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Presenting Air Quality Data

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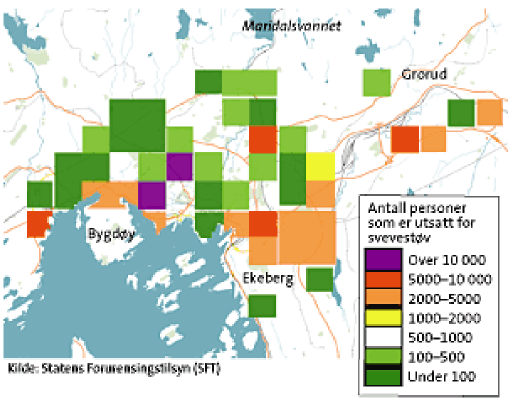

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Presenting Air Quality Data

1 Introduction

The air that we breathe consists of a number of naturally occurring and man-made chemical compounds. The polluted atmosphere is generally associated with man's industrial and domestic activities. However, natural processes also emit many of the major gaseous pollutants. On a worldwide basis, the total mass of trace gases emitted by nature may in many cases exceed those emitted by human activities by several orders of magnitude.

Nonetheless, human activities do adversely affect the air quality and the air we breathe, particularly in urban areas and close to large emission sources. When presenting air quality data we are often most concerned about man-made pollutants, from anthropogenic sources. These are the most important air pollution indicators and they will normally give the largest gradients in the atmosphere, and the largest differences from "clean" to "polluted" air, as seen in the table below.

Table 1: Typical trace gas concentrations (ppm) in clean and in polluted air.

Compound	Clean air	Polluted air
CO_2	320	400
CO	0,1	40-70
CH_4	1,5	2,5
N_2O	0,25	?
NO_2	0,001	0,1-0,5
O_3	0,02	0,2-0,5
SO_2	0,0002	0,1-0,5
NH_3	0,01	0,02

Air pollution comes from many different sources:
- Stationary sources such as factories,
- Power plants,
- Smelters and different types of industries,
- Smaller sources such as dry cleaners and degreasing operations,
- Mobile sources such as cars, buses, planes, trucks, and trains,
- Naturally occurring sources such as windblown dust, and volcanic eruptions.

All of these sources contribute to air pollution. Air Quality can be affected in many ways by the pollution emitted from these sources. These pollution sources can also emit a wide variety of pollutants, which have been classified as the six principal pollutants (or criteria pollutants as the US EPA also defines them).

The six criteria pollutants defined by US EPA are:
- Carbon Monoxide (CO)
- Lead (Pb)
- Nitrogen Dioxide (NO_2)
- Ground-Level Ozone (O_3)
- Particulate Matter (PM_{10})
- Sulphur Dioxide (SO_2)

These pollutants are also the indicators selected for classifying air pollution and are normally monitored by national and international organisations. Environmental Laws (such as the US EPA Clean Air Act, the European Air Quality Framework Directives) provides the principal framework for national, state, and local efforts to protect air quality.

2 Air quality standards and limit values

Air pollution measurement data are most often, when presented, compared to air quality standards or guideline values. Air quality standards or limit values are used differently than the guideline values. A standard is often accepted by the national authorities as a basis for control purposes, while a guideline value give some indications as to the impact of pollution on health, nature or materials. The most recognised guideline values used by international bodies and as a background for national standard setting is the air quality guidelines issued by the World Health Organisation (WHO 2000). Several national authorities have issued limit values and standards. The most recent and complete limit values are those issued by the European Commission (ECE, 1996) and by the US EPA.

2.1 WHO Air Quality Guidelines

The most famous and most used air quality guidelines used worldwide has been the World Health Organisation guidelines for Europe (WHO 1987). These guidelines have been updated and revised in 1996 and published again in 2000 (WHO 2000).
A summary of the guideline values is presented in the following table.

Table 2: WHO 1996 Air Quality Guidelines for Europe.

	Averaging period	**Concentration (µg/m^3)**
Sulphur dioxide: health	10 minutes	500
	24 hours	125
	one year	50
Sulphur dioxide: ecotoxic effects	annual and winter mean	10 - 30 depending on type of vegetation
Nitrogen dioxide: health	1 hour	200
	one year	40
Nitrogen dioxide and nitric oxide: ecotoxic effects	one year	30
PM_{10}	24 hours	dose/response
	one year	dose/response
Lead	one year	0.5

2.2 European Air Quality Directives

European Air Quality Directives have been presented to provide a high level of protection for public health throughout the European Union, and to set for the first time ambient air quality limit values designed to protect the environment.

The new limit values are based on the revised Air Quality Guidelines for Europe adopted by the World Health Organisation in 1996. Main elements of the proposal are:

- Health-based limit values for sulphur dioxide, lead and particulate matter to be met by 2005,
- Health-based limit values for nitrogen dioxide
- A tighter set of limit values for particulate matter to be met by 2010;
- Limit values to protect the rural environment against the effects of sulphur dioxide and oxides of nitrogen;
- Details of how levels of the pollutants should be assessed throughout the European Union; and a requirement that up to date information on all four pollutants should be easily available to the public.

For each of the four pollutants, the proposal sets out new air quality standards as well as the date by which these air quality standards must be achieved. A summary of the air quality standards is presented below:

Table 3: A summary of limit values as presented by the EU Air Quality Daughter Directives

Averaging time	1 h	24 h	year	To be met
SO2	350 (24)	125 (3)	20 '	1 Jan 2005
Toler margin	+150			
NO2	200 (18)		40	1 Jan 2010
Toler margin	+100		+20	
PM10		50 (35)	40	1 Jan 2005
Toler margin		+25	+8	
PM10		50 (7)	20	1 Jan 2010
Pb (lead)			0,5	1 Jan 2005
Toler margin			0,5	

In order to ensure that the standards are respected air quality must be monitored on a regular and systematic basis. The directive requires standard methods to be used for measuring pollution and also sets down minimum requirements concerning the design of the air quality monitoring networks (number and location of measuring stations etc).

Citizens should have access to information concerning air quality. The directive sets out some basic rules concerning how and when the authorities should provide information on pollution episodes and on air pollution in general. Also guidelines for what information is to be presented is given in the Directives.

2.3 The US clean Air act

Under the Clean Air Act, the Office of Air Quality Planning and Standards (OAQPS) is responsible for setting standards, also known as national ambient air quality standards (NAAQS), for pollutants which are considered harmful to people and the environment. OAQPS is also responsible for ensuring that these air quality standards are met, or attained (in co-operation with state, Tribal, and local governments). Air pollution control strategies are based on national standards and options to control pollutant emissions from automobiles, factories, and other sources should be evaluated and applied. EPA is also dedicated to monitoring the quality of the air we breathe.

3 Typical levels of priority pollutants around the world

Among the most common and poisonous air pollutants are sulphur dioxide (SO_2), formed when fossil fuels such as coal, gas and oil are used for power generation; suspended particulate matter (SPM) also denoted Total Suspended Particulate matter (TSP), which consists of solid and liquid particles emitted from numerous man-made and natural sources such as industrial dust, diesel powered vehicles, resuspension of wind blown dust; and nitrogen oxides (NOx), from traffic, combustion of fossil fuels, as well as natural sources such as lightning, forest fires, volcanoes and microbes in soil.

Other pollutants include carbon monoxide (CO), emitted mainly from gasoline powered motor vehicles; and lead, which can occur naturally in wind-blown dust and volcanoes but is also man-made, resulting from lead smelters and from the use of alkyl lead as an anti-knock agent in gasoline.

3.1 Suspended particulate matter

Total Suspended Particulate matter (TSP) is the most important pollutant worldwide, both indoors and outdoors, in terms of human health effects. Particulates, especially fine particles, contain large amounts of inorganic and organic toxic materials, such as heavy metals and polycyclic aromatic hydrocarbons. The weight of evidence from numerous epidemiological studies on short-term effects points clearly to associations between concentrations of particulate matter and adverse effects on human health at low levels of exposure commonly encountered in developed countries.

Effects on mortality, respiratory and cardiovascular hospital admissions have been observed at daily average PM_{10} (particles below 10 micrometer) levels well below 100 micrograms per cubic metre (µg/m3). In Western Europe, North America and Western Pacific, except China, annual mean TSP concentrations range between 20 and 80 $\mu g/m^3$, and PM_{10} levels are between 10 and 55 $\mu g/m^3$.

High TSP and PM_{10} annual mean concentrations are found in South East Asia ranging between 100-400 µg/m3 for TSP and 100-300 µg/m3 for PM_{10}. However, the highest recorded annual TSP concentrations of 300-500 $\mu g/m^3$ are observed in the larger cities of China. TSP and PM_{10} concentrations measured in Cairo may also occasionally exceed several hundred µg/m3. Much of these dust particles originates from wind blown dust.

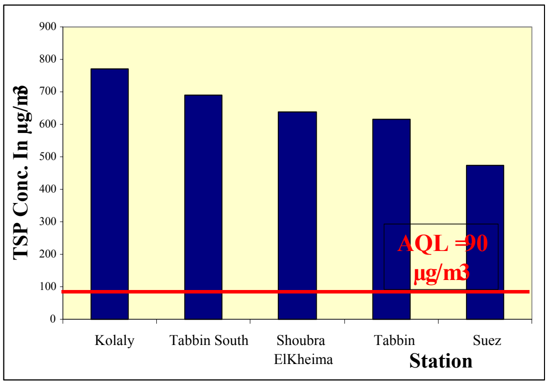

Figure 1: Suspended dust in the air is a major air pollution problem in Cairo. Dust is generated from open air burning, traffic, and industries and by natural dust from the dessert areas surrounding Cairo.

3.2 Sulphur dioxide

In many countries concentrations of sulphur dioxide in urban areas have declined in recent years as a result of emission controls and modification of fuel composition. Annual mean concentrations in North America and Western Europe are now mainly in the range of 20 to 60 µg/m^3. In some Eastern European countries sulphur dioxide levels have decreased from around several hundred micrograms per cubic metre to 100 µg/m^3 in the last ten years. In urban areas of Latin America annual mean concentrations of sulphur dioxide range between 5 to 80 µg/m^3, which corresponds to the data available for many South-East Asian and Western Pacific cities. In some Chinese cities, however, where coal is still widely used for domestic heating or cooking or where there are poorly controlled industrial sources, mean concentrations range between 40 and 250 µg/m^3.

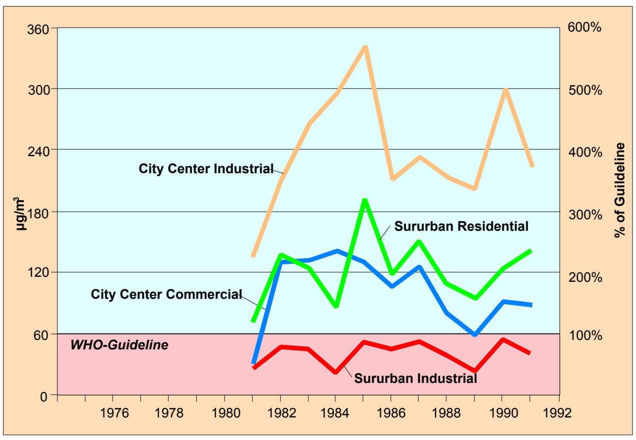

Figure 2: The annual average SO2 concentrations in the city of Shenyang, China, exceeded the WHO guideline values by a factor of 2 to 5 in the eighties and early nineties.

Extremely high annual levels are found in Chongqing, China, amounting to 300-400 µg/m^3. Data from a number of African countries suggest that sulphur dioxide is a serious pollutant on the continent. Concerns about sulphur dioxide levels exist not only in case of power plants and other industrial areas but also in respect of numerous informal and squatter settlements, where fossil and biomass combustion occurs extensively. A Chinese study reported the three-year average mortality from pulmonary heart disease and respiratory diseases in a community with a long exposure to sulphur dioxide concentrations of 175 µg/m^3 to be twice as much as that of the control group.

3.3 Nitrogen dioxide

Levels of nitrogen dioxide, a reddish brown gas with a readily recognisable pungent odour, vary dramatically from country to country. In European urban areas, for example, they range from 75 to 1,000 µg/m^3. Nitrogen oxides are becoming the principal pollutants in large cities in countries as far apart as China and Egypt, as traffic is increasing.

Nitrogen dioxide is also a problem in many larger cities in Europe mainly due to emissions of NO_x from traffic. Even if the measurements show a slowly decreasing trend, many of the urban areas have exceedances of guidelines and limit values.

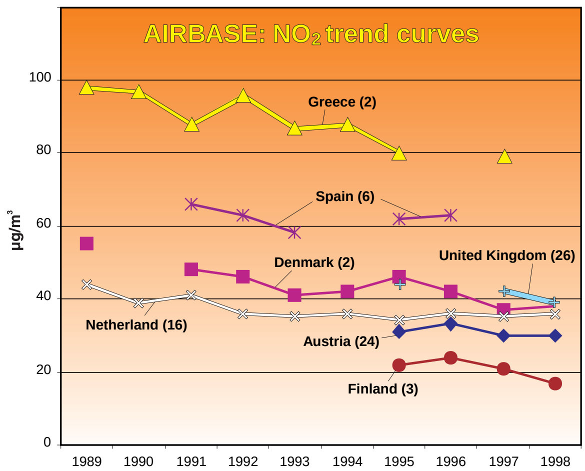

Figure 3: Long term trend of annual average NO_2 concentrations in Europe, 1989 to 1998.(EEA/NILU: European Air Quality in Europe 1998 Report).

Nitrogen oxides mainly affect the human respiratory system. At different dosages, the pollutant could produce different medical conditions, from functional and morphological changes of the lung to slowing growth-rate and affecting immunity response.

3.4 Ozone

Surface level ozone is becoming a prevalent pollutant in large cities of Latin America. In Mexico City, ozone levels are high despite efforts to control air pollution. In 1995, ozone levels exceeded the national standard level on 324 days. In Santiago, Chile, the one-hour average concentration limit was exceeded 404 times in the same year. Several studies conducted in Mexico City revealed the acute effects of ozone exposure on respiratory health.

Figure 4: The classical Los Angeles smog (May 1989), in which the ozone concentrations exceeded all standards and limit values.

From studies undertaken in urban areas it was reported that for children exposed two days in a row to a combination of high ozone levels and relatively low temperatures, the risk of respiratory illness increased by 40%. Researchers have also found that asthma-related emergency visits were associated with increased ozone concentrations.

4 Presenting Air Quality data

4.1 Air quality assessment

Standardised statistical analysis should be performed to assess air quality trends, changes in emissions or impact from specific types or groups of sources. The severity of the air pollution problem or the air quality should be specified relative to air quality guideline (AQG) or limit values, standards or pre defined levels of classification (e.g. good, moderate, unhealthy, hazardous).

The number of hours and days, or percentage of time when the air pollution concentrations have exceeded AQG values should be presented. This will also need minimum requirements of data base completeness. Long-term averages (annual or seasonal) should be presented relative to AQG. In the Norwegian surveillance programme the winter average values of SO_2 and NO_2 are presented on maps in percent of the national air quality guideline values. In Egypt annual average concentrations measured by a variety of measurement methods have been compiled into one graph showing the distribution of annual average concentrations over the country.

Air quality data are visualised in different ways based on different types of statistics. Some of the typical presentations may be:

- Time series and average concentrations,
- Cumulative frequency distributions, where the frequency distribution should be referred to air quality standards,
- Average concentration distributions at various monitoring sites as function of wind directions (Breuer diagrams or concentration "roses"),
- Scatter plots which can be used for interrelation between simultaneous air quality measurements, meteorological variables or other relevant data,
- Average concentration as function of time of day.

4.2 Time series

Before undertaking statistical evaluations the data should be presented and validated based upon a time series of raw data. These data must be evaluated logically to correct for drift in instruments, and eliminate data that are identified to be including errors. It is also important that the data are checked with other relevant information.

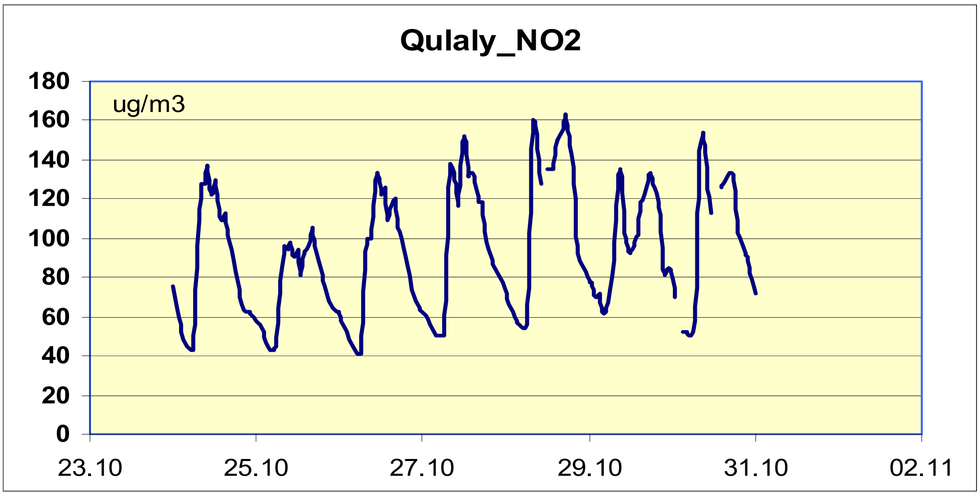

Figure 5: Time plot of NO_2 concentrations from Quolaly, Cairo, October 1999.

The time series shown above indicate clearly diurnal variations in the NO_2 concentrations measured along the streets of Cairo. Morning and afternoon rush hour traffic gives an increase of NO_x emissions. At daytime the ozone concentrations in ambient air will be sufficient to transform NO to NO_2 and we see high levels of NO_2 throughout the day.

From the modern on-line air quality monitoring system data can be transferred automatically to a central database for quality control, and immediately transferred to an Internet presentation page, where the authorities and the public may access data updated every hour. An example of a time plot of this kind is shown in Figure 6.

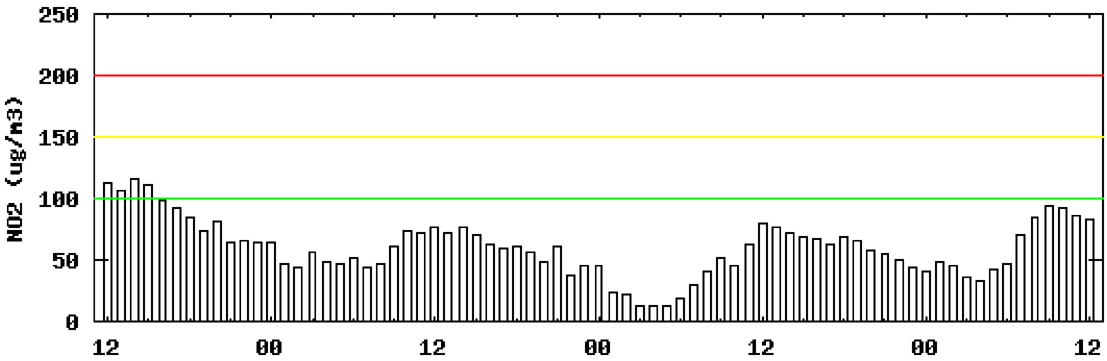

Figure 6: Hourly NO_2 concentrations measured at one of the sites in Oslo, Norway, 17-19 February 2002. The measured concentrations are compared to guidelines and limit values.

4.3 Annual average concentrations

A first indication of the air pollution level in an area may be seen in the presentation of annual average concentrations as presented in Figure 7. The annual average concentrations of SO_2 as measured at 9 locations in Egypt ranged from 18 to 105 μg/m^3 .

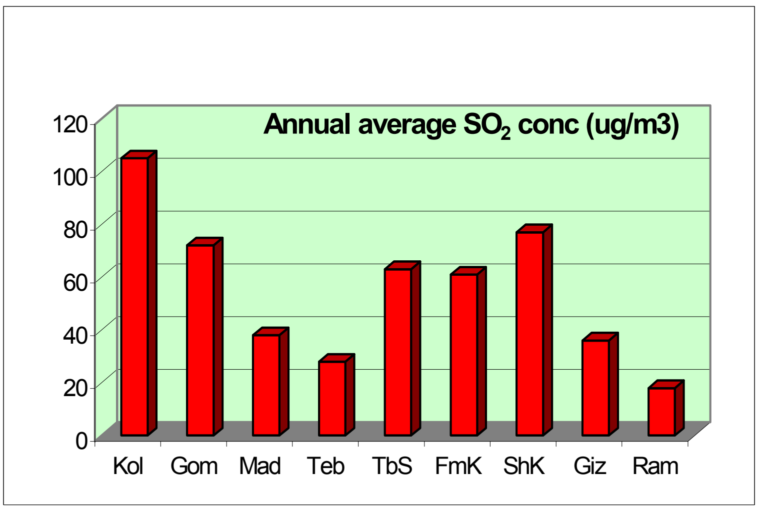

Figure 7: Annual average concentrations of SO_2 at 9 sites in Egypt (1998).

The levels exceeding 60 μg/m^3 (the Air Quality Limit value for Egypt) were found in the streets of Cairo and at some industrial sites. The SO_2 concentrations measured in the Alexandria area by sequential samplers during the last two months of 1998 were lower than in Cairo. A study has been initiated to investigate possible chemical reactions in the atmosphere, leading to a fast formation of SO_2 to sulphate.

4.4 The highest 1-hour average concentrations of SO_2 and NO_2

The maximum 1-hour average concentrations of SO_2 and NO_2 recorded during 14 months is presented in Figure 8. Again we have used measurements from Egypt as an example.

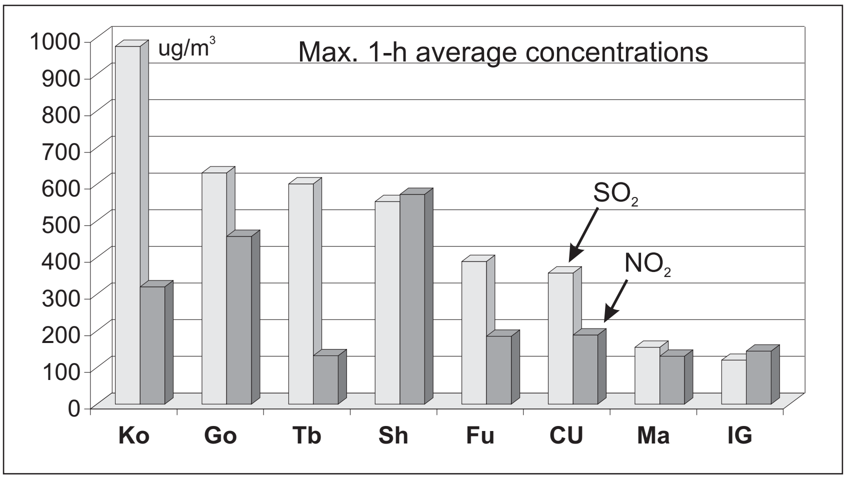

Figure 8: The highest SO_2 and NO_2 concentrations (□g/m^3) measured at 8 sites from January 1998 to April 1999.

The selection of the absolute highest 1-hour average concentration measured during the period is very sensitive to data quality assurance. Normally we will prefer to present the 95 percentile or the 99 percentile. However, for this analyses this information was not available.

The results show that 1-hour average concentrations were highest in the city centre of Cairo (El-Kolaly (Ko) and El-Gomhoriya (Go)) and at the industrial sites in Tebbin (Tb) and Shoubra El-Kheima (Sh). At all these sites the Air Quality Limit values were exceeded.

The highest NO_2 concentration was measured at Shoubra El-Kheima and at El-Gomhoriya Street in Cairo.

5 Air Quality statistics

To evaluate the average concentrations and discuss levels of impact as well as the frequency of exceedances, different statistical procedures may be applied and presented together with guidelines or limit values.

Some of these statistical procedures can easily be handled in a normal spreadsheet like Excel on a personal computer. Other objectives may need more advanced statistical programmes. At NILU the AirQUIS system has been developed to store data in the database, to access the data and to perform statistical analyses as a basis for presentation of results.

Examples of concentration frequency distribution and a scatter plot are shown in the Figure below.

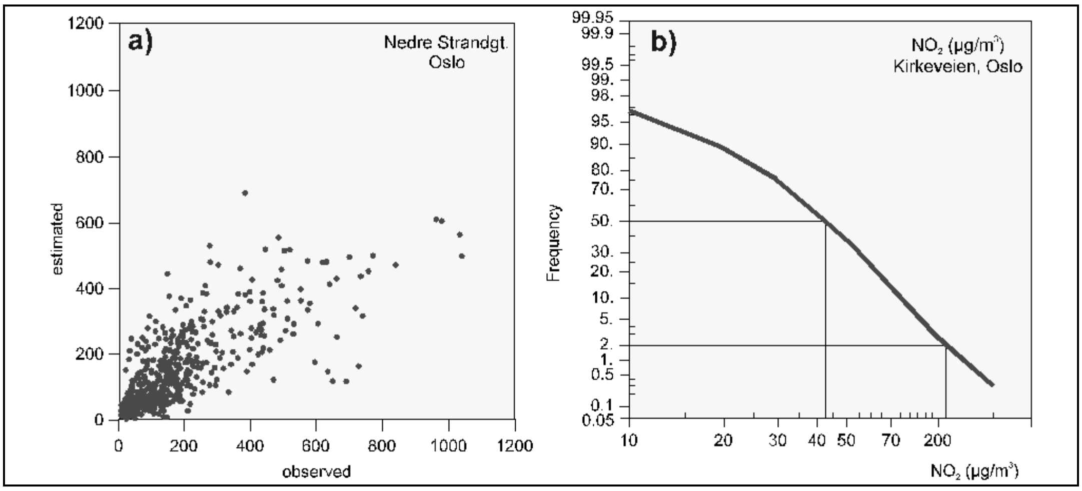

Figure 9: a) Scatter plot of estimated vs. observed data.
b) Cumulative frequency distribution of NO_2 concentrations.

5.1 Are air quality limit values exceeded?

Cumulative frequency distributions are used to evaluate how often Air Quality Limit values are exceeded. An example of a distribution of 1-hour average SO_2 concentrations at 8 sites in the Cairo area is presented in Figure 10. The curves show the frequency of occurrence of hourly concentrations exceeding the values given on the abscissa. The Air Quality Limit value of 350 $\mu g/m^3$ is indicated in the Figure below.

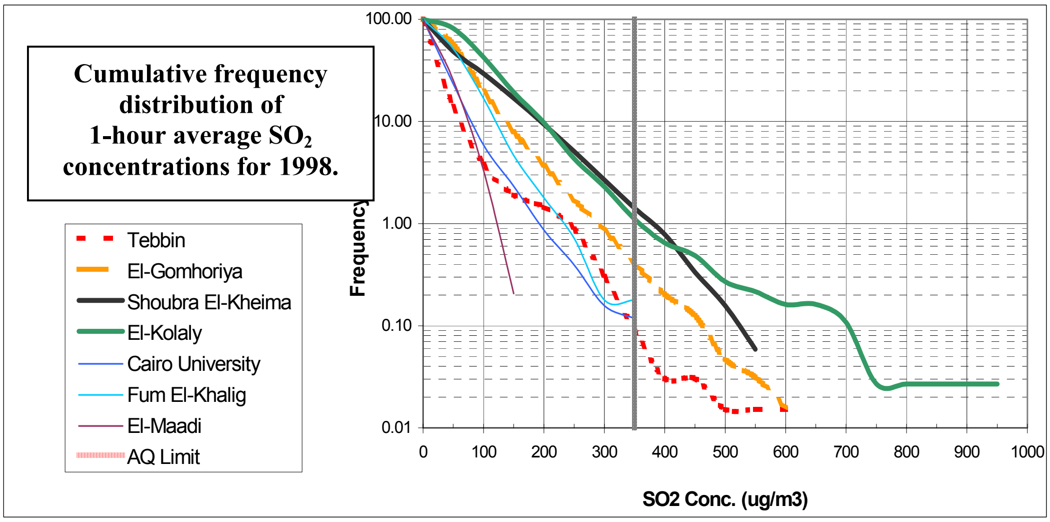

Figure 10: The occurrence of hourly SO2 concentrations exceeding values presented on the abscissa. All available data for the Cairo area 1998 has been used.

The Air Quality Limit value was most often exceeded at Shoubra El-Kheima (1,5% of the time) and at El-Kolaly (1%). El-Gomhoriya, Tebbin, Fum El-Khalig, Giza and Tebbin also had a few exceedances of the 1-hour average Air Quality Limit value.

5.2 The Breuer Diagram

To evaluate the importance of different sources on the measured air quality, air pollution concentrations can be combined with meteorological data. The "concentration rose", also called a Breuer Diagram, is handy when investigating the impact of specific sources located in a certain direction from the measurement site. These analyses will give the average concentration as a function of wind direction. An example of a "concentration rose" is shown in Figure 11.

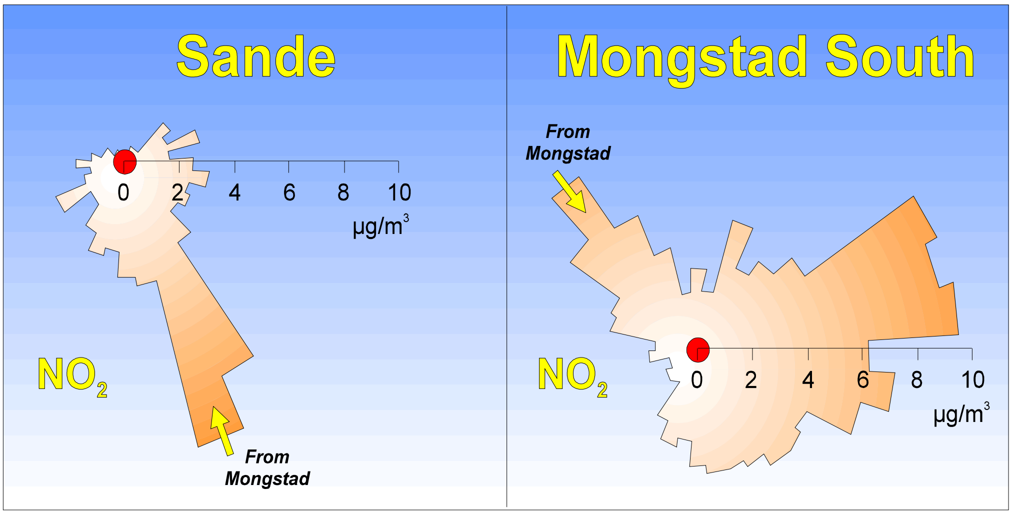

Figure 11: "Concentration rose", (Breuer diagram) established for two measurement sites at an oil refinery.

At the site Sande we can see that the highest average concentration occurred when the wind was blowing FROM south-southeast. There is definitely a source of NO_x, as a refinery is located 3 km from the site in this direction. The high impact of NO_2 from around east at Mongstad South is due to traffic along a road passing close by the site in this direction.

5.3 Meteorological data

To produce a Breuer diagram as presented above it is necessary to have access to meteorological data. Different procedures are available to examine the quality and representativeness of meteorological data.

The most commonly used methods are:

- Time series of selected meteorological variables,
- Wind roses (wind direction frequency distribution),
- Different types of frequency distributions,
- Joint frequency distribution to establish the relationships between wind direction, wind speed, atmospheric stability and/or other variables,.
- Different types of scatter plots to establish connections between different parameters collected at the same site or at different measurement sites,
- Frequency distribution of stability or other meteorological data as a function of time of day and time of year (seasonal)

The presentation of measured meteorological data is of great importance to understand the physical properties of the local atmospheric conditions. A presentation of any kind of data is helpful to visualise to the user the most important features of the data and of the meteorology and climatology of the area. It is therefore important to choose a representative tool.

Results from wind measurements are usually presented in the form of frequency distributions. Frequency distributions are either presented as matrixes (wind speed versus wind direction) or as wind roses. Wind roses are used to visualise the frequency distribution of wind speed versus wind direction for different measurement stations

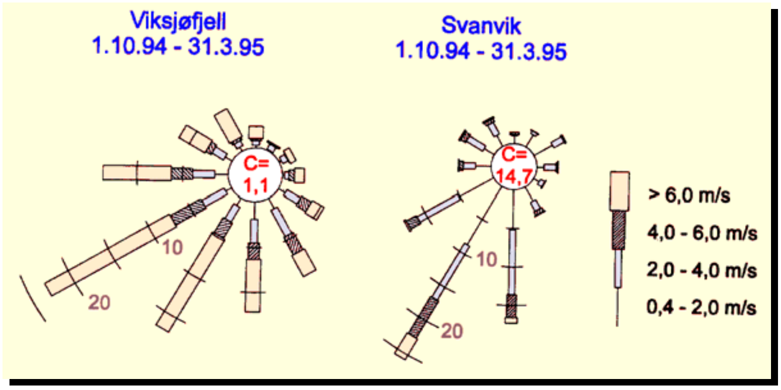

Figure 12: Wind roses for two different measurement sites; Viksjøfjell at a hill top (low friction), Svanvik in a valley (high surface roughness).

The thermal stability of the atmosphere is an important factor for the vertical dilution of air pollution. The stability is measured as the vertical temperature gradient of the atmosphere, and is also a measure of thermally induced turbulence. The turbulence is given by the small-scale fluctuations in the wind and is a measure for the dilution of air pollutants.

The atmospheric stability in this example is measured as the temperature difference (DT) between two levels at a tower and divided into 4 classes. Each of these 4 classes indicate the stability of the atmosphere and hence, the vertical dilution of air pollutants. The classes are:

Unstable	$\Delta T \leq -0.5\ ^oC$
Neutral	$-0.5\ ^oC < \Delta T \leq 0.0\ ^oC$
Light stable	$0.0\ ^oC < \Delta T \leq 0.5\ ^oC$
Stable	$0.5\ ^oC < \Delta T$

Neutral atmospheric stability (often characterised by strong winds and cloudy conditions) and unstable atmospheric stability usually results in good dispersion of air pollutants emitted into the atmosphere

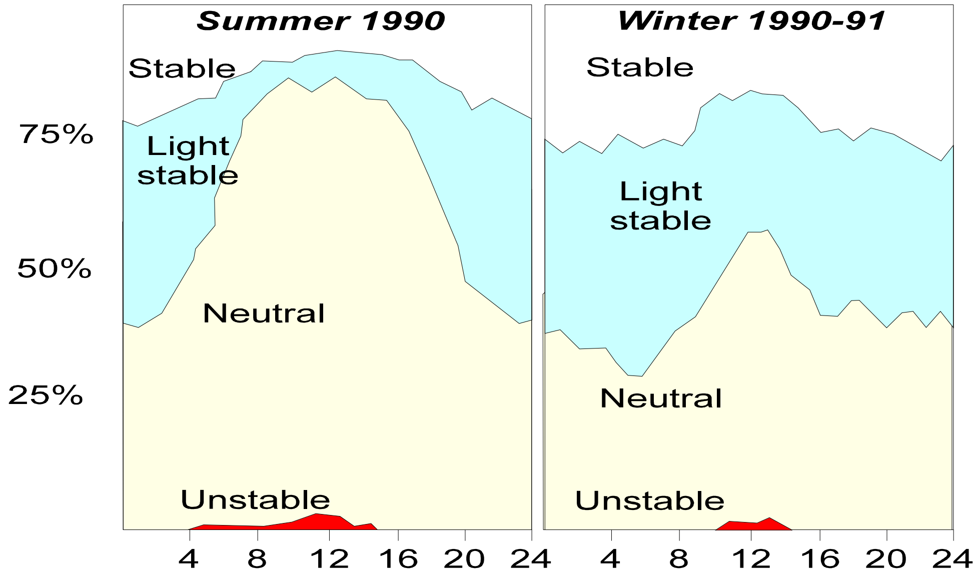

Figure 13: Frequency distribution of the four stability classes during the summer and winter season. (Sivertsen et al. 1991).

During night-time and winter when there is a net outgoing radiation from the earth, the ground cools off rapidly resulting in cold air at the surface and a temperature increase with height (light stable /stable or inversions). An inversion layer is formed, and the dispersion of pollutants is suppressed.

5.4 Trend analyses

To present trend analyses and air pollution variation over time, box plots have been developed to include average concentrations as well as percentiles and peak values.

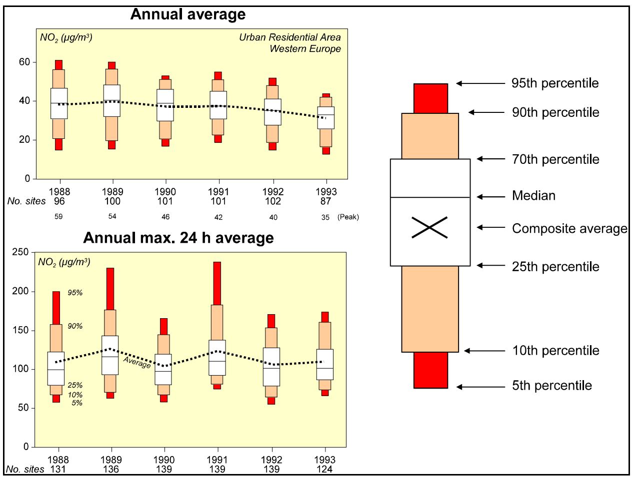

Figure 14: An OECD trend analysis presenting annual NO_2 data (average and max. 24 h average) from 1988 to 1993 from up to 139 measurement sites in Western Europe. (Sivertsen 2000).

The box plot represents a uniform method for pollutant specific (indicator) air quality trends reporting. It increases the comparability; it can present national or international wide trends and represents a standardised reporting procedure.

Box plot diagrams have been generated for several combinations of regions, site categories and defined pollutant indicators. In cases of insufficient monitoring sites, or unavailability of data, the establishment of trend can be difficult.

Bar charts can also be used to generate urban peak statistics. The bar charts show the highest, composite average and lowest values of annual maximum values for each defined indicator as segments of a bar. The bar chart may represent all recorded data by monitoring sites located in the city or in a country.

5.5 Spatial distributions

Different statistical analysis of calculated concentrations can give additional information of the air pollution distribution for areas where measurement data are not available. This is usually done with the same type of statistical methods as mentioned above.

Special statistical analysis of comparison between measured and calculated parameters is available. Different interpolation routines are available for handling of measured data in a grid. One such method, which is frequently applied, is kriging - an interpolation of measured concentrations in a grid. (Grønskei et al. 1993)

When a large number of measurement site data are available it is possible to present a spatial concentration distribution based upon statistical averaging procedures. Such a distribution is shown in for a weekly average SO_2-concentration distribution based upon measurements with passive samplers in Cairo.

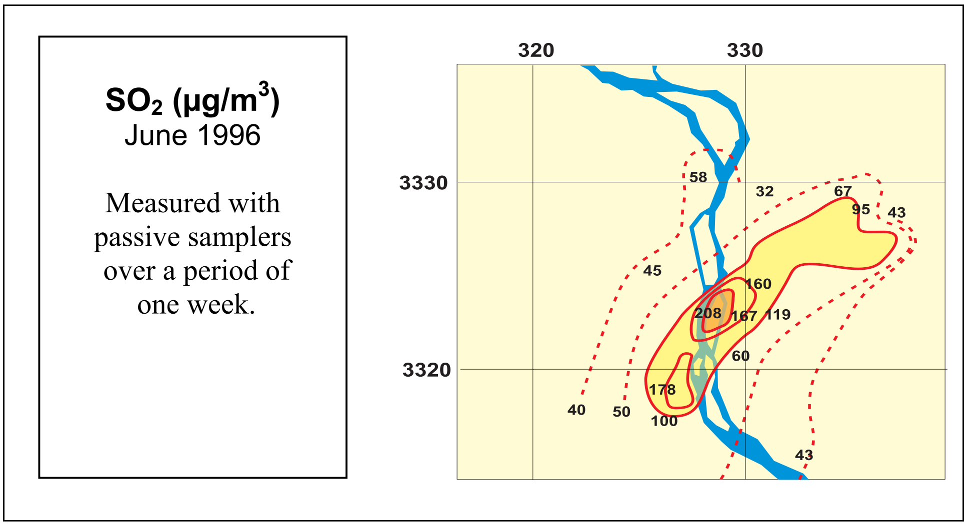

Figure 15: SO_2 concentration distribution for Cairo, based upon one-week measurements with passive samplers, June 1996. (Sivertsen 2001a).

5.6 Diurnal variations

The indicators generated from traffic, such as NO_x, SO_2 (diesel buses) and CO, show strong diurnal variations when measured in streets or close to roads. Figure 16 shows an example of the CO concentrations as a function of the hour of the day at El-Gomhoriya and at Fum ElKhalig, two streets in the city of Cairo. The concentrations represent the average for the whole year 1998 at each hour.

At both sites the CO concentrations were lowest at nighttime between 0200 and 0600 hrs. When the traffic increases in the morning, the levels are being doubled. It is temporarily being reduced in the afternoon, partly due to better movement of the traffic and improved dispersion conditions at daytime. In the evening we again see an increased in CO concentrations due to changes in atmospheric conditions and traffic. After sunset the surface layer stabilise, and an inversion causes accumulation of CO close to the surface.

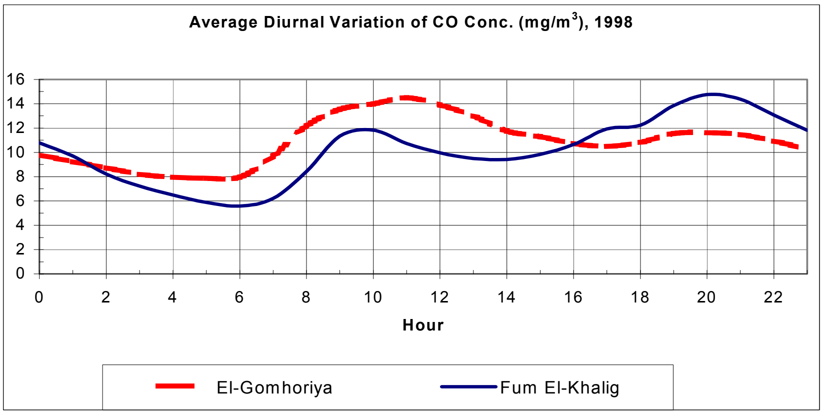

Figure 16: Average diurnal variation of CO concentrations (mg/m3) El-Gomhoriya and at Fum El-Khalig for 1998.

5.7 Air pollution episodes

To present and explain air pollution episodes a combination of air quality data and meteorological data is needed. Air pollution episodes have been recorded in many cities around the world. The background, sources and meteorological conditions may vary from one city to another. Locations, topography and latitude will also influence the type of air pollution episode experienced.

To use Cairo as an example again, the episodes here are results of specific meteorological conditions combined with air pollution created by several ground-based sources. Millions of people experienced very high levels of pollutants during these episodes. The main sources are traffic, open-air waste burning and a large number of small enterprises releasing air pollutants near the surface. Low wind speed conditions combined with stable atmospheric conditions created the problem.

During such episode at the end of October 1998, the winds were blowing from around north during the whole period. At night the winds weakened to become almost calm conditions at the surface level. In addition cooling of the air at the surface gave rise to temperature inversions, which put a lid above Cairo, hindering air pollution to be diluted in the atmosphere.

During these relatively cool nights wide spread burning took place at the surface. Smoke was observed both from local waste burning, burning of rubbish, from various types of fires and from small industries burning rubbish, tires and mazoot. Hundreds of small private industries contribute in this way to an undesirable high pollution level, giving rise to health impacts.

During another episode in November 1999 it was clear from international weather maps that a front system passed over Cairo during the day on 20 November 1999. Very low wind speeds, less than 1 m/s, were recorded during the afternoon at stations inside and south of Cairo. The wind was slowly moving from southerly directions until about 16:00 hrs, when (a cold front?) changed the wind to blow from northerly and easterly directions.

A dark layer of pollutants was observed under about 300 m above the surface, covering large areas of Cairo.

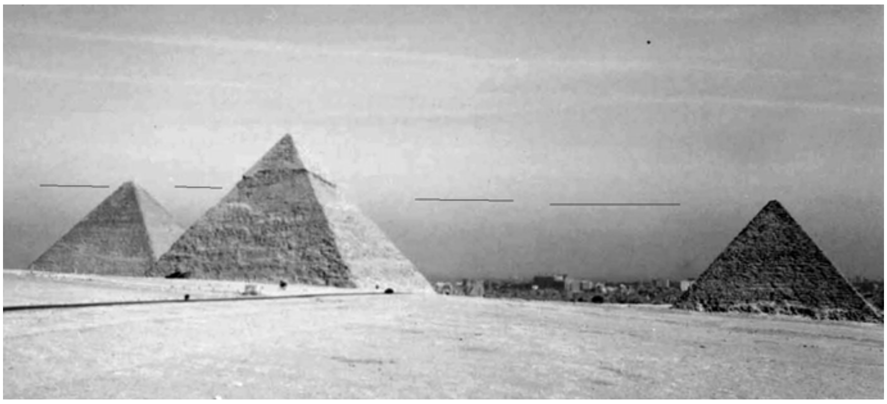

Figure 17: The photo taken from the Giza plateau 20 November 1999 at 16:00 hrs show a dark cloud covering the bottom layer of the atmosphere over Cairo.

The analyses of data from central Cairo; El-Gomhoriya indicate that the highest concentrations of NO_2 and PM_{10} occurred during the southerly winds before noon.

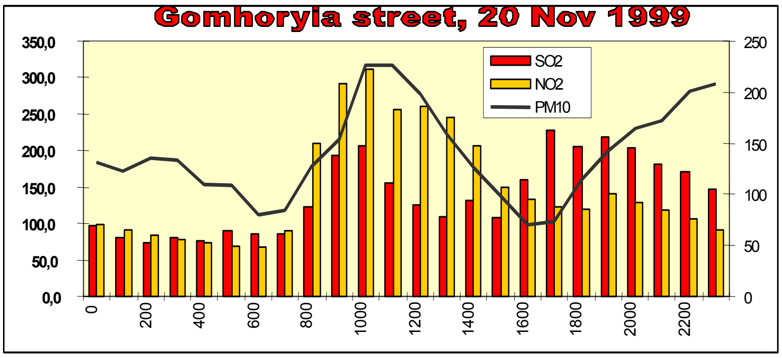

Figure 18: The concentration of SO_2 , NO_2 and PM_{10} at one of the Cairo sites during an episode in November 1999. (Sivertsen 2001b).

To explain the impact of temperature inversions together with low and variable winds, let us look at the episode that occurred on 23 October 1999. A major high-pressure area was covering the Middle East area and southern part of Russia on 23 October 1999. Another high-pressure area was located on the Sahara dessert setting up the usual northerly winds across Egypt. Between these high-pressure areas, smaller low pressures with frontal systems were moving eastwards across the Mediterranean Sea, north of Egypt

Subsidence of air in the high pressure caused the formation of a temperature inversion in the lower atmosphere, which created a “ceiling” on the Cairo air mass.

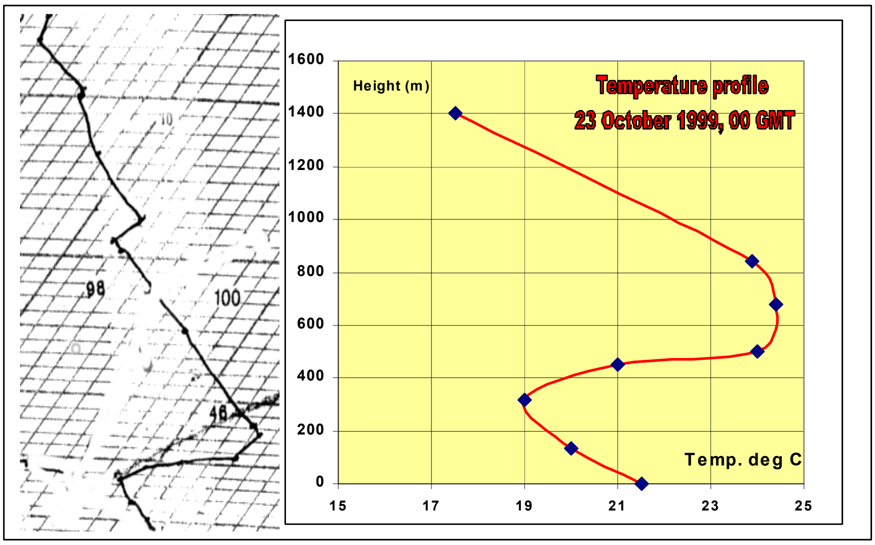

Figure 19: A strong inversion (ceiling) can be seen above the Cairo atmosphere at a height of about 300-400 m above the ground. All vertical dispersion of air pollutants is caught up by this inversion

Open air waste burning has been observed in several areas of Egypt. This type of burning at large waste collection areas may create considerable health impact to the population. Presently no measurements have been performed of PAH (polycyclic aromatic hydrocarbons) and dioxins downwind from these sources.

6 References

EU (1996) Council Directive 96/62/EC of 27 September 1996 on ambient air quality assessment and management (Framework Directive) (Official Journal L296, 21.11.1996, p. 55-63).

EU (1999) Council directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air. *Official Journal L 163, 29 June 1999*, 41-60.

Grønskei, K., Walker, S.E. and Gram, F. (1993) Evaluation of a model for hourly spatial concentration distributions. *Atmos. Environ*., *27B*, 105-120.

Gryning, S.E., Holtslag, A.A.M., Irwin, J.S. and Sivertsen, B. (1987) Applied dispersion modelling based on meteorological scaling parameters. *Atmos. Environ*., *21*, 79-89.

Sivertsen, B. (1998) DANIDA/EIMP. Air quality monitoring programme. Annual summary report 1997. Kjeller (NILU OR 2/98).

Sivertsen, B. (1999) DANIDA/EIMP. Air pollution in Egypt. Status after the first year of EEAA/EIMP measurements. Kjeller (NILU OR 33/99).

Sivertsen, B. (2000) Understanding air quality measurements. Kjeller (NILU TR 4/2000).

Sivertsen, B (2001a) Passive sampling of SO_2 and NO_2 ambient air concentrations in Cairo, October 2000. Kjeller (NILU OR 16/2001).

Sivertsen, B., Ahmed Aboud El Seoud, Hebatalla Fathy and Haytham Ahmed (2001b) Air pollution in Egypt. *Presented at the 12th World Clean Air & Environment Congress, 26-31 August 2001*, Seoul, Korea. Kjeller (NILU F 2/2001).

Sluyter, R.J.C.F., ed. (1995) Air quality in major European cities. Part I: Scientific background document to Europe’s environment. Bilthoven/Kjeller, RIVM/NILU (RIVM report ; no. 722401004).

WHO (1987) Air quality guidelines for Europe. Copenhagen, World Health Organization, Regional Office for Europe (WHO Regional Publications, European Series No. 23).

WHO (2000) Guidelines for air quality. Geneva, World Health Organization (WHO/SDE/OEH/00.02).