National Environmental Research Institute
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The Danish Air Quality Monitoring Programme

Annual Summary for 2005

NERI Technical Report, No. 584

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2006

Kåre Kemp
Thomas Ellermann
Finn Palmgren
Peter Wåhlin

Data sheet

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Authors:	Kåre Kemp, Thomas Ellermann, Finn Palmgren & Peter Wåhlin
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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 2005 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.
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Contents

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 2005 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.

The concentrations were in 2005 almost the same as in 2004. Changes may mainly be due to meteorological conditions. Three exceedances of the limit value occurred for PM_{10}.

NO_2

The limit value + the margin of tolerance for the annual average of NO_2 (50 µg/m^3 in 2005) 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 2005 exceeded at three street stations. The NO_2 concentrations seem to have been almost unchanged during the last ten years.

O_3

The ozone level was in 2005 - 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 three urban background and rural stations. The long term objective for AOT40 at 6000 µg/m^3 · hours were exceeded in one case. The O_3 pollution in Denmark is to a large extent caused by emissions in other European countries.

PM_{10}

The limit value for the 35th highest daily average value for PM_{10} (50 µg/m^3 for 2005) was in 2005 exceeded at 3 stations. The limit value for the yearly average (40 µg/m^3) was exceeded at one out of these stations. (The margin of tolerance is =0 from 2005). At all stations the indicative limit 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 (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.

Dispersion models

Supplementary assessment of the air quality was carried out using NERI's air quality models in the agglomerations Copenhagen and Aalborg. An assessment for 2004 for NO_x / NO_2, CO, O_3, and PM_{10} / PM_{25} in urban background and in selected streets in Copenhagen and Aalborg was described in last years annual report (Kemp et al. 2005). The work is continuing.

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

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 (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 Environmental Protection Agency of the Municipality in Copenhagen, the Municipality of Aarhus, 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 (e.g. last years report Kemp et al. 2005). This report includes results from the LMP network and a station in Greater Copenhagen organised by the Environmental Protection Agency of the Municipality in Copenhagen. 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.

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 (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 Environmental Protection Agency of the Municipality in Copenhagen is responsible for a street station in the central part of Copenhagen (www. miljoe.kk.dk). The site (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.

Further measurements are carried out in the counties of Aarhus (http://www.aaa.dk/aaa/index/serviceomraader/nm/nm-industri_affald_jord_luft/nm-mfs-luft.htm and Funen (www.fyns-amt.dk/wm108516/).

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 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.

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 rural stations monitor the pollution outside the city areas. Further information about the program and results is found at the website: http://www.dmu.dk/International/Air.

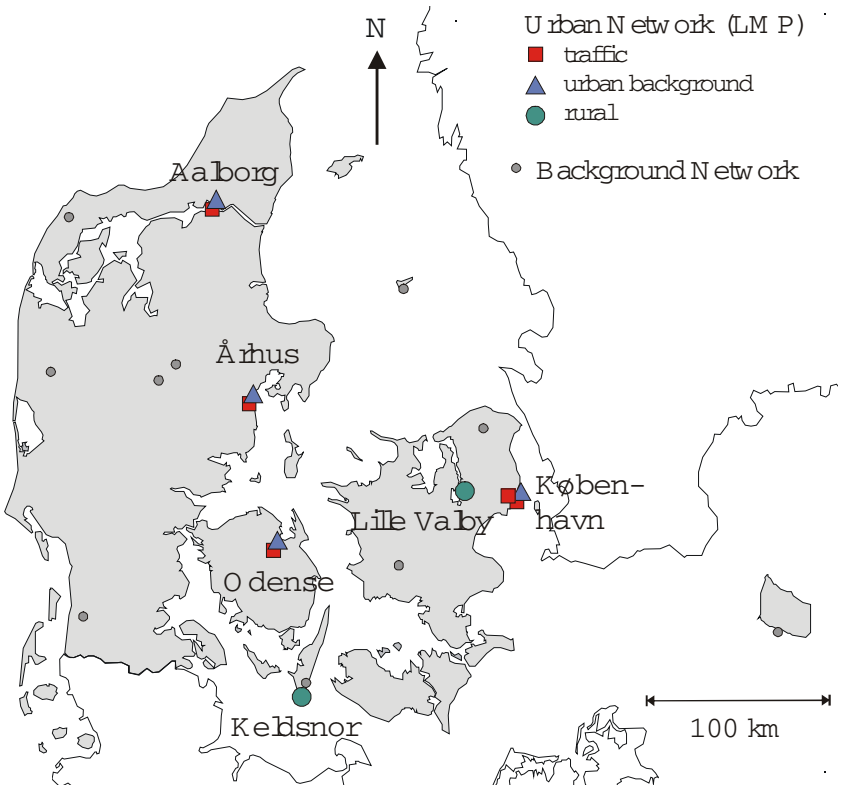

Figure 2-1 Monitoring stations in the two nation-wide air quality networks (including the Copenhagen Municipality Station).

Table 2-1 Stations in the LMP IV network and the Copenhagen Municipality included in this report for 2005

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	
Lille Valby/2090	-	Rural	CO measurements startet February 2006
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.
- $PM_{2.5}$ 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/1257
- 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.

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. TEOM results are recorded as ½-hour averages for PM_{10} and $PM_{2.5}$.

Other information

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

3 Nitrogen oxides

3.1 Yearly Statistics

Table 3-1 Nitrogen dioxide (NO_2) 2005. All parameters are calculated with hourly averages.

Unit: µg/m^3	Number	Average	Median	98. percentile	19. highest
Traffic:					
Copenhagen/1257	8616	47	45	103	133
Copenhagen/1103	8348	54*)	53	111	147
Århus/6153	8617	47	44	107	137
Odense/9155	8477	31	26	89	114
Aalborg/8151	8671	40	34	102	127
Urban Background:					
Copenhagen/1259	8662	23	19	59	82
Århus/6159	8631	22	18	66	92
Odense/9159	8244	18	15	54	75
Aalborg/8158	8711	18	15	57	77
Rural:					
Lille Valby/2090	8348	12	9	38	54
Keldsnor/9055	8130	10	7	38	59
Limit values/limit value + margin of tolerance for 2005	>7884	40/50			200/300

*) Limit value + margin of tolerance exceeded.

Table 3-2 Nitrogen oxides (NO_x=NO+NO_2) 2005. All parameters are calculated with hourly averages.

Unit: µg/m^3 (as NO_2)	Number	Average	Median	98. percentile	19. highest
Traffic:					
Copenhagen/1257	8616	109	88	364	579
Copenhagen/1103	8348	133	110	402	695
Århus/6153	8617	106	83	366	639
Odense/9155	8477	78	48	334	631
Aalborg/8151	8671	111	77	405	649
Urban Background:					
Copenhagen/1259	8664	29	23	95	182
Århus/6159	8631	33	22	142	295
Odense/9159	8244	25	19	96	242
Aalborg/8158	8711	29	20	132	367
Rural:					
Lille Valby/2090	8348	14	10	55	124
Keldsnor/9055	8130	12	8	46	69

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) 2005. All parameters are calculated with hourly averages.

Unit: µg/m^3	Max. 3 hours	Date:hour	Max. hour	Date:hour
Traffic:				
Copenhagen/1257	173	051019: 6	222	051019: 7
Copenhagen/1103	195	051019 5	248	051019: 6
Århus/6153	158	051128: 10	236	051019: 6
Odense/9155	116	051017: 6	139	050401: 7
Aalborg/8151	125	051128: 8	154	051128: 9
Urban Background:				
Copenhagen/1259	85	050304: 1	102	050404: 6
Århus/6159	107	050303: 19	122	050303: 20
Odense/9159	82	051017: 6	94	051017: 7
Aalborg/8158	87	051128: 8	113	051128: 8
Rural:				
Lille Valby/2090	56	050304: 6	65	050304: 8
Keldsnor/9055	60	050521: 18	83	050521: 19
Alert threshold	400	-	-	-

Table 3-4 Episodic results for Nitrogen oxides (NO_x=NO+NO_2) 2005. 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	1300	051019: 6	1669	051019: 7
Copenhagen/1103	1205	051019: 5	1817	051019: 6
Århus/6153	709	051128: 10	1571	051019: 6
Odense/9155	788	051017: 6	1075	051017: 7
Aalborg/8151	744	051005: 7	920	051128: 9
Urban Background:				
Copenhagen/1259	229	051019: 7	474	051019: 7
Århus/6159	302	051128: 16	424	051128: 10
Odense/9159	374	051017: 6	469	051128: 9
Aalborg/8158	416	051128: 8	667	051128: 8
Rural:				
Lille Valby/2090	126	051128: 19	274	050203: 11
Keldsnor/9055	76	050925: 15	130	050203: 15

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

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

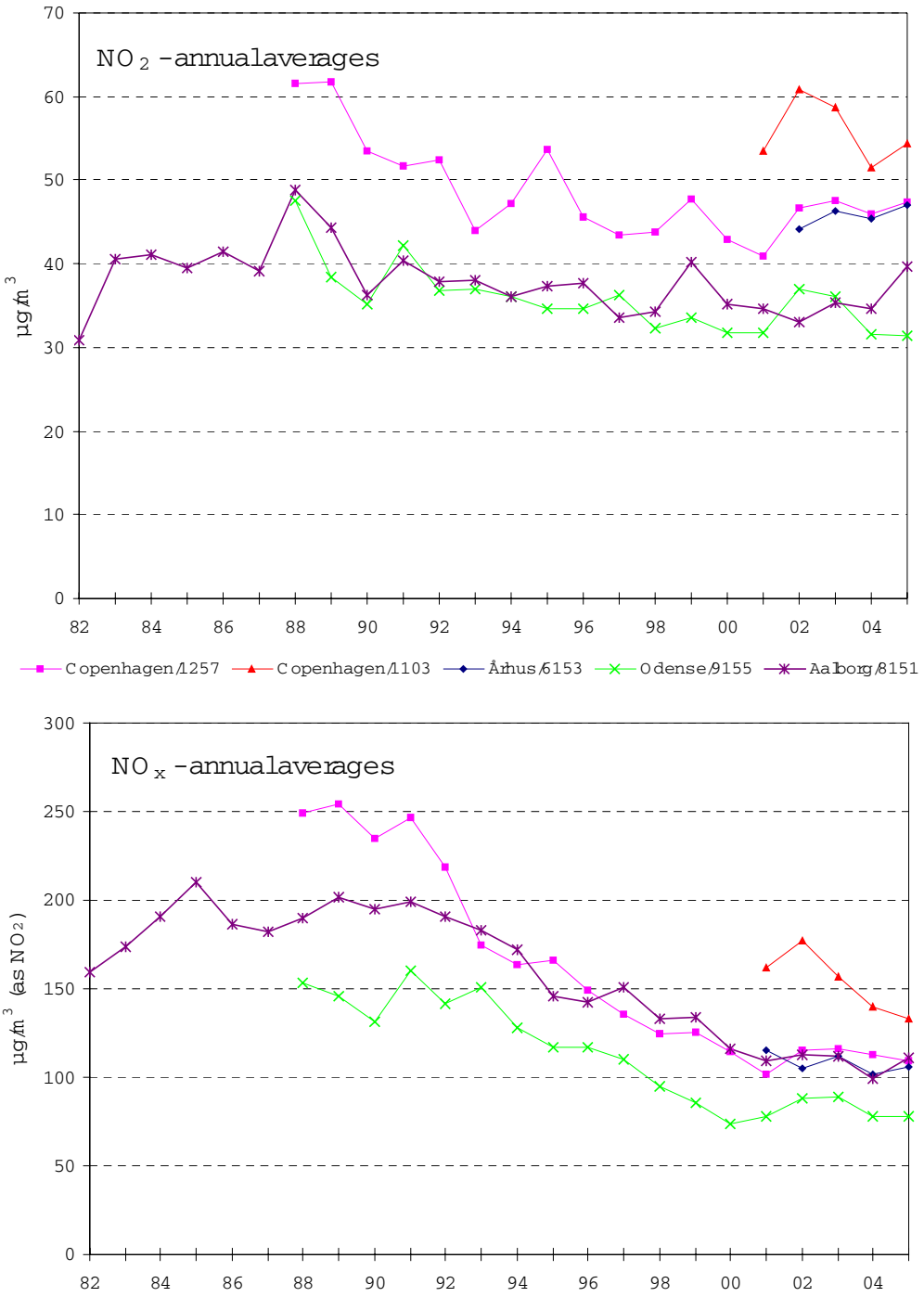

Figure 3-1 The graphs show the time series for the annual average values measured at street stations. Previous results from Copenhagen/1103 can be found at the homepage of Copenhagen Environmental Protection Agency (www.Miljoe.kk.dk)

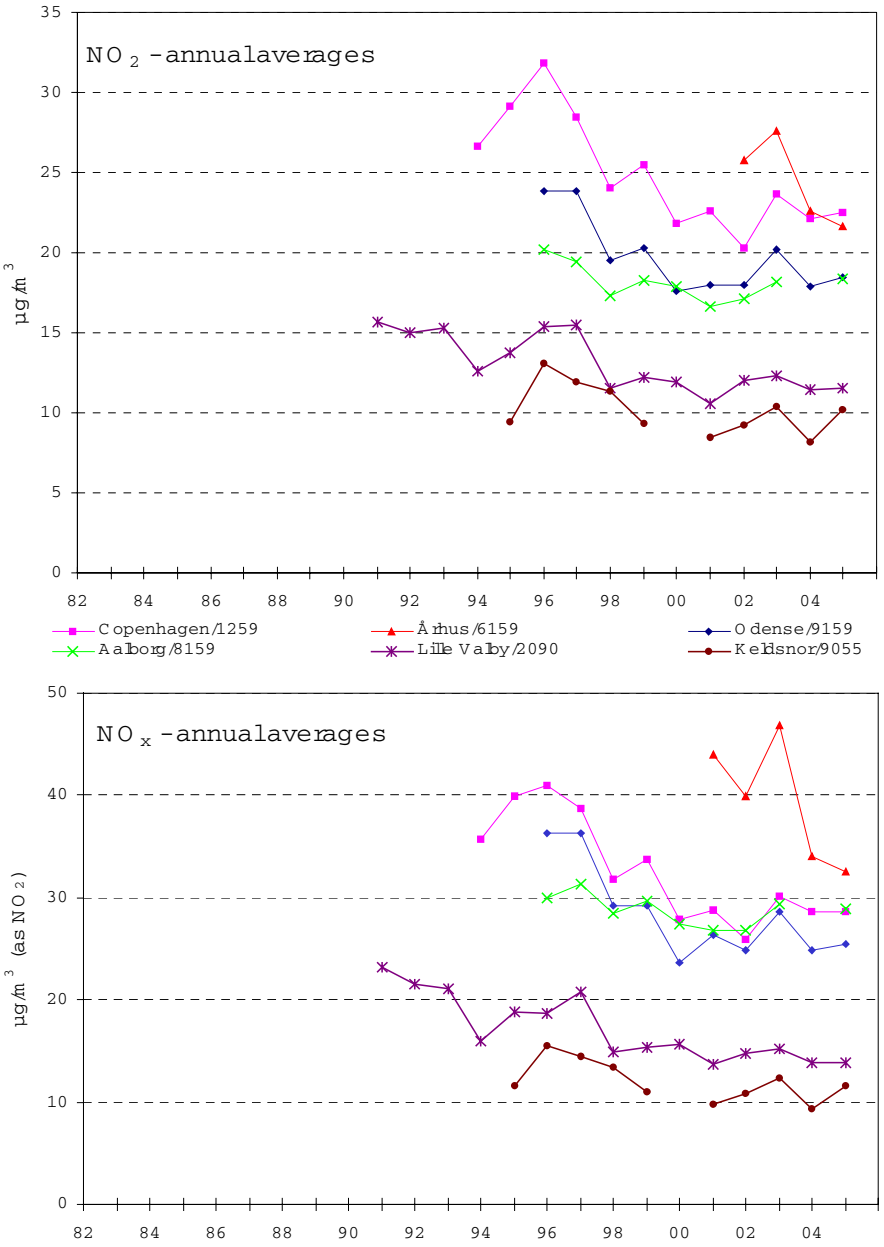

Figure 3-2 The graphs show the time series for the annual average values measured at urban background and rural stations.

4 Ozone

4.1 Annual statistics

*Table 4-1 O*zone (O_3) 2005. 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	8176	48	50	110	75	124	1839
Århus/6159	8541	46	49	119	71	158	3715
Odense/9159	8388	50	51	129	95	138	4866
Aalborg/8158	8715	46	49	116	81	136	1341
Rural							
Lille Valby/2090	8419	56	58	140	104	156	10990
Keldsnor/9055	8032	56	57	126	98	140	4912
Traffic							
Copenhagen/1257	8628	33	32	83	68	97	19
Copenhagen/1103	8424	31	29	102	69	121	26
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 2005: 0.

Number of information to the public due to exceedance of the alert threshold (240 µg/m^3) in 2005: 0.

4.2 Trends

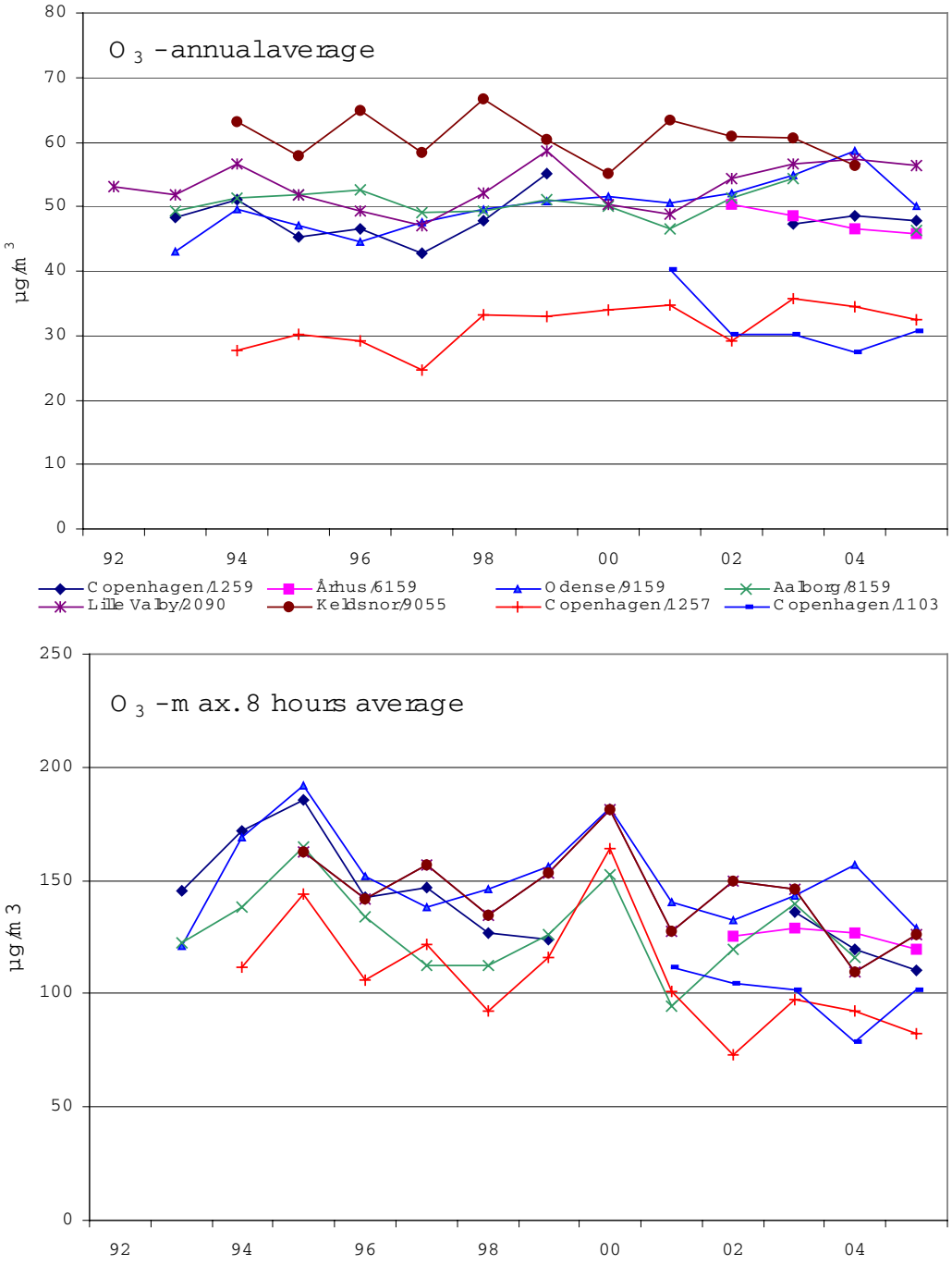

Figure 4-1 Annual average values and the max. 8 hour average value. The latter is calculated as hourly moving 8 hour averages according to the provisions in the EU Council Directive (EC, 2002). Previous results from Copenhagen/1103 can be found at the Website of the Copenhagen Environmental Protection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

5 Carbon monoxide

5.1 Annual statistics

Table 5-1 Annual statistics for carbon monoxide (CO) 2005. 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	8629	769	640	2142	4255	4076	7984
Copenhagen/1103	8419	713	640	1747	3026	2610	5550
Århus/6153	8446	433	379	1122	2335	1882	2983
Odense/9155	8139	564	423	1861	3593	3148	4420
Aalborg/8151	8679	739	601	1987	3075	2504	3538
Urban Background:							
Copenhagen/1259	8686	287	264	640	1356	1238	2460
Rural							
Lille Valby/2090	7110	244	233	457	926	909	1281
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

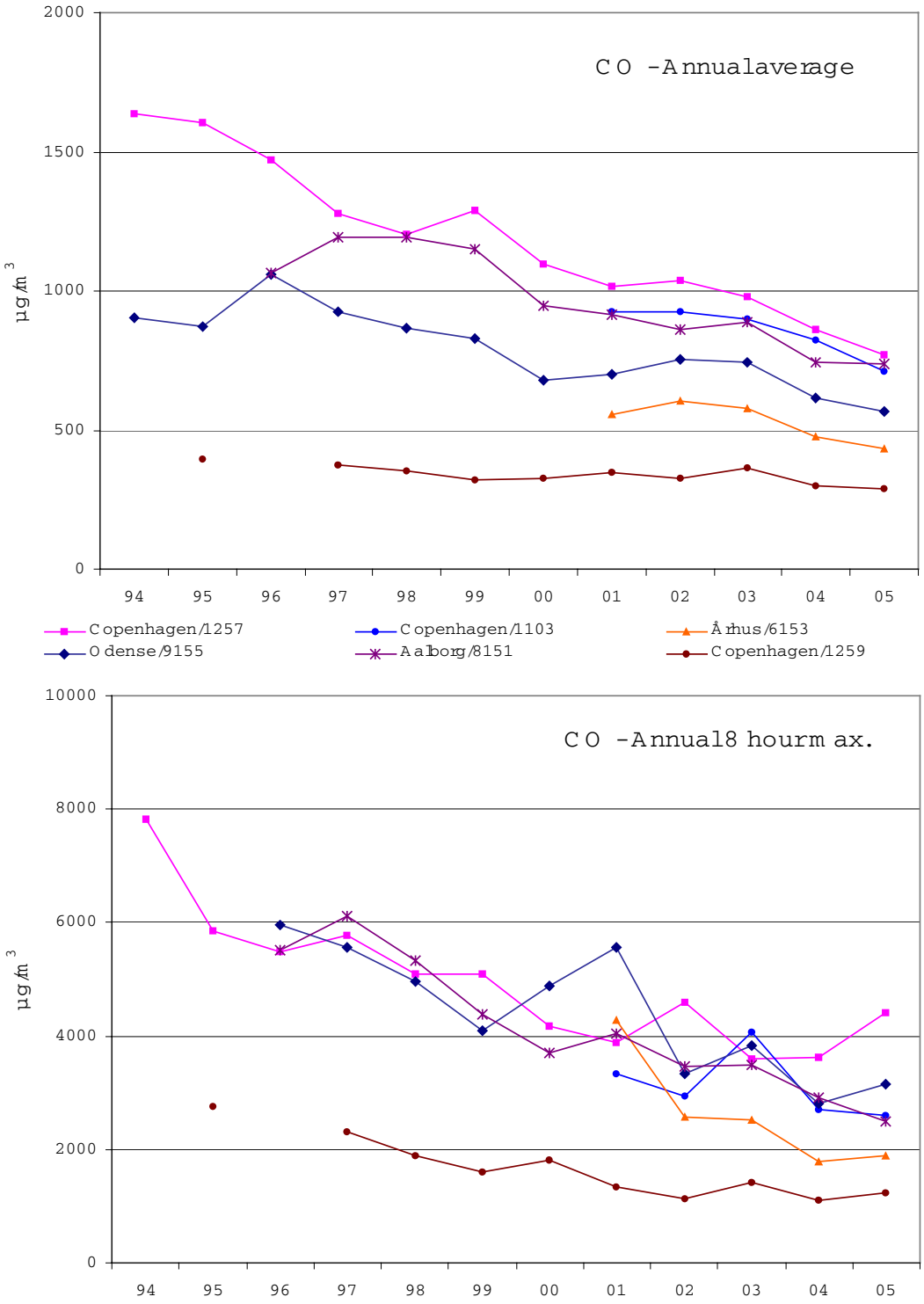

Figure 5-1 Annual average values and highest 8-hour value calculated based on an hourly moving average. Previous results from Copenhagen/1103 can be found at the website of the Copenhagen Environmental Protection Agency (www. Miljoe.kk.dk).

6 Benzene and Toluene

6.1 Annual statistics

Table 6-1 Annual statistics for Benzene 2005. 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	7504	2.8	14	33
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 2005. 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	7347	11.2	76	152
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°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 textbox 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).

Estimated PM_{10} (and $PM_{2.5}$) at H.C. Andersens Boulevard, 2005

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

PM_{10} (and $PM_{2.5}$) is 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 PM10 and $PM_{2.5}$ correct, because the high collecting temperature (50°C) results in losses of volatile material from the collecting filter. A comparison of PM_{10} and 24h averages of TEOM PM_{10} 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 8-10 $\mu g/m^3$ in average on an annual basis. The average PM_{10}/TEOM_PM_{10} ratio is approximately 1.4 at JGTV, and 1.7 (in 2003) at HCOE. The EU commission has accepted that TEOM PM_{10} 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_PM_{10} average at HCAB on days when measurements of the PM loss at JGTV or HCOE are available. The results of this correction for 2005 are shown in the table below together with results corrected using the correction factor 1.3. Using the measured PM_{10} loss as an upper estimate of the TEOM $PM_{2.5}$ loss, an upper estimate of the corrected $PM_{2.5}$ at HCAB is calculated are shown in last column.

	TEOM PM_{10} (HCAB)	TEOM $PM_{2.5}$ (HCAB)	PM_{10} loss (HCOE)	PM_{10} loss (JGTV)	PM_{10} loss (JGTV and HCOE combined)	TEOM PM_{10} corrected for losses (HCAB)	1.3* TEOM PM_{10} (HCAB)	TEOM $PM_{2.5}$ corrected for PM_{10} losses (HCAB)
Average value	33.2	15.3	9.1	9.5	9.3	43.2	43.2	24.9
Number of 24h values	308	314	265	216	278	232	308	230
90% percentile	49.7	23.1	17.2	17.8	16.9	64.7	64.6	43.1
36th highest value	48.6	21.9	15.1	15.5	15.6	60.6	63.1	34.0
Unit: μgm^{-3}								

We can conclude that the factor 1.3 gives corrected PM10 values that are close to 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 value corrected for losses to be the most reliable estimate of PM10 at HCAB. According to both values the limit value (40 $\mu g/m^3$) for the annual average is exceeded in 2005. 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. Both the 90% percentile and the 36th highest value clearly exceed the limit value (50 $\mu g/m^3$).

Table 7-1 Annual statistics for PM_{10} 2005. 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	351	33	**53*)**	54	63	70	110
Århus/6153	337	29	45	45	55	65	83
Odense/9155	348	34	**55*)**	55	68	86	140
Aalborg/8151	319	33	49	52	63	68	189
Urban background							
Copenhagen/1259	320	23	37	39	50	54	67
Århus/6159	330	24	39	39	49	55	88
Odense/9159	297	27	43	44	52	57	79
Aalborg/8158	338	25	39	41	49	55	88
Rural							
Lille Valby/2090	356	25	40	40	49	57	69
Keldsnor/9055	231	26	37	42	52	52	63
Limit values (2005)	>329	40	50	-	-		
Limit values (2010) (indicative)		20		-	-	50	-

***)** Limit value exceeded.

Table 7-2 Annual statistics for TSP (Total Suspended Particles) 2005. 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	361	80	129	129	156	188	279

Table 7-3 Annual statistics for PM_{10} measured 2005 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	342	24	36	36	31	46
Copenhagen/1103	308	33	49	50	43*)	63*)
Urban background						
Copenhagen/1259	334	17	25	26	22	33
Limit values	>329	-	-	-	40	50

***)** Limit value exceeded.

Table 7-4 Annual statistics for $PM_{2.5}$ measured in 2005 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
Traffic				
Copenhagen/1103	315	15	24	22
Urban Background				
Copenhagen/1259	333	11	19	18
Rural				
Lille Valby/2090	275	11	18	16

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} measurements are started at all stations except Copenhagen/1103 where the TSP measurements were 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.

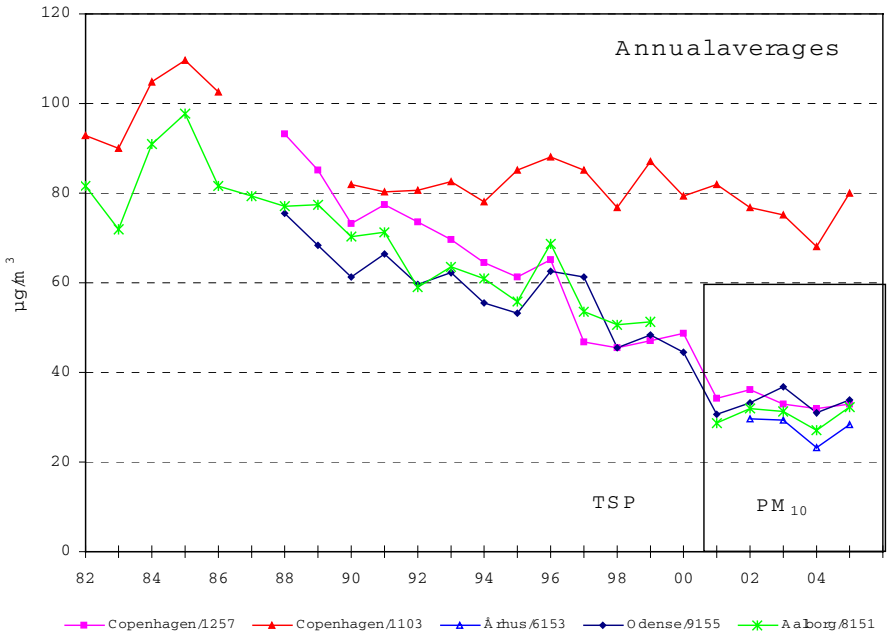

Figure 7-1 Annual averages for TSP and PM_{10} measured at street stations. Results from 2000 and earlier are for TSP, while later results are for PM_{10} – except for Copenhagen/1103, where TSP measurements are continued. The PM_{10} results are shown in the area in the bottom left of the plot area.

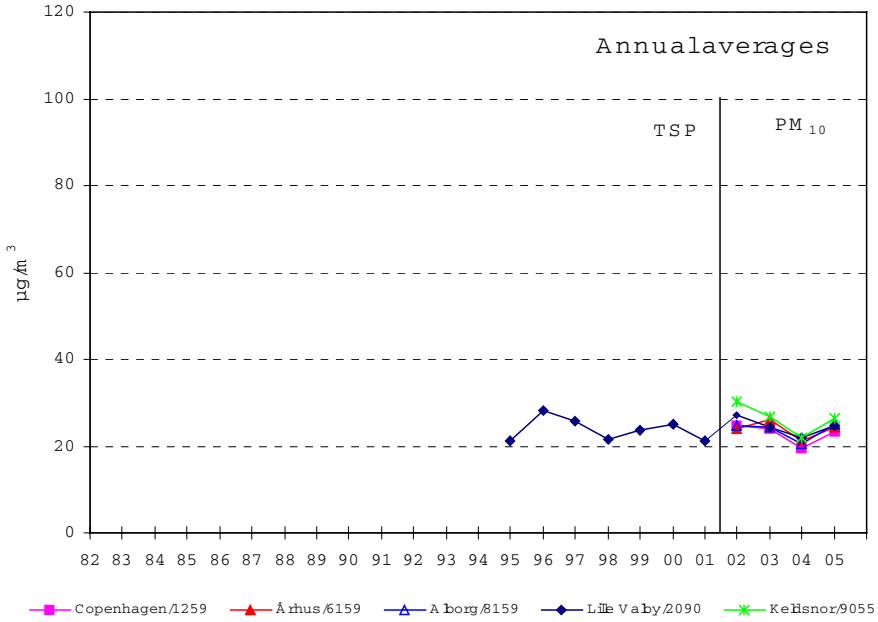

Figure 7-2 Annual averages for TSP and PM_{10} measured at urban background and rural stations.

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 2005 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 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	7.0	6.8	14.6	4.2	60.9	39.5	0.7	0.4	< 1.3	9.1
Copenhagen/1103 +)	10.7	16.7	72.3	5.0	104.7	106.4	0.8	0.3	< 0.7	15.6
Århus/6153	6.0	3.7	11.1	5.6	33.9	35.8	0.9	0.4	< 1.3	7.6
Odense/9155	5.4	5.9	20.5	3.0	44.6	68.2	1.0	0.5	< 1.4	11.8
Aalborg/8151	4.4	5.9	11.0	2.8	44.1	66.9	0.7	0.4	< 1.3	7.5
Urban background										
Copenhagen/1259	7.2	2.2	6.9	3.9	10.9	21.3	0.6	0.4	< 1.3	6.8
Århus/6159	4.9	< 1.9	5.6	6.0	9.3	24.2	0.8	0.4	< 1.3	6.3
Odense/9159	4.3	< 1.9	7.2	2.2	9.4	39.0	0.8	0.5	< 1.3	8.6
Aalborg/8159	4.1	< 2.0	7.2	3.2	10.2	44.3	1.3	0.5	< 1.3	11.5
Rural										
Lille Valby/2090	4.9	< 2.8	4.5	2.4	6.7	17.8	1.0	0.4	< 1.3	6.1
Keldsnor/9055	8.0	2.3	3.7	4.5	12.8	23.3	< 0.5	0.5	< 1.3	6.4
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

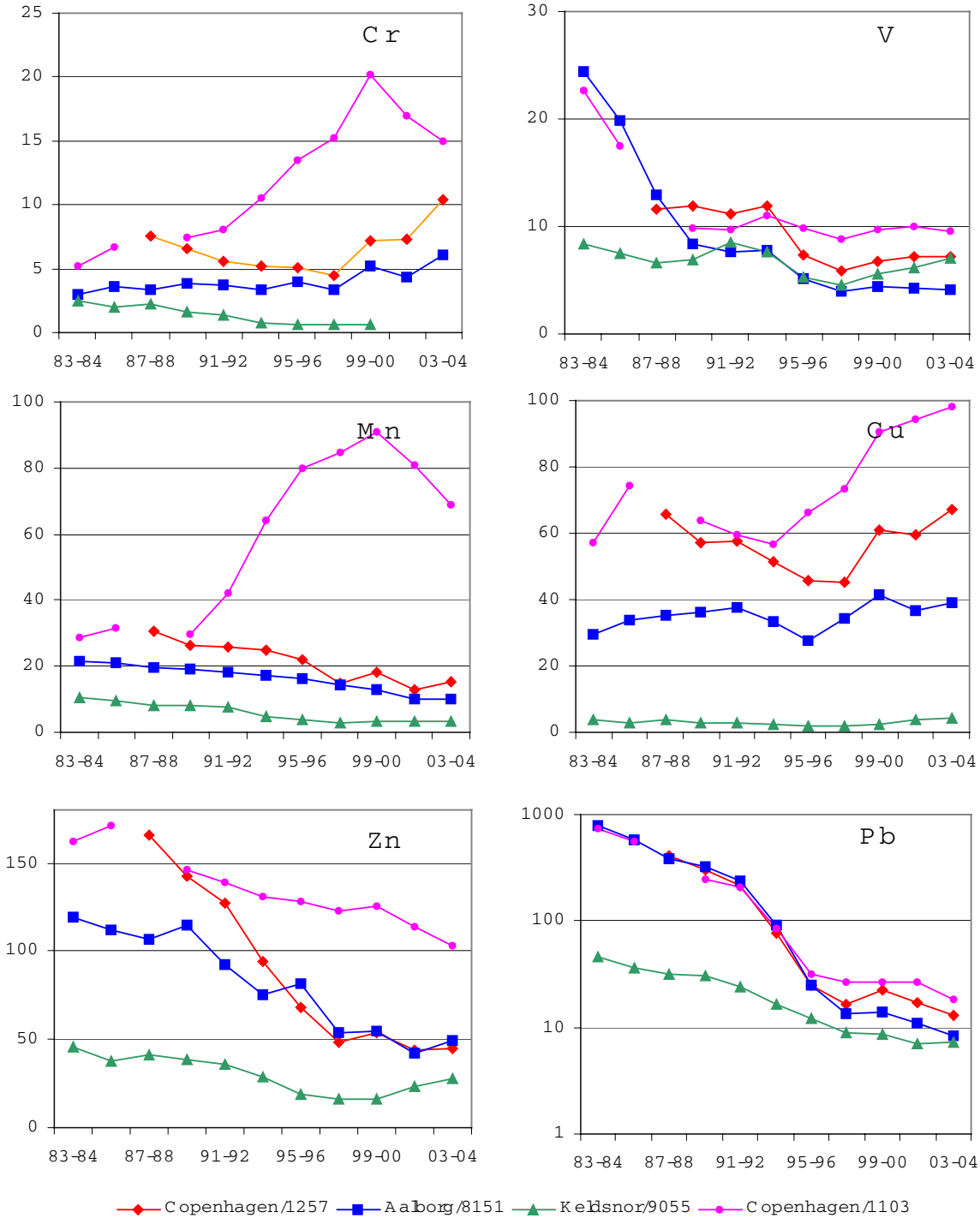

Figure 8-1 Biannual averages from selected stations for some Heavy Metals in particulate matter. Until 2000 in TSP and later in PM_{10} – except for Copenhagen/1103 where TSP measurements continue. The heavy metals are usually found in fine particles, which makes the TSP and the PM_{10} values comparable. 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. The increase of 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 2005. 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/m^3	Number of results	Average year	Average winter	Median	98-percentile	Max. Hour	4. highest day
Traffic							
Copenhagen/1103	7609	4.2	3.6	2.9	18	71	9
Aalborg/8151	8671	2.8	2.8	1.7	11.5	45	28
Limit values	>7884	20	20			350	125

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} 2005 (for Copenhagen/1103 in TSP). 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)/m^3	Number of results	Average
Traffic		
Copenhagen/1257	353	0.85
Copenhagen/1103	361	1.13
Århus/6153	346	0.92
Odense/9155	349	0.98
Aalborg/8151	324	0.80
Urban background		
Copenhagen/1259	321	0.82
Århus/6159	331	0.80
Odense/9159	299	0.87
Aalborg/8158	340	0.77
Rural		
Lille Valby/2090	363	0.79
Keldsnor/9055	231	0.92

9.2 Trends

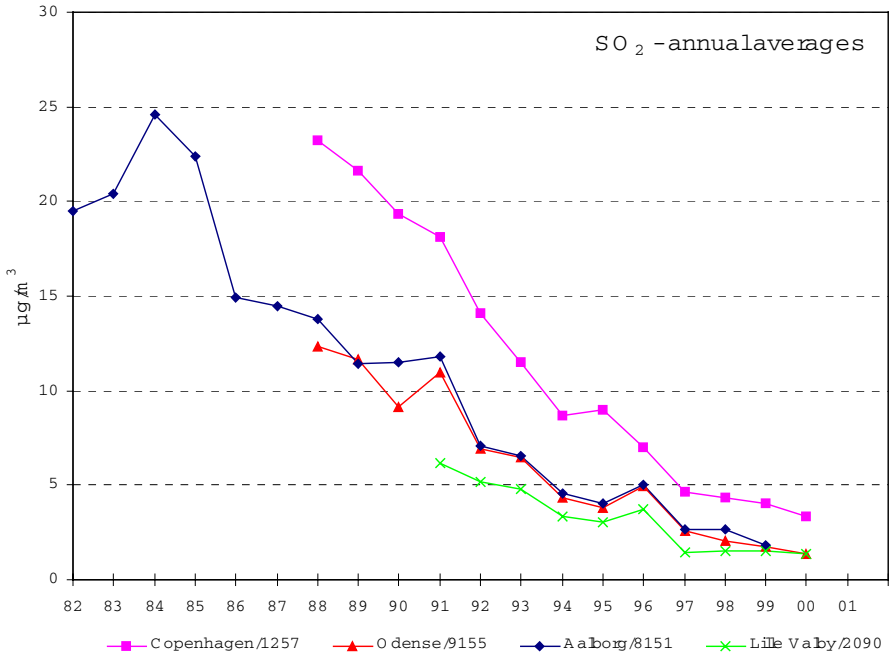

Figure 9-1 Annual averages for SO_2. The results are obtained using KOH impregnated filters for collection of SO_2. These measurements ceased in 2000 because the concentrations had become far below the limit and guideline values.

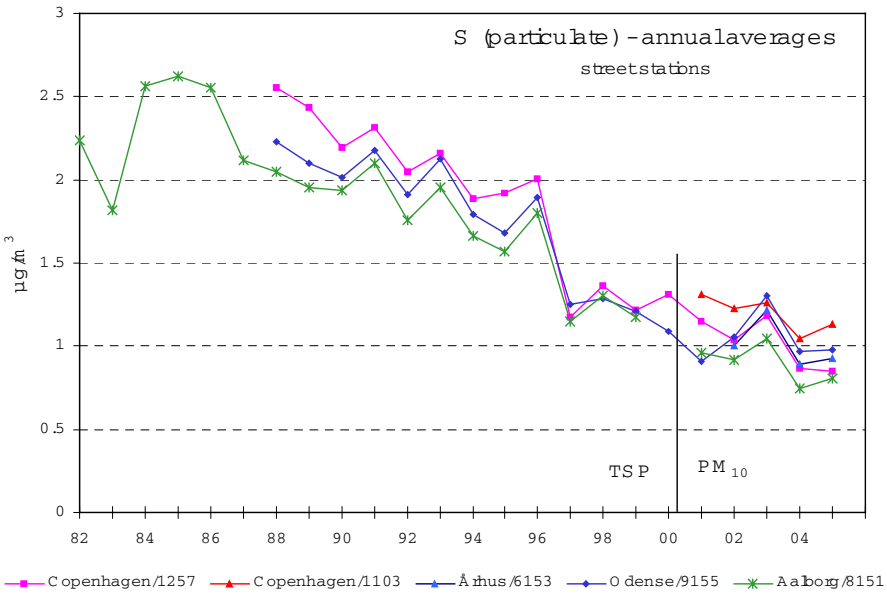

Figure 9-2 Annual averages for particulate sulphur at street stations. The particulate sulphur from 2000 and earlier is determined in TSP, and the 2001 results and later are for PM_{10} – except for Copenhagen/1103, where TSP measurements are continued. The sulphur containing particles are mainly present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

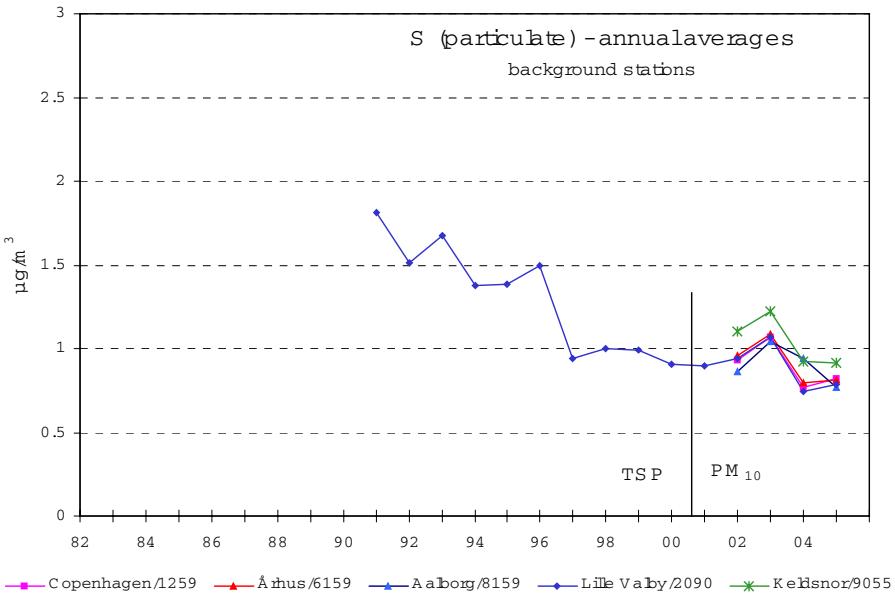

Figure 9-3 Annual averages for particulate sulphur at urban background and rural stations. The particulate sulphur from 2000 and earlier is determined in TSP and the 2001 results and later are for $PM_{10.}$ The sulphur containing particles are mainly present in sub-micron particles, which makes the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

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Danish summary - Dansk resumé

Rapporten præsenterer resultaterne fra overvågningsprogrammet for luftkvalitet i danske byer (LMP IV) for 2005. 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 2005 på samme niveau som i 2004. Ændringer kan for en stor del skyldes meteorologiske forhold.
- Indholdet af kvælstofdioxid (NO_2) overskred i 2005 grænseværdierne, som skal overholdes fra 2010 på flere målestationer. Grænseværdien + tilladte margin (i 2005: 50 µg/m^3) blev i 2005 overskredet på H.C. Andersens Boulevard i København.
- Indholdet af partikler mindre end 10 µm (PM_{10}) overskrider grænseværdierne som skal overholdes fra 2005 på tre gadestationer (H.C. Andersens Boulevard og Jagtvej i København samt Albanigade i Odense).
- Der er ikke fastsat egentlige grænseværdier for ozon (O_3), 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 gennemføres ved hjælp af DMU's luftkvalitetsmodeller i byområderne København og Aalborg. En fyldig vurdering af resultater fra 2004 var indeholdt i sidste årsrapport. Arbejdet fortsættes og vil blive rapporteret når nye resultater foreligger.

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 (O_3)

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 12341).
- The particles are collected on a "tapered oscillating microbalance" (TEOM) and heated to $50^{\circ}C$. 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.

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Addresses:

URL: http://www.dmu.dk

National Environmental Research Institute
Frederiksborgvej 399
PO Box 358
DK-4000 Roskilde
Denmark
Tel: +45 46 30 12 00
Fax: +45 46 30 11 14

Management
Personnel and Economy Secretariat
Monitoring, Advice and Research Secretariat
Department of Policy Analysis
Department of Atmospheric Environment
Department of Marine Ecology
Department of Environmental Chemistry and Microbiology
Department of Arctic Environment
Project Manager for Quality Management and Analyses

National Environmental Research Institute
Vejlsøvej 25
PO Box 314
DK-8600 Silkeborg
Denmark
Tel: +45 89 20 14 00
Fax: +45 89 20 14 14

Department of Terrestrial Ecology
Department of Freshwater Ecology

National Environmental Research Institute
Grenåvej 12-14, Kalø
DK-8410 Rønde
Denmark
Tel: +45 89 20 17 00
Fax: +45 89 20 15 15

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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 2005 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.

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