Conseil Exécutif des Transports
Urbains de Dakar (CETUD)
Route de Front de Terre, B.P. 17 265 Dakar–Liberté
Tél. n°(221) 859 47 20 - Fax n°(221) 832 47 44
E-mail.: cetud@telecomplus.sn

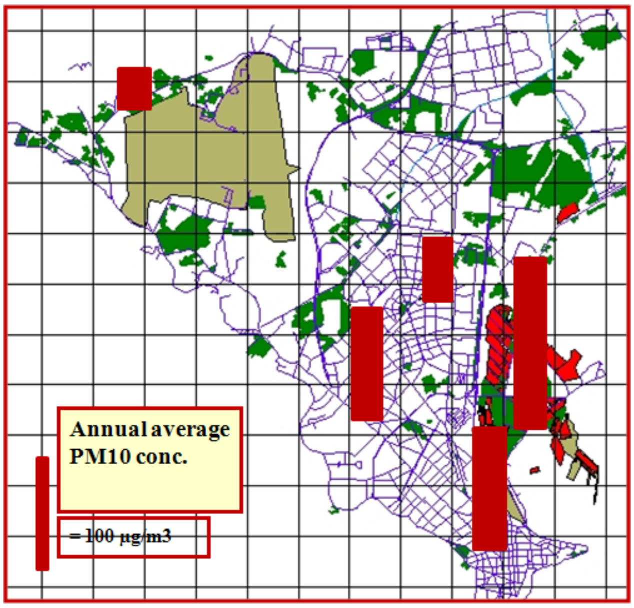
Norwegian Institute for Air Research
P.O. Box 100, N-2027 Kjeller, Norvège
Tél. n°(47) 63898000 – Fax n°(47) 63898050
e-mail: cbg@nilu.no

FINANCEMENT: **Fonds Nordique de Développement**	**Rapport de projet**	QA DAK

Projet:	ASSISTANCE TECHNIQUE A LA MISE EN PLACE DU LABORATOIRE CENTRAL ET DES STATIONS DE MESURES POUR L'AMELIORATION DE LA QUALITE DE L'AIR EN MILIEU URBAIN DE DAKAR
Contrat:	No 003/C/FND/05

Reporting air quality in Dakar, Senegal

Bjarne Sivertsen



REPORT NO:	10 a
CONSULTANTS REFERENCE:	OR 18/2010 (O-105010)
REV. NO:	Version 1 (18 Jan 2010)
NAME OF TASK:	Task 10 Dissemination and reporting
ISBN:	978-82-425-2194-1

Summary

The objectives of establishing the complete Air Quality Management System in Dakar has been to obtain a better understanding of the urban air pollution as prerequisite for finding effective solutions to air quality problems and for sustainable development of Dakar's environment.

The Norwegian Institute for Air Research (NILU) has developed the air quality monitoring and management programme for Dakar, Senegal. Part of this project involves the development of templates for reporting of the air quality based on measurements of air pollution and meteorology.

The examples of reporting procedures presented in the present report are strictly limited to the reporting of measurement results. Templates are presented for:

- Daily and weekly reports
- Monthly data reports
- Quarterly assessment reports
- Annual "State of the environment" report.

The templates indicate typical content with different examples of presentations, air quality statistics and figures and tables prepared in order to assess the air quality in Dakar. Similar procedures are being used by different authorities worldwide.

Contents

1 Introduction

The Norwegian Institute for Air Research (NILU) has been developing the air quality monitoring and management system for Dakar, Senegal.

Part of this project involves the development of templates for reporting measurements of air quality and meteorology.

This report gives examples of typical contents for:

- Daily and weekly reports
- Monthly data reports
- Quarterly assessment reports
- Annual “State of the environment” report.

Daily “reports” may be generated through Internet presentations based on simplified Air Quality Index generators. This report is presented on-line as a service to authorities and to the public.

A weekly internal report is only produced for internal use in order to have a basis for correcting data. The data collected and evaluated here will not be presented outside the expert group working at the monitoring centre at CGQA.

The Monthly Report will be a technical and scientific report describing the operation of the monitoring stations in detail. It describes the data capture, irregularities of instrument operations in addition to detailed statistics and graphical presentation of the measurements addressed to be used by technically experienced and trained personnel.

The Quarterly Assessment Report is meant to be a summary for outside users and the authorities to give a short and concise description of the air quality levels in Dakar. Average concentrations and number of exceedings compared to national air quality standards and international air quality guidelines should be given. A summary of statistics prepared for the monthly reports may be summarised in the quarterly report. The monthly report may include a limited amount of statistics and assessment as this will be prepared and presented as part of a quarterly report.

The annual summary (state of environment) report will present a short summary based on the results of the monthly and quarterly reports. This report will give a general and user friendly presentation to be disseminated to the public and placed on the web for downloading. The annual report should give annual averages, trends and general descriptions of the last year in a user friendly way

This report gives examples of presentations of annual averages, trends, statistical evaluations, wind- and concentration roses used by authorities worldwide.

2 Daily and weekly reports

Daily reports of the air quality in Dakar may be needed on request from the central Environmental Authorities. This will particularly be the case when an Internet site for air quality information has been developed.

We suggest that the daily reports to be produced will contain a short statement on the general air quality of Dakar. A table should show the highest concentration during the last day as well as the concentration during the last hour (at data retrieval).

An air quality index (AQI) value will be developed automatically based on measured concentrations and the national limit values for Senegal (see specific attachment).

2.1 Air Quality Index (AQI) developed for Dakar

The daily reports of the air quality in Dakar as shown above are using the air quality index (AQI) for characterising the air quality through simple index values. The approach has been tried in a simplified form through a classification scheme linked to the development of air quality forecasts. A first classification for the Dakar air quality was based on only measurements of PM_{10}. We recommend that the AQI system developed for Senegal is harmonised and used in the future for classifying the air quality, especially in Dakar, in an objective and systematic way.

The purpose of the AQI is to help you understand what local air quality means to your health. To make the AQI as easy to understand as possible, the AQI scale was divided into four categories, shown below:

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
When the AQI is in this range:	*...air quality conditions are:*	*...as symbolized by this color:*
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 200	Unhealthy	Orange
>201	Very unhealthy	Red

Each category corresponds to a different level of health concern. For example, when the AQI for a pollutant is between 51 and 100, the health concern is “Moderate.” Here are the six levels of health concern and what they mean:

- **“Good”** The AQI value for your community is between 0 and 50. Air quality is considered satisfactory and air pollution poses little or no risk.
- **“Moderate”** The AQI for your community is between 51 and 100. Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of individuals. For example, people who are unusually sensitive to ozone may experience respiratory symptoms.
- **“Unhealthy”** Certain groups of people are particularly sensitive to the harmful effects of certain air pollutants. This means they are likely to be affected at lower levels than the general public. For example, children and adults who are active outdoors and people with respiratory disease are at greater risk from exposure to ozone, while people with heart disease are at greater risk from carbon monoxide. Some people may be sensitive to more than one pollutant. When AQI values are

between 101 and 200, members of sensitive groups may experience health effects. With AQI values between 151 and 200 the general public may begin to experience health effects, while members of sensitive groups may experience more serious health effects**.**

- **“Very Unhealthy”** AQI values above 201 trigger a health alert, meaning everyone may experience more serious health effects.

2.1.1 How is the Air Quality Index Calculated?

An index, AQI, for any given pollutant is its concentration expressed as a percentage of the relevant limit value or standard:

$$\boxed{\mathrm{AQI} = \frac{\text{Pollutant concentration}}{\text{Pollutant limit value}} \times 100}$$

An index value greater than 100 means the pollutant has exceeded the relevant air quality limit value or standard. Air quality limit (AQL) values are available for Senegal, and will be used as a basis for the AQI.

To assess the overall air quality at a particular monitoring station, an index is calculated for each measured pollutant. The maximum of these figures is taken to be the Air Quality Index for that monitoring station as it represents the worst of the pollutants measured. The worst site is then used to summarise the air quality of Dakar

2.2 Weekly report

The weekly report is a plain data report presenting all air quality indicators in graphical form. Based on these graphs the QA/QC responsible expert should evaluate the quality of the data and perform necessary corrections.

Weekly data graphs could be collected in a folder with written remarks and comments in order to enable a revisit when or if odd features in the final statistics appear.
An example of two weeks of data for PM10 is presented in Figure 1 below. These data seem to be okay. The diurnal variations as well as the range of concentrations between 40 and 270 µg/m3 seem to be relevant.

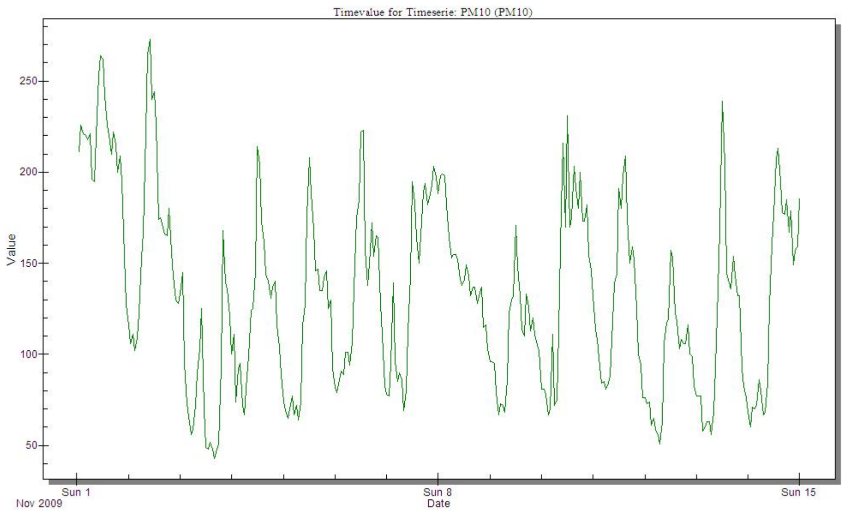


Figure 1: Two weeks of “raw data” of PM10 from BelAir station November 2009.

A look at NO2 data from Yoff station in November have been added to obtain a monthly graph as seen in Figure 2.

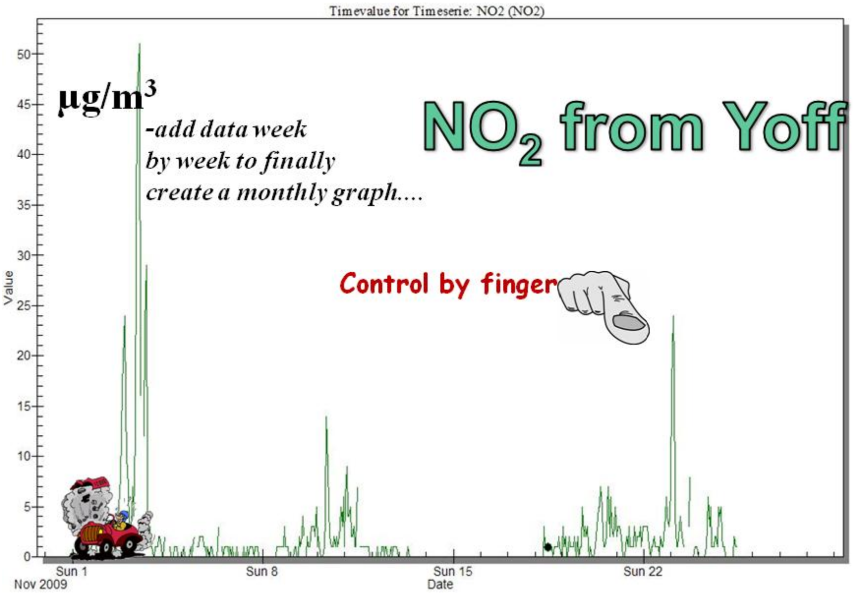


Figure 2: Evaluated NO2 data from Yoff for November 2009.

The data have been "controlled by finger", and evaluated based on experience. Three short lasting peak concentrations have been discussed. They are at this point not taken out of the data as long as there may be local sources in the area.

We investigated the possibilities for real peak concentrations, and found that both short term traffic emissions from the road passing on the upwind side of the station, as well as random open air burning in the vicinity of the station could cause such peak concentrations.

3 Monthly reports

3.1 Introduction

The monthly report is the detailed technical and scientific report describing the operation of each station in detail. It describes the data capture, irregularities of instrument operation in addition to detailed statistics and graphical presentations of the measurements addressed to more experienced and trained personnel.

The monthly report should be a summary overview of the data, data quality and data availability. The report should also include summaries of the monthly average concentrations of all parameters (indicators) as well as exceeding of air quality standards..

The monthly report should include topics such as:

- Sites
- Maps
- Data quality
- Data availability
- Explain errors
- Graphs
- Simple statistics

3.2 Sites

Give a brief introduction of the monitoring stations including sites, positions and station types, as shown in Table 1.

Table 1: Site name, coordinates and station type: Example 1

#	Site name	Coordinates		Station type
		N	W	
1	Bd Republique	14deg 40' 14"	17deg 26'11"	Urban roadside
2	Medina	14deg 41'14"	17deg 26'54"	Suburban roadside
3	HLM4	14deg 42'37"	17deg 27'09"	Urban background
4	BelAir	14deg 40'50"	17deg 25'58"	Urban industrial rd
5	Yoff	14deg 44'51"	17deg 27'35"	Regional background

An alternative presentation of the positions is given in the next table where the co-ordinates are given in the UTM reference system.

Table 2: Site name, locations, coordinates and station type: Example 2

#	Locations	Coordinates		Station type
1	Bd Republique	N242946.6	E542222.0	Urban ,Near Road station
2	Medina	N242902.6	E542150.6	Suburban roadside
3	HLM4	N242902.6	E542150.6	Urban background
4	BelAir	N242902.6	E542150.6	Urban industrial and traffic
5	Yoff	N242902.6	E542150.6	Background station

The table here under in an example showing stations and compounds measured:

		Parameters							
	Site	SO2	NOx	NO2	PM10	PM2,5	O3	CO	Benz
1	Bd.Republique	X	X	X	X	X	X	X	
2	Medina		X	X	X			X	
3	HLM4	X	X	X	X		X		
4	BelAir	X	X	X	X	X			X
5	Yoff		X	X	X		X		

A map of the sites is presented in Appendix 3A.

3.3 Air Quality Standards for Senegal

A summary of air quality standards for Senegal together with WHO air quality guidelines is presented in the following table:

Pollutant	Averaging time	Maximum Limit Value	
		WHO	Senegal
Sulphur Dioxide (SO_2)	1 hour 24 hours Year	500 (10 min) 125 50	- 125 50
Nitrogen Dioxide (NO_2)	1 hour Year	200 40-50	200 40
Ozone (O_3)	1 hour 8 hours	150-200 120	- 120
Carbon Monoxide (CO)	1 hour 8 hours	30 000 10 000	- 30 000 (24h)
Particles <10 µm (PM10)	24 hours Year	50 * 20 *	260 80
Lead (Pb)	Year	0.5-1,0	2

3.4 Data Capture

Describe the data capture for the station and any irregularities.

The station operation has been good this month with a data capture of 90 % for all monitors except for one component, which was out of order for one week. The reason for this was that the instrument was taken for maintenance.

Data capture during the month is presented in the following tableL

		Parameter, November 2009							
	Site	SO2	NOx	NO2	PM10	PM2,5	O3	CO	Benz
1	Bd.Republique	30% OK	50% OK	50% OK	no	50% OK	Ok? low	low	--
2	Medina	--	No data	No data	Ok? >22nov	--	--	Low 22nov	--
3	HLM4	No !	miss	no	no	--	20% low	--	--
4	BelAir	30% OK ?	OK	OK	OK? > 26n	OK? > 26n	--	--	OK
5	Yoff	--	Low Ok?	Low Ok?	no	--	Low ?	--	--

Another example of data availability presented in percentage of total possible data capture is presented based on another project in the table below.

No.	Station Name	Parameter									
		SO_2	NO_2	CO	O_3	PM_{10}	H_2S	CH_4	BETX	Met.	Noise
1	Hamdan Street	87.8	96.3	68.6	---	99.4	---	0	0	100	66.6
2	Khadejah School	66.5	66.9	---	67.5	67.1	67.5	0	---	67.5	67.5
3	Khalifa School	99.6	94.3	---	100	74.5	99.1	0	---	100	33.8
4	Mussafah	100	92.7	---	---	99.6	100	0	---	100	0
5	Baniyas School	96.9	99.4	---	100	100	93.3	0	---	93.5	100
6	Al Ain Islamic Institute	94	0	---	100	99.7	91.4	0	---	99	100
7	Al Ain Street	0	85.4	83.2	---	99.9	---	0	98	100	100
8	Bida Zayed	93	0	---	0	99.3	97.9	0	---	97.1	100
9	Gayathi School	90.5	100	---	73.8	100	98.2	0	---	98	100
10	Liwa Oasis	92.4	78.7	---	98.2	100	---	0	---	100	100

A typical comment to the data capture overview could be:
The data capture for the components were all above 75% except for …..
<component>, where the data capture was <60 %. The reason for this was …

3.5 Results

The statistical evaluation of the measurement is given for the station should be divided into two parts meteorology and air quality. Meteorological data are important both for describing the general dispersion conditions and climate and as a support information in order to explain the air quality.

The combination of wind and air pollution concentrations may explain the impact of sources and which sources give the highest impact.

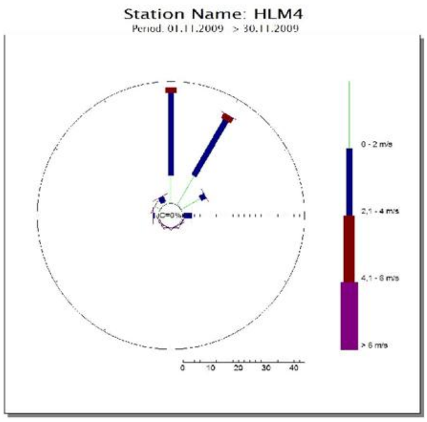
3.6 Meteorology

The prevailing winds were from northwest, which is normal for this time of the year. The wind speed was on average 3.2 m/s which lower than normal but the maximum wind speed was around 15 m/s which were higher than same month last year.

Statistics on meteorology, such as wind rose, wind speed vs. wind direction, and standard statistics on meteorological parameters measured such as (average, maximum and minimum values for the period.

Examples is given below.

Wind rose



The wind rose shows that the prevailing winds are from northerly directions.

Average wind speed per wind sector

This figure shows that the highest average wind speed occurs in the sector around northwest (270^0 – 330^0) with the highest averaged wind speed from west-northwest of 4.8 m/s.

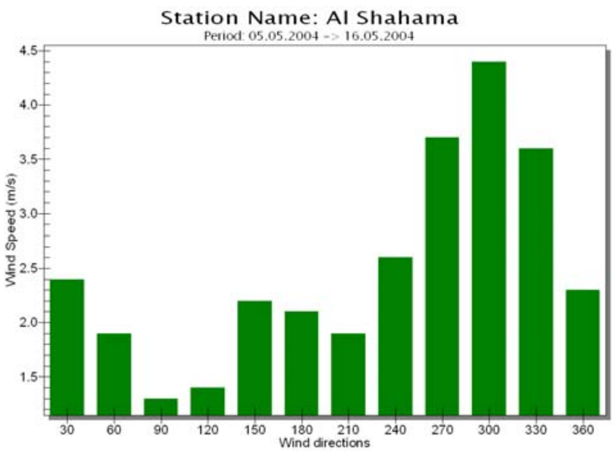


Figure 3: Average wind speed for each of twelve 30-degree sectors.

Diurnal variation of wind directions

This figure shows that the dominant wind direction during daytime is from around west-northwest with almost 100% occurrence from this sector around 1400. Similar, during night time and morning hours the prevailing wind is from around east-southeast with occurrence of above 30% in sector east-southeast (120^0 – 150^0) for the period 044 – 1000). This clearly describes the diurnal land-see breeze circulation.

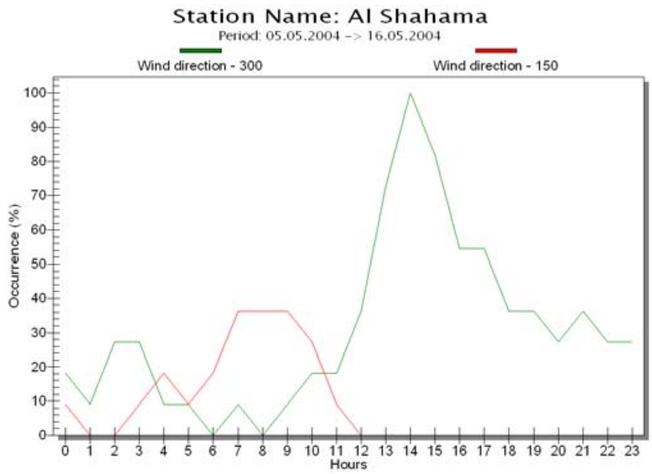


Figure 4: Daily variation of the two most prevailing wind sectors of onshore and shore winds

Temperature, relative humidity and barometric pressure.

The maximum and minimum temperature was 41.9 and 21.7 deg C, respectively. The average value was 30.2 deg C. The highest daily average temperature of 33.4 deg C occurred on Friday 14.

Parameter	Minimum	Maximum	Average
Temperature	21.7	41.9	30.2
Relative humidity			
Pressure			

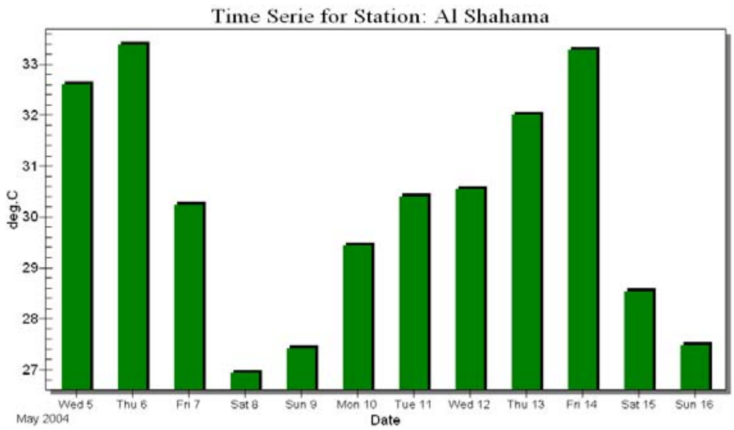


Figure 5: Daily averaged temperatures for the measuring period.

3.7 Ambient air quality

Some summary statistics of the air quality measured during this month is presented in the following.

The simplest overview could be presented in one Table where the following parameters are shown for each indicator at each of the monitoring stations:

- Data availability (%)
- The 98-percentaile concentration
- The maximum one hour average concentration
- The monthly average concentration

An example of such a table is shown in the table below.

Table 3: Summary of statistics of the air quality measurements during month 03-2005.

Variables	Sites	Total N	Valid N	%	98-Percentile	Max hour	Average 03-2005	Average 03-2004
PM10 µg/m³	BC	731	668	91.3	207.	248.	110.0	71.4
	QT	731	699	95.6	201	246	101.6	-
	TN	731	727	99.4	157	304.	52.0	67.8
	ZO	731	705	96.4	216	248	90.0	73.9
	D2	731	720	98.4	193	300	71.4	64.3
O_3 µg/m³	ZO	731	720	98.4	164	205	49.9	60.8
	DOSTE	697	669	95.9	147	199	44.7	3.6
	QT	731	721	98.6	195	246	68.4	43.0
	D2	731	721	98.6	181	215	53.4	44.4
	HB	731	726	99.3	127	190	41.6	37.4
CO mg/m³	BC	731	661	90.4	7.8	11	2.8	4.5
	HB	731	506	69.2	8.9	18	3.0	2.5
	DOSTE	696	622	89.3	10.9	15	4.3	-
	TN	731	730	99.8	10.1	16	2.9	2.7
NO_2 µg/m³	BC	731	664	90.8	92.8	128	44.0	37.8
	D2	731	723	98.9	39.9	70	16.7	13.5
	TN	731	373	51.0	37.7	148	34.5	74.8
	ZO	731	729	99.7	48.4	107	21.5	19.6
SO_2 µg/m³	QT	731	141	19.2	74.6	83	16.9	34.7
	TN	731	727	99.4	97.0	185	26.0	17.7
	D2	731	643	87.9	102.5	168	35.8	14.9

A summary of monthly average concentrations of the most important indicators may also be presented in a figure as shown below.

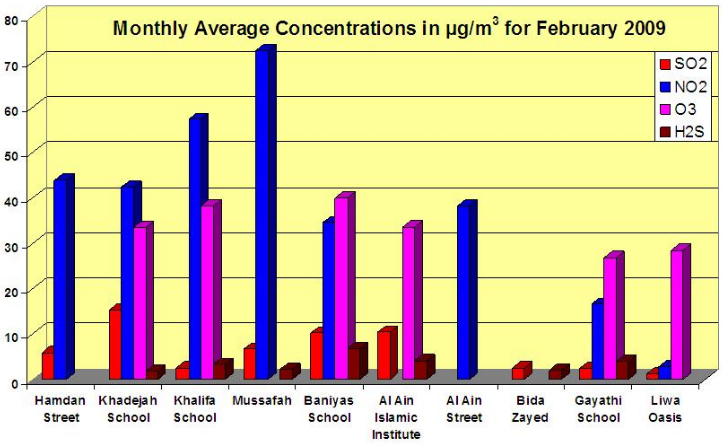


Figure 6: Monthly average concentrations of SO2, NO2, O3 and H2S at 10 monitoring stations.

3.7.1 PM_{10} concentrations

PM_{10} concentrations represent the highest air pollution load in Dakar compared to air quality standards and guidelines. Exceeding of limit values are frequently observed at all stations. The monthly average concentrations are presented in Table 3 above. The figure below shows 24-hour average PM10 concentrations for the month.

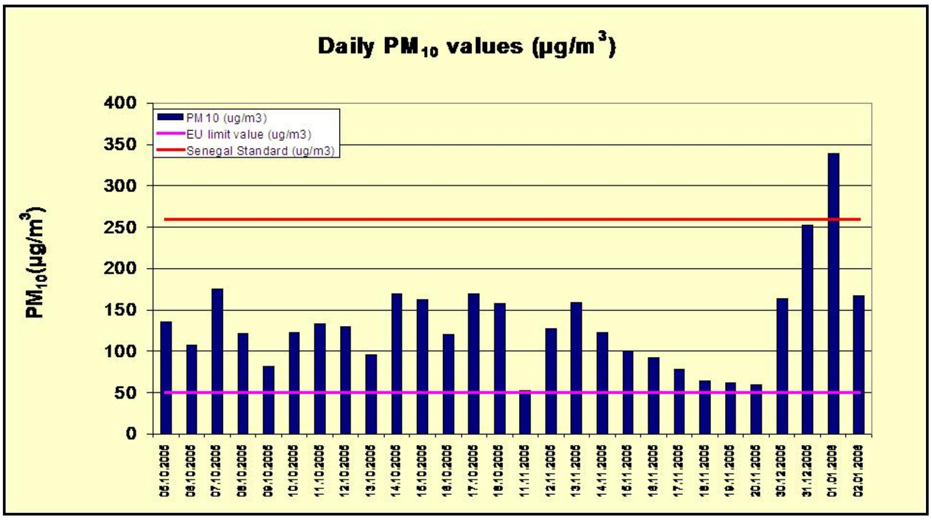


Figure 7: 24-hour average PM10 concentrations measured at Rue Carnot.

A similar presentation of daily average concentrations is shown for 4 measurement sites in the figure below.

These types of figures may give the best overview of the PM situation in Dakar.

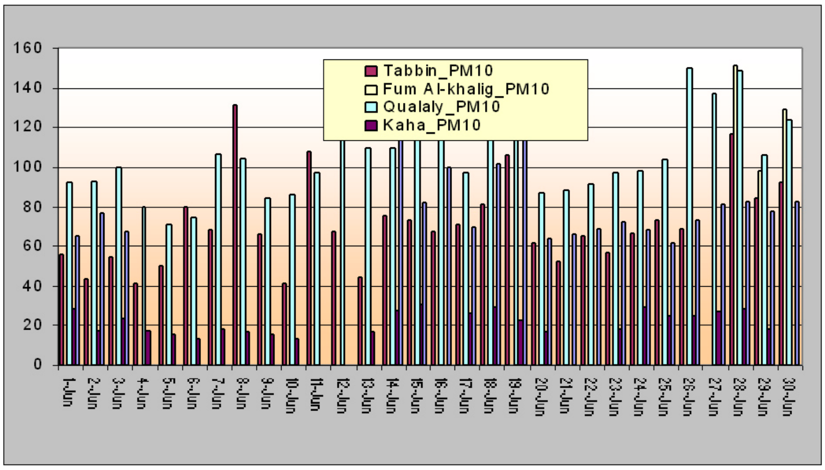


Figure 8: Daily average PM10 concentrations at 4 sites for measurements collected during one month.

The PM10 concentration measurements should be commented:

- The most polluted sites
- The day/period with highest concentration
- The reason for these high concentrations?

3.7.2 SO_2 concentrations

Monthly average concentrations are presented in the figure below for all monitoring stations. This figure is most interesting if there are many stations to report data from.

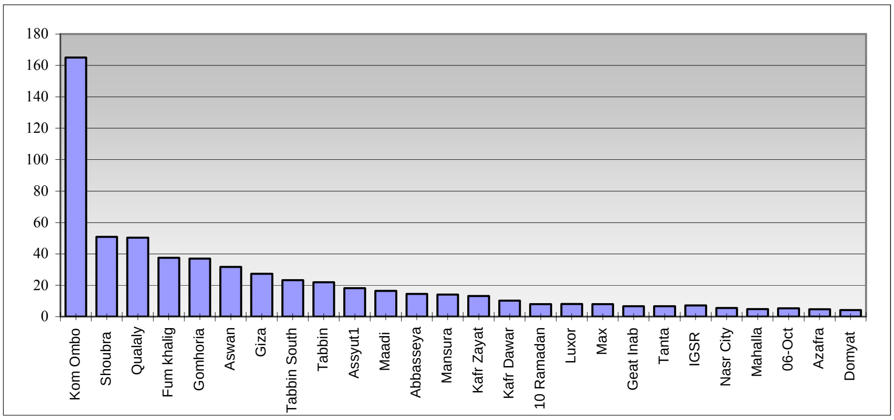


Figure 9: Monthly average SO2 concentrations at all sites in Egypt, June 2004

Comments to the figure above could be:
Exceedance of 60 µg/m^3 (annual average AQL) was found in at Komombo. The data from Maadi, however, has been questioned and is being studied in more details. The monthly average concentrations at Shoubra ElKheima and Quolaly were between 40 and 60 µg/m^3. The typical monthly average concentrations of SO_2 ranged between 30 and 50 µg/m^3 in the greater Cairo area.

It may be in this case also interesting to compare data from this month with results from previous months or earlier years.

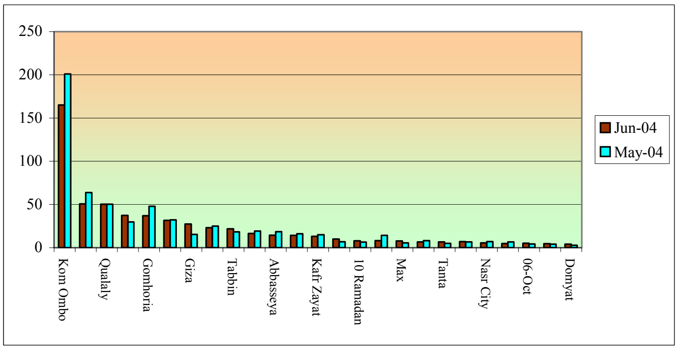


Figure 10: Monthly average SO2 concentrations measured in June 2004 compared to concentrations of May 2004.

Concentrations at the most impacted sites were all lower in June than in May 2004. The data from Shoubra, which normally is one of the most impacted sites, were not available in June.

3.7.3 NO_2 concentrations

NO_2 concentrations can be presented in the same way as for SO2 shown in the previous chapter.
Comments to the results should indicate that e.g. the average highest concentrations are measured along streets in the urban city centre, or downwind from large industrial sources.

The average diurnal variation of NO2 concentrations at the BelAir station as presented in the figure below indicates that a major source for this pollution originate from traffic. The highest concentrations of NO2 occurred during rush hour traffic.

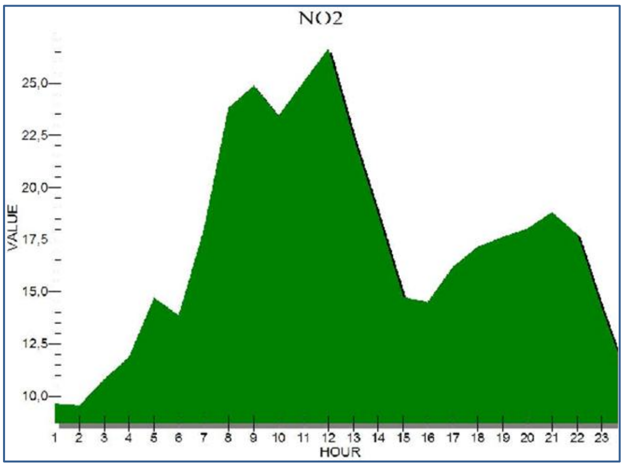


Figure 11: Monthly average diurnal variation of NO2 concentrations measured at the BelAir station in November 2009.

3.7.4 Measurements exceeded of Air Quality Standards

As a summary one table will be prepared presenting the number or frequency of pollution concentrations exceeding the air quality standards.

Example:

Number of exceeding of Air Quality Standards

Component	1 hour	8 hour	24 hour
Sulphur dioxide	0	-	0
Nitrogen Dioxide	0	-	-
Ozone	-	3	-
PM_{10}	-	-	1
$PM_{2.5}$	-	-	1
Carbon Monoxide	0	0	-

This summary table could be supported by a cumulative frequency distribution prepared for selected pollutants. For Dakar this may be especially interesting for suspended particulates measured as PM10 or PM 2,5.

An example of a cumulative frequency distribution of PM10 concentrations measured at BelAir during 1 to 15 November 2009 is shown in the figure below. The 24 hour average limit value for Senegal indicated at 260 µg/m3 is shown in the figure. A similar WHO guideline value of 50 µg/m3 has been violated 100% of the time. Even 150 µg/m3 was exceeded during about 35% of the time in November at BelAir.

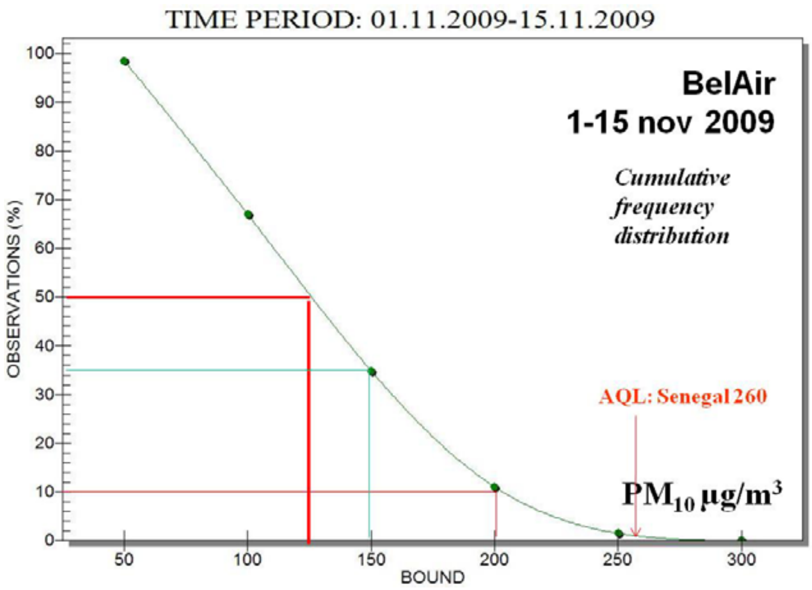


Figure 12: Cumulative frequency distribution for PM10 measured at BelAir during 1 to 15 November 2009.

3.8 Discussions

Discussion and explanation of specific episodes when air pollutants have exceeded the air quality standards or guidelines should be discussed.

How often was the standards exceeded?
Why did the air pollution concentrations of compound x exceed the national standard?

3.9 Conclusions

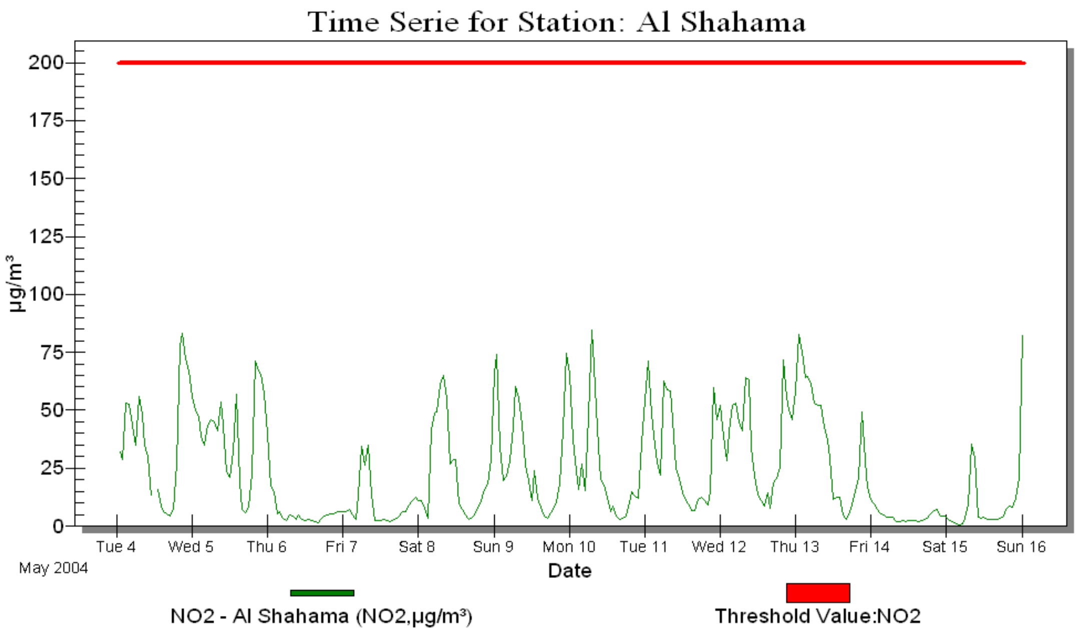
Short description of the main conclusions about meteorology (compared to long term statistics) and air quality (compared to standards and previous measurements).

3.10 Appendix 3A

<u>Measurement time series</u>

This appendix should be attached to the station monthly reports only.

Graphical presentations or table of the time series.
If plot, the comparable standard for one hour average should be presented.



4 Quarterly reports

4.1 Typical contents of the Quarterly report

The quarterly reports from the air quality monitoring network of Dakar should contain:

- Summary
- Introduction to the Monitoring Network
- The Data
- Network performance
- One Hour Average Data
- Daily and 8-hour Average Data
- Monthly Average Data
- Meteorological Data
- Exceeding standards
- Explain sources, Breuer diaggrammes
- Conclusions

The quarterly reports produced by the monitoring institutions have been used as part of the training in understanding the air pollution data collected. They were presented to the Monitoring Institutions again and some on-the-job training in data interpretation and data evaluation was undertaken.

4.2 Summary

The most important pollutant was PM10. We observed one specific high polluted episode in Dakar during this quarter. The air pollution episode was caused by emissions from traffic and from re-suspension of dust deposited on the ground surface. Some residential PM10 monitoring sites in the network recorded several days when the daily averaged concentrations exceeded the air quality standard.

There were no incidences of high concentrations of SO2, CO or NO2 where concentrations exceeded the air quality standards.

There were some days when the 8 hour averaged ozone limit values were exceeded. High concentrations of NO2 were recorded at BelAir.

4.3 Introduction to the monitoring network

The air quality monitoring network in Dakar consists of 5 automatic monitoring stations. The table below is showing stations and compounds measured:

		Parameters							
	Site	SO2	NOx	NO2	PM10	PM2,5	O3	CO	Benz
1	Bd.Republique	X	X	X	X	X	X	X	
2	Medina		X	X	X			X	
3	HLM4	X	X	X	X		X		
4	BelAir	X	X	X	X	X			X
5	Yoff		X	X	X		X		

The final selection of sites for the permanent monitoring of air quality in Dakar was decided during field studies performed on 28 February and 1 March 2006. An important part of the design has also been to clearly define the objectives of the air quality monitoring programme (see NILU OR 37/2006). The positions of the sites are presented in the map below.

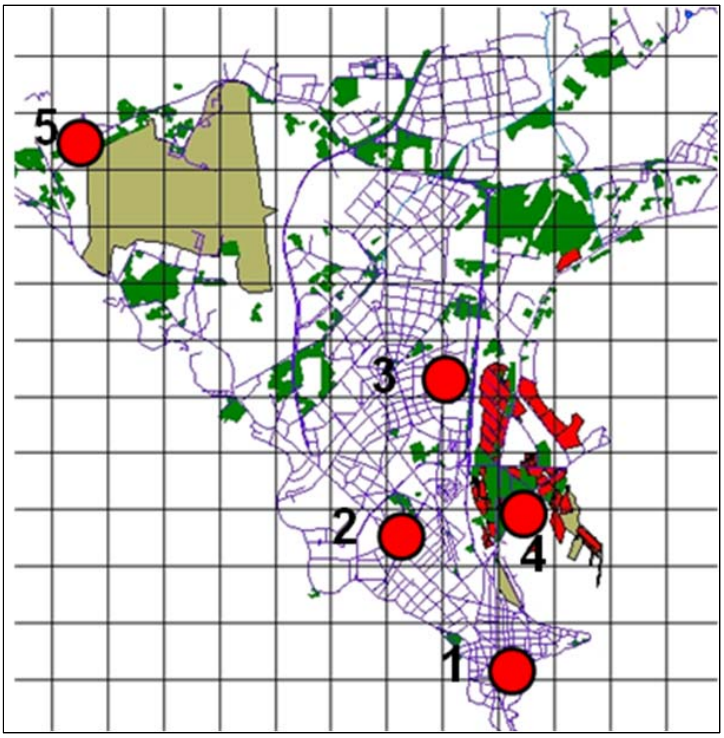


Figure 13: The five automatic monitoring stations are marked with red circles .

The classification of measurement stations is divided into 3 types of areas; urban, suburban and rural. In each of the areas there may be 3 types of stations; traffic, industrial and background. The background stations are divided into; near-city background, regional and remote background stations.

4.4 The Data

Data listings have been presented in monthly reports (ref!). Also some of the statistics have been prepared on a monthly basis and presented in some of the monthly reports.

Data quality and data availability have also been presented on a monthly basis.

The air quality in Dakar has been assessed and compared to the air quality limit values given by Senegal. (ref?).

The last version of these limit values are presented in the Table 4 below together with the World Health Organisation (WHO) guideline values.

Table 4: Air Quality limit values for Senegal and WHO guidelines.

Pollutant	Averaging time	Maximum Limit Value	
		WHO	Senegal
Sulphur Dioxide (SO_2)	1 hour 24 hours Year	500 (10 min) 125 50	- 125 50
Nitrogen Dioxide (NO_2)	1 hour Year	200 40-50	200 40
Ozone (O_3)	1 hour 8 hours	150-200 120	- 120
Carbon Monoxide (CO)	1 hour 8 hours	30 000 10 000	- 30 000 (24h)
Particles <10 µm (PM10)	24 hours Year	50 * 20 *	260 80
Lead (Pb)	Year	0.5-1,0	2

4.5 Network performance

Table 5 shows data capture rates for the criteria pollutants each network analyser during the measurement period. Low capture rates may be caused by repeated or prolonged analyser or logger breakdown, communications problems or interruptions in power supply.

Table 5: Analysers capture rates (%) for the present quarter.

Capture rate (%)	Particles PM10- PM2,5	Nitrogen Dioxide	Ozone	Sulphur Dioxide	Carbon monoxide
Blv Republique					
Medina					
HLM4					
BelAir					
Yoff					

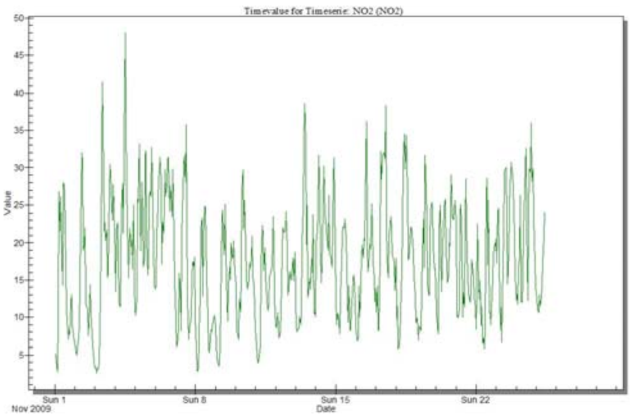
4.6 One Hour Average Data

One hour average data have been assessed for compounds/indicators where air quality standards are given for Senegal.

Nitrogen dioxide

NO2 concentrations never approached the limit values given by the Senegal government. Hourly concentrations of NO2 are presented in the Figure.

The highest 1-hour average concentration was 45 µg/m3, which is only 22 % of the air quality limit value given for Senegal.



Ozone (O3)

There were some days of exceedences of ozone recorded at three sites throughout the summer. The distribution of these days is illustrated in Figure

Peak hourly ozone concentrations appear during the early afternoon hours. The highest concentrations inside Dakar are shown at HLM4, while the concentrations outside the city as measured at Yoff station, the maximum ozone concentration was..xx µg/m3.

4.7 8-hour average concentrations

Average concentrations given for each “floating eight hour” is interesting when discussing impact of ozone and CO. The reason for this is that these indicators usually show strong diurnal variations with high daytime concentrations and low night time concentrations. The vegetation impact of ozone is of particular interest during the daytime.

4.7.1 8-hour average ozone concentrations

During daytime the 8 hour average ozone concentrations may reach the limit values and even exceed these. This is especially the case at Yoff station.?

4.7.2 8-hour average CO concentrations

The highest running 8-hour average concentration in Dakar during this quarter was measured at BelASir on dayxxx between 0800 and 1000 in the morning.

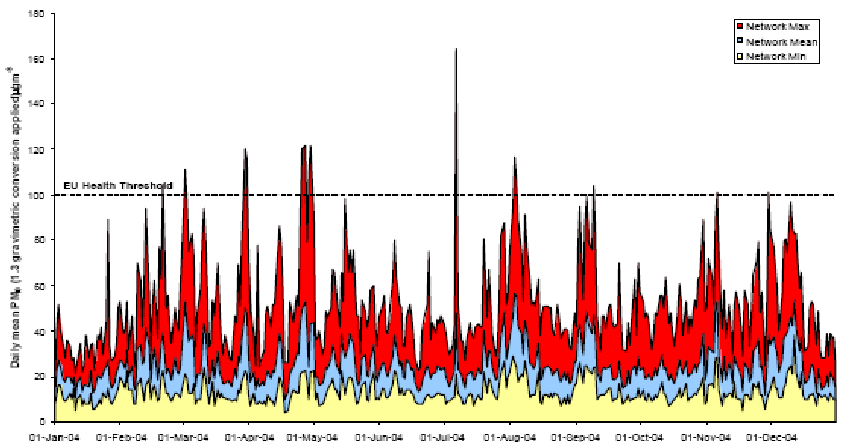
4.8 Daily average concentrations

The air quality standards for Senegal present limit values for averaging times of 24 hours for only two indicators: PM10 and SO2.
Daily average concentrations have therefore been estimated for these indicators and for PM2,5 in addition.

4.8.1 Particulates; PM_{10} and PM2,5

Some residential PM_{10} monitoring sites in the network recorded several days with exceedences of the daily averaged limit value. An example of the daily averaged PM_{10}-concentrations is given in the figure below.

Figure 1.4 Daily mean PM_{10} concentrations across the network during 2004 (TEOM sites only)



PM10 exceeded the daily limit value of 50 µg/m3 (WHO intermediate guideline value) during more than 50 % of the time.

4.8.2 Daily SO2 concentrations

The daily average SO2 concentration never exceeded the Senegal air quality limit value of 125 µg/m3. However, if we compare with the WHO guideline values we will find exceedances.

4.9 Average diurnal variations

Average diurnal variations of some selected pollutants are presented in order to explain the possible impact of changes in emission sources from hour to hour.

These changes may be typical for traffic sources, where rush hour traffic can impact on the concentrations of NO2 and CO.

The running 8-hour average CO concentrations are presented in Figure 14.

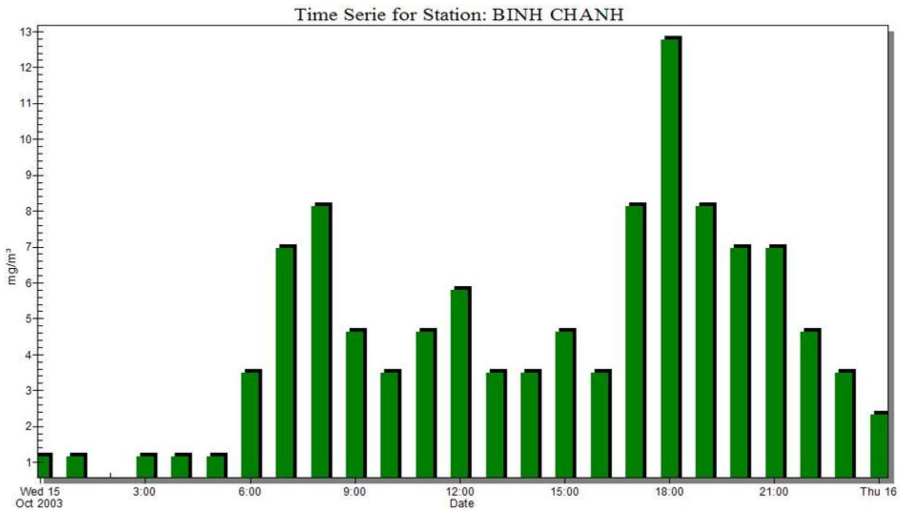


Figure 14: Running 8-hour average CO concentrations

The Figure above shows that high CO concentrations where reported during morning rush hours and especially in the afternoon and early evening.

The reason for these high evening concentrations is rush hour traffic jam combined with stable atmospheric conditions (inversions) after sunset.

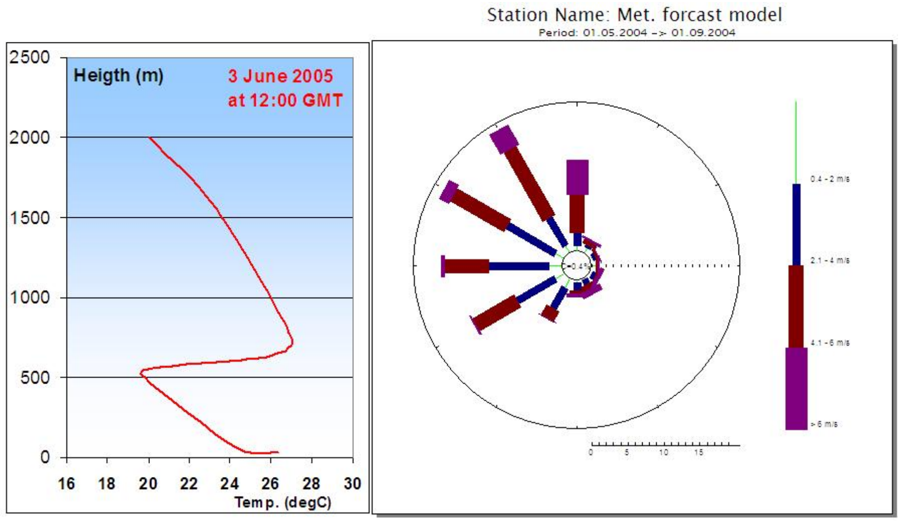
4.10 Summary of monthly average concentrations

The table below presents an example of monthly average concentrations of all indicators.

	month	PM10	PM2,5	SO2	NO2	Ozone	CO
Blv Republique	1-2-3						
Medina	1-2-3						
HLM4	1-2-3						
BelAir	1-2-3						
Yoff	1-2-3						

4.11 Meteorological Data

An example of temperature profiles and wind frequency distributions is presented in the Figure below.



The most frequent wind directions in Dakar, as measured by the 10 m tower at HLM4 station was from north and north-west.

Temperature profiles measured by the radio sondes at the airport, operated by the met office, show a daytime upper inversion at about 500m above the surface.

Here we should present statistics for mixing heights as well as wind and stability statistics for the period in question.

4.12 Explain sources, Breuer diagrams

An air pollution rose shows the average concentration of a selected pollutant as a function of wind directions. By combining wind and air pollution in this way it is possible to point at the direction of the most important sources that will impact the measurements at the given site.

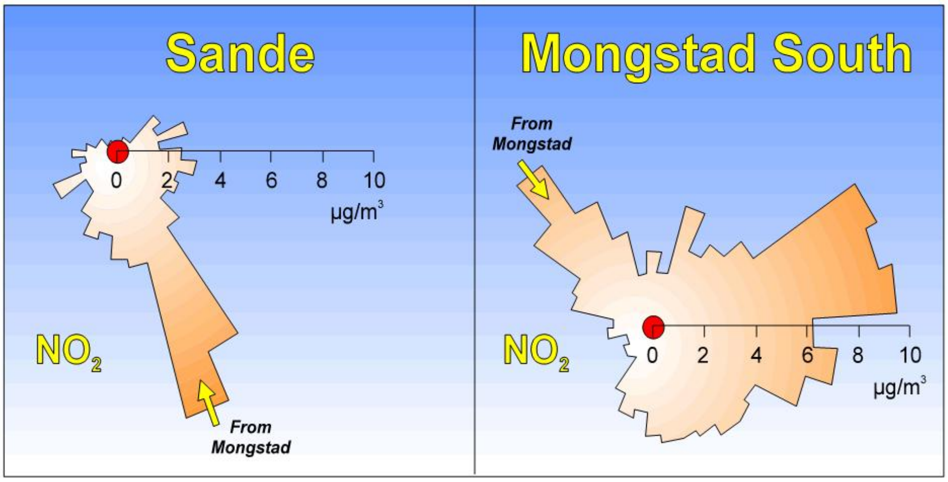


Figure 15: Air pollution concentration roses (Breuer diagrammes)

Figure 15 shows an example of a pollution rose (Breuer diagramme).
“Mongstad” a petrochemical factory complex located in the direction indicated in the graph. The two monitoring sites are called Sande and Mongstad south.

4.13 Exceeding standards

The development of cumulative frequency distributions represents the basis for evaluating the frequency of exceeding of air quality limit values.

Figure 16 below shows the percentage (%) of observations exceeding concentrations (“Bound”) given on the abscissa. The data are taken from PM_{10} measurements at BelAir during 1 to 15 November 2009.

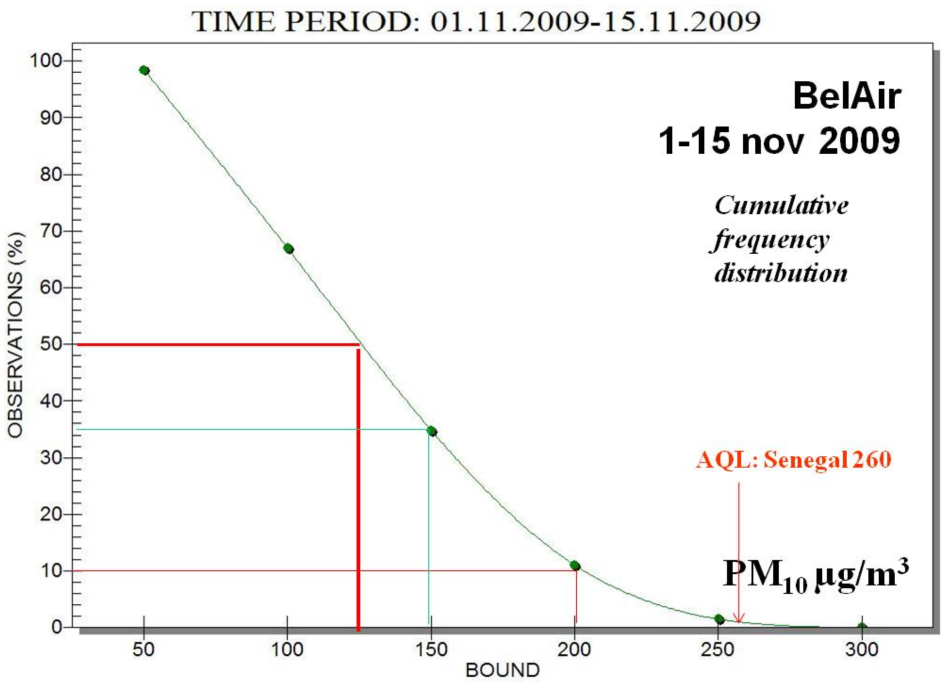


Figure 16: Percentage (%) of observations exceeding concentrations ("Bound") given on the abscissa.

The figure shows that 50% of the PM_{10} observations (the median value) exceeded 125 µg/m3.
PM_{10} concentrations exceeded 200 µg/m3 in 10 % of the time (of the observations).

4.14 Conclusion

The air quality monitoring programme in Dakar operated satisfactory during the first quarter 2010.
In conclusions we can summarize the results as follows:

- The most critical pollutants was PM_{10}
- PM_{10} concentrations measured during the period exceeded Senegal limit values ? % of the time.
- High concentrations of NO_2 were measured at Medina and BelAir. However they never exceeded limit values
- Concentrations of ozone could during day time reach up to xx % of the given limit values.
- CO concentrations were never close to limit concentrations at any of the measurement sites in Dakar.

Specific periods with unusual high concentrations occurred during the period from xx to yy

5 Annual report

The annual summary report should contain a short description of the data quality and network operation, the typical air pollution situation in Dakar, possible air pollution episodes, compliance with standards and trends. Below are some examples of a typical content.

5.1 Typical table of contents

A typical table of content of the annual report could be as follows:

1. Summary
2. Introduction
3. Data quality
4. The air quality in Dakar, main features
5. A statistical overview
6. Air pollution episodes
7. Exceeding standards
8. Conclusions

Within each main chapter there may be several different sub chapters specific for the situation.

5.2 Summary

PM_{10} and PM2,5 seem to be the main air pollution problem in Dakar. There were xx numbers of exceedings of air quality standards for these compounds.

There were some days when the 8 hour averaged ozone concentrations at Yoff exceeded the standard during the summer season.

Sulphur dioxide one hour average limit concentrations were exceeded once at BelAir station during the year.

Concentrations of carbon monoxide (CO) or nitrogen dioxide (NO_2) never exceeded the air quality standards for Senegal during this year.

5.3 Introduction

The air quality monitoring and management programme for Dakar, Senegal has been developed in co-operation with the Norwegian Institute for Air Research (NILU). Part of this development has been the reporting procedures based on the AirQUIS database and management system including air quality statistics.
This annual report is based on daily, monthly and quarterly reports (ref).

5.4 Data quality

The first year of operation of the Air Quality Monitoring Network in Dakar gave good data capture and new information about the ambient air quality in Dakar.

Daily and weekly procedures have been established as part of the QA/QC programme. The data have thus been checked and verified every day and every week.

A summary of data availability is presented in the following table

Capture rate (%)	PM10	PM2,5	Nitrogen Dioxide	Ozone	Sulphur Dioxide	Carbon monoxide
Blv Republique						
Medina						
HLM4						
BelAir						
Yoff						

All analysers operating for the full year met the 75% target capture rate threshold and most achieved the higher target of 90%. Below the 75% threshold, annual statistics are generally considered unrepresentative of the full year.

5.5 The air quality in Dakar, main features

The network Internet pages have been used to present daily information of air quality based on Air Quality Index (AQI) estimates. A summary of two AQI values (urban background and traffic) for one year is presented in the figure below.

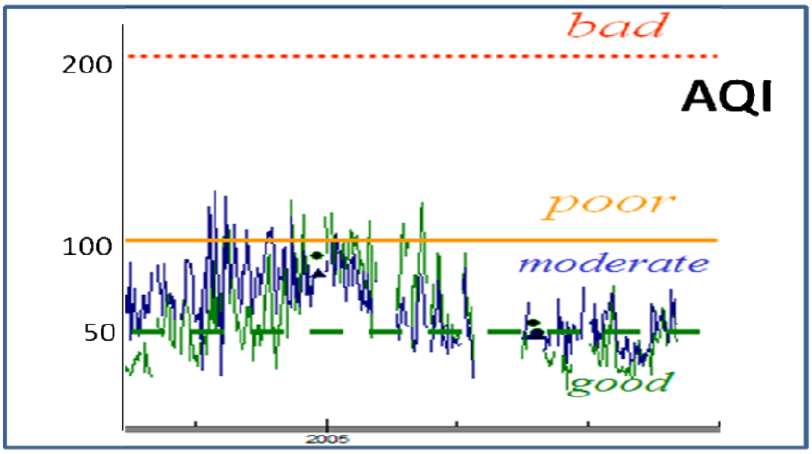


Figure 17: Daily Air Quality Index (AQI) values presented for urban background (green) and traffic site (blue) for one years

Figure 17 above shows that the air was of poor quality for a period especially during the winter season. The most “critical” pollutant in Dakar has been PM_{10} (and also PM2,5).

A summary of the air pollution situation in Senegal has been prepared. PM10, which has been shown to be most often exceeding air quality standard values, is presented on a map for Dakar below.

The highest PM concentrations were in general measured at the BelAir station. PM concentrations in the city of Dakar were higher than outside the urban area.

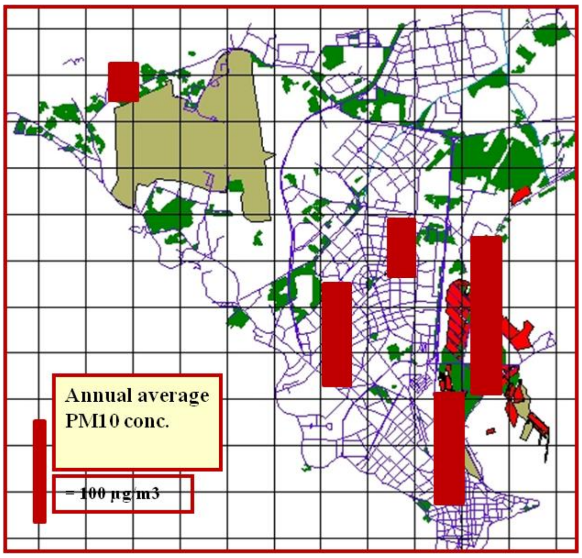


Figure 18: Annual average PM10 concentrations at five monitoring sites in Dakar, 2010.

5.6 A statistical overview

5.6.1 Annual average concentrations

Annual mean concentrations for all indicators measured at the five measurement sites in Dakar is presented in Figure 19 below.

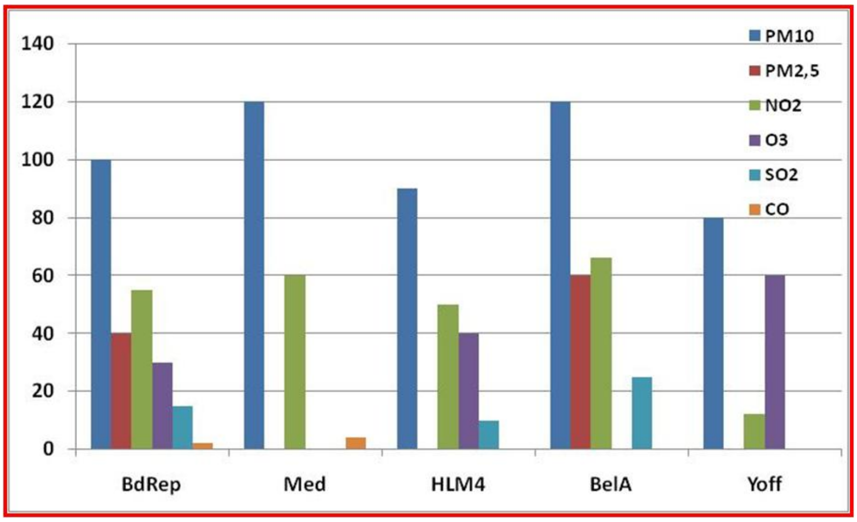


Figure 19: Annual average concentrations (µg/m3) of 6 indicator pollutants measured at 5 sites in Dakar during 2010.

A summary of annual average concentrations may also be presented in a table 6 presented below. Where a site has a data capture rate of less than 75% over the year the value is shown in parentheses, as the result may not be representative of the full year.

Table 6: Example of table presenting the Annual Mean concentrations.

Annual Means (ug/m3)	PM10	PM2,5	Ozone	Nitrogen Dioxide	Sulphur Dioxide	Carbon Monoxide
Blv Republique						
Medina						
HLM4						
BelAir						
Yoff						

5.6.2 PM10 concentrations

High concentrations of PM10 were measured at BelAir and Medina during the first year of measurements. Average concentrations for each month of the year are shown in the figure below.
This figure may also include the monthly average PM10 concentrations at all sites for each month of the year.

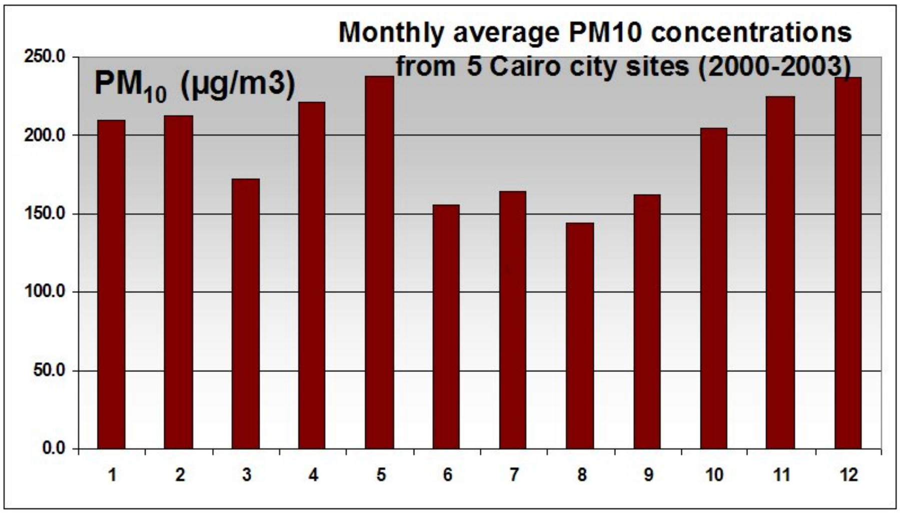


Figure 20: Example of monthly average concentrations of PM10.

The highest average PM_{10} concentrations were measured in the months of May, December and November. Generally we see that the PM_{10} concentrations are lower in the summer months from June to September than in the winter months. The high concentrations observed in April and May might be caused by a few days of air pollution episodes over Dakar.

The monthly average PM_{10} concentration levels as observed at two of the urban locations during the year ranged between 150 and 230 µg/m^3. The conclusion is that Dakar is more polluted than many cities in the world when it comes to suspended particulate matter.

5.6.3 Comments to the level of other indicators

PM2,5
High concentrations of PM2,5 were measured during 5 days at BelAir.

Carbon Monoxide (CO)

There were no incidences of exceedences of carbon monoxide recorded by any network site during the year.

Nitrogen Dioxide (NO_2)

There were no incidences of exceedences of nitrogen dioxide recorded by any network site during 2005.

.

Sulphur Dioxide (SO_2)

Concentrations of sulphur dioxide did not exceed the national or international air quality standards. However, the WHO guideline value of 20 µg/m3 was exceeded at several occasions. This was especially the case at the industrial impacted site at BelAIR.

Ozone (O3)

There were some days of exceedences of ozone recorded at the sites throughout the summer. The distribution of these days is illustrated in Figure 1.1. There is a gradual increase during the spring, followed by the worst episodes of the year in early August.

5.7 Air pollution episodes

Comment on extremely high concentrations if recorded.

5.8 Exceeding standards

The largest air pollution problem in Senegal has several times been proven to be linked to suspended particulate matter.
The figure below shows an example from for 4 years based on data from 7 sites. The daily PM10 concentrations were exceeded in between 30 and 100 % of the time.

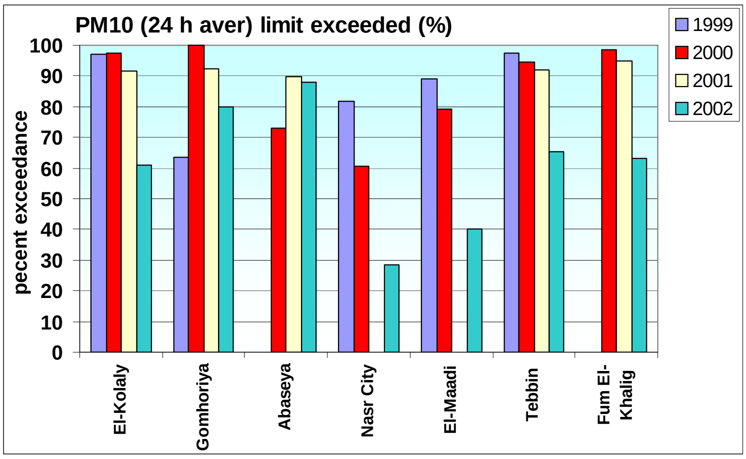


Figure 21: *The frequency of the exceedance of the PM_{10} limit value for 24-hour average concentrations as measured at 7 sites in Senegal for 4 years (1999-2002).*

There was a tendency for fewer exceeding in 2002 than in 2000. This situation is studied in more details in the state of the environment report.

The basis for evaluating how many times the air quality standards have been exceeded (number or %) is the cumulative frequency distribution as shown below.

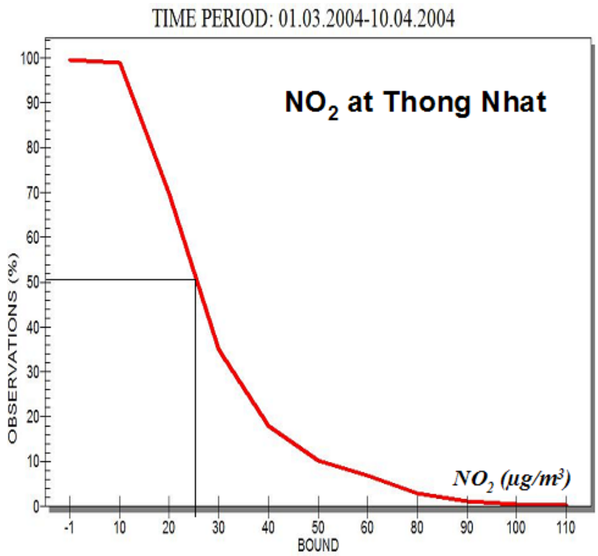


Figure 22: *The cumulative frequency distribution of NO2 for one year of measurements at Thong Nhat.*

In summary the frequency of exceeding together with the annual average concentrations of PM10 could be presented as shown in the following figure.

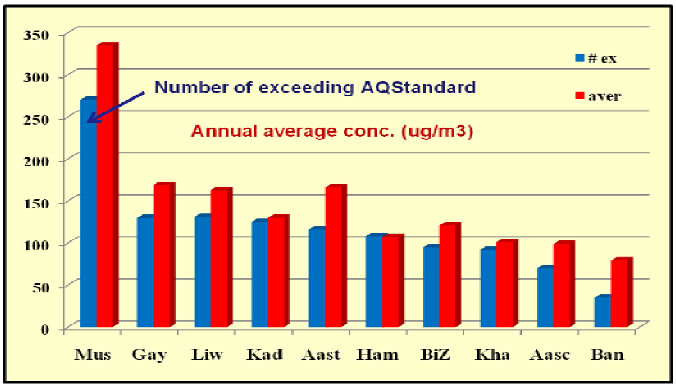


Figure 23: The number of exceeding of the daily PM10 standards presented together with the annual average PM10 concentrations at ten measurement sites.

Table 7 below compares results of monitoring in the relevant year to the EAD's Air Quality Strategy Objectives. There is often more than one objective per pollutant reflecting the differing health effects of short and long term exposure. Each objective has an achievement date, between 2012 and 2016 depending on the pollutant. Where a site has achieved less than 75% data capture for the year, the statistic cannot be calculated and is entered as 'not applicable'.

Example of text :

The two network roadside sites failed to meet the annual mean nitrogen dioxide objective of 40 ug/m3. In addition, one of the roadside stations exceeded the hourly mean nitrogen dioxide objective. Network sites met all carbon monoxide and sulphur dioxide objectives. The ozone standard was exceeded at 4 of 10 sites and the daily averaged PM10 standard was exceeded in 7 out of 10 stations.

Table 7: Comparison with Air Quality Standards, achieved(yes) – *exceeded(no).*

Compliance?	**Particles PM10**		**Ozone**	**Carbon monixide**	
	24 hour	**Annual**	**8- hour**	**1-hour**	**8-hour**
Blv Republique					
Medina					
HLM4					
BelAir					
Yoff					

Table 7 continued

Compliance?	**Sulphur Dioxide**			**Nitrogen dioxide**	
	1 hour	**24-hour**	**Annual**	**1 hour**	**Annual**
Blv Republique					
Medina					
HLM4					
BelAir					
Yoff					

5.9 Explain sources; (Breuer diagram)

Presentation of concentration roses for all or the most important components to describe from which direction the pollution come from.

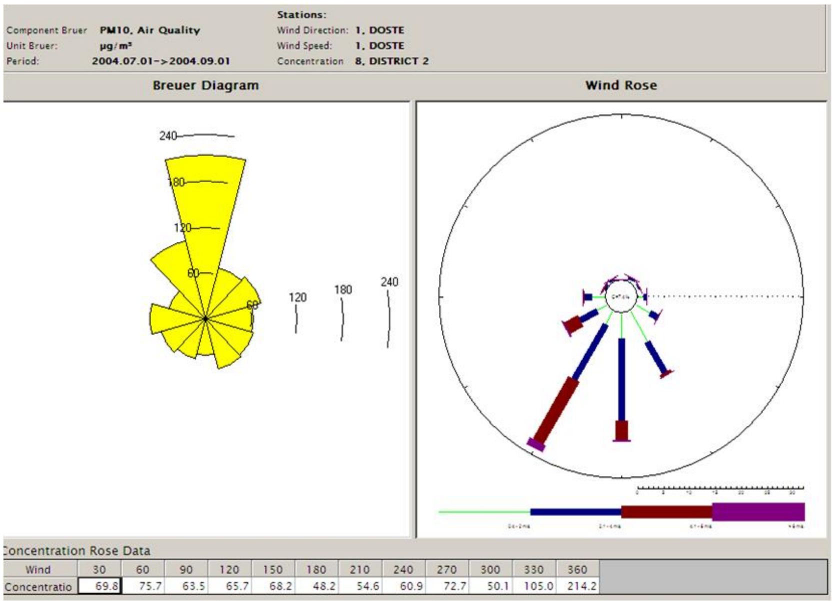


Figure 24: Concentration rose (Breuer diagram) for PM10.

Figure 24 above shows both the pollution rose (Breuer diagram) and the wind direction frequency distribution; the wind rose. We see that the most frequent wind directions are from around south- south west, while the highest concentrations of PM10 occurred during winds from the north.

Pollution roses (Breuer diagram) can also be plotted on maps in order to pinpoint major sources in the area. The figure below shows the Breuer diagram based on SO2 measurements at two sites. The both point to a major point source, which in this case is a polluting smelter.

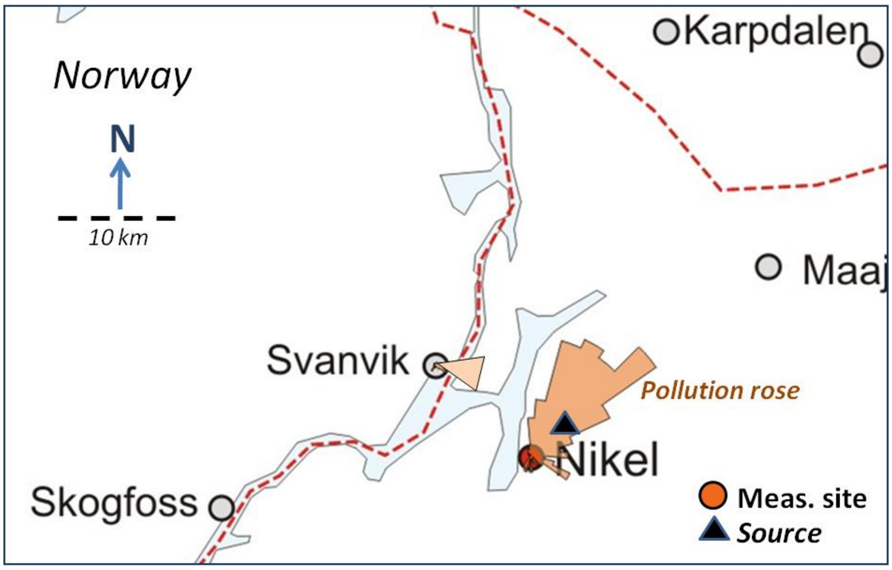


Figure 25: *Pollution roses presented at two measurement sites.*

Another simpler way to generate the wind direction dependency of air pollution measured at one specific site is to prepare a scatter pøot with the hourly pollution concentration as a function of the simultaneous wind direction measured at the same site. An example of this is shown below.

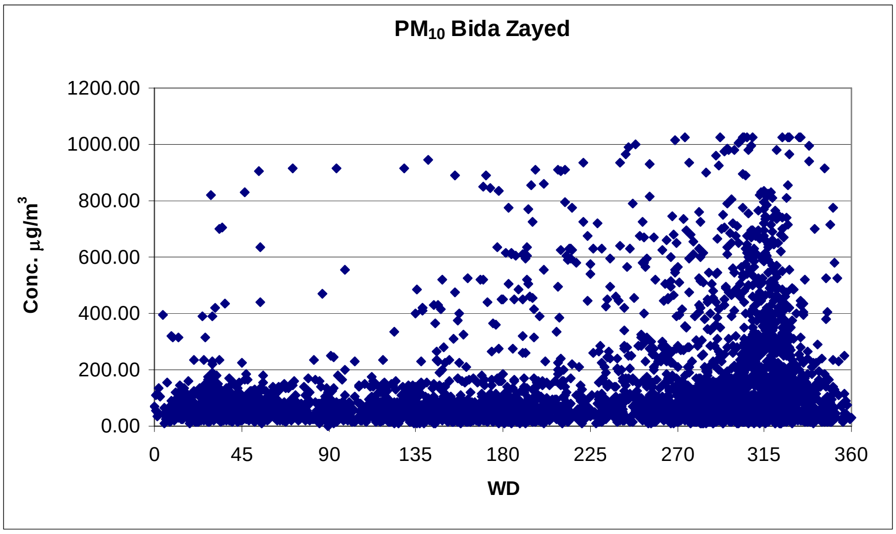


Figure 26: *Scatter plot of PM10 concentrations measured at Bida Zayed as a function of wind direction.*

The highest concentrations at the station have been measured when the wind was blowing from north-westerly directions.

5.10 Trends in Pollution Levels,

This Chapter aims to illustrate trends in pollution levels since the start of the network. This chapter should therefore be included after three years of operation. There are many reasons why pollution levels go up and down. Weather conditions can have influence in how traffic and industrial emissions are dispersed. In the short term, this can cause pollution episodes, but the weather can also influence longer-term annual mean trends.

Separating trends in pollution levels caused by meteorological conditions from those caused by changes in traffic volume or emissions levels can be very difficult. Identifying trends caused through local air quality management, such as traffic management schemes, if even harder. Independent of the weather, increased or decreased volumes of traffic, a change in the speed or composition of the vehicles or larger-scale influences not connected to road itself may cause pollution trends adjacent to a specific road.

Figure 27 below shows one type of summary statistics used in order tp present trands over time. This figure is called a box plot, and may be used for individual compounds of pollutants selected as especially interesting.

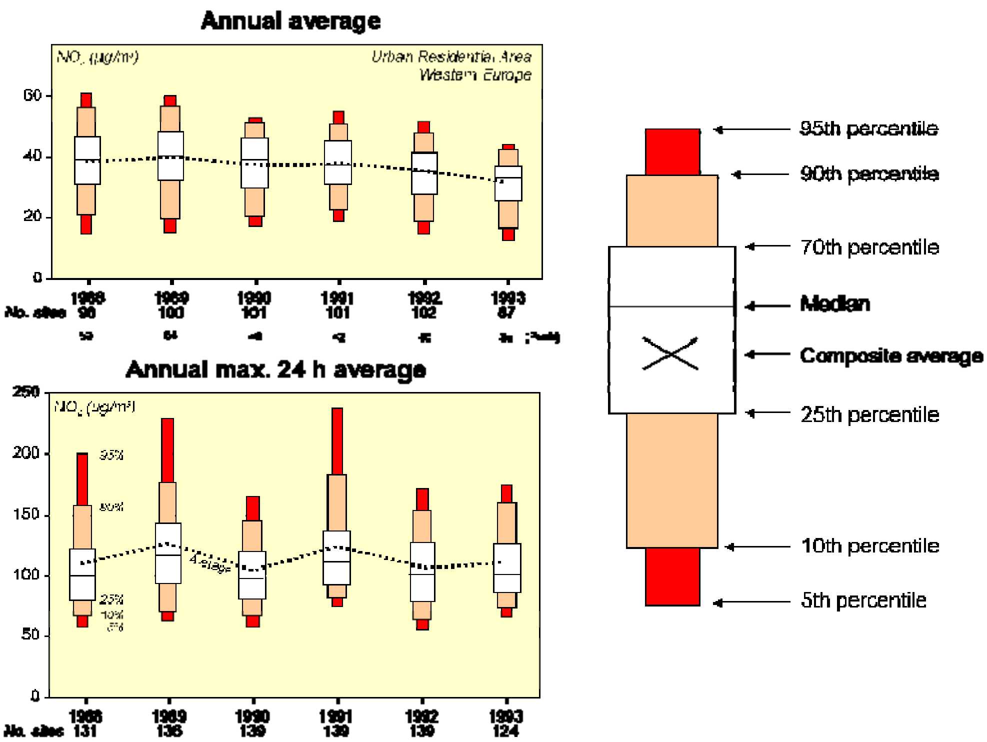


Figure 27:Ttype of summary statistics used in order to present trends over time.

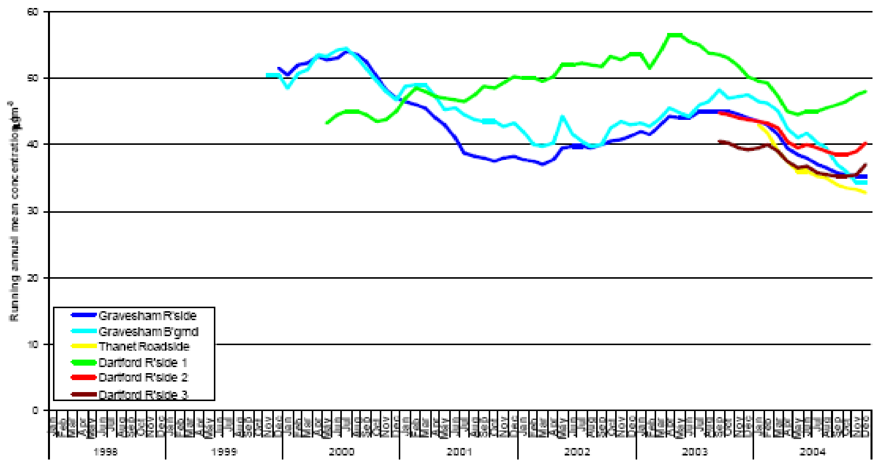
For all of these complications, charts of pollution trends must be considered with care. It is important to look at as long a time period as possible to try and smooth out meteorological variation. For this reason, sites with less than three years of data should not be included. Charts are grouped by pollutant to allow comparison of trends across the county to help separate local from county-wide trends.

Different examples of presentation of trends both as tables and figures used by different authorities worldwide is given below. One charts appearing is running annual mean concentrations from a specified start date to January 2005. These are termed 'running' because a separate annual mean is calculated each month. Such means illustrate gradual changes in pollution levels, which are not apparent from a single annual figure.

5.10.1 PM10 Particulates

An example of running annual mean particulate trends at network continuous monitoring sites are shown in the Figure below. Sites are shown one year after they are commissioned, i.e., when the first annual mean calculation is possible.

Figure 2-2 Trends in running annual mean PM $_{10}$ concentrations (BAM analysers)



A varying portion of the particulate matter present in the city stations is from natural sources outside of the cities. PM_{10} concentrations at urban locations are lower than those of urban background locations due to the natural background of dust.

5.11 Conclusions

The following conclusion can be drawn:

- ✓ The main problem is PM
- ✓ PM exceeds all standards!
- ✓ High CO in streets with dense traffic
- ✓ NO_2 may exceed standards near streets and roads
- ✓ SO_2 has not been identified as a major problem yet
- ✓ PM + VOC in industrial areas

6 Conclusions

The Norwegian Institute for Air Research (NILU) has developed the air quality monitoring and management programme for Dakar, Senegal. Part of this project involves the development of templates for reporting of the air quality based on measurements of air pollution and meteorology.

Examples of reporting procedures and contents have been presented in this report for guidance on how to report air quality and meteorological measurements in:

- Daily and weekly reports;
- Monthly data reports;
- Quarterly assessment reports;
- Annual “State of the environment” report.

The templates indicate typical content with different examples of presentations, air quality statistics and figures and tables prepared in order to assess the air quality in Dakar. Similar procedures are being used by different authorities worldwide.

7 References

CETUD (2004) Demande de propositions DP N. PAMU/FND/C/08/04. L'assistance technique a la mise en place du laboratoire central et des stations de mesures pour l'amélioration de la qualité de l'air en milieu urbain de Dakar. Version 08-04-04.

Commission Nationale sur le Développement Durable (CNDD) (2002) Sommet Mondial sur le Développement Durable, Rapport National du Senegal, Johannesburg, 26 Août – 04 Septembre 2002.

Guerreiro, C., Laupsa, H. and Sivertsen, B. (2005) Passive sampling of SO_2 and NO_2 in ambient air in Dakar, Preliminary study, June 2005. Kjeller (NILU OR 39/2005).

Guerreiro, C., Sivertsen, B. and Laupsa, H. (2005) QADAK Mission 1, May-June 2005. Kjeller (NILU OR 45/2005).

Guerreiro, C., Sivertsen, B. and Laupsa, H. (2006a) QADAK Mission 2, 3-12 October 2005. Kjeller (NILU OR 8/2006).

Guerreiro, C., Sivertsen, B. and Laupsa, H. (2006b) QADAK Mission 3, 27 Février-10 Mars 2006. Kjeller (NILU OR 72/2006).

NILU Norwegian Institute for Air Research

Norwegian Institute for Air Research
P.O. Box 100, N-2027 Kjeller, Norway
Associated with CIENS and the
Environmental Research Alliance of Norway
ISO certified according to NS-EN ISO 9001

REPORT SERIES SCIENTIFIC REPORT	REPORT NO. OR 18/2010	ISBN: 978-82-425-2194-1 (printed) 978-82-425-2195-8 (electronic) ISSN: 0807-7207
DATE	SIGN.	NO. OF PAGES: 41 / PRICE: NOK 150.-
TITLE Reporting air quality in Dakar, Senegal		PROJECT LEADER Cristina Guerreiro NILU PROJECT NO. O-105010
AUTHOR(S) Bjarne Sivertsen		CLASSIFICATION * A CONTRACT REF.A No 003/C/FND/05

REPORT PREPARED FOR
CETUD
Route de Front de Terre,
B.P. 17 265 Dakar–Liberté
Senegal

ABSTRACT

The Norwegian Institute for Air Research (NILU) has developed the air quality monitoring and management programme for Dakar, Senegal. Part of this project involves the development of templates for reporting of the air quality based on measurements of air pollution and meteorology. This example of reporting procedures is strictly limited to the reporting of measurement results. Templates are presented for:

- Daily and weekly reports
- Monthly data reports
- Quarterly assessment reports
- Annual "State of the environment" report.

The templates indicate typical content with different examples of presentations, air quality statistics and figures and tables prepared in order to assess the air quality in Dakar. Similar procedures are being used by different authorities worldwide.

NORWEGIAN TITLE

KEYWORDS

Air quality monitoring	Air quality reporting	Senegal

** Classification*

A	*Unclassified (can be ordered from NILU)*
B	*Restricted distribution*
C	*Classified (not to be distributed)*

REFERENCE: O-105010
DATE: MARCH 2010
ISBN: 978-82-425-2194-1 (printed)
978-82-425-2195-8 (electronic)

NILU is an independent, nonprofit institution established in 1969. Through its research NILU increases the understanding of climate change, of the composition of the atmosphere, of air quality and of hazardous substances. Based on its research, NILU markets integrated services and products within analyzing, monitoring and consulting. NILU is concerned with increasing public awareness about climate change and environmental pollution.

NILU Norsk institutt for luftforskning
Norwegian Institute for Air Research