BOREAL ENVIRONMENT RESEARCH 4: 55–65
Helsinki 18 March 1999
ISSN 1239-6095

Review of urban air quality in Finland

Jaakko Kukkonen, Timo Salmi, Helena Saari, Mervi Konttinen and Raimo Kartastenpää

Finnish Meteorological Institute, Air Quality Research, Sahaajankatu 20 E, FIN-00810 Helsinki, Finland

Kukkonen, J., Salmi, T., Saari, H., Konttinen, M. & Kartastenpää, R. 1999. Review of urban air quality in Finland. *Boreal Env. Res.* 4: 55–65. ISSN 1239-6095

We present a review of the air quality in Finnish cities and towns, based on the data from urban measurement networks. The data were compiled from 42 Finnish cities and towns, from measurements conducted in 1990–1993. These data show that the newly-introduced (1996) national air quality guidelines have been fairly often exceeded in urban areas, most commonly for particulate matter, both PM_{10} and total suspended particles (TSP). Some exceedances have also occurred for NO_2 and CO, at sites with high traffic densities. Some TSP values in the largest cities in Finland are exceptionally high, caused by the resuspension of dust from street surfaces. However, the European Union air quality limit values were only exceeded at one measurement station for TSP in 1990, 1991 and 1992. We also analysed seasonal variation of the guideline exceedings.

Introduction

A new air protection act was introduced in Finland in 1995. This law also allowed for the requirements of the air protection legislation of the European Union (EU) at the national level. New national air quality guidelines and limit values were subsequently issued in 1996. The preparation of the new, stricter guidelines made a re-evaluation of urban air quality in Finland necessary.

Air quality assessments have previously been conducted for numerous cities and districts in Finland (e.g., Pohjola *et al*. 1995). Some of these have been integrated studies, including results obtained with emission surveys, dispersion model computations, air quality measurements and bioindicator methods. This study presents, for the first time, a comprehensive compilation and review of air quality data in Finnish municipalities.

The results of this study are based on the data from urban measurement networks. The data were compiled from 42 cities and towns, from measurements conducted in 1990–1993. The networks are set up and maintained by local authorities, who also process the monitoring data and compute statistical concentration parameters. The information is inserted into the National Urban Air Quality Database. The statistical concentration parameters were compared with the air quality guidelines and limit values. Preliminary results have been presented by Saari *et al*. (1996).

The local siting of the monitoring stations varies considerably, but most of them are located near busy streets or in industrial areas, in urban or suburban environments. We focus on the pollutants included in the health-based guidelines, i.e., carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), total suspended particles (TSP) and thoracic particles (PM_{10}). We also address some results concerning malodorous sulphur compounds (TRS), which have also been included in the health-based guidelines. In Finland, O_3 concentrations do not exceed the health-based guidelines in urban areas.

Recently, several reviews have been presented on urban air quality and its monitoring in Europe. Larssen and Hagen (1996a) reviewed urban and regional pollution in Europe in 1993. The report 'Air Pollution in Europe 1997' by the European Environment Agency (EEA) discusses various air pollution problems in Europe, including urban nitrogen oxides and ozone (Jol and Kielland 1997). Larssen and Hagen (1996b) addressed the problems and trends of air pollution monitoring in Europe.

Materials and methods

The climate, population and sources in the study area

Finland is situated by the Baltic Sea in Northern Europe, between the latitudes of 60°N and 70°N. The climate in this area is relatively mild, compared with the climate in other areas at the same latitudes. This is due to warming by the Gulf Stream and the prevailing global atmospheric circulation. However, the ground surface remains covered with snow for one to four months of the year in the south, and up to seven months in the north (Heino 1994).

Finland is fairly sparsely populated, with an average of 15.1 inhabitants per square kilometre. The total population is about 5.1 million. The south and southwest are the most densely populated areas. The largest urban agglomeration is the Helsinki Metropolitan Area, comprising four cities (Helsinki, Espoo, Vantaa and Kauniainen) with a total population of approximately 890 000 (Statistics Finland 1996).

The prevailing northern meteorological conditions can be very unfavourable for the dilution of air pollution. Particularly in winter, stable conditions with light winds may prevail in Finland for long periods. It is not uncommon for such conditions to last for several days in southern Finland and from one to two weeks in northern Finland (Huovila *et al.* 1991); then, mixing heights may be very low, and strong ground-based temperature inversions may prevail. These situations result in fairly high hourly or daily maximum pollutant concentrations in urban areas, even for moderate levels of emissions.

In Finland, road traffic is the source of approximately 70% of the emissions of CO, almost half of the emissions of NO_x and about 30%–45% of the hydrocarbon emissions. For SO_2, 96% of the emissions originate from energy production and industry (Statistics Finland 1996). The particulate matter emissions from road traffic (primary emissions and resuspension from street surfaces) are also substantial. The TRS emissions mainly originate from pulp industry.

Urban air quality monitoring networks

In Finland, local authorities are responsible for measurements of urban air quality, including the processing of the measured concentrations and computation of the statistical concentration parameters, which have been defined in the national air quality guidelines. Fig. 1 presents the location of the networks, which were included in this study, in 1993. There were 31 monitoring networks comprising in all 112 monitoring stations. The geographical distribution of the networks is comprehensive and includes all the cities in Finland, which have more than 50 000 inhabitants.

Historically, the local authorities decided the siting of the monitoring stations and the pollutants measured, using a variety of criteria. In many cases, the stations were located with the purpose of monitoring 'hot spots' near major local energy production and industrial sources, or the busiest traffic environments. Some stations are located in order to measure concentrations in the city centre or in other densely populated areas.

Local authorities of each municipality are responsible for the quality control and assurance (QC/QA) of the measurements and for the validation of the data. There are differences in levels of QC/QA procedures between networks, but generally most of the networks still do not have well-documented quality control. We did not ask for detailed information on the QC/QA procedures from the measurement networks considered.

The concentration statistics are inserted into the National Urban Air Quality Database. The database has been developed and updated by the Finnish Meteorological Institute (FMI) over the period 1987–1996. In 1997–1998, this work has been carried out jointly by the Finnish Environment Institute and the FMI.

National air quality guidelines and limit values

Air quality guidelines (Table 1) and limit values (Table 2) were issued in Finland in 1996. The guidelines were implemented in order to prevent the possible adverse health effects of air pollution in urban areas. The guidelines are based on a separate study, concerning national and international aspects of air quality and influence of air pollutants (Ministry of the Environment 1993). The guidelines of the World Health Organisation (WHO 1987 and 1995) were also taken into consideration.

The national authorities apply widely the health-based air quality guidelines in practical work, for instance in local and regional planning and in environmental permit procedures. The air quality guidelines are concrete objectives for the environmental policy, in the process of improving urban air quality.

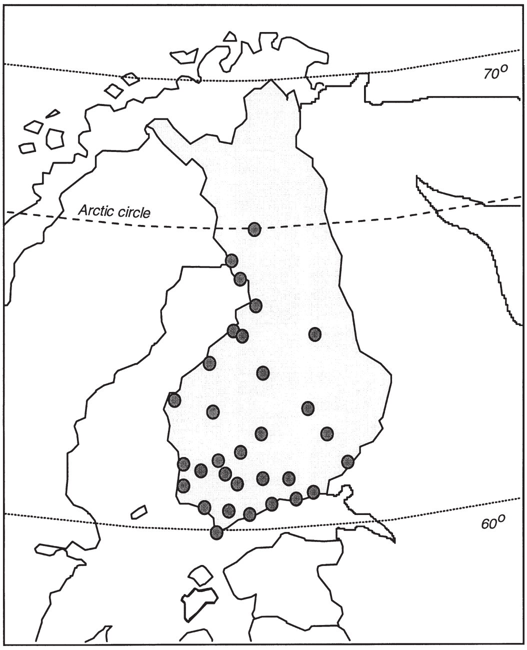


Fig. 1. Location of the urban air quality monitoring networks in Finland in 1993. The total number of networks is 31, comprising a total of 112 monitoring stations.

The EU limit values were implemented in the national limit values and they are the same, except for the more strict national limit value for lead (the corresponding EU limit value for lead is 2 μg m^{-3}). The guidelines are applied as practical objectives in environmental policy, while the limit

Table 1. The Finnish national air quality guidelines. The concentrations correspond to a temperature of 20 °C and a pressure of 101.3 kPa.

Pollutant	Guideline	Statistical definition
Carbon monoxide (CO)	20 mg m^{-3}	Mean value over one hour
	8 mg m^{-3}	Moving average value over eight hours
Nitrogen dioxide (NO_2)	150 μg m^{-3}	99th percentile of the hourly values in each month
	70 μg m^{-3}	Second highest daily mean value in each month
Sulphur dioxide (SO_2)	250 μg m^{-3}	99th percentile of the hourly values in each month
	80 μg m^{-3}	Second highest daily mean value in each month
Thoracic particles (PM_{10})	70 μg m^{-3}	Second highest daily mean value in each month
Total suspended particulates (TSP)	120 μg m^{-3}	98th percentile of the daily mean values in a year
	50 μg m^{-3}	Arithmetic mean of daily mean values in a year
Malodorous sulphur compounds (TRS) TRS is measured as sulphur	10 μg m^{-3}	Second highest daily mean value in each month

values are considered as strict limits. If the limit value is exceeded, the city or municipality has to take measures, in order to ensure that the limit value will not be exceeded again in the future.

Results

Classification of the urban monitoring stations

The urban monitoring stations were classified according to the guidelines of the European Union council decision for reciprocal data exchange (97/101/EC). The main classification indicates the type of zone (urban, suburban or rural) and the influence of each pollution source category (traffic, industry or background). The distribution of the different classes for all considered monitoring stations in 1993 presented in Fig. 2 is based on information concerning the location of the stations collected from the local authoritites, and further information on local pollution sources.

The classification method has some inherent deficiencies. Each monitoring station has been defined to represent only one combination of the two classifying parameters (for instance, urban and traffic). However, one station is often used for more than one purpose, for instance, for measuring SO_2 from an industrial source and NO_2 from traffic. Further, the definition of the classes is not always straightforward, since clear criteria for the classification are missing. For instance, it is not always clear whether a station is located in an 'urban' or a 'suburban' environment.

In Finland, the concentration level of the pollutants CO, NO_2, TSP and PM_{10} near ground level in urban areas mainly originate from traffic. For CO and NO_2 this has also been shown by dispersion model computations, conducted nationally in several cities (for instance, Valkonen *et al*. 1995, 1996, Karppinen *et al*. 1997a, Karppinen *et al*. 1997b). Concentrations of SO_2 mainly originate from energy production and industry (for instance, Valkonen *et al*. 1995, 1996).

Majority of stations are located in urban or suburban environments, in the vicinity of traffic or industrial sources (Fig. 2). However, very few stations are located in street canyons. The pollutants mainly originating from traffic (CO, NO_2, TSP and PM_{10}) are monitored mostly in 'traffic' environments, although TSP and NO_2 are also monitored extensively in 'industry' environments. The pollutants originating mainly from energy production and industry, SO_2 and TRS, are mostly monitored in industrial environments.

There are no monitoring stations in 'urban background' environments. Such a station could be located, for instance, in the centre of a city at some distance from the immediate pollution sources. Urban background stations would better represent the overall air quality in an urban area, compared with 'hot spot' stations. These stations would also improve the basis for estimating the exposure of urban populations to air pollution. Urban measurement strategies should therefore

Table 2. The Finnish national air quality limit values. The concentrations correspond to a temperature of 20 °C and a pressure of 101.3 kPa.

Pollutant	Limit value	Statistical definition
Carbon monoxide(CO)	–	–
Nitrogen dioxide (NO_2)	200 µg m^{-3}	98th percentile of the hourly mean values in a year
Sulphur dioxide (SO_2)	250 µg m^{-3} 80 µg m^{-3}	98th percentile of the daily mean values in a year Median of daily mean values in a year
Thoracic particles (PM_{10})	–	–
Total suspended particulates (TSP)	300 µg m^{-3} 150 µg m^{-3}	95th percentile of the daily mean values in a year Arithmetic mean of daily mean values in a year
Malodorous sulphur compounds (TRS)	–	–
Lead Pb	0.5 µg m^{-3}	Arithmetic mean of daily mean values in a year

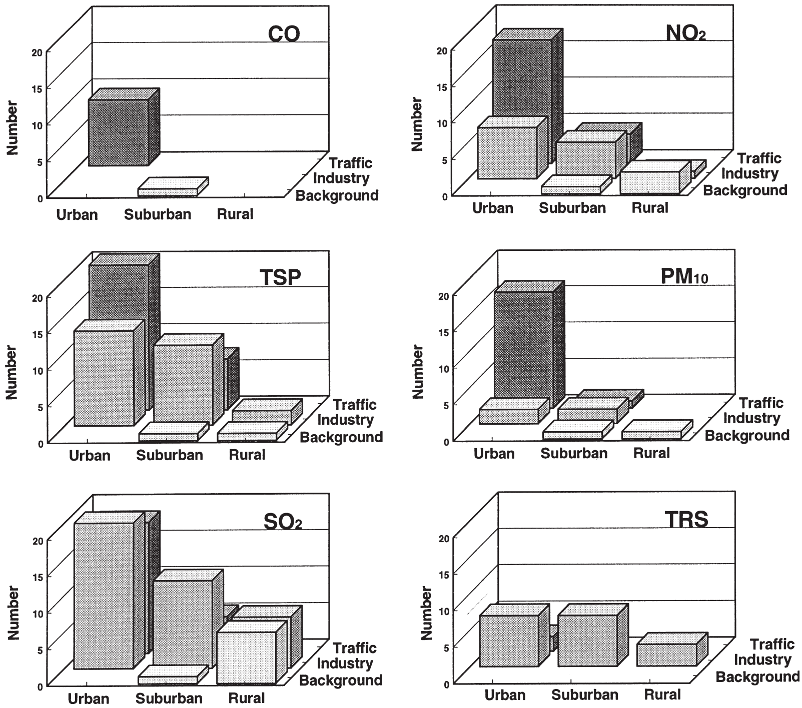


Fig. 2. Classification of the monitoring stations measuring the specified pollutants in 1993. The classification is based on the guidelines of the European Union council decision for reciprocal data exchange (97/101/EC).

be revised to include urban background stations. This would also make it easier to conduct intercomparisons of air quality in different cities.

The number of stations is largest for TSP and SO_2, mainly for historical reasons. More stations are needed particularly for NO_2, PM_{10} and $PM_{2.5}$. The number of SO_2 stations could be substantially reduced, together with a gradual reduction in TSP measurements. This change of emphasis would be in accordance with current knowledge on the adverse health effects of pollution. Fine particles and NO_2 are nowadays considered as more important pollutants in view of population exposure and human health, compared with TSP and SO_2.

Overview of the exceedances of guidelines and limit values

We have considered the concentration data from 1990–1993, and analysed whether these values exceed national guidelines and European Union limit values. We have applied the new guidelines and limit values (1996), as these were considered to better represent the actual health effects of pollution, compared with the older, outdated guidelines and directives.

The concentration data from 1990–1993 show that the national air quality guidelines were exceeded in 23 of the 42 cities examined. The guidelines for particulate matter, both TSP and PM_{10}, were most often exceeded.

During the period 1990–1993, the limit values were exceeded at only one measurement station, and only for TSP. The daily mean limit value for TSP (150 $\mu g\ m^{-3}$) was exceeded in 1990, 1991 and 1992 at the Aninkaistenkatu measurement point in the city of Turku, in street canyon conditions with dense traffic. In 1993, the concentrations did not exceed the limit values for any pollutant at any measurement station.

The overall results from the cumulative number of urban measurement sites in Finland in 1993, at which a given percentage of the national guideline or limit value was exceeded, indicate a clear difference between gaseous and particulate pollutants (Fig. 3). The data from all the 112 measurement stations considered in 1993 have been compiled in this figure. For instance, the total number of stations measuring SO_2 and TSP are 62 and 56, respectively.

Summarising, exceedances of the CO, NO_2,

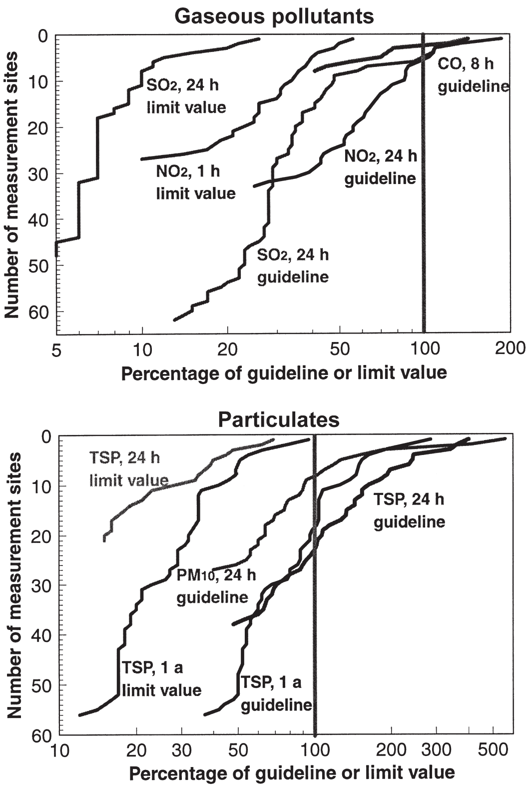


Fig. 3. The cumulative number of urban measurement sites in Finland in 1993 exceeding the given percentage of the national guideline or limit value, indicated by a vertical line. The upper figure shows the situation for gaseous pollutants and the lower figure for particulates. Notation: 1 a = annual value, 24 h = daily value.

PM_{10} and TSP guideline values were mostly caused by local vehicular sources, while those of SO_2 resulted from energy production or industry (Table 3).

In the following we discuss in more detail the cases in which the national guidelines were exceeded, first for gaseous pollutants and then for particulate matter.

Exceedances of guidelines for gaseous pollutants

For the gaseous pollutants CO, NO_2 and SO_2, there were less values in excess of the hourly guideline, compared with the eight-hourly or daily guidelines (Fig. 3). The eight-hourly and daily concentration parameters for all three gaseous pollutants considered exceeded the guidelines, at a moderate number of measurement locations. Hourly guidelines have been omitted for simplicity (cf. Table 1).

For CO, the eight-hourly guideline was exceeded at three of the eight stations considered (corresponding to 38%). For NO_2, the daily guideline was exceeded at approximately 18% of the 33 stations. The hourly guidelines for CO and NO_2 were not exceeded in 1993. The exceedances of the CO and NO_2 guidelines occurred in urban or suburban locations with dense traffic. For SO_2, the daily and hourly guidelines were exceeded at approximately ten and five per cent of the 62 sta-

Table 3. Summary of exceedances of the national air quality guidelines (1996) in Finland. The table is based on measured data from towns and urban districts between 1990 and 1993.

Pollutant	Time	Exceedance
Carbon monoxide (CO)	1 hour	Seldom
	8 hours	Occasionally near busy streets
Nitrogen dioxide (NO_2)	1 hour	Seldom
	24 hours	Fairly frequently at traffic hot-spots
Sulphur dioxide(SO_2)	1 hour	Both values near major emission sources
	24 hours	
Thoracic particles (PM_{10})	24 hours	Commonly at traffic hot-spots in spring
Total suspended particulates (TSP)	24 hours	Both values commonly at traffic hot-spots
	1 year	
Malodorous sulphur compounds, total (TRS)	24 hours	At many industrial locations

tions, respectively. All of these exceedances were measured in the vicinity of industrial installations.

Exceedances of guidelines for particles

The number of exceedances of guidelines for particulate pollution was clearly higher as compared with gaseous pollutants (Fig 3). Particularly the daily and annual guidelines for TSP were exceeded in approximately 61% and 34% of the 38 and 56 stations, respectively. For PM_{10}, the daily guideline was exceeded at approximately 30% of the 27 stations.

The exceedances of the guidelines for particles usually occurred near roads with dense traffic; obviously due to direct emissions from traffic and resuspended particles from road surfaces. For instance, the measurements by Larssen and Hagen (1997) showed that wearing of street surfaces caused by studded tires has a significant influence on concentrations of PM_{10} in major cities. Emissions from industry or energy production caused exceedances of the guidelines only at a few monitoring stations.

Summary of the annual mean and 98th-percentile concentrations

Measured concentrations in the largest Finnish cities and towns, presented in order of decreasing population (Statistics Finland 1996), show no clear correlation (Table 4). The range of values represents all measurement stations (1–5 in each city) and years (four years of data). For instance, the range of the annual mean for NO_2 values in Helsinki represents the minimum and maximum values measured at two stations during four years.

The concentrations presented in Table 4 can be compared with the corresponding values in other European cities (Larssen and Hagen 1996a, Jol and Kielland 1997) and western German cities (Schatzmann 1995). Clearly, the results are dependent on the representativity of the locations of urban monitoring stations. In Central European cities, many of the stations measure urban background concentrations, while in the Finnish cities a larger fraction of the stations monitor the most polluted locations. This has to be taken into account, when the measured concentration values are compared.

According to the compilation of Larssen and Hagen (1996a), the NO_2 concentrations in Helsinki are comparable with those in the major Central European cities. A comparison with the study of Schatzmann (1995) also shows that the annual concentrations of NO_2 in Helsinki are comparable with the values in the major western German cities. In other Finnish cities, the NO_2 concentration levels are usually somewhat lower than those in the capital city.

The 98th percentile CO concentrations in major Finnish cities are comparable with the corresponding concentrations in the major Central European cities and also in western German cities. However, in Finland many of the monitoring stations for CO are located in busy traffic environments in urban areas (cf. Fig. 2), which tend to produce higher concentrations.

The median O_3 concentrations in Finnish cities are comparable with those in Central European cities, but the maximum concentrations are clearly lower in Finland. The SO_2 concentrations in Nordic countries are rather low (Larssen and Hagen 1996a) and in Finnish cities they are clearly lower than e.g., in Germany.

From the data reported by Larssen and Hagen (1996a), the highest TSP levels in 1993 were measured in Southern and Eastern European cities. The concentration levels considered here for Helsinki were comparable with those in Central European cities. However, the TSP concentrations vary substantially from year to year, and some TSP values in the largest cities in Finland (in particular Turku) are exceptionally high. However, the TSP concentrations are very sensitive to the siting of monitoring stations.

Seasonal variation of exceedances

The seasonal variation of the guideline exceedances for CO, NO_2, SO_2, TSP and PM_{10} in 1990–1993 had both distinct and common features (Fig. 4). The occurrences exceeding half the guidelines values are also shown, in order to achieve a better statistical reliability. All exceedances have been considered on a monthly basis, also for TSP, although its guidelines represent annual statistics.

The seasonal variation of exceedances is caused by the variation in emissions and meteorological conditions. The seasonal variation of traffic volumes in the major Finnish cities is typically smaller than 20% on a monthly basis (for instance, Valkonen *et al.* 1995, 1996). The seasonal varia-

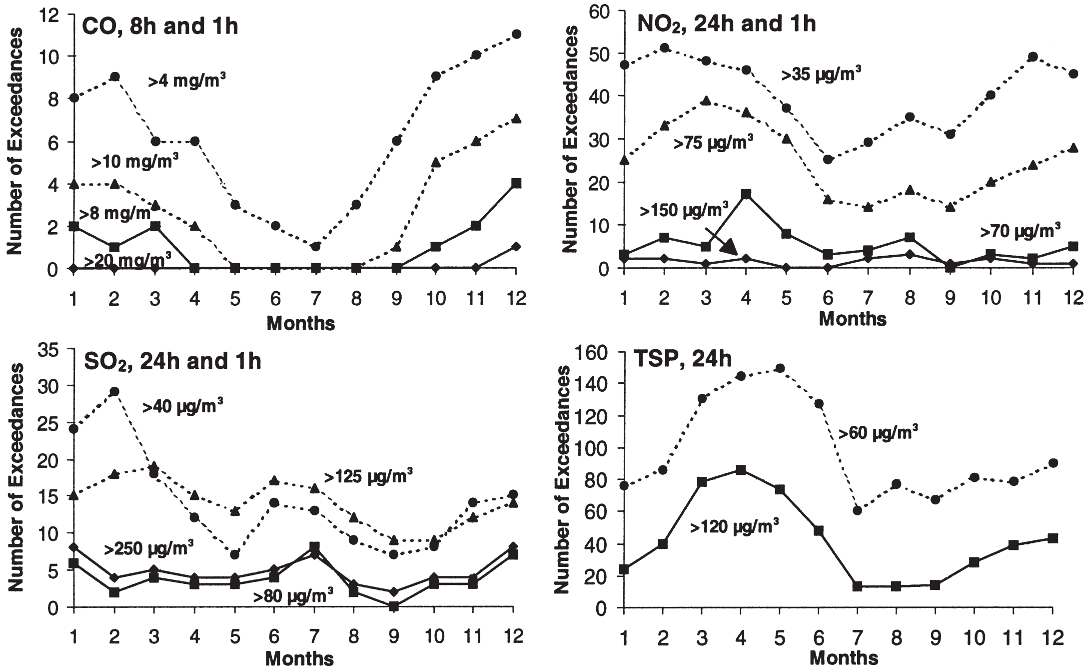
Table 4. A compilation of the measured annual mean and 98-percentile concentrations at major Finnish cities in 1990–1993. The concentrations correspond to a temperature of 20 °C and a pressure of 101.3 kPa. The table also shows the population of the cities (Statistics Finland, 1996) and the number of monitoring stations, at which each pollutant has been measured.

	NO_2 (µg m^{-3})		CO (mg m^{-3})		O_3 (µg m^{-3})	
	Annual mean	98th percentile [1)]	Annual mean	98th percentile[1)]	Annual mean	98th percentile[1)]
Helsinki	36–46	81–122	0.4–1.6	1.0–5.0	17–30	62–78
Espoo	7–32	33–77	0.5	1.6	41–54	87–115
Tampere	11–33	46–73	0.7–1.0	2.3		98–109
Turku	40	81	1.9–2.1	7.2–8.6		
Vantaa	21–29	65–89			31–43	79–102
Oulu	14–39	61–96	1.0–1.4	3.4–5.1		
Lahti	8–32	34–70	0.9–1.0	4.7		
Kuopio	15–44		1.1	3.7		
Pori	4–23	20				
Jyväskylä	12–35	43–103	1.0–1.3	5.3–6.7		

	SO_2 (µg m^{-3})		PM_{10} (µg m^{-3})		TSP (µg m^{-3})	
	Annual mean	98th percentile[1)]	Annual mean	98th percentile[1)]	Annual mean	98th percentile[1)]
Helsinki	5–16	15–71	17–33	53	34–104	99–517
Espoo	2–5	10–25	20	53	20–36	52–121
Tampere	2–16	10–16	23		22–116	92–425
Turku	4–9	12–29	112–139[3)]		64–246[3)]	240–1000[3)]
Vantaa	5–9	16	15–21		30–41	91–149
Oulu	3–7	8–26	13–27	32–91		
Lahti	5–7	19	12–15		29–69	156–312
Kuopio	2–13	7–38	38–42[3)]	160–210[3)]	19–68	61–423
Pori	1–13	7–17	18	56	27–77	56–304
Jyväskylä	2–10	12–42	16	50–63	17–60	65–233

	Population (1995)	Number of stations					
		NO_2	CO	O_3	SO_2	PM_{10}	TSP
Helsinki	525 031	2	2	1	2	3	3
Espoo	191 247	2	1	1	2	1	2
Tampere	182 742	3	2	2	3	1	3
Vantaa	166 480	1	1	1	1	1	1
Turku	164 744	1	1	–	2	1	2
Oulu	109 094	2	1	–	3	2	–
Lahti	95 119	3	1	–	1	2	2
Kuopio	84 733	1	1	–	1	1	4
Pori	76 627	1	1	–	3	1	2
Jyväskylä	74 072	4	1	–	4	1	4

1) Based on annual hourly values. 2) Based on annual daily values. 3) Measurements are based on inertial impaction



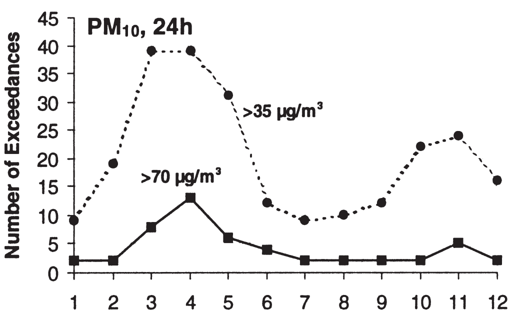


Fig. 4 (above and on the left). Seasonal variation of the exceedances of national guidelines in Finnish cities and towns in 1990–1993. The occurrences exceeding half the guideline values are also shown.

tion of the emission factors (g km^{-1}) depends on the pollutant considered, the vehicle class and the distance travelled. For instance, for CO, cold-start emissions in winter in Finland can cause a tenfold increase in the emission factors for very short journeys (Laurikko 1997). The seasonal variation of the emissions caused by energy production can be substantial. For instance, NO_x emissions from energy production and industry in 1993 in the Helsinki metropolitan area were more than four times larger in January than in July (Pesonen *et al.* 1996).

However, the main part of the seasonal variation of the short-term concentrations in urban air under northern climatic conditions is caused by a corresponding variation in the meteorological conditions. The yearly variation is substantial regarding atmospheric stability and the occurrence of inversion layers, wind velocity, ambient temperature, solar radiation, precipitation and the presence of snow cover. This causes the most unfavourable conditions for mixing of pollutants during the winter half-year.

CO concentrations exceed the guidelines or half of the guideline value most frequently in late autumn, winter and early spring (Fig. 4). The maximum number of exceedances occur in December.

The seasonal variation of the guideline exceedances for NO_2 is not so apparent as for CO, but the curves have similar shape. The guidelines or half the guidelines are exceeded most frequently in late autumn, winter and spring. In spring the transformation of NO into NO_2 is more efficient, due to higher tropospheric ozone concentrations (Laurila 1996, Härkönen *et al.* 1997).

The corresponding curves for SO_2 have a slightly different form, compared with CO and NO_2. Concentrations exceed the guidelines or half the guideline value most frequently in winter. The seasonal variation of SO_2 is caused by the variation in the unfavourable meteorological conditions and the variation of the emissions from energy production, which are largest during the cold winter months.

Airborne particulate matter originates not only directly from combustion processes, but also from, for instance, wintertime sanding of streets, and from wearing of the street surfaces because of studded tyres. When streets are humid, dust gathers on streets as depots, which may contain a substantial amount of material, during the winter (Larssen and Haugsbakk 1996). In spring, after the snow has melted and streets dry out, particles are resuspended from the street surface.

Resuspension commonly takes place in late autumn also, probably due to the start of street salting and sanding. In Northern Europe, the snow can be melted (sometimes several times), before a permanent snow cover is obtained. The resuspension affects not only the TSP concentrations, but is important also for PM_{10} concentrations.

TSP and PM_{10} concentrations exceed the guidelines most frequently in late winter, spring or early summer and late autumn. In contrast to the corresponding curves for the gaseous pollutants considered, the exceedances for TSP and PM_{10} have a minimum in winter (December or January). This is presumably caused by periods of snow cover and wet streets.

We have not analysed here the contribution to particle concentrations of various sources, e.g., the regional and long-range transported contribution. Comparable background measurements are scarce.

Summary

This study presents a comprehensive compilation and review of air quality data in Finnish municipalities. The data were compiled from measurements conducted in 1990–1993 in 42 Finnish cities and towns.

First, the urban monitoring stations were classified according to European Union guidelines. The total number of measurements is largest for TSP and SO_2, due mainly to historical reasons. More measurements would be needed for PM_{10}, $PM_{2.5}$ and NO_2, and the number of measurements of SO_2 could be substantially reduced, together with a gradual reduction of TSP measurements. This change of emphasis would be in accordance with current knowledge on the adverse health effects of air pollution.

Further, there are no monitoring stations in urban background environments. Urban background stations would better represent the overall air quality and their data would be useful in order to evaluate exposure of population to air pollution in urban areas. Urban measurement strategies should therefore be revised to include urban background stations. This would also make it easier to conduct intercomparisons of air quality in different cities.

Local authorities of each municipality are responsible for the quality control and assurance (QC/QA) of the measurements. Many of the networks do not have well-documented quality control. Consequently, there is an urgent need for the implementation of national and international QC/QA procedures.

The air quality limit values were only exceeded at one measurement station, in the city of Turku for TSP in 1990, 1991 and 1992, in street canyon conditions with dense traffic. In 1993 the concentrations did not exceed the limit values for any pollutant at any measurement station.

Measured data show that the national air quality guidelines (1996) would have been fairly often exceeded in urban areas in 1990–1993. The occurrence of such situations were most common for particles, both for PM_{10} and for total suspended particles. Excess values have also occurred occasionally for NO_2 and CO, mainly at sites with high traffic densities.

The measured NO_2 and CO concentrations in Helsinki are similar to corresponding concentrations in the major Central European cities, while the urban SO_2 concentrations are rather low. However, the highest TSP concentrations in Finnish cities can in some cases be higher than the corresponding maximum concentrations in Central, Southern and Eastern European cities. The exceptionally high particle concentrations are caused by the resuspension of dust from street surfaces. Clearly, the TSP concentrations are strongly dependent on the location of monitoring stations.

The main part of the seasonal variation of the concentrations in urban air in northern climate conditions is caused by variations in the meteorological conditions. Meteorological conditions in Finland are most unfavourable for the efficient mixing of pollutants during the winter half-year, when the highest gaseous pollutant concentrations are also measured.

Acknowledgements: The local authorities in Finland are acknowledged for their continued cooperation and release of the monitoring data. We wish to thank Ms. Tarja Lahtinen (Ministry of the Environment) for her interest in and guidance of this work. We are also grateful to Mr. Veijo Hiltunen for carefully updating the air quality data in the database. The Ministry of the Environment is thanked for financial support for this work.

References

Heino R. 1994. *Climate in Finland during the period of meteorological observations*. Finnish Meteorological Institute Contributions, No. 12, Helsinki, Finland, 209 pp.

Huovila S., Luukkanen M.L. & Tuominen A. 1991. *Some features of ground inversions in Finland*. Meteorological Publications, Finnish Meteorological Institute, Helsinki, Finland, 51 pp.

Härkönen J., Kukkonen J., Valkonen E. & Karppinen A. 1997. The influence of vehicle emission characteristics and meteorological conditions on urban NO_2 concentrations. In: Joumard R. (ed.), *Proceedings of the 4th international scientific symposium "Transport and Air Pollution"*, Avignon, France, 9–13 June 1997, pp. 113–119.

Jol A. & Kielland G. (eds.) 1997. *Air Pollution in Europe 1997*. EEA Environmental Monograph No. 4. European Environment Agency, Copenhagen, 107 pp.

Karppinen A., Kukkonen J., Konttinen M., Härkönen J., Valkonen E., Rantakrans E., Koskentalo T. & Elolähde T. 1997a. The emissions, dispersion and chemical transformation of traffic-originated nitrogen oxides at the Helsinki metropolitan area. In: Joumard R. (ed.), *Proceedings of the 4th international scientific symposium "Transport and Air Pollution"*, Avignon, France, 9–13 June 1997, pp.121–127.

Karppinen A., Kukkonen J., Konttinen M., Rantakrans E., Valkonen E., Härkönen J., Koskentalo T. & Elolähde T. 1997b. Comparison of dispersion model predictions and the results from an urban air quality measurement network. In: Power H., Tirabassi T. & Brebbia C. A. (eds.), *Air Pollution V — Modelling Monitoring and Management*, Computational Mechanics Publications, Southampton, pp. 405–411.

Larssen S. & Hagen L.O. 1996a. *Air quality in Europe, 1993 — a pilot report*. European Topic Centre on Air Quality, Report 25, European Environment Agency, Copenhagen, 131 pp.

Larssen S. & Hagen L.O. 1996b. *Air pollution monitoring in Europe — problems and trends*. European Topic Centre on Air Quality, Report 26, European Environment Agency, Copenhagen, 88 pp.

Larssen S. & Hagen L.O. 1997. *Suspended particulate matter caused by studded tyres*. Norsk institut for luftforskning, NILU, 16/97, 40 pp.

Larssen S. & Haugsbakk I. 1996. *Road dust depot and dust concentrations based upon measurements at the E6 road at Mortensrud/Klemetsrud winter 1995/96*. Norsk institut for luftforskning, NILU, 53/96, 53 pp.

Laurikko J. 1997. Regulated and unregulated exhaust emissions from in-use catalyst cars at normal and low ambient temperatures. In: Joumard R. (ed.), *Proceedings of the 4th international scientific symposium "Transport and Air Pollution"*, Avignon, France, 9–13 June 1997, pp. 161–168.

Laurila T. 1996. Effects of environmental conditions and transport on surface ozone concentrations in Finland. *Geophysica* 32: 167–193.

Ministry of the Environment 1993. *Ilmanlaadun ohjearvotyöryhmän mietintö*. Department for Environmental Protection, Helsinki, 72/1993, 186 + 20 pp.

Pesonen R., Rantakrans E., Pietarila H., Karppinen A., Koskentalo T., Elolähde T., Haarala S. & Lesojeff K. 1996. *The evaluation of the deposition of nitrogen oxides in the Helsinki metropolitan area*. Finnish Meteorological Institute, Report, Helsinki, 61 + 30 pp.

Pohjola V., Pesonen R., Kartastenpää R., Rantakrans E., Kukkonen J., Jokinen J., Mäkinen E., Saari H. & Hiltunen V. 1995. Review of urban and industrial air quality assessments at the Finnish Meteorological Institute. In: Kämäri J., Tolvanen M., Anttila P. & Salonen R.O. (eds.), *Proceedings of the 10th World Clean Air Congress*, Espoo, Finland, May 28–June 2, 1995. Vol. 3. The Finnish Air Pollution Prevention Society, Helsinki, p. 518 (4 pages).

Saari H., Salmi T., Kukkonen J. & Kartastenpää R. 1996. Review on urban air quality in Finland. In: Kretzschmar J. & Cosemans G. (eds.), *Proceedings of the 4th Workshop on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes*, Oostende, Belgium, 6–9 May 1996. Vol. 2. Vlaamse Instelling voor Technologisch Onderzoek, Mol, Belgium, pp. 611–612.

Schatzmann M. 1995. Atmospheric dispersion models for regulatory purposes in the Federal Republic of Germany. Part II: The current situation. *International Journal of Environment and Pollution* 5: 431–440.

Statistics Finland 1996. *Statistical Yearbook of Finland*. Official statistics of Finland, Helsinki, 661 pp.

Valkonen E., Härkönen J., Kukkonen J., Rantakrans E., Jalkanen L. & Haarala S. 1995. Application of dispersion models for evaluating the influence of urban air pollution on human health. *International Journal of Environment and Pollution* 5: 557–566.

Valkonen E., Härkönen J., Kukkonen J., Rantakrans E., Jalkanen L. & Haarala S. 1996. Modelling urban air pollution in Espoo, Finland. *The Science of the Total Environment 189/190:* 205–211.

WHO 1987. *Air quality guidelines for Europe*. World Health Organization, Regional Office for Europe, WHO Regional Publications, Copenhagen. European Series 23. 426 pp.

WHO 1995. *Update and Revision of the Air Quality Guidelines for Europe — Meeting of the Working Group on "Classical" Air Pollutants*, 11–14 October 1994, Bilthoven, NL. Regional Office for Europe, Report EUR/ICP/EHAZ9405/PB01 (EUR/HFA target 21). 29 pp.

Received 18 March 1998, accepted 13 October 1998