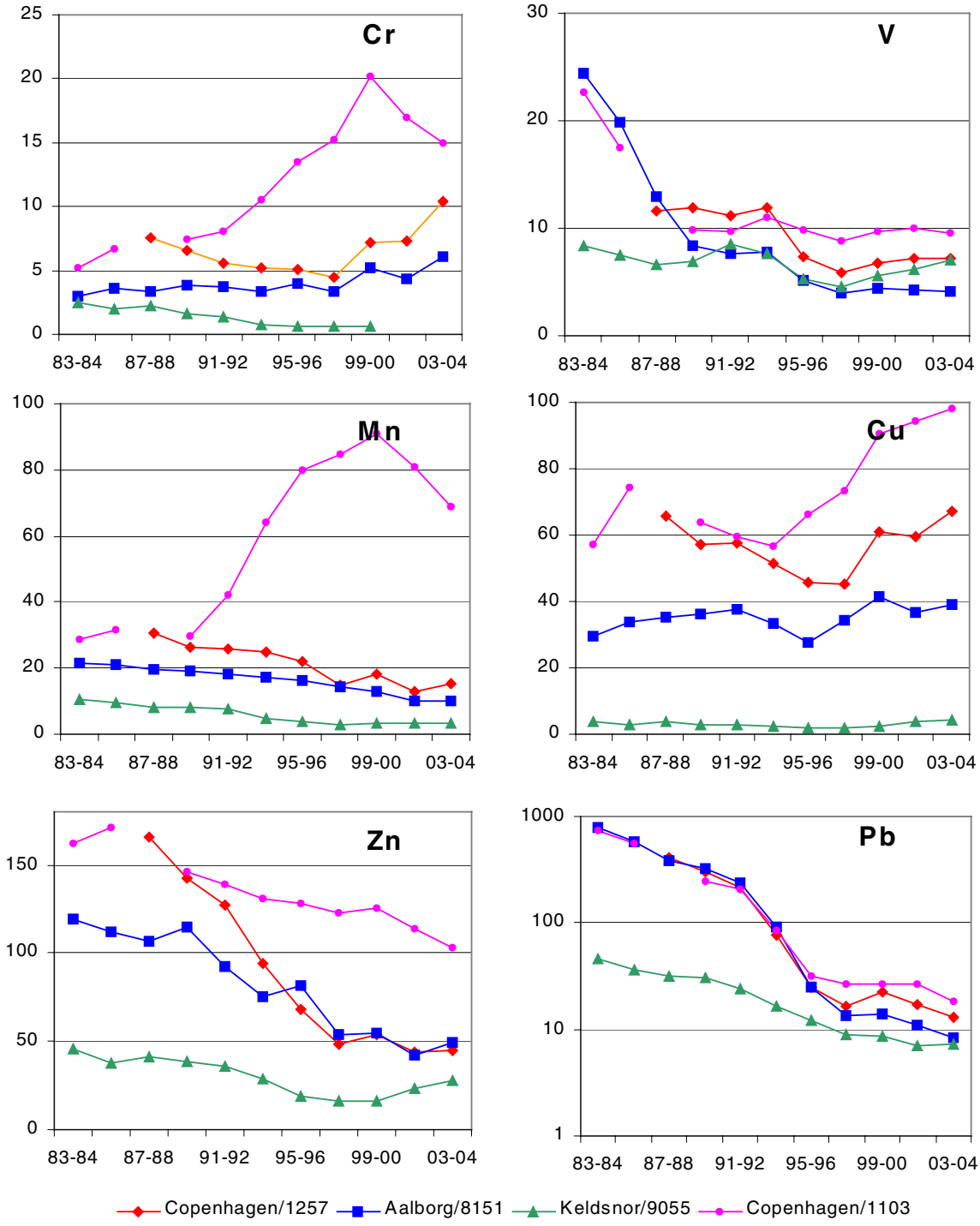

Figure 8-1 Biannual averages from selected stations for some Heavy Metals in particulate matter. Until 2000 in TSP and later in PM_{10} – except for Copenhagen/1103 where TSP measurements continue. The heavy metals are usually found in fine particles, which makes the TSP and the PM_{10} values comparable. 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. - 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 2004. All parameters are calculated based on hourly averages.

Unit: µg/m^3	Number of results	Average year	Average winter	Median	98-percentile	Max. Hour	4. highest day
Traffic							
Copenhagen/1103	7496	3.8	4.4	2.7	15	66	14
Aalborg/8151	8664	2.6	2.6	1.7	10.7	31	7
Limit values	>7884	20	20			350	25

The limit values are based on EU Council Directive (EC, 1999) and implemented through a national Regulation from the Ministry of Environment (Miljøministeriet 2003A).

Table 9-2 Annual averages for particulate sulphur (S) measured in PM_{10} 2004 (for Copenhagen/1103 in TSP). The sulphur containing particles are mainly present in sub-micron particles, which makes the TSP and PM_{10} results comparable. Measurements are daily averages.

Unit: µg(S)/m^3	Number of results	Average
Traffic		
Copenhagen/1257	343	0.86
Copenhagen/1103	333	1.04
Århus/6153	290	0.89
Odense/9155	337	0.96
Aalborg/8151	308	0.74
Urban background		
Copenhagen/1259	346	0.77
Århus/6159	263	0.80
Odense/9159	143	-
Aalborg/8159	153	-
Rural		
Lille Valby/2090	345	0.74
Keldsnor/9055	251	0.92

9.2 Trends

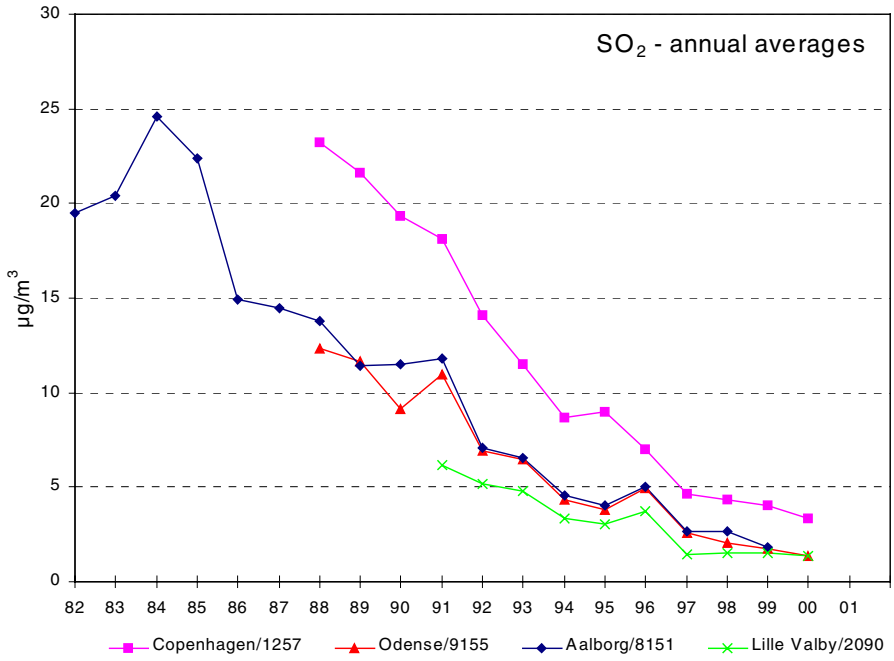

Figure 9-1 Annual averages for SO_2.

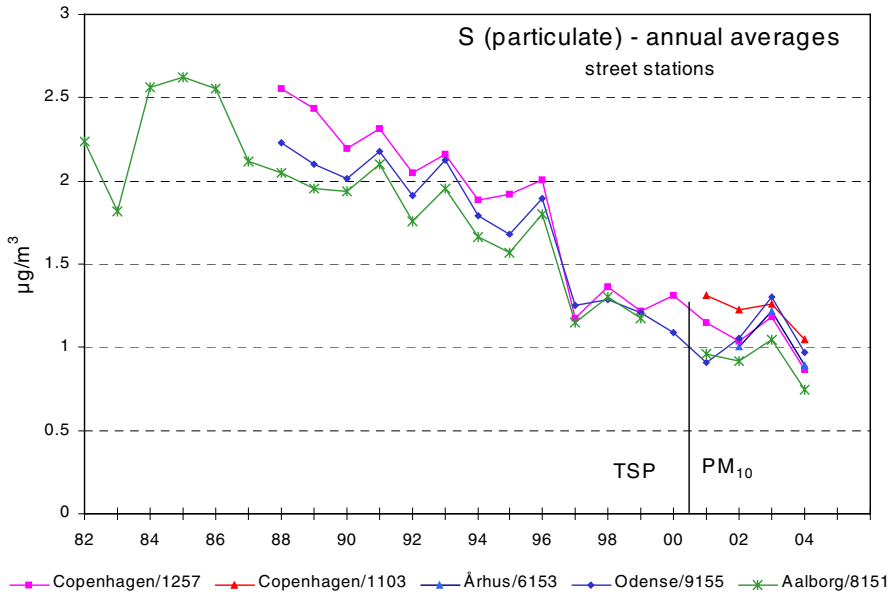

Figure 9-2 Annual averages for particulate sulphur at street stations. The particulate sulphur from 2000 and earlier is determined in TSP, and the 2001 results and later are for PM_{10} – except for Copenhagen/1103, where TSP measurements are continued. The sulphur containing particles are mainly present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

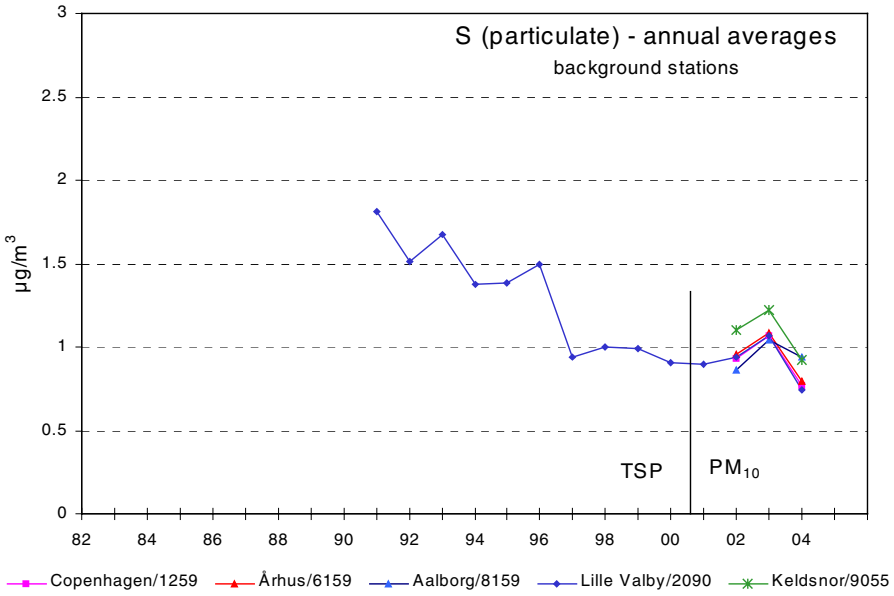

Figure 9-3 Annual averages for particulate sulphur at urban background and rural stations. The particulate sulphur from 2000 and earlier is determined in TSP and the 2001 results and later are for $PM_{10.}$ The sulphur containing particles are mainly present in sub-micron particles, which makes the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

10 Model calculation

A supplementary assessment of the air quality has been carried out using NERI's air quality models in the agglomerations Copenhagen and Aalborg. The assessment was performed for NO_x/NO_2, CO and O_3 in urban background and in selected streets, 138 streets in Copenhagen and 10 streets in Aalborg. Modelling was also performed for $PM_{10}/PM_{2.5}$ in Copenhagen. The model results give an overview of the air pollution over the urban areas and in many streets.

10.1 Calculations for Copenhagen

10.1.1 Methodology and data

The Operational Street Pollution Model (OSPM; Berkowicz, 2000a) and the Urban Background Model (UBM; Berkowicz, 2000b) were used to calculate the traffic related pollution in Copenhagen. The data used for these calculations are essentially the same as used in the recent project on evaluation of exceedance of NO_2 limit values in Copenhagen (Jensen et al., 2005) but the only results presented here are those referring to the situation in the year 2004.

Traffic data originate mainly from a traffic model for the Danish and Swedish Øresund region in the Greater Copenhagen region – the so-called Ørestadstrafikmodel (OTM; Ørestadsselskabet, 2002) – but also from a traffic model that only covers the Danish part of the Øresund region – the so-called København-Ringsted Trafikmodel (KRT). These traffic data, covering the whole Copenhagen Metropolitan Area, were distributed on 1x1 km^2 gridnet and subsequently used for calculation of traffic emissions in this area. The gridded annual emissions of NO_x and CO are shown in *Figure 10-1*, while the corresponding emissions for PM_{10} and $PM_{2.5}$ are shown in *Figure 10-2*. The estimated PM_{10} emissions are rather uncertain, because a significant fraction of these emissions (up to 50%) is due to the so-called non-exhaust emissions, which are difficult to quantify (Winther and Berkowicz, 2004; Ketzel et al., 2004;Wåhlin, 2004).

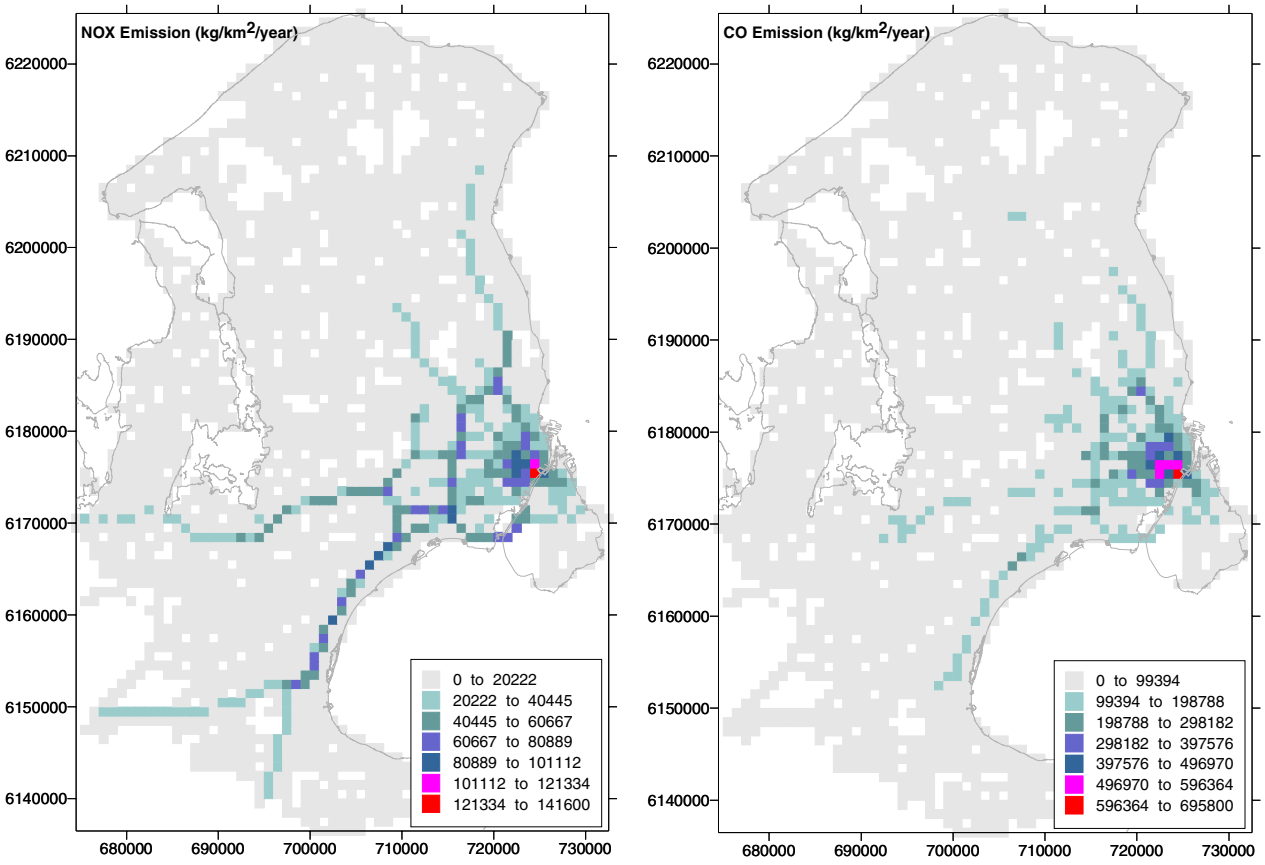

Figure 10-1. Annual traffic emissions of NO_x (left) and CO (right) for the year 2004.

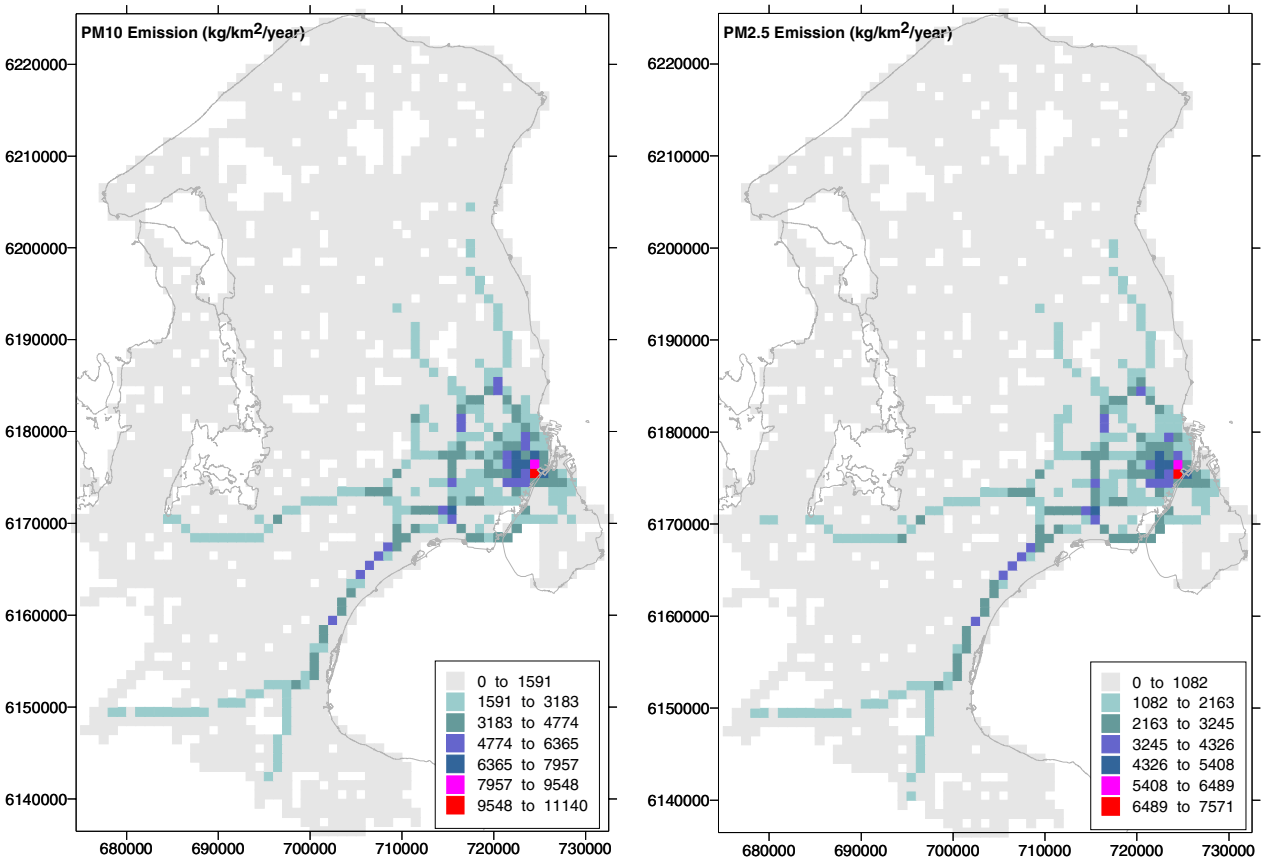

Figure 10-2. Annual traffic emissions of PM_{10} (left) and $PM_{2.5}$ (right) for the year 2004.

A more detailed discussion of the emission estimations is given in Jensen et al., (2005).

All calculations presented here are performed using meteorological data measured from the LMP meteorological mast located on the roof of H.C. Ørsted Institute (Copenhagen/1259).

Table 10-1. Annual average concentrations of the regional background used for the model calculations.

Station	NO_X ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	O_3 ($\mu g/m^3$)	CO[1] (mg/m^3)	PM10 ($\mu g/m^3$)	PM2.5[2] ($\mu g/m^3$)
Keldsnor	10.5	9.0	58.8	0.12	21.5	19.3

[1]No measurements were available. A constant value (0.1 ppm) was assumed.
[2]No measurements were available. A value of 0.9 PM10 concentrations was assumed.

Regional background concentrations are required for modelling the urban background concentrations. Measurements from the rural monitoring station at Keldsnor are used here to represent the regional background concentrations. Concentrations of NO_X/NO_2, O_3 and PM_{10} are measured at this location. Because no data on CO concentrations were available, a constant value of 0.1 ppm was assumed. Neither are any data on $PM_{2.5}$ concentrations available from Keldsnor. Therefore, it was assumed that $PM_{2.5}$ constitutes 0.9 of PM_{10} concentrations. A summary of the regional background data, presented here as annual averages, is given in *Table 10-1*.

The procedure applied for selection of street locations for street level calculations with OSPM is described in details in Jensen et al., (2005). Shortly speaking, a pre-selection of all street links with annual diurnal traffic (ADT) of more than 15000 veh/day was done and among these only locations with buildings on at least one side were selected for calculations. This has resulted in 138 street locations. The required data on street geometry were obtained using the AIRGIS model (Jensen et al., 2001), which using a GIS based road network with both traffic and buildings data generates the necessary input-data for OSPM calculations.

10.1.2 Urban background concentrations

Results of the modelled urban background concentrations in Copenhagen are shown in *Figure 10-3*, *Figure 10-4* and *Figure 10-5* in terms of annual average concentrations. For comparison, the measured concentrations from the Copenhagen LMP urban background station, Copenhagen/1259 are shown. Also measurements from the two street locations, Jagtvej (Copenhagen/1257) and H.C. Andersens Boulevard (Copenhagen/1103), are presented but they should not be compared with the modelled background concentrations. The $PM_{2.5}$ concentrations at Copenhagen/1259, as well as at the street stations, are only measured with TEOM and because of this they are not comparable with the modelled PM concentrations (see Chapter 7.1 for explanation of the TEOM measurements).

Figure 10-3 shows a very pronounced variation of NO_x and NO_2 concentrations across the city area. The highest concentrations are calculated in the city centre and they gradually decline with the distance from the centre. The background concentrations at the location of the street monitoring station - Copenhagen/1103, are remarkable higher than the background concentrations at Copenhagen/1259. The difference is however still small compared to the NO_x and NO_2 concentrations measured at the street level.

A similar picture is observed for the CO concentrations (*Figure 10-4*, left), although the gradients are somewhat smaller than in the case of NO_x. This is mainly because the CO concentrations are very dominated by emissions from gasoline passenger cars and these are by now significantly reduced. Air concentrations of NO_x are, on the contrary, dominated by heavy diesel traffic. The modelled CO concentration for the location of Copenhagen/1259 is somewhat smaller than the measured one. This might be due to underestimation of the regional background, which rather arbitrary was set to 0.1 ppm (see *Table 10-1*).

The ozone concentrations (*Figure 10-4*, right) exhibit behaviour, which is largely an inverse picture of the NO_x concentrations. This is due to the well-known effect of destruction of ozone concentrations by the reaction with NO. The highest concentrations are observed outside the city centre with values approaching the regional background concentrations (see *Table 10-1*).

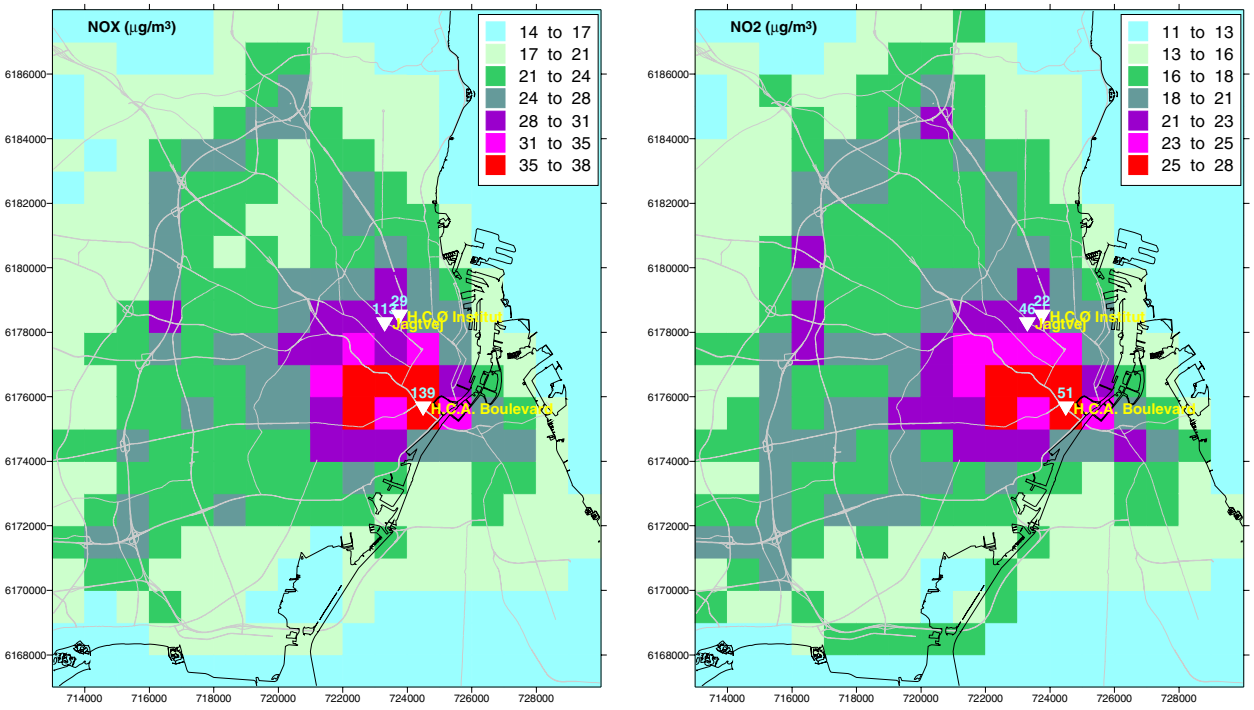

Figure 10-3. Annual average urban background concentrations of NO_x (left) and NO_2 (right) and annual mean concentrations at street and urban background stations

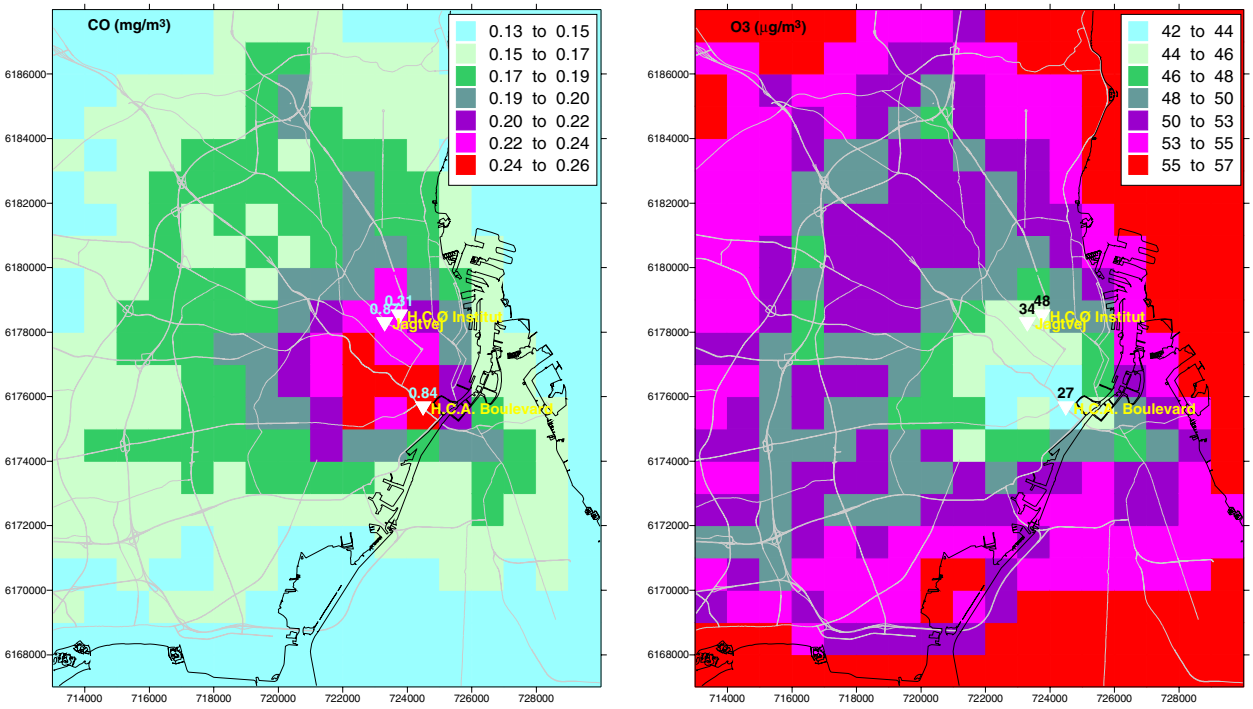

Figure 10-4. Annual average urban background concentrations of CO (left) and O_3 (right) and annual mean concentrations at street and urban background stations

The picture is totally different for the urban background concentrations of PM_{10} and $PM_{2.5}$ (*Figure 10-5*). Variation of the concentrations across the city area is very small and the difference between the maximum concentration in the city centre and the regional background is less than 2 µg/m^3. This illustrates that the contribution of urban traffic to the particle mass concentrations is marginal. The measured concentration of PM_{10} at Copenhagen/1259 is smaller then any modelled concentration in the area. However, this measured value is also smaller than any other measured PM_{10} concentration in 2004 at all LMP monitoring stations, incl. all background locations. This might be an indication of malfunctioning of the monitoring instrument at Copenhagen/1259.

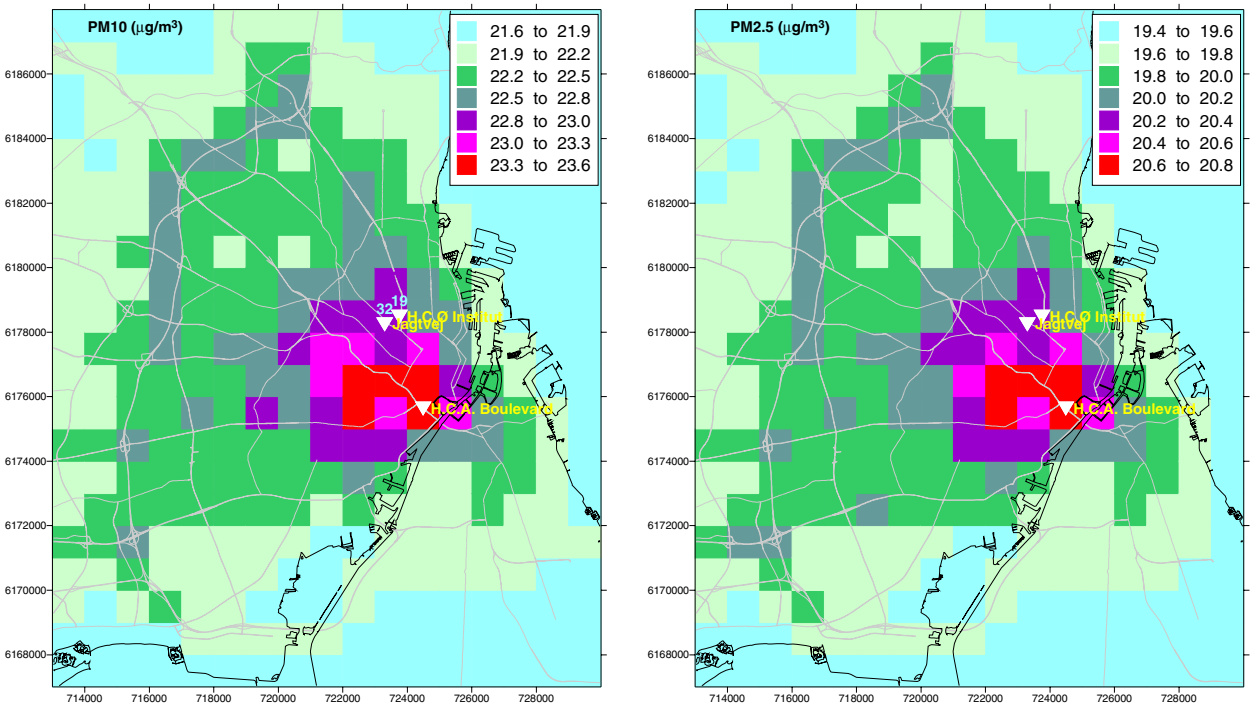

Figure 10-5. Annual average urban background concentrations of PM_{10} (left) and $PM_{2.5}$ (right) and annual mean concentrations at street and urban background stations

10.1.3 Street-level concentrations

Street level calculations are performed for all the selected 138 street locations using the Windows version of OSPM – WinOSPM. The urban background concentrations, used for modelling of the street level concentrations are generated with the UBM model. Hourly values were stored in files for the 56 1x1 km^2 grid cells in which the 138 street links were located, and these files were used as input for model calculations. The model output of WinOSPM is generated both in form of files and as computer graphics. The last is used for graphical presentation of the results in this report. Although the model output provides results for both sides of a street location, for clarity of presentation, only the highest value of the 2 street sides is reported here.

Modelling results for all the 138 streets are shown in *Figure 10-6* to *Figure 10-10*. Only annual average concentrations are presented here. More details, incl. the relevant percentile values are given in *Table 10-2* but only for 20 streets with the highest modelled NO_x- concentration. The same 20 streets are labelled in the figures with the Map Index, which is given in *Table 10-2*.

All the street links presented in the graphs are shown with dimensions (width and length) corresponding to the real street dimensions but all scaled by factor of 2. This is done so because several narrow street links would have been otherwise practically invisible when shown on the map in 1:1 scale.

Table 10-2. Annual averages and percentiles for the 20 selected streets in Copenhagen. These streets represent locations with the highest modelled NO_x concentrations. The respective limit values are shown in the last row. The Map Index refers to labels identifying the 20 selected streets on Figure 10-6 to Figure 10-10.

Street	Map Index	Annual averages					Hourly Percentiles		Daily Percentiles	
		NO_X ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	CO (mg/m^3)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	99.8 Perc. NO_2 ($\mu g/m^3$)	Max Running 8h CO (mg/m^3)	90.4 Daily Perc. PM_{10} ($\mu g/m^3$)	98 Daily Perc. PM_{10} ($\mu g/m^3$)
Lyngbyvej	1	214.7	57.3	1.0	37.0	29.9	153.8	3.0	53.2	71.6
Nørre Søgade	2	209.8	62.6	1.1	36.8	30.0	153.4	3.0	52.4	71.8
Ågade	3	205.6	60.0	1.0	36.4	29.5	145.9	2.8	53.9	70.5
Gyldenløvesgade	4	180.8	57.9	0.8	34.3	28.0	139.0	2.5	49.4	65.9
Åboulevard	5	171.6	56.4	0.8	33.7	27.6	139.1	2.7	49.0	65.7
Øster Søgade	6	151.3	47.1	0.8	32.2	26.8	135.8	2.4	47.8	63.4
Sydhavnsgade	7	147.6	49.1	0.7	31.8	26.6	128.8	2.3	47.0	63.3
Sallingvej	8	143.4	43.6	0.7	31.6	26.2	134.1	2.5	47.5	63.5
H.C.A. Boulevard	9	142.4	53.9	0.7	32.0	26.4	127.6	2.2	47.1	62.0
(Copenhagen/1103)		139	52	0.82	-	-	130	2.7	-	-
Nordre Fasanvej	10	141.6	48.1	0.9	31.3	26.0	133.9	3.2	47.7	64.1
Jyllingevej	11	136.7	44.4	0.7	31.1	26.0	132.0	2.4	47.0	63.1
Tuborgvej	12	136.4	47.5	0.7	31.2	26.1	138.1	2.4	48.3	65.3
Frederikssundsvej	13	135.9	44.8	0.7	31.0	26.0	132.7	2.5	47.3	64.2
Vesterbrogade	14	135.0	48.7	0.7	30.9	25.9	133.5	2.4	46.6	63.1
Gammel Kongevej	15	134.1	48.6	0.8	30.8	25.7	131.3	2.9	47.0	63.3
Østerbrogade	16	132.8	44.8	0.7	30.6	25.5	133.1	2.5	46.6	61.8
Borups Alle	17	130.8	44.1	0.8	30.7	25.4	131.0	2.4	46.0	61.7
Rosenørns Alle	18	128.6	47.0	0.8	30.4	25.4	131.5	2.8	46.4	62.7
Rolighedsvej	19	126.6	47.7	0.8	30.3	25.3	134.1	2.8	46.1	63.3
Jagtvej	20	112.5	45.0	0.7	29.4	24.6	127.0	2.4	45.5	62.2
(Copenhagen/1257		113	46	0.86	32	-	130	3.6	50	64
Limit Values		**-.-**	**40[1]**	**-.-**	**40[2]**	**-.-**	**200[1]**	**10[2]**	**50[2]**	**-.-**

[1]To be attained in 2010, [2] To be attained in 2005

In each of the graphs there are additionally shown bar charts with values for all the 138 street locations, but all sorted with respect to the modelled NO_X-concentration. In these bar charts, also the urban background concentration applied for the particular street link is shown. Exception is the PM-exhaust concentration (*Figure 10-10*), which refers only to the contribution from the traffic in the particular street.

According to the presented modelling results, exceedance of limit values (considering annual averages) is only observed for NO_2, and in this case the exceedance is quite massive. The problem with exceedance of NO_2 limit values in Copenhagen is in more details discussed in Jensen et al., (2005). However, it should also be noted that due to large uncertainties in determination of PM_{10} emissions, exceedances of limit values for PM_{10} can not be excluded. The part of PM concentrations, which can be attributed to the exhaust emissions only, is shown separately in *Figure 10-10*.

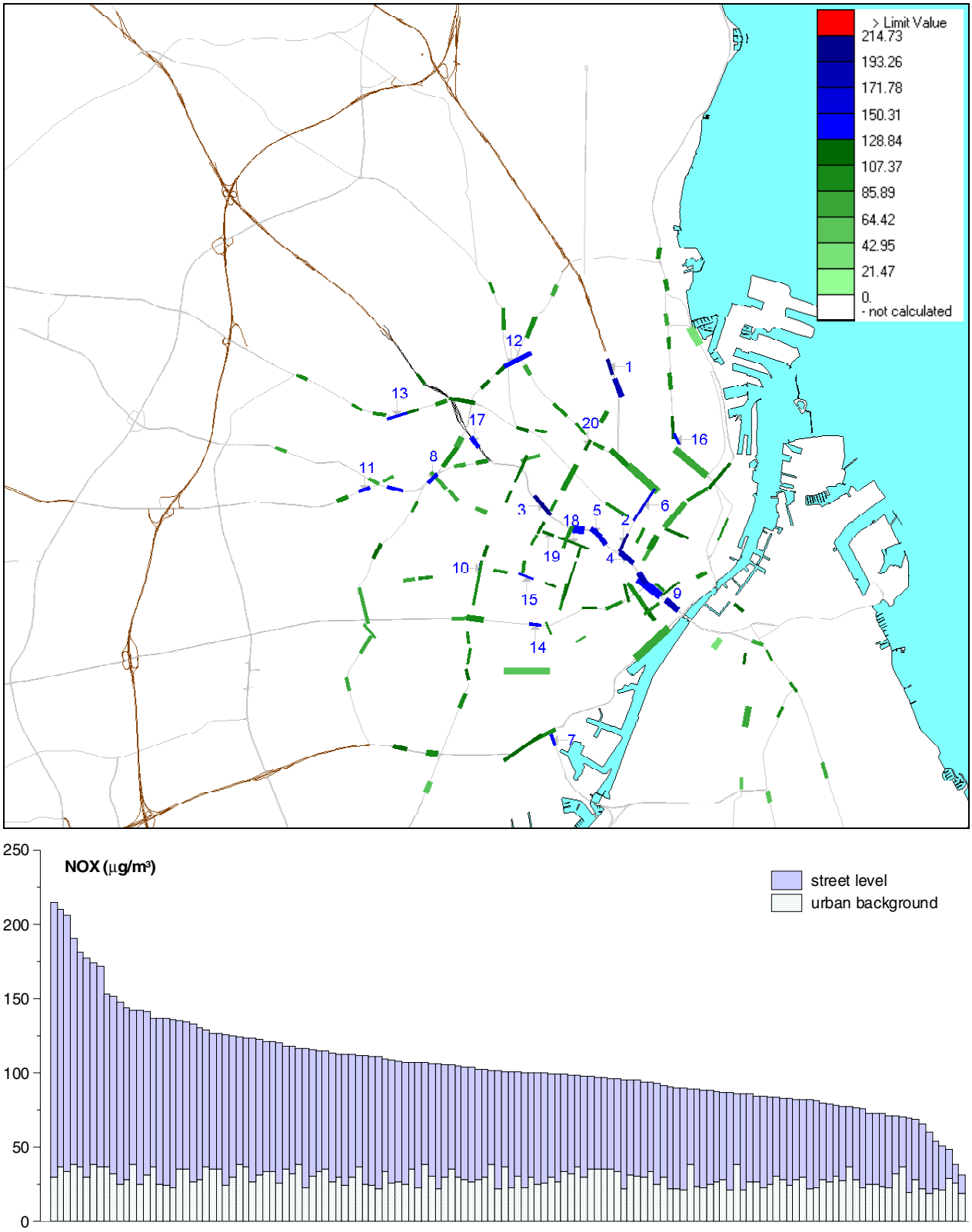

Figure 10-6. Modelled Annual concentrations of NO_x. The 20 selected streets are labelled with the Map Index as indicated in Table 10-2. The Bar Chart shows all 138 street locations ordered with respect to the NO_x concentrations. Urban background concentrations are shown too.

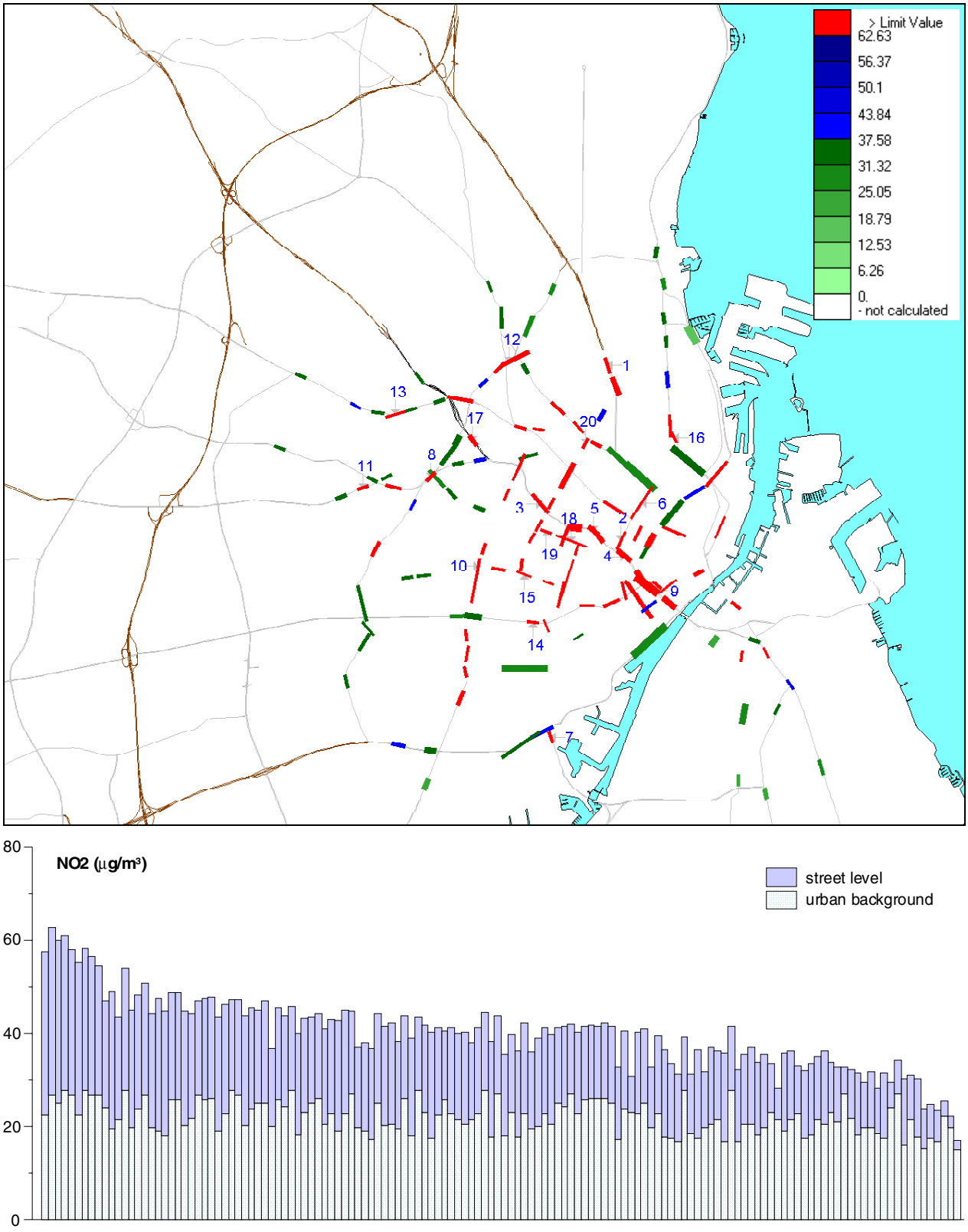

Figure 10-7. Modelled Annual concentrations of NO_2. The 20 selected streets are labelled with the Map Index as indicated in Table 10-2. Links with exceedance of the limit value are coloured in red. The Bar Chart shows all 138 street locations ordered with respect to the NO_X concentrations. Urban background concentrations are shown too.

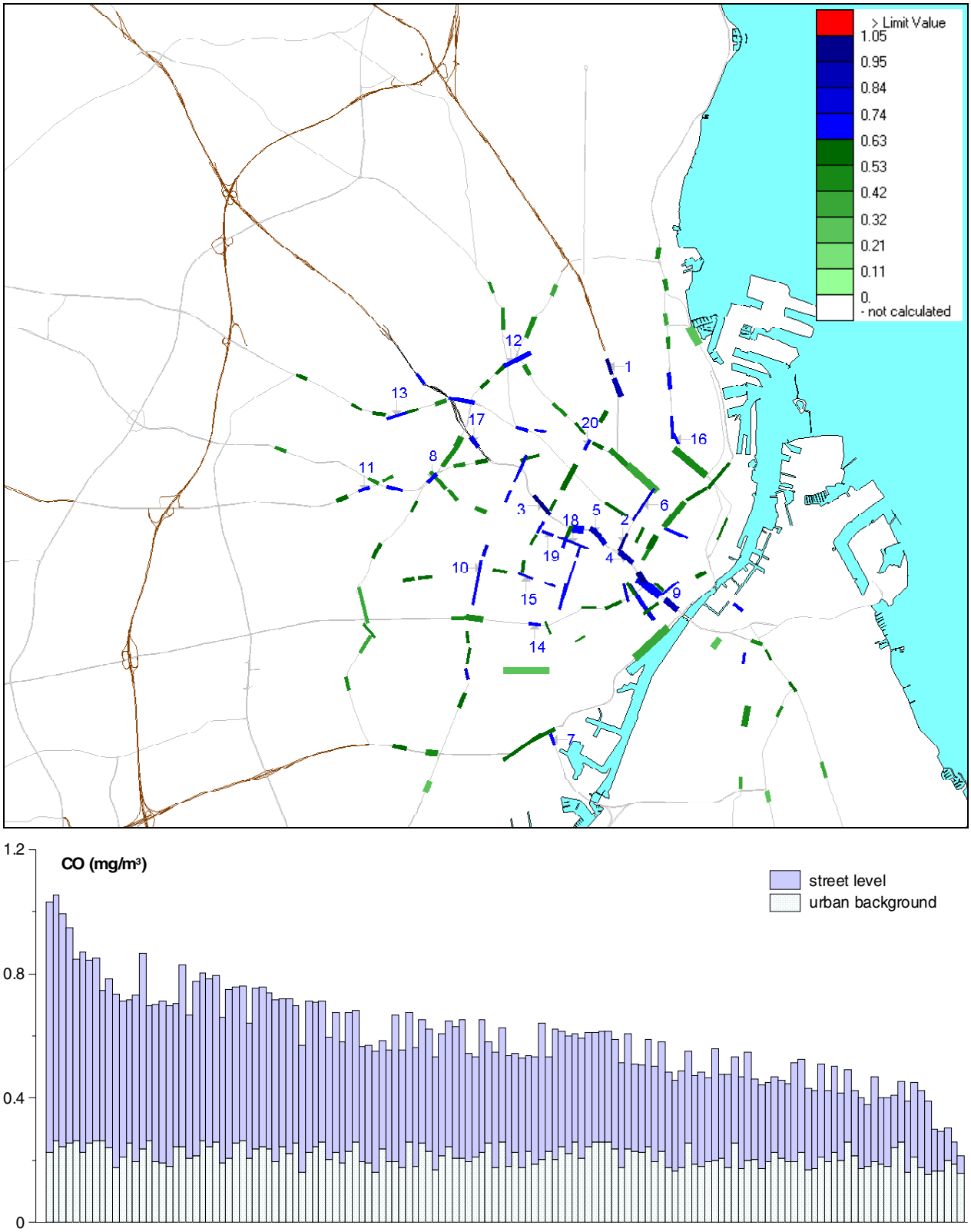

Figure 10-8. Modelled Annual concentrations of CO. The 20 selected streets are labelled with the Map Index as indicated in Table 10-2. The Bar Chart shows all 138 street locations ordered with respect to the NO_x concentrations. Urban background concentrations are shown too.

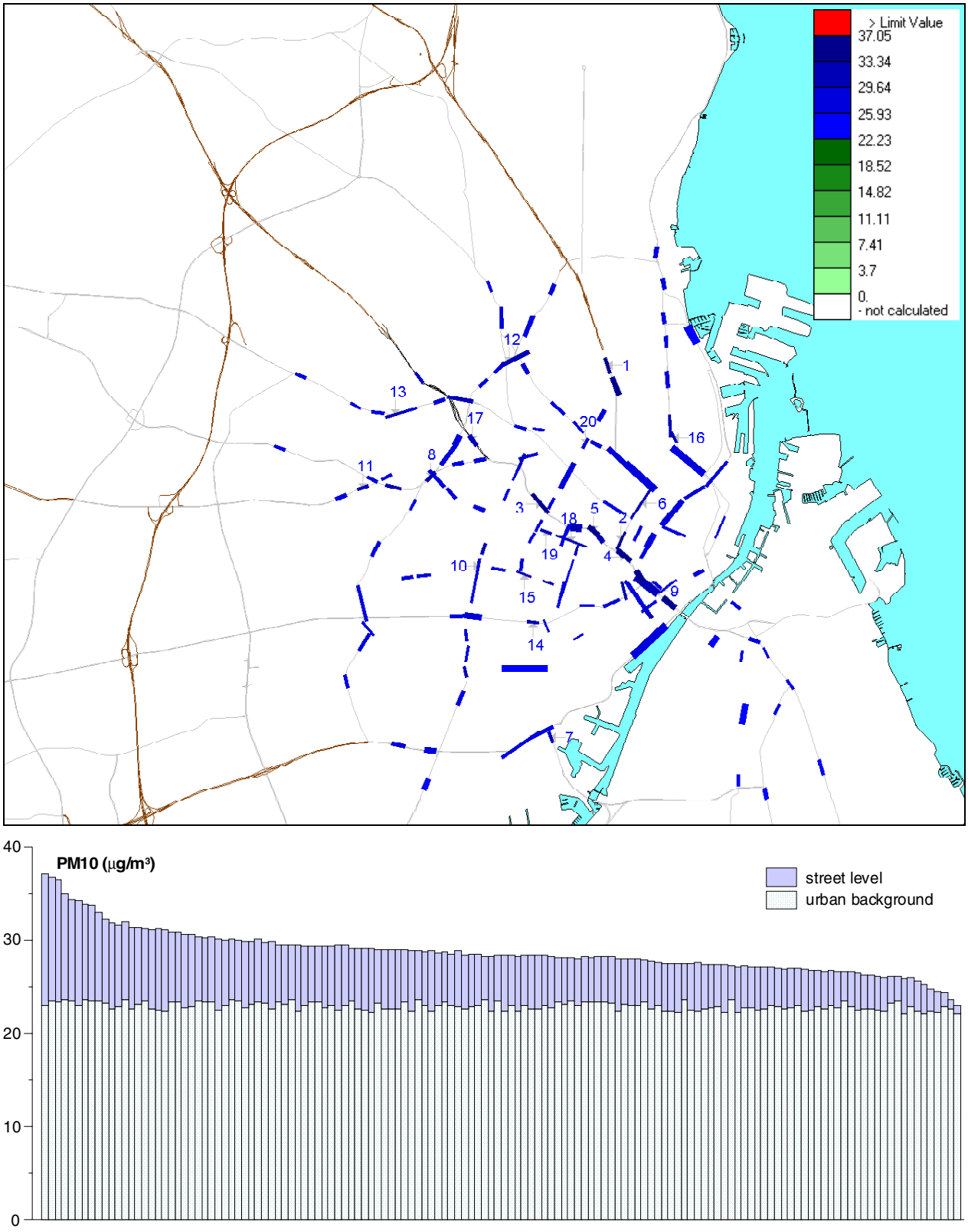

Figure 10-9. Modelled Annual concentrations of PM_{10}. The 20 selected streets are labelled with the Map Index as indicated in Table 10-2. The Bar Chart shows all 138 street locations ordered with respect to the NO_X concentrations. Urban background concentrations are shown too.

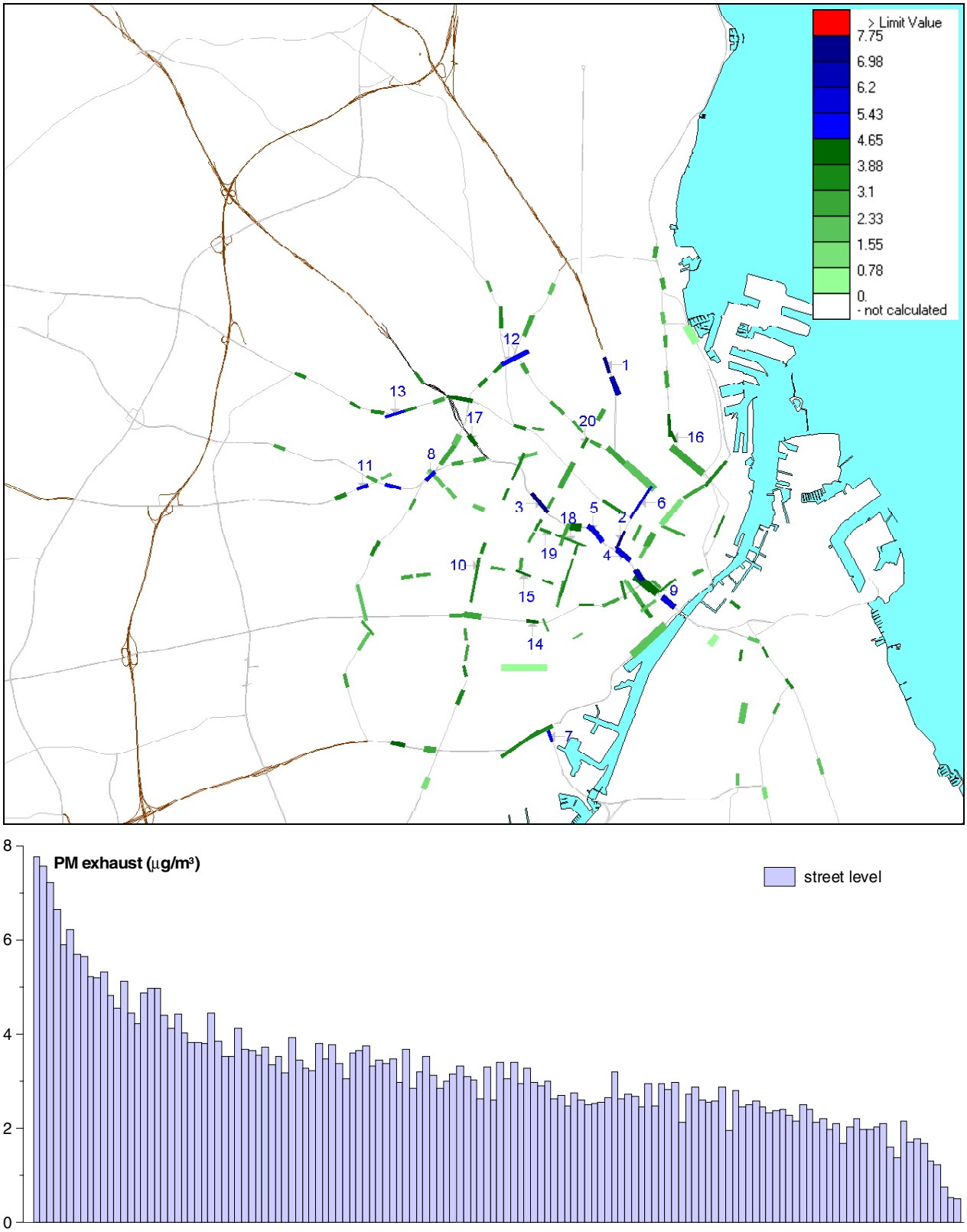

Figure 10-10. Modelled Annual concentrations of the PM exhaust concentrations. The 20 selected streets are labelled with the Map Index as indicated in Table 10-2. The Bar Chart shows all 138 street locations ordered with respect to the NO_x concentrations.

10.2 Calculations for Aalborg

10.2.1 The model system

The model calculations for the city of Aalborg are based on the existing air pollution forecasting system (the THOR Model System). The system is an integrated model system, which consist of a weather forecast model and a series of air pollution models, covering a wide range of scales (European scale, urban background scale and street scale in cities) and applications (forecasting, monitoring and scenarios). The system is designed to automatically produce 3 days air pollution forecasts of some of the most important air pollution species on different scales and on a continuous basis. A schematic diagram of the different modules and the data flow chart of the THOR system is shown in *Figure 10-11*. For more details see Brandt et al. 2000).

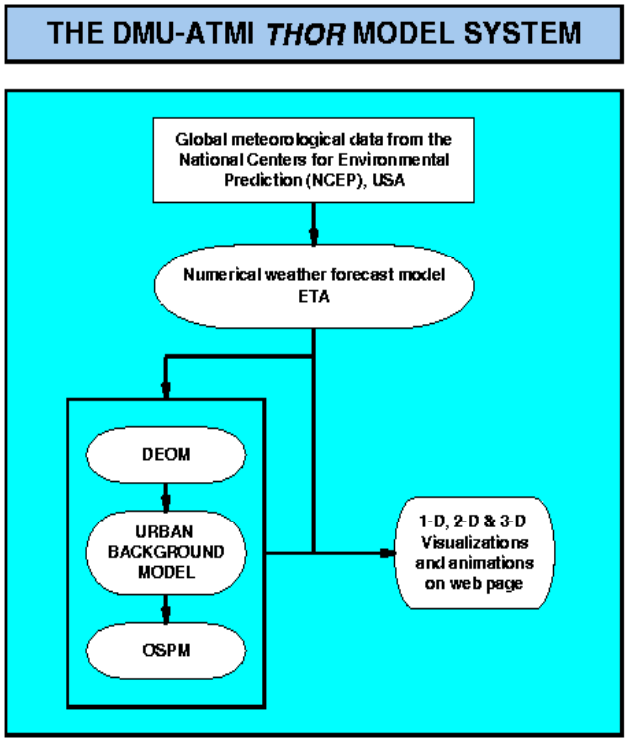

Figure 10-11 A schematic diagram of the main modules and the data flow in the DMU-ATMI THOR air pollution forecast system.

10.2.2 Urban background calculations

The Urban Background Model needs emission data, which have been constructed from information about the "traffic work" and the main point sources in the area. This information is used to estimate the emissions on a grid covering the city using emission factors for the different vehicles. Information about the traffic work, in km/day for passenger cars, vans, buses and trucks on a grid with 1 km x 1 km resolution was provided by the city of Aalborg. Emission factors were then used to calculate the total emission rates. The emission factors for NO_x used are the following (in g/km/vehicle):

- Passenger cars without catalyst: 2.0
- Passenger cars with catalyst: 0.2

– Vans: 2.0

– Trucks and busses: 19.0

The percentage of passenger cars with catalyst in the year 2000 is approximately 75%. However, the catalyst works only when it is warm after a few kilometres. Therefore the percentage of cars with catalyst has been set to 60%.

The resulting emission data for NO_x for Aalborg, including traffic and point sources, are shown in *Figure 10-12*. The corresponding emission factors for CO are calculated using a constant ratio to NO_x.

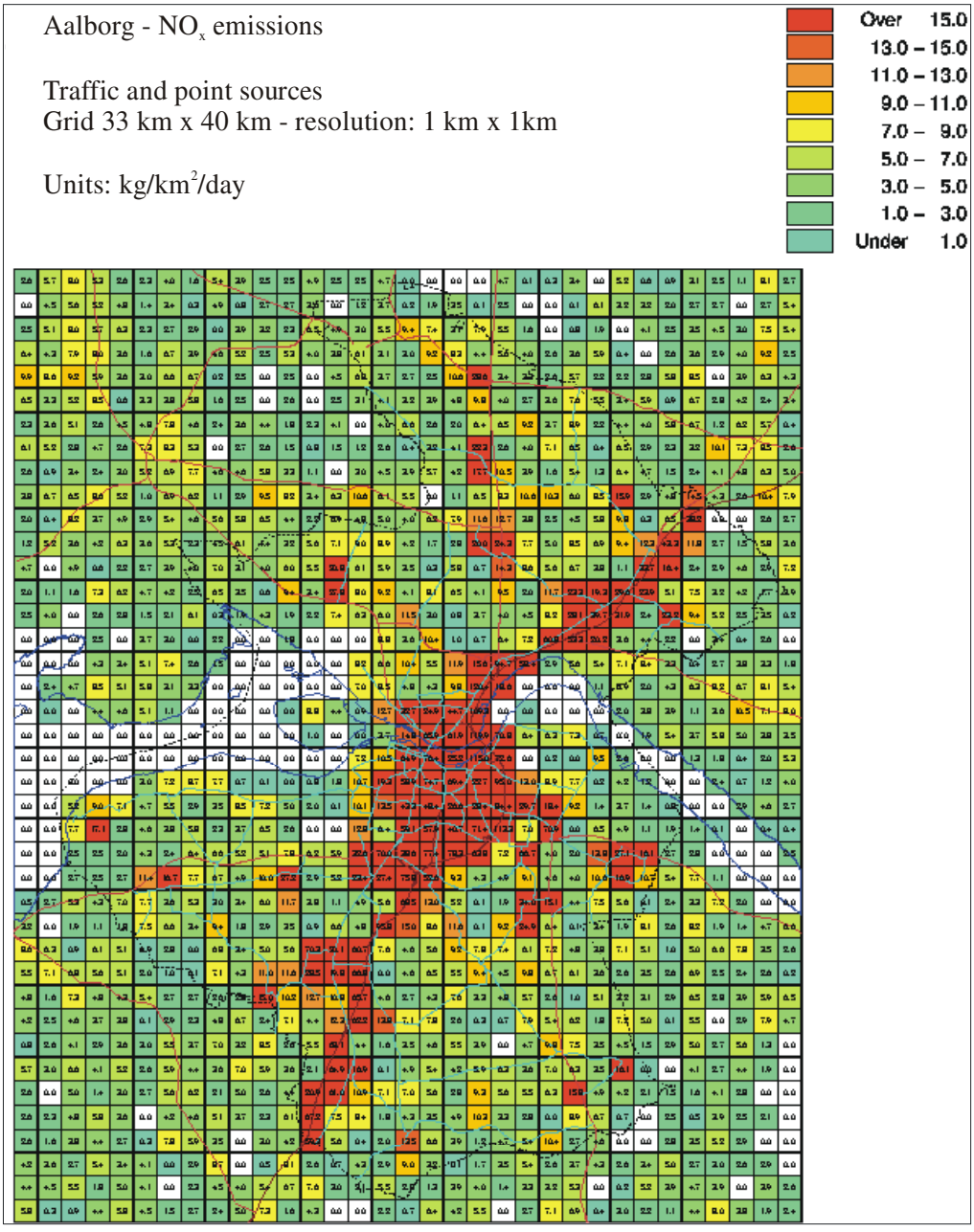

Figure 10-12 Average daily NOx emission data for the area of Aalborg.

10.2.3 The model calculations

The air pollution concentrations of NO_x, NO_2, O_3 and CO were calculated by the system, using meteorological data for 2004.

Urban background

The annual averages for the urban background of NO_x, NO_2, O_3 and CO are shown on *Figure 10-13*, *Figure 10-14*, *Figure 10-15* and *Figure 10-16* respectively.

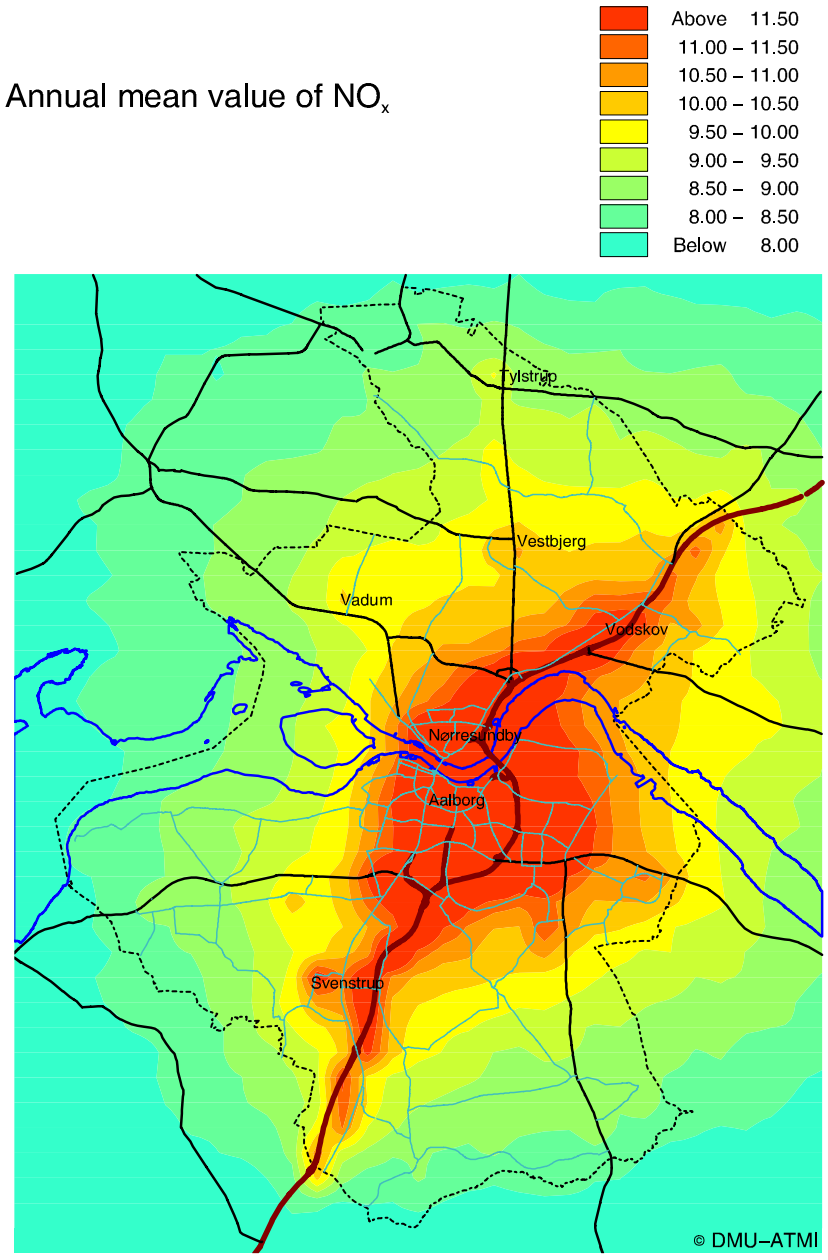

Figure 10-13 Calculated annual averages for NO_x (in ppb) in urban background in Aalborg 2004.

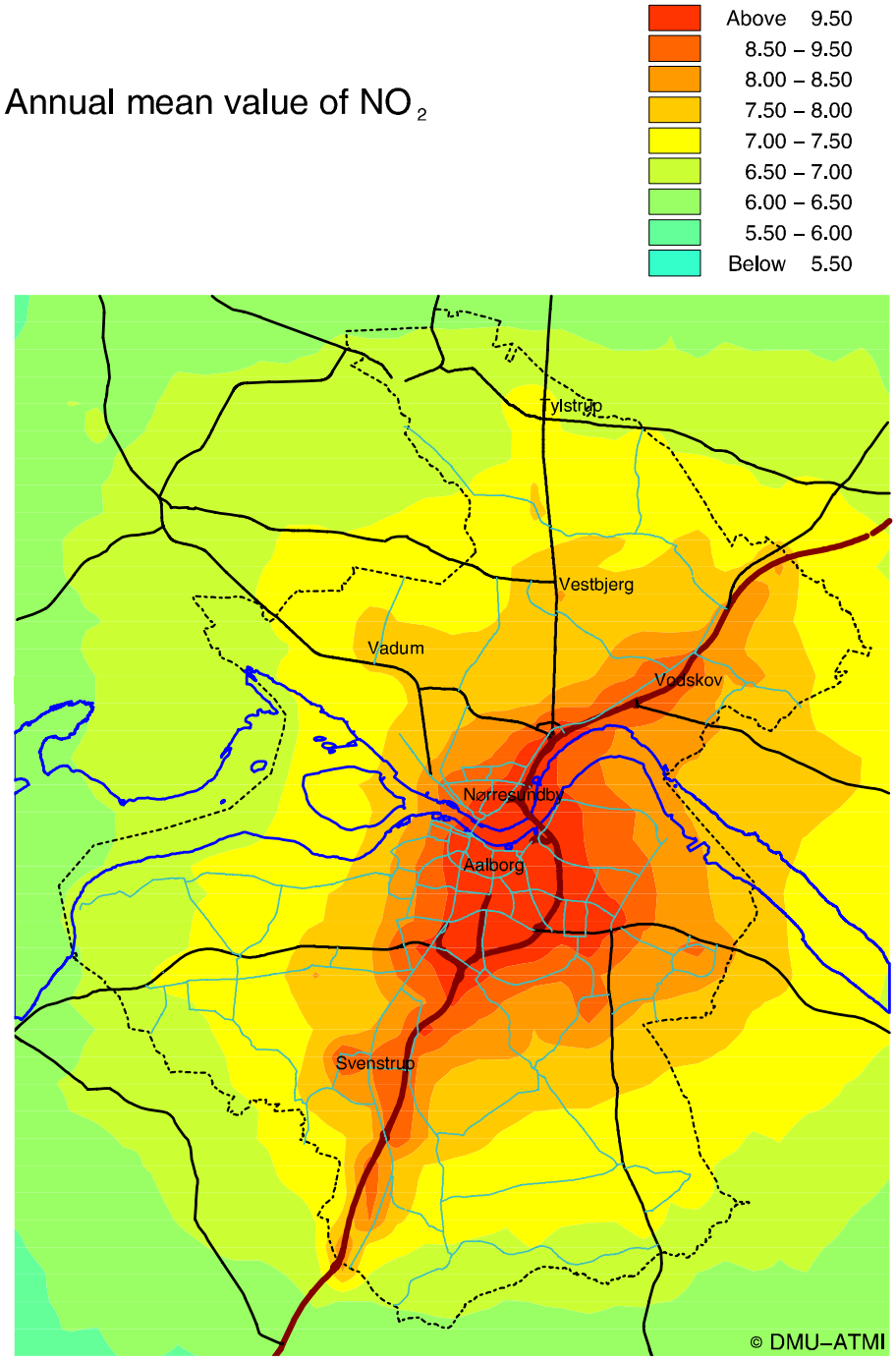

Figure 10-14 Calculated annual averages for NO_2 (in ppb) in urban background in Aalborg 2004.

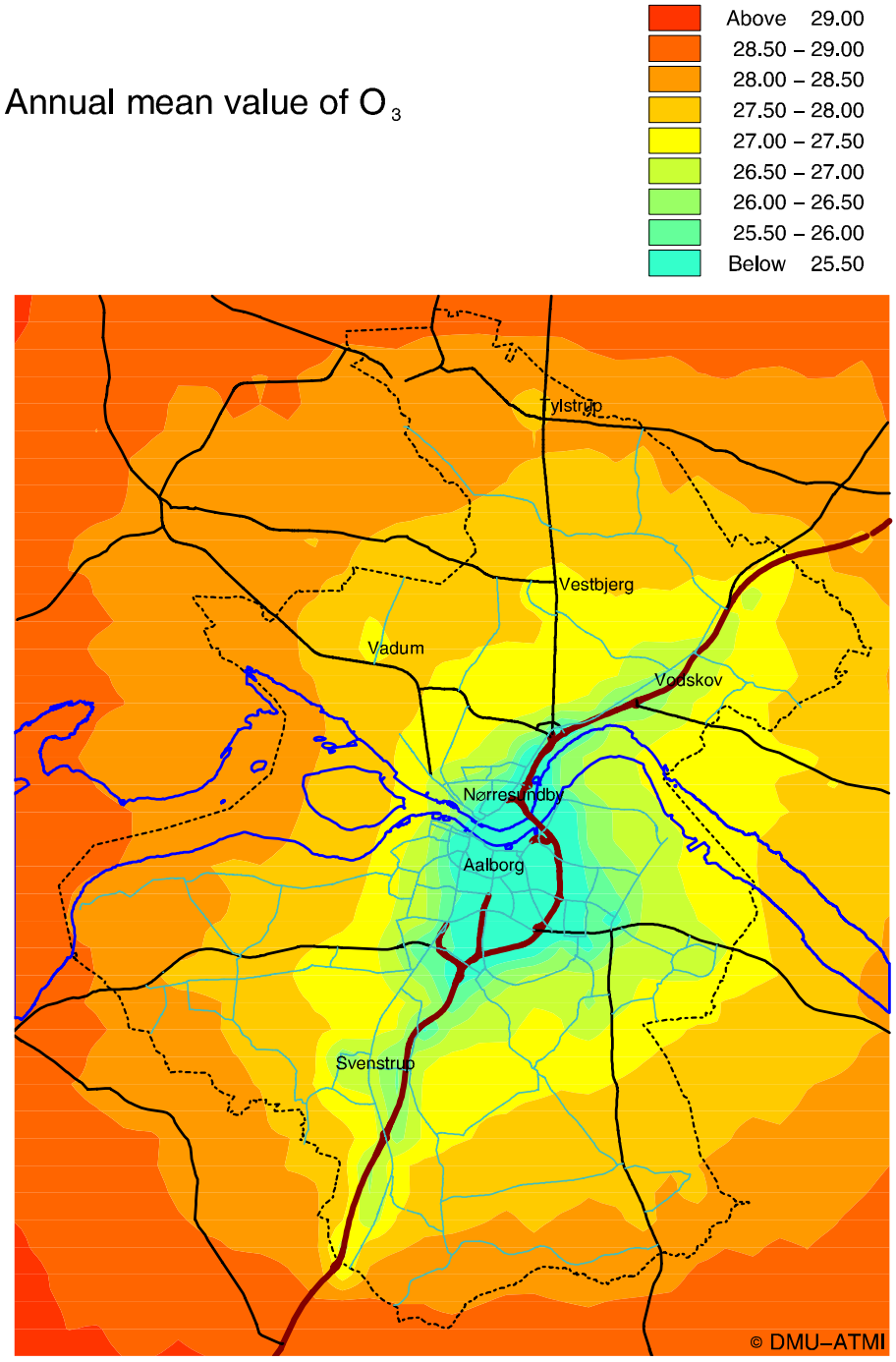

Figure 10-15 Calculated annual averages for O_3 (in ppb) in urban background in Aalborg 2004.

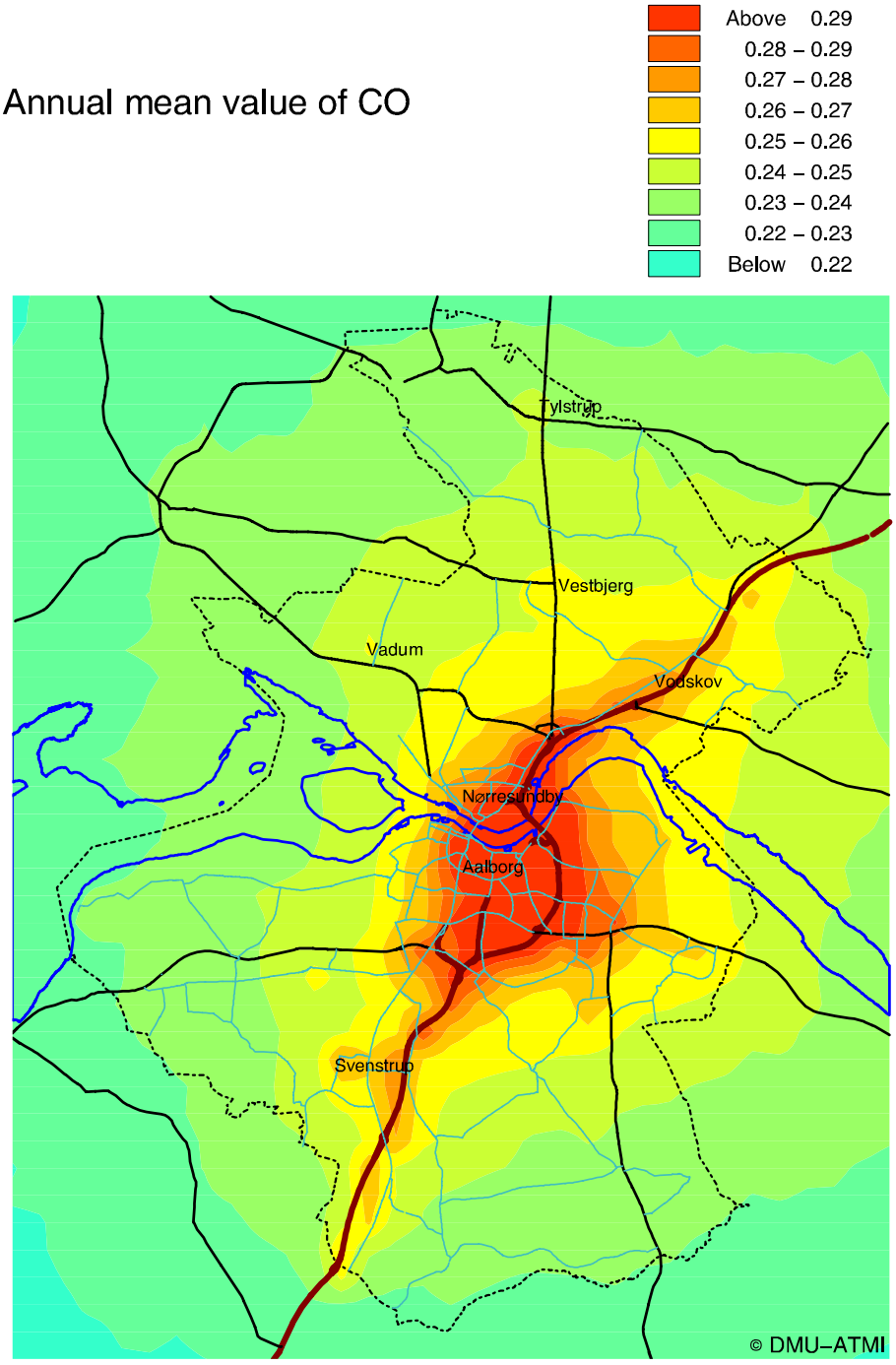

Figure 10-16 Calculated annual averages for CO (in ppm) in urban background in Aalborg 2004.

10.2.4 Street calculation

Calculation for 10 streets

Based on the Operational Street Pollution Model (OSPM, Berkowicz, 2000a and Hertel and Berkowicz, 1989) and traffic information on an hourly basis and street configuration provided by the city of Aalborg model calculations were performed for 10 streets in the central area of the city for the year 2004, see *Figure 10-17*.

Figure 10-17 Streets in the centre of Aalborg used for the model calculations. The measuring station Aalborg/8151 is placed on the east side of Vesterbro app. 100 m north of the marked area.

The results of the model calculations for the 10 streets are shown in Table 10-3, Table 10-4 and Table 10-5 for NO_x, NO_2 and CO respectively. The annual and the 19 highest values are given for both sides of the streets.

Table 10-3 Calculated annual statistics for NO_2 2004 based on the Thor-model system. Calculated for hourly results for both sides of the streets.

	NO_2			
	West-North		East-South	
Unit: µg/m^3	Average	19. highest	Average	19. highest
Vesterbro	44	120	39	119
Vesterbro measured			35	116
Boulevarden	41	114	39	118
Danmarksgade	29	108	30	110
JFK Plads	38	114	35	114
Jyllandsgade	39	114	36	112
Kjellerupsgade	35	115	33	114
Nyhavnsgade	38	113	35	113
Nytorv	40	119	44	125
Prinsensgade	37	116	39	118
Vingårdsgade	36	112	39	115

Table 10-4 Calculated annual statistics for NO_x 2004 based on the Thor-model system. Calculated for hourly results for both sides of the streets.

	NO_x			
	West-North		East-South	
Unit: µg/m^3	Average	19. highest	Average	19. highest
Vesterbro	167	611	135	596
Vesterbro measured			99	590
Boulevarden	116	533	111	543
Danmarksgade	56	324	63	338
JFK Plads	99	438	89	430
Jyllandsgade	105	465	89	454
Kjellerupsgade	90	432	83	431
Nyhavnsgade	127	527	112	512
Nytorv	114	580	139	585
Prinsensgade	102	509	111	530
Vingårdsgade	87	434	108	458

Table 10-5. Calculated annual statistics for CO 2004 based on the Thor-model system Calculated for hourly results for both sides of the streets.

	CO			
	West-North		East-South	
Unit: mg/m^3	Average	19. highest	Average	19. highest
Vesterbro	1.14	3.23	0.96	3.03
Vesterbro measured			0.74	2.92
Boulevarden	0.67	2.11	0.64	2.16
Danmarksgade	0.53	1.86	0.57	1.95
JFK Plads	0.59	1.86	0.55	1.93
Jyllandsgade	0.71	2.22	0.64	2.14
Kjellerupsgade	0.81	2.42	0.75	2.53
Nyhavnsgade	1.24	3.53	1.10	3.51
Nytorv	0.50	1.80	0.54	1.82
Prinsensgade	0.66	2.23	0.70	2.26
Vingårdsgade	0.71	2.34	0.84	2.58

The annual averages from the two sides of the streets are given in *Figure 10-18*. In addition, the measured data at Vesterbro (Aalborg/8151) are given for comparison.

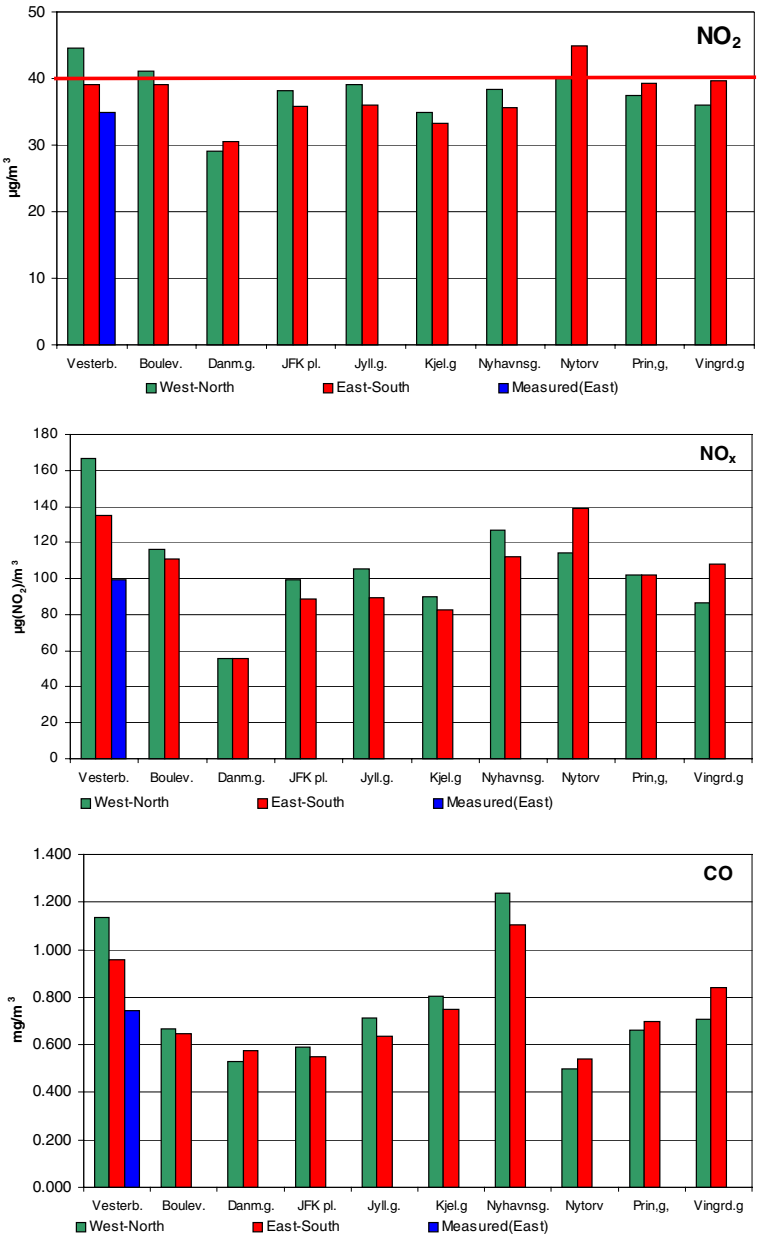

Figure 10-18 Calculated annual averages 2004 for NO_2, NO_x and CO for the two sides of 10 streets in Aalborg. The measured values for Vesterbro station (Aalborg/8151) are included for comparison.

10.3 Conclusions

The modelling data of annual averages at urban background show good agreement with measurement data from the corresponding monitoring stations for the gaseous pollutants in Copenhagen as well as in Aalborg, within + 15%. The PM_{10} model results, which only were available for Copenhagen, are more uncertain, mainly due to uncertain emission factors. The modelling results for the streets are also in acceptable agreement with the available measurement data.

The model results for 3-5 streets in Copenhagen show 10-50% higher concentrations than measured at the most polluted street station (H.C. Andersens Boulevard). Direct comparison between measurements and model results in streets in Aalborg is not possible, because

model calculations were not made for the location of the measurement station (Vesterbro at Limfjordsbroen). The model results show that most of the streets in Aalborg are less polluted than at the measurement location, and no locations show significantly higher pollution.

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11 Danish summary - Dansk resumé

Rapporten præsenterer resultaterne fra overvågningsprogrammet for luftkvalitet i danske byer (LMP IV) for 2004. 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 tolerance margin, som løbende reduceres. En detaljeret beskrivelse af gældende mål- og grænseværdier og deres gennemførelse findes i bekendtgørelser fra Miljøministeriet (se referencerne Miljøministeriet 2003A og 2003B). Bekendtgørelserne er baseret på EU-direktiverne (EC 1996, 1999, 2000, 2003 og 2005).

De væsentligste konklusioner er at:

- generelt var niveauerne i 2004 relativt lave p.g.a de meteorologiske forhold.
- indholdet af kvælstofdioxid (NO_2) overskred i 2004 grænseværdierne, som skal overholdes fra 2010 på flere målestationer. Men i modsætning til 2003 er grænseværdi + tilladte margin (i 2004: 52 $\mu g/m^3$) ikke overskredet i 2004.
- indholdet af partikler mindre end 10 µm (PM_{10}) overskrider grænseværdierne som skal overholdes fra 2005 på to gadestationer. Den tilladte tolerancemargin er endda overskredet på H.C. Andersens Boulevard.
- der ikke er fastsat egentlige grænseværdier for ozon (O3) men kun "målværdier" og "langsigtede mål" (hensigtsværdier). Flere langsigtede mål er overskredet på flere stationer.
- De øvrige målte stoffer findes i koncentrationer under grænseværdierne, og for flere stoffer (fx svovldioxid og bly) er indholdet faldet kraftigt siden målingernes start.

Supplerende vurdering af luftkvaliteten er gennemført ved hjælp af DMU's luftkvalitetsmodeller i byområderne København og Aalborg. Vurderingen blev gennemført for NO_x/NO_2, CO og O_3 i bybaggrund og i udvalgte gader, 138 gader i København og 10 gader i Aalborg. Modelberegninger blev endvidere gennemført for $PM_{10}/PM_{2.5}$ i København. Modelresultaterne giver et overblik over luftforureningen over byområderne og i mange gader.

Modeldata for årsgennemsnit for bybaggrund viser god overensstemmelse med målte data fra tilsvarende målestationer for de luft-

formige forureninger både i København og i Aalborg, indenfor ± 15%. PM_{10} modelresultater, som kun findes for København, er mere usikre, hovedsageligt på grund af usikre emissionsfaktorer. Modelresultaterne for gader er også i acceptabel overensstemmelse med måleresultater.

- Modelresultaterne viser at 3-5 gader i København er 10-50% mere forurenet end ved den mest forurenede målestation (H.C. Andersens Boulevard). Direkte sammenligning mellem modelresultater og målinger i gader i Aalborg er ikke gennemført, fordi modelberegninger blev ikke gennemført ved denne station (Vesterbro ved Limfjordsbroen). Modelresultaterne viser, at de mest forurenede gader i Aalborg er mindre forurenet end ved målestationen og ingen lokaliteter viser signifikant højere luftforurening.

Appendix

Pollutants measured in the LMP Network

Nitrogen oxides (NO and NO_2)

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.

Nitrogen dioxide (NO_2)

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.

Ozone (O3)

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.

Carbon monoxide (CO)

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

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.

Other volatile organic compounds (VOC's)

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.

Particles smaller than 10µm (PM_{10})

The main sources for PM_{10} are resuspended dust and combustion. PM_{10} particles are also created in the atmosphere by oxidation of nitrogen dioxide and sulphur dioxide. 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 will be revised within a few years, when better knowledge about the adverse health effects of fine particles influence on health has been obtained.

PM_{10} 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 weighing after storage in a conditioned climate room. This method is considered to be equivalent to the reference method (EN 23451).
- The particles are collect on a "tapered oscillating microbalance" (TEOM) and heated to 50^{0} C. During heating volatile compounds may evaporate. The loss will be most pronounced for "secondary aerosols" containing ammonia, nitrate and sulphate.

Heavy metals (HM's)

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 compounds

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 of 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.

National Environmental Research Institute

The National Environmental Research Institute, NERI, is a research institute of the Ministry of the Environment. In Danish, NERI is called *Danmarks Miljøundersøgelser (DMU)*.
NERI's tasks are primarily to conduct research, collect data, and give advice on problems related to the environment and nature.

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The air quality in Danish cities has been monitored continuously since 1982 within the Danish Air Quality (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 2004 the air quality was measured in four Danish cities and at two background sites. NO2 and PM10 were at several stations found in concentrations above EU limit values, which the Member States have to comply with in 2005 and 2010. While the concen-trations for most other pollutants have been strongly decreasing since 1982, only a slight decrease has been observed for NO2. The measurement have been supplemented with dispersion models (the OSPM model) for a number of streets in Copen-hagen and Aalborg.

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