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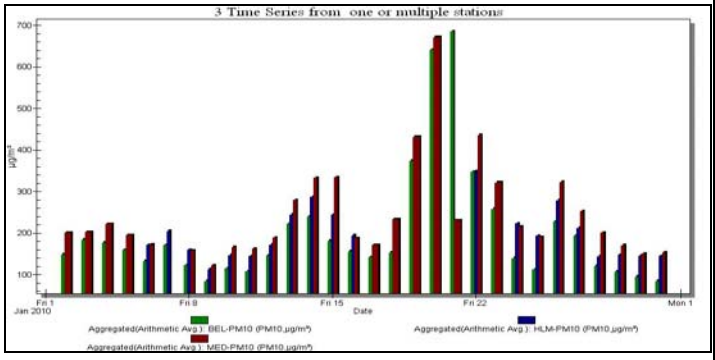
Projet:	ASSISTANCE TECHNIQUE A LA MISE EN PLACE DU LABORATOIRE CENTRAL ET DES STATIONS DE MESURES POUR L'AMELIORATION DE LA QUALITE DE L'AIR EN MILIEU URBAIN DE DAKAR
Contrat:	No 003/C/FND/05

Air Quality Monitoring in Dakar

Monthly Report N° 01/2010

Bjarne Sivertsen, Abdoulaye Ndiaye and Mbaye Diop



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Summary

The current report on air quality in Dakar has been based on measurement data from five (5) air quality monitoring stations operating in Dakar for the month of January 2010. The data have been evaluated by the Air Quality Management Centre (CGQA) assisted by NILU. The data was quality controlled and prepared as a basis for the statistics presented in this report. Air pollution in Dakar is dominated by suspended particles in the air. The main sources are linked to dust from traffic, industries and desert.

The stations as well as their monitoring equipment are presently operated and maintained by CGQA personnel.

Generally there is frequent exceeding of the national limit values for particulate matter measured as PM_{10}. The 24-hour limit value of 260 $\mu g/m^3$ has been exceeded at all monitoring station in Dakar. Violations of PM10 limit values varied between 3 and 70% of the time in January 2010.

The range of air quality measurements during January 2010 in Dakar varied between 5 and 150 $\mu g/m^3$ for SO_2, 5 and 60 $\mu g/m^3$ for NO_2 and ozone between 5 and 45 $\mu g/m^3$, not exceeding the national limit values for these components. CO concentrations measured along the roads did not exceed limit values during January 2010.

Contents

1. Introduction

This monthly report is describing the operation of the air quality monitoring network in Dakar and is based on data collected during January 2010. It describes the data capture, irregularities of instrument operation, in addition to some statistics and graphical presentations of the measurements.
The monthly report represents a summary overview of the data, data quality and data availability. The report also includes summaries of the monthly average concentrations of all parameters (indicators), as well as exceeding of air quality standards given for Senegal.

The monthly report includes:

- Sites and maps
- Data availability and data quality
- Air quality results
- Simple statistics

2. Sites

The five air quality monitoring sites selected for Dakar are presented in Table 1 with, positions (geographical coordinates) and station types.

Table1. Stations coordinates and sites characteristics

#	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

The parameters selected for each station are characteristic for the sources expected to impact at the different sites. The different compounds or indicators are presented in Table 2 for each of the five stations.

Table 2. The air pollution indicators measured at each of the stations in Dakar.

		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		

SO_2 = sulphur dioxide, NOx = nitrogen oxides, NO_2 = nitrogen dioxide, PM_{10} and $PM_{2,5}$ = suspended particles with diameter less than 10 and 2,5 micrometer respectively, O3 = ozone, CO = carbon monoxide and Benz = benzene.

The locations of the five air quality monitoring stations in Dakar are presented in Figure 1. Meteorology is measured at station # 3 in the HLM4 area.

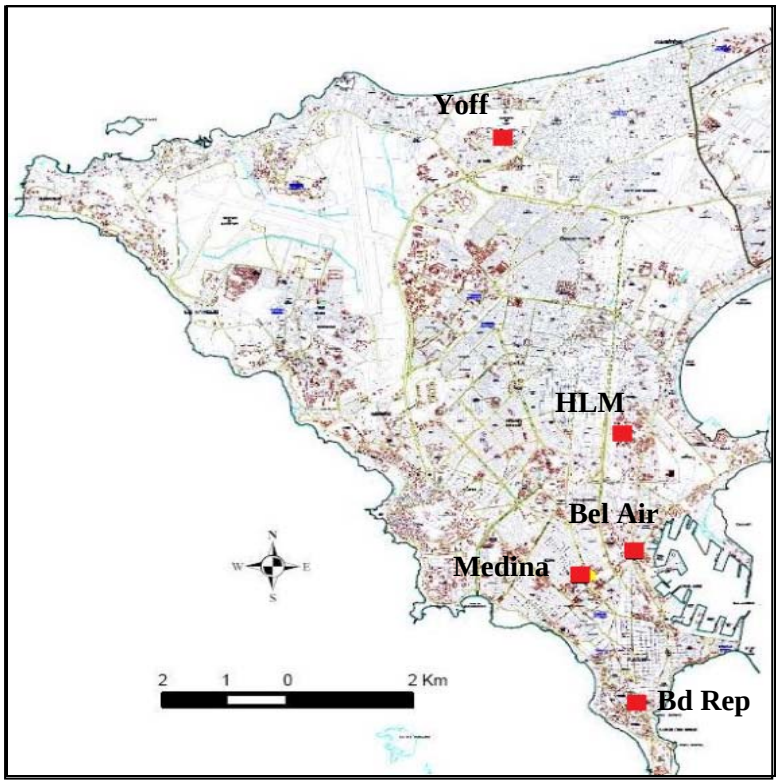


Figure 1. Location of the air quality monitoring stations in Dakar

In 2001, Senegal adopted a new air quality standard (NS-05-62). This national standard specifies limit values for ambient air pollution concentrations. Table 3 presents a summary of these limit values, compared to World Health Organisation air quality guidelines. The PM_{10} limit value for Senegal is higher compared to other guidelines and standards.

Table 3: Senegalese air quality standard 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

As seen from the table there is still no limit value for $PM_{2,5}$ for Senegal The limit value for PM_{10} is much higher than normally the case in other countries. These matters will have to be discussed further.

3. Monthly air quality

The data presented in this report are based on measurements during January 2010. In Table 4, the following parameters are shown for each indicator at each of the monitoring station:

- Data availability (%)
- The monthly average concentration ($\mu g/m^3$)
- The 98-percentile concentration ($\mu g/m^3$)
- The maximum one hour average concentration ($\mu g/m^3$)

Table 4: Data capture, average and maximum concentrations shown for all stations and all parameters in Dakar, January 2010.

		Data availability			Concentration		
Variables	**Sites**	**# total data**	**# of valid data**	**% valid data**	**Average**	**98-percentile**	**Maximum**
PM10 (µg/m^3)	Bel Air	720	719	99,86	200,5	458.7	936
	Medina	720	691	95,97	243,8	476	970
	HLM	720	525	72,92	207,1	314.5	924
	Yoff	720	665	92,36	393,9	772	?
PM2.5 (µg/m^3)	Bel Air	720	662	91,94	47,7	119	233
	Bd Rép.	720	616	85,56	58,3	71.0	243
SO2 (µg/m^3)	Bel Air	720	719	99,86	22,0	77.4	171
	Bd Rép.	720	676	93,89	19,1	38	69
	HLM	720	526	73,06	1,3	9	23
NO2 (µg/m^3)	Bel Air	720	719	99,86	21,6	41	54
	Medina	720	687	95,42	20,9	55.0	55
	Bd Rép.	720	677	94,03	26,1	44.7	58,9
	HLM	720	177	24,58	7,4	30,6	31,1
	Yoff	720	602	83,61	3,8	20,4	284
O3 (µg/m^3)	Bd Rép.	720	513	71,25	8.0	23,7	38,4
	HLM	720	595	82,64	20,6	31,3	45
	Yoff	720	496	68,89	27,4	31,3	42
CO (mg/m^3)	Medina	720	564	78,33	0.4	1,17	1,47
	Bd Rép.	720	358	49,72	0.4	1,04	1,58

Data availability (valid data) varied for most of the parameters from 73 to 99, 9 % of all hours. Exceptions were the NO_2 monitor of HLM4 and the CO data from Boulevard Republique. The main reason for this was power failures and bad performance of the instruments. The ozone data from Yoff are also questionable for this period.

The statistical evaluation of the measurement presented in the following chapters is divided into two parts: meteorology and air quality. Meteorological data are important both for describing the general dispersion conditions and climate and as support information in order to explain the air quality. The combination of wind and air pollution concentrations may explain the impact of sources and indicate which sources give the highest impact.

4. Meteorology

Statistics on meteorological parameters such as wind, temperatures and atmospheric stability measured at the HLM4 station in Dakar during January 2010 is presented in the following.

The wind frequency distribution (wind rose) is presented in Figure 3.

Wind rose

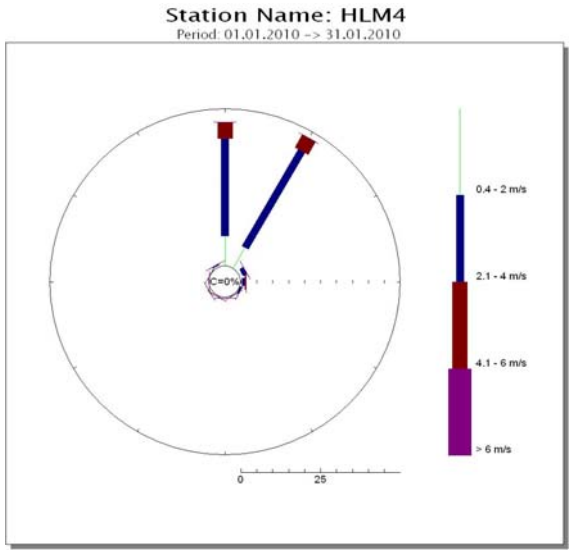


Figure 2. Wind rose for HLM4 station, January 2010

The prevailing winds were in January 2010 from north to north-northeast, which is normal for this time of the year. The wind speed was on average 2,9 m/s and the maximum was 6,2 m/s.

Figure 3 shows that the highest average wind speed occurred when the wind was blowing from the sectors north and north-northeast.

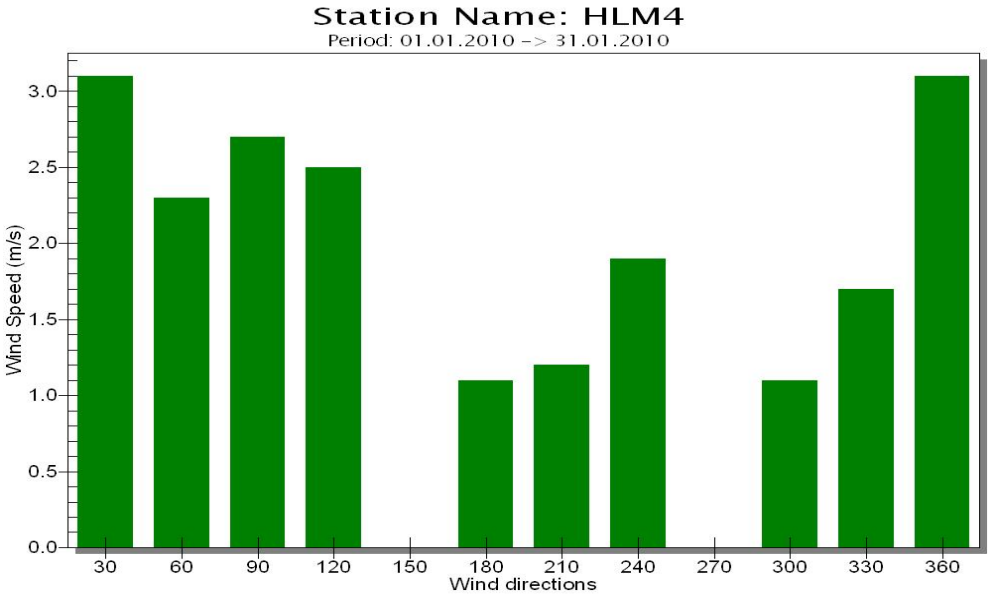


Figure 3: Average wind speed for each of twelve 30-degree sectors.

The average wind speed when it was blowing from northerly directions was about 3 m/s, while the winds from southerly direction 1 to 1,7 m/s.

The atmosphere stability is estimated as the difference of temperature between 10 meters and 2 meters at the meteorological tower station of HLM4.
A stable condition occurs during night time, whereas the daytime condition is mostly unstable (figure 4).

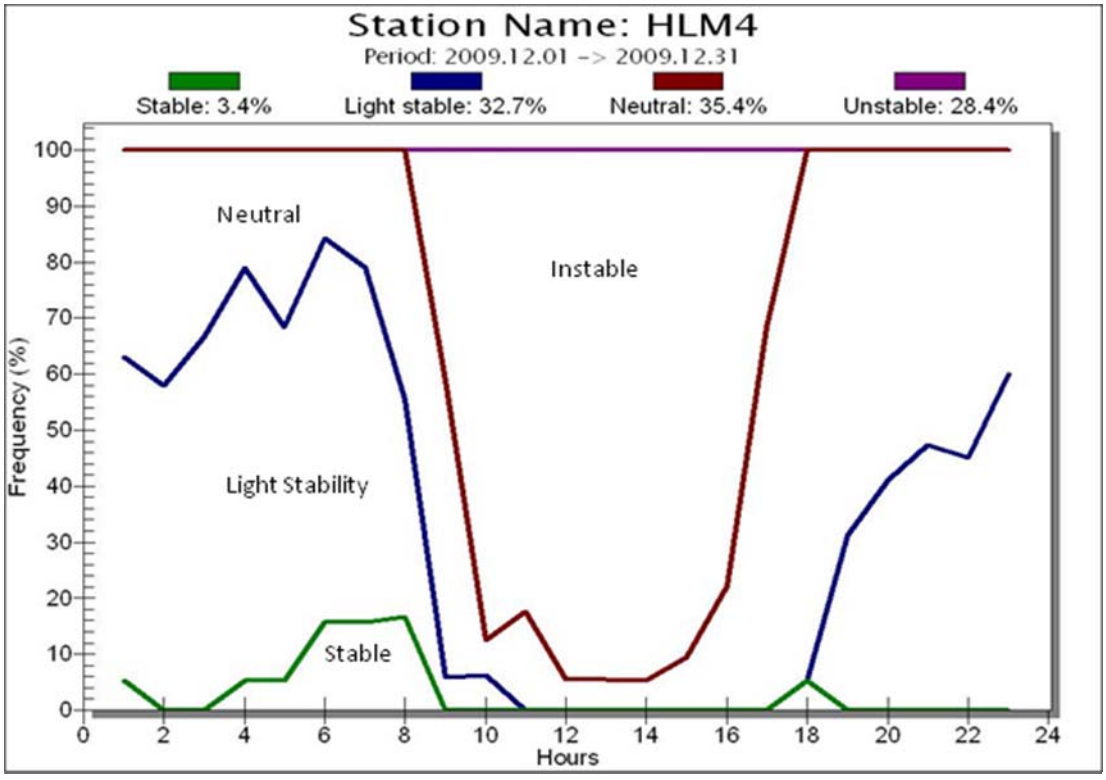


Figure 4: Stability conditions in Dakar in January 2010

The following limits have been selected for the stability classes presented in figure 4:

- Stable atmosphere. Dt > 0,3ºC
- Light stability. 0 ºC <Dt<0,3 ºC
- Neutral. –0,3 ºC <DT<0 ºC
- Unstable. Dt < -0,3 ºC

(Dt is the temperature difference between 10m and 2m measured at the tower at HLM4 (T10-T2).

The maximum and minimum temperatures measured in January 2010 were 36,3 and 15,8 degrees C, respectively. The average value was 23,5 deg C. The highest daily average temperature of 36,3 degrees C occurred on Monday 16 January at 14:00 hours.

Table 5: Temperature, humidity and pressure measured at HLM4 January 2010.

Parameters	AVERAGE	MIN	TIME FOR MIN	MAX	TIME FOR MAX
Temperature	23.5	15.8	2010.01.08 22:00	36.3	2010.01.16 14:00
Relative Humidity	61.9	11	2010.01.14 15:00	97	2010.01.01 08:00
Pressure	1008.9	961	2010.01.19 14:00	1013	2010.01.11 23:00

5. Ambient air quality

5.1 Suspended particles PM_{10}

Suspended particles represent the most important air pollution problem in Dakar. Hourly and 24-hour average concentrations for January 2010 are presented in Appendix A for all stations.
The daily average PM_{10} concentrations are also presented in Figure 5. These 24-hour average concentrations varied between 100 and 650 µg/m^3 at all stations, and exceeded the NS-05-62 limit value of 260 µg/m^3 during 1 to 8 days at the three stations.

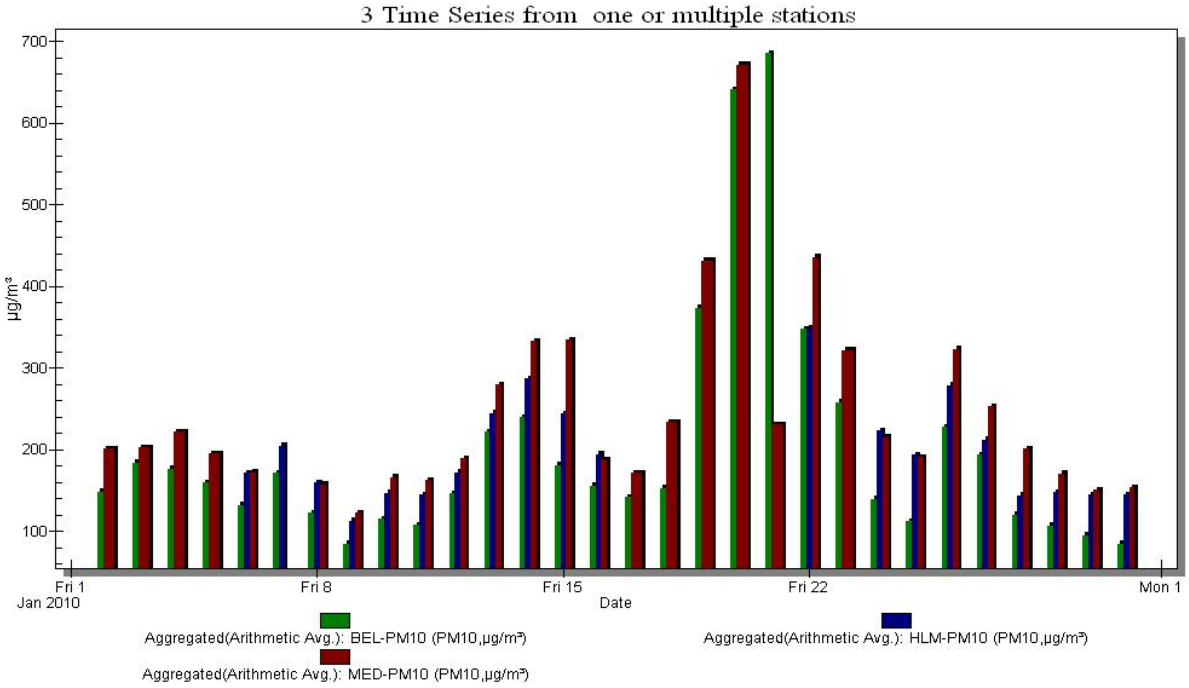


Figure5: Daily average PM_{10} concentrations as measured at Bel Air, Medina and HLM4 during January 2010

The daily PM_{10} concentrations also exceeded the WHO guideline value of 50µg/m^3 every day in January 2010.

Between 19 and 22 January 2010 very high concentrations of PM_{10} occurred at all stations in Dakar. The period seemed to identify an "air pollution episode" with daily average concentrations at BelAir and Medina exceeding 650 µg/m^3. We have not analysed the situation detailed enough to explain the reasons for this episode.

The cumulative frequency distribution of PM_{10} for January 2010 based on measurements at Bel Air and Medina stations shows in Figure 6 the frequency in % of exceeding of the concentrations presented at the abscissa. The figure represents 24-hour average PM_{10} concentrations.

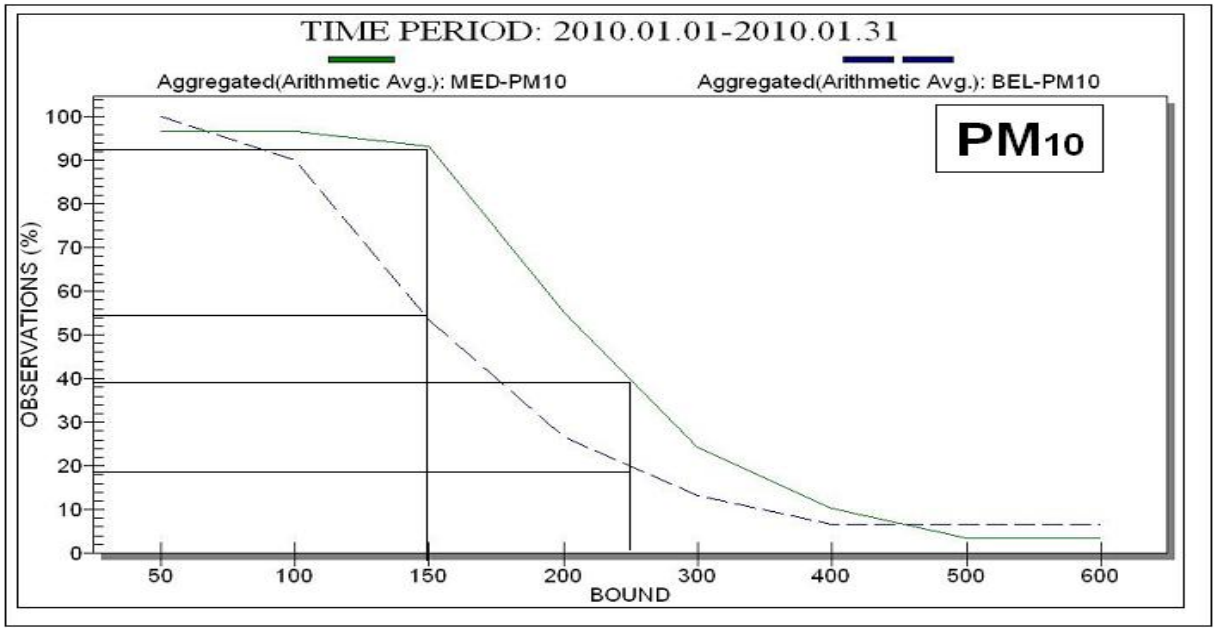


Figure: 6 Cumulative frequency distribution of PM_{10} at Medina and Bel Air, January 2010

The PM_{10} Senegalese limit value (260 µg/m^3) was exceeded during 20 percent of the time at Bel-air and about 40 percent of the time at Medina.

The former WHO guideline value of 150 µg/m^3 was exceeded during 55 percent of the time at Bel-Air and 91 percent of the time at Medina.

5.2 Suspended particles $PM_{2,5}$

Suspended particles with aerodynamic diameter less than 2,5 micro metre has been introduced as a better indicator for potential health effects than PM_{10}. PM $_{2,5}$ has been measured at two sites in Dakar; Boulevard Republique and Bel Air.

Figure 7 shows the relationship between $PM_{2,5}$ and PM_{10}.

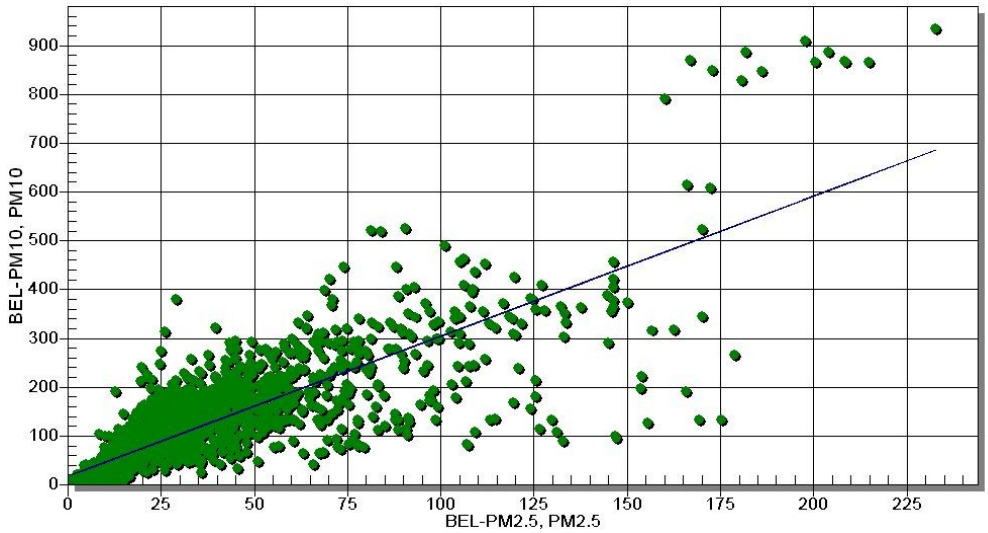


Figure 7: Relationship between $PM_{2,5}$ and PM_{10} at Bel Air in January 2010.

The average ratio $PM_{2,5}/PM_{10}$ has been estimated for the Bel air station to be about 0,3, which implies that the PM_{10} concentrations on an average is about 3 times the $PM_{2,5}$ concentrations. This means that

about 1/3 of the suspended particles PM_{10} have diameter less than 2,5 µm and about 2/3 have diameter between 2,5 µm and 10 µm. This is in accordance to what has been found in other African cities.

5.3 NO_2 concentrations

Hourly NOx and NO_2 concentrations are shown for all stations in Appendix A. The average diurnal variation of NO_2 concentrations are shown based on data from four stations in Figure 8.

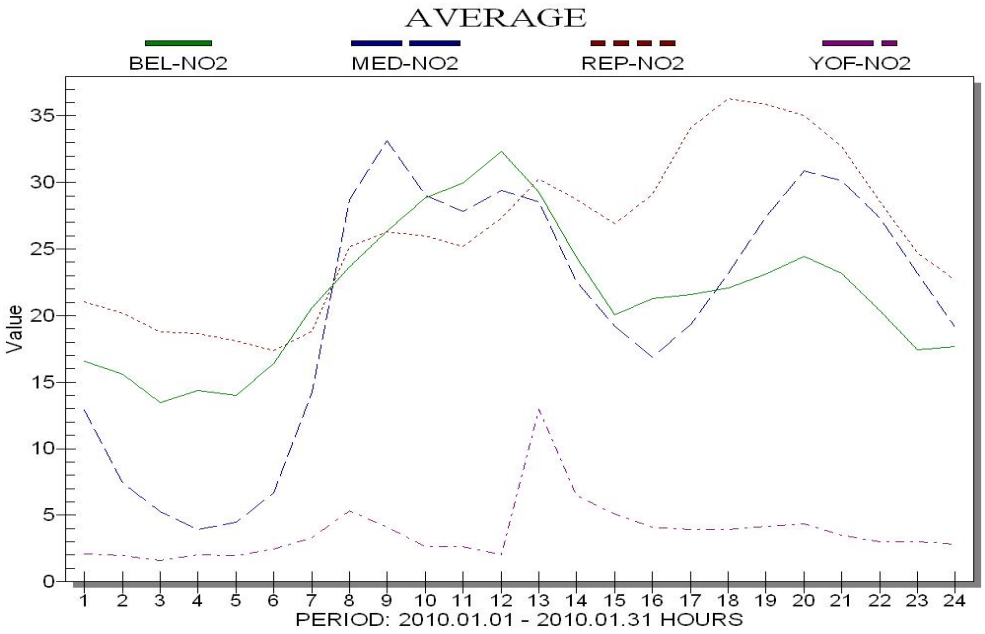


Figure 8: Average diurnal variation of NO_2 concentrations at Bel Air, Boulevard Republique, HLM4 , Medina and Yoff in January 2010.

NO_2 did not exceed the Senegalese air quality limit concentration during January 2010.
The highest concentrations were observed during daytime especially between 8:00 and 11:00 and between 18:00 and 21:00. Especially at Boulevard Republique there seemed to be a clear rush hour impact in the morning rush hour. The high concentrations observed in the evening (after sunset) at the urban stations are due to a combination of traffic emissions and meteorological conditions (temperature inversions near the surface).
NO_2 concentrations measured at Yoff in January indicated a low background concentration of less than 5 µg/m^3.

5.4 SO_2 concentrations

Hourly and daily SO_2 concentrations are presented for January 2010 in Appendix A.

The measured SO_2 concentrations never exceeded the Senegalese limit values. The highest hourly concentration was measured at Bel Air at 150 µg/m3 on 18 January 2010 during daytime. It might have been caused by a combination of diesel traffic emissions and industries activities.

The Breuer diagram (SO_2 concentration rose) in Figure 9 indicates that most of the SO_2 at Bel Air came from northeast. This is the direction to one of the main industrial areas in Dakar.

Figure 9 also shows the average diurnal variation of SO_2 concentrations at Bel Air. This clearly shows that the highest SO2 concentrations at Bel Air occurred during daytime hours between 07:00 and 14:00 hrs.

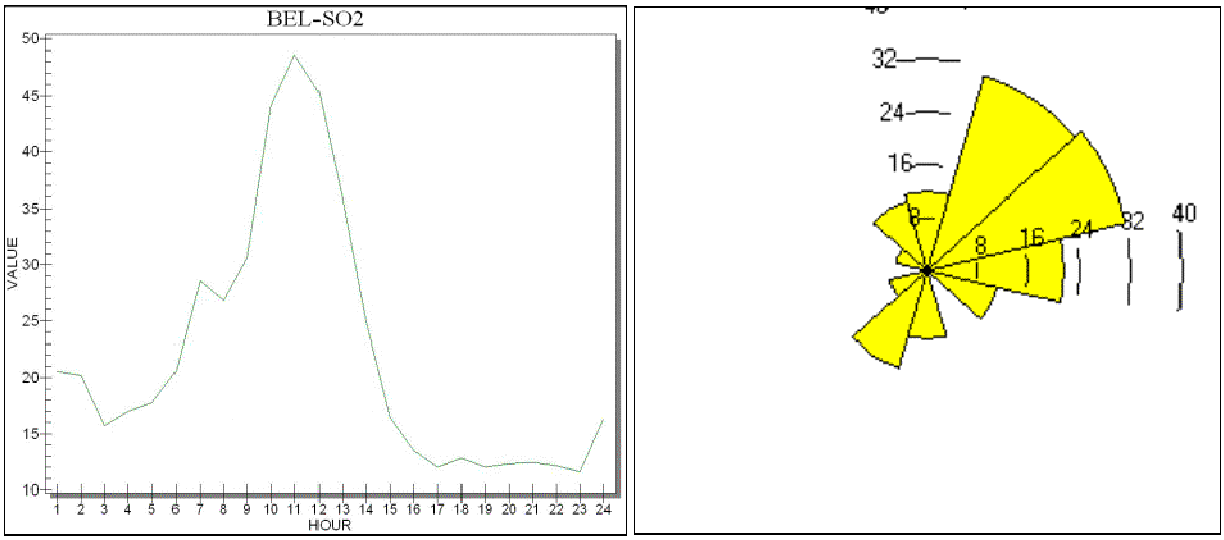


Figure 9: Average diurnal variation of SO_2 concentrations at the Bel Air station and the Breuer Diagram (SO_2 concentration rose) based on data for January 2010

5.5 Ozone

Ozone concentrations are measured at three sites, which are Boulevard de la Republique, Yoff and HLM4. Hourly concentrations of ozone are presented in Appendix A.

The hourly average concentrations in January 2010 were low ranging between 5 and 45µg/m^3. Even daytime hourly concentrations did not reach levels that should be expected for Dakar. We will have to evaluate more data to draw any conclusions concerning typical ozone concentration levels for Dakar.

6. Measurements exceeding Air Quality Standards

PM_{10} concentrations were the only air quality indicator exceeding Senegalese air quality limit values for January 2010. The concentrations of SO_2, NO_2 and ozone never exceeded the limit values.

Table 6 presents the number of 24-hour average PM_{10} concentrations exceeding the Senegalese air quality standard of 260 µg/m^3.

Table 6: Number of days when PM_{10} concentration exceeded NS-05-062 limit values

Station	Number of days exceeding air quality standard
Bel air	4
Medina	8
Yoff	22
HLM4	1

We see that at Yoff daily PM_{10} concentrations exceeded 260 µg/m^3 as much as 22 out of the 31 days in January 2010. We believe that this is an overestimate, and we will thus have to look into these measurements again. We cannot clearly state whether these are real concentrations caused by a combination of sea salt and windblown sand or there have been a malfunction in the instrument.

For the other sites the PM10 concentrations were higher than 260 µg/m3 during 1 to 8 days in January.

Table 7 presents the range of hourly concentrations of SO_2, NO_2 and ozone measured at the 5 sites in Dakar.

Table 7: Range of air quality measurement in Dakar

Component	**SO_2**	**NO_2**	**Ozone**
Bd Republique	5-68	5-60	5-40
Bel Air	5-150	5-55	-
HLM4	5-23	5-30	5-45
Medina	-	5-50	-
Yoff	-		5-40

SO_2 concentrations at Bel Air station were probably the second highest relative to limit values. As seen from Table 7 NO_2 and ozone concentrations were not any problem in January 2020.

7. Summary and conclusion

Data from five air quality monitoring stations in Dakar have been used for reporting the air quality in Dakar for January 2010. Data availability ranged between 24 and 99% for the different stations and compounds. The following conclusion can be drawn:

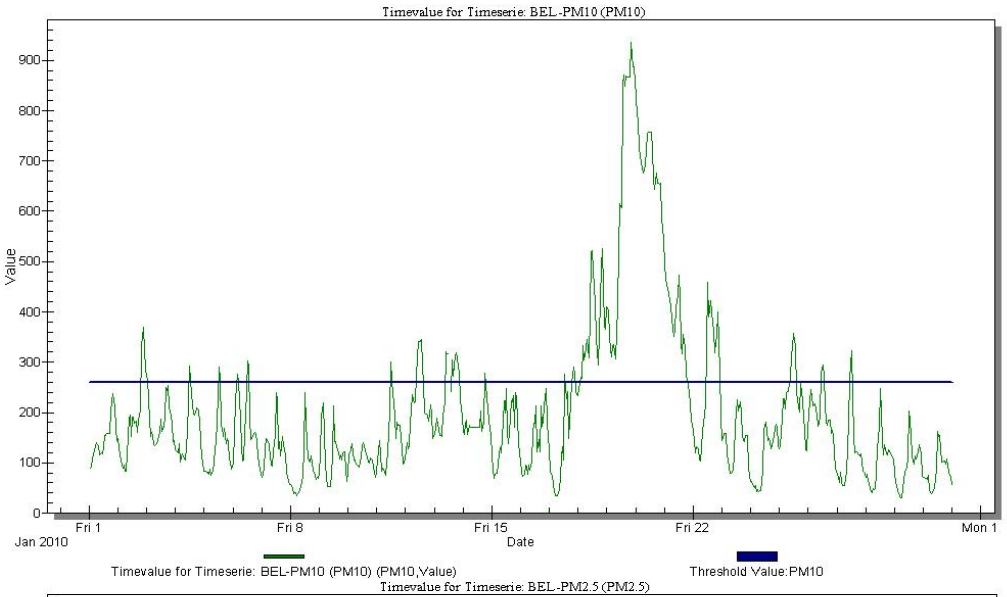
- PM_{10} and $PM_{2,5}$ are the most critical pollutants.
- The 24-hour average PM_{10} concentrations exceeded limit values during one to twenty-two days at the different stations.
- SO_2 concentrations were influenced by industrial emissions at Bel Air, but did not exceed limit values.
- Others gaseous pollutants did not exceed limit values.

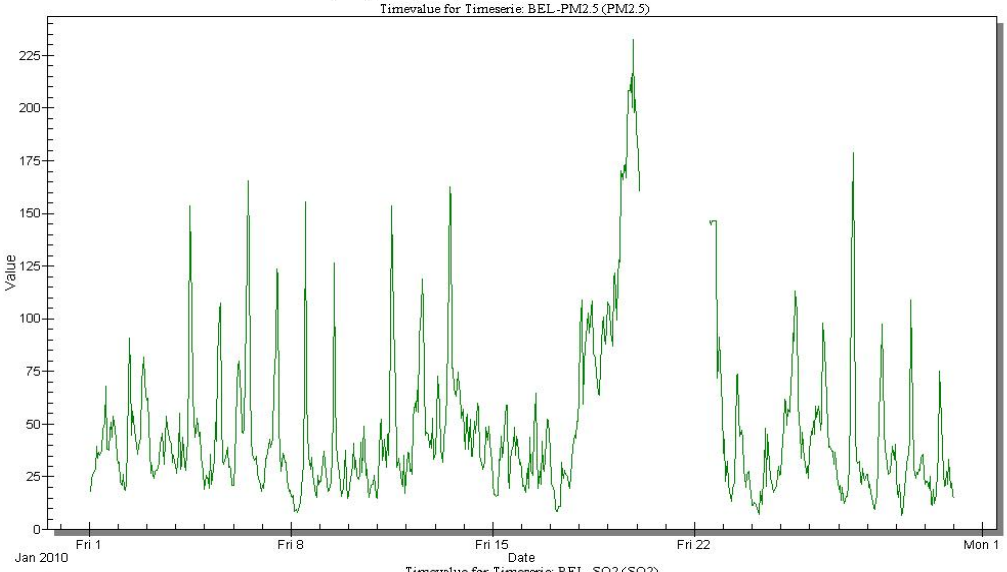
This report represents the first data reported from the new air quality monitoring network in Dakar. There are evidently still some questions linked to the quality of some of the parameters. However, this is now being worked to solve and we are sure that the strict quality assurance programme that has been developed for this programme will improve the data quality.

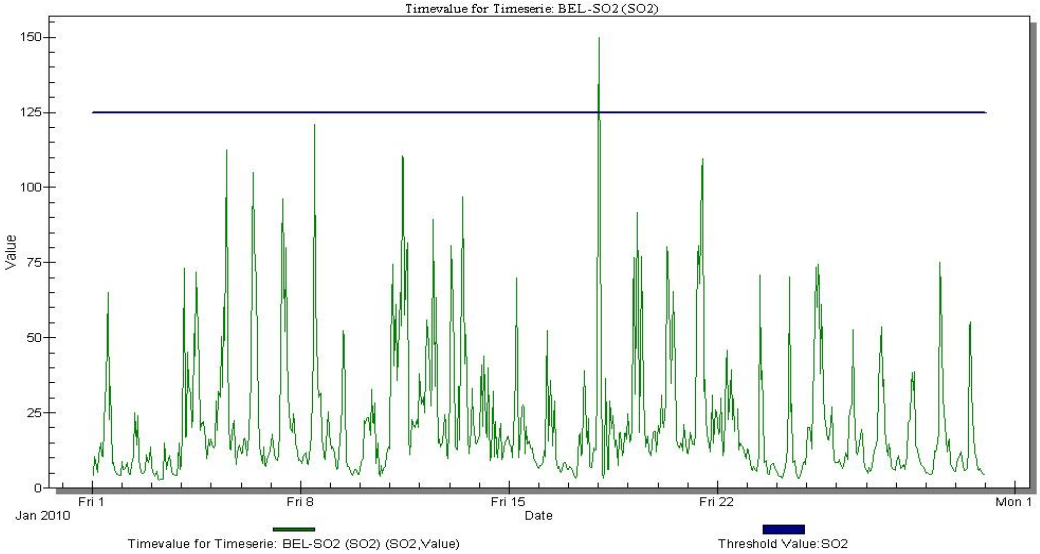
Appendix A

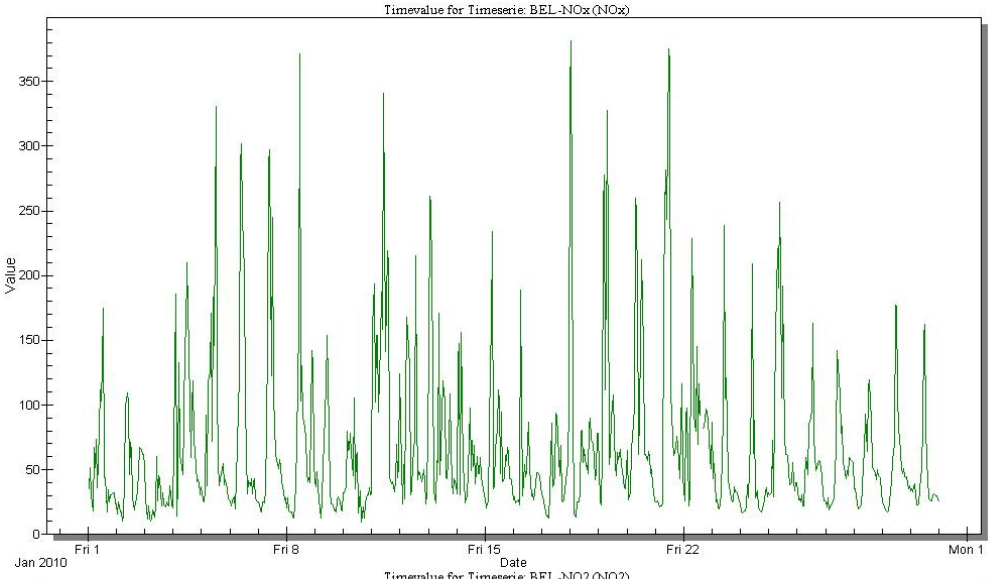
1 Hourly concentrations of air pollutants measured in Dakar in January 2010

Bel Air





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Fri 22
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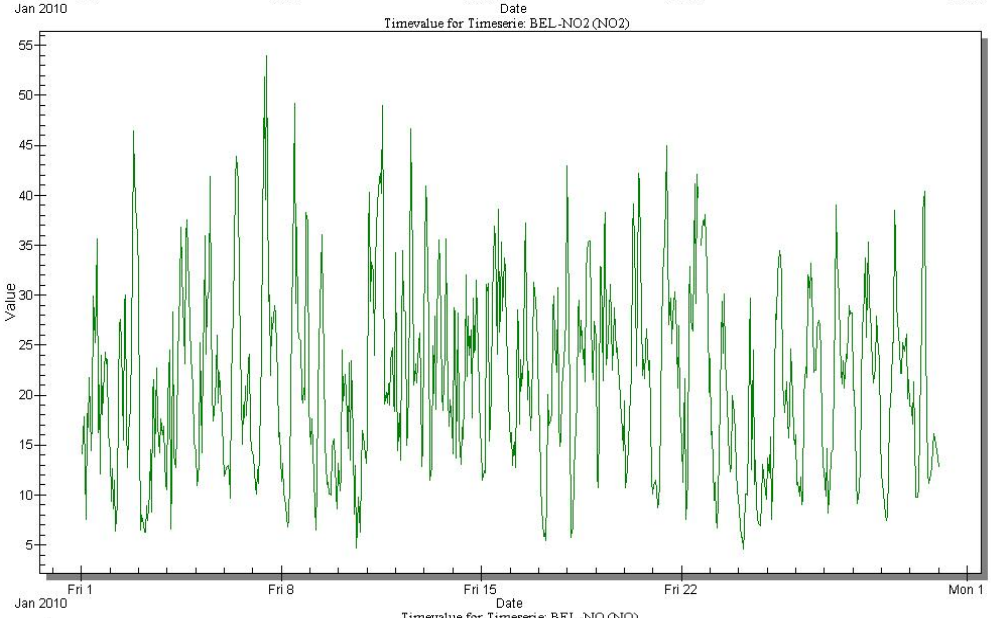
Date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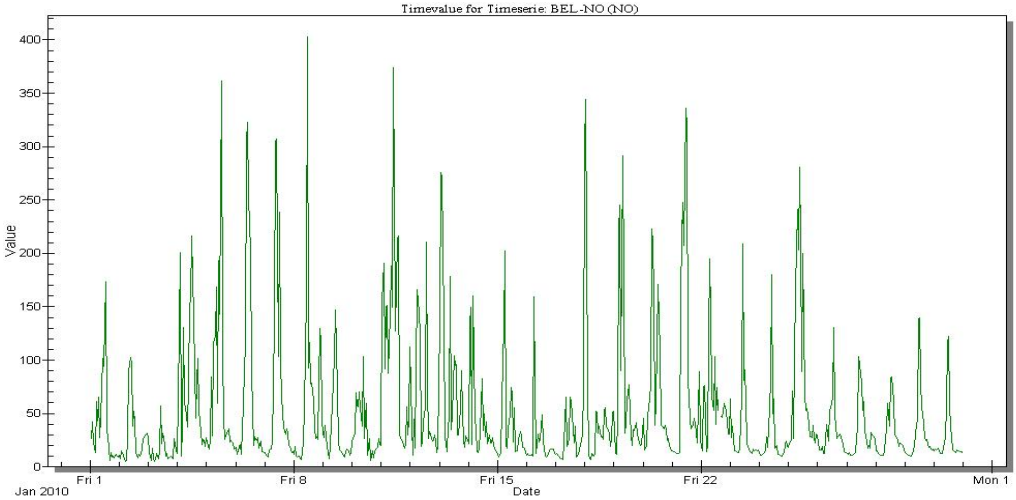
Mon 1
Date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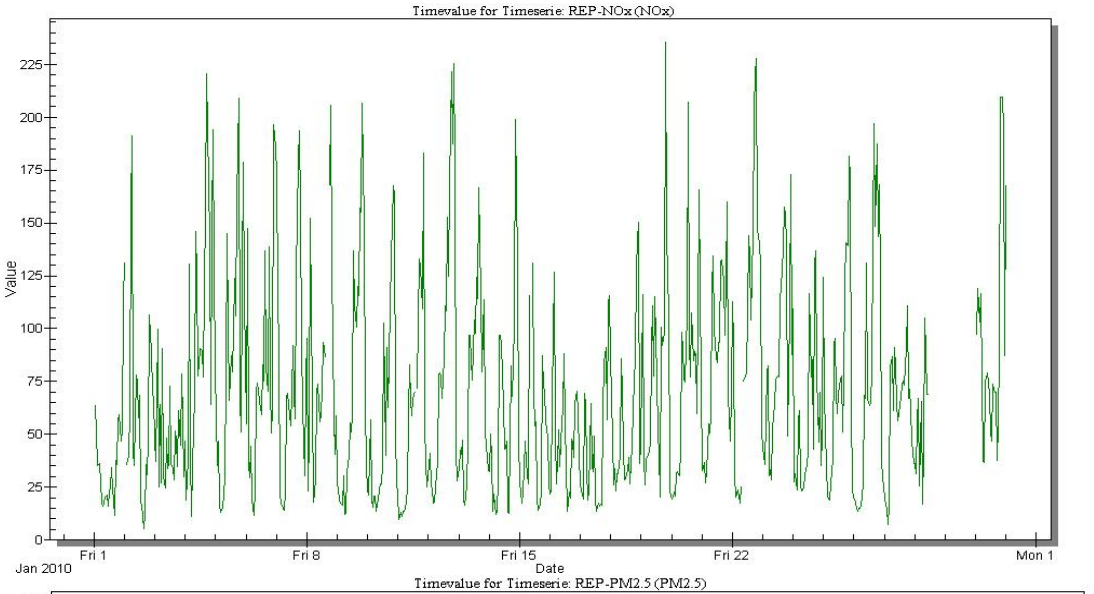
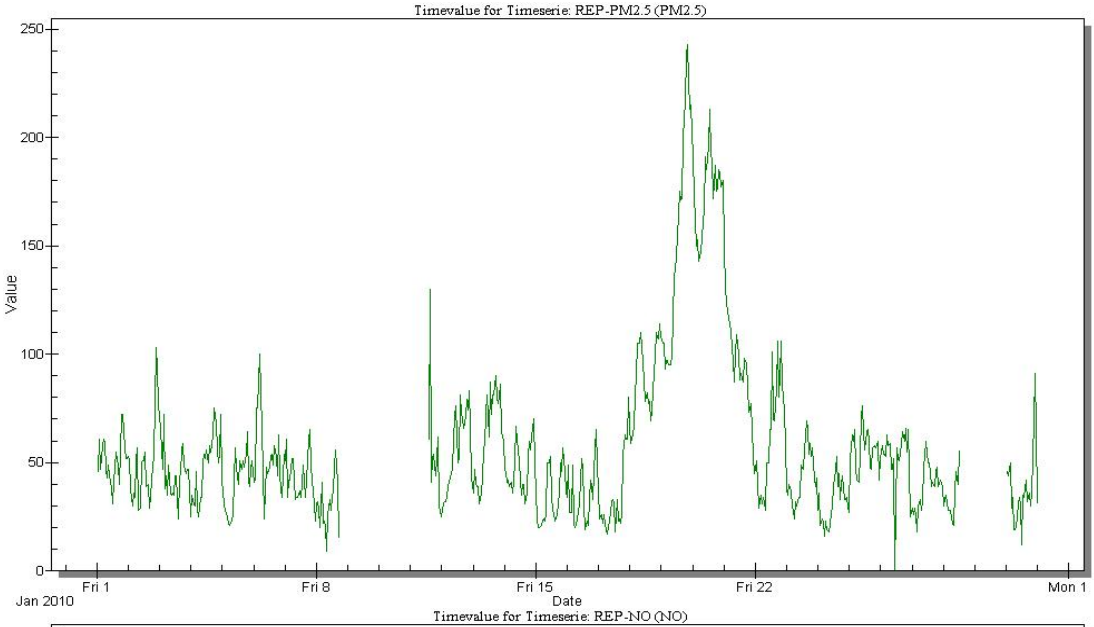
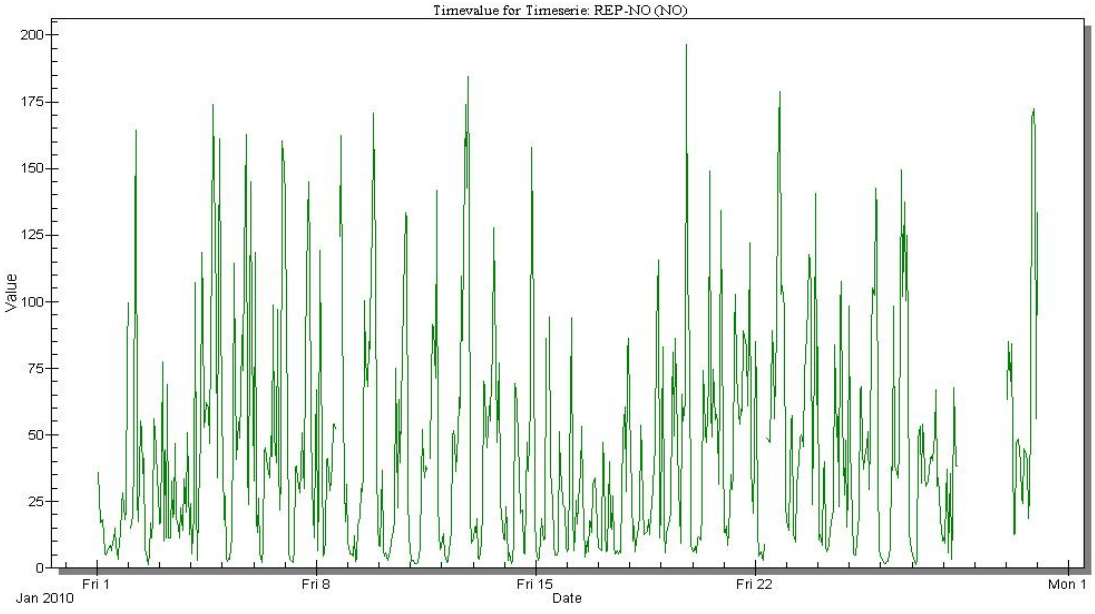
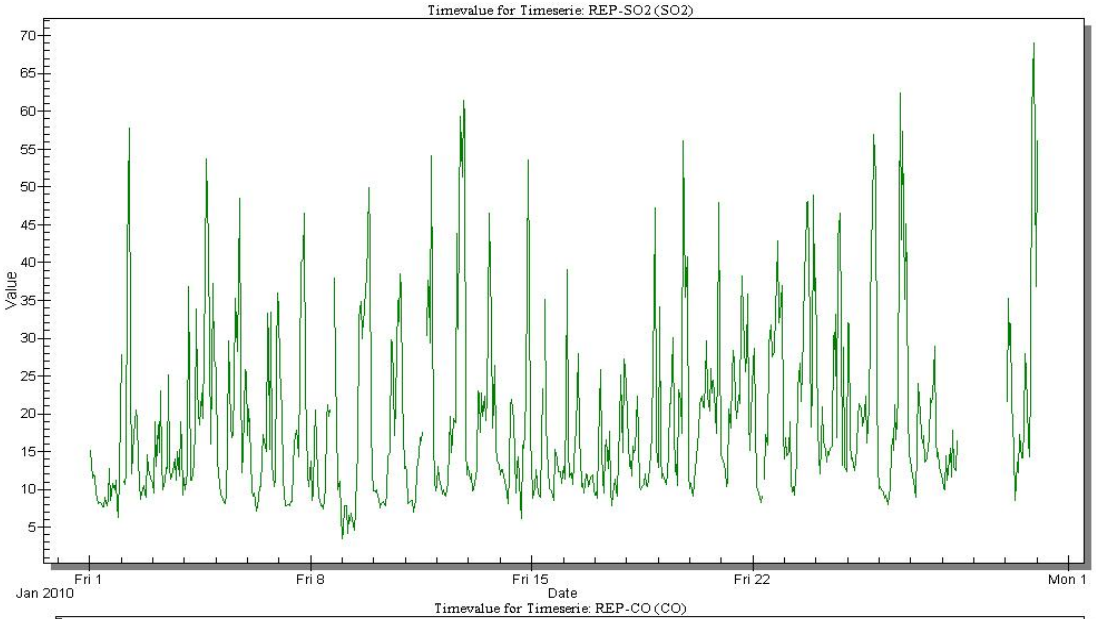
Mon 1
Date

Boulevard de la Republique





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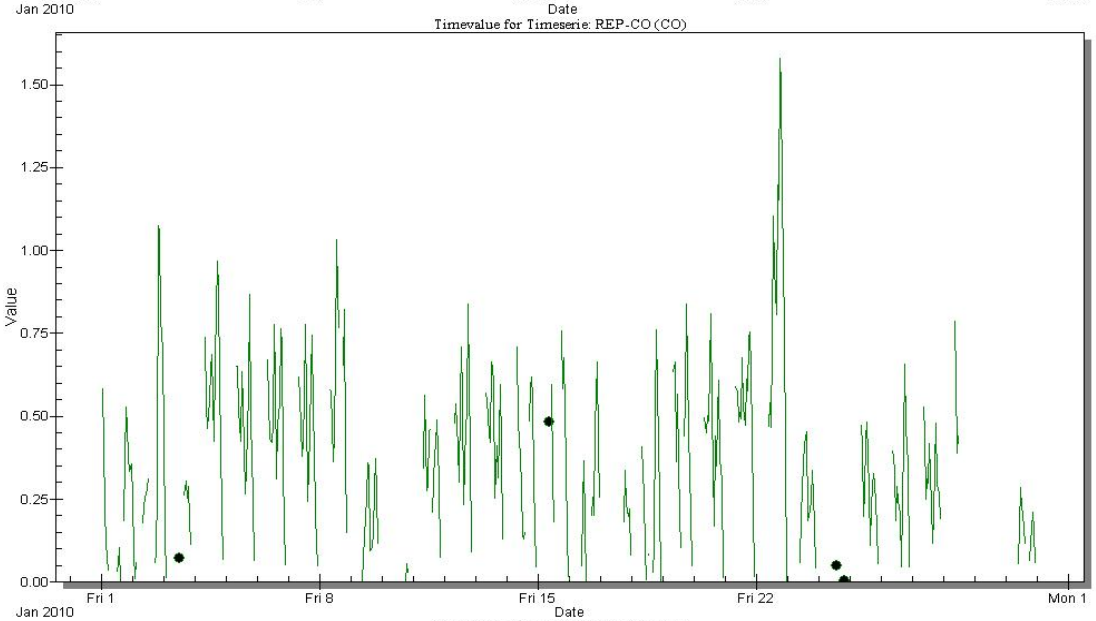
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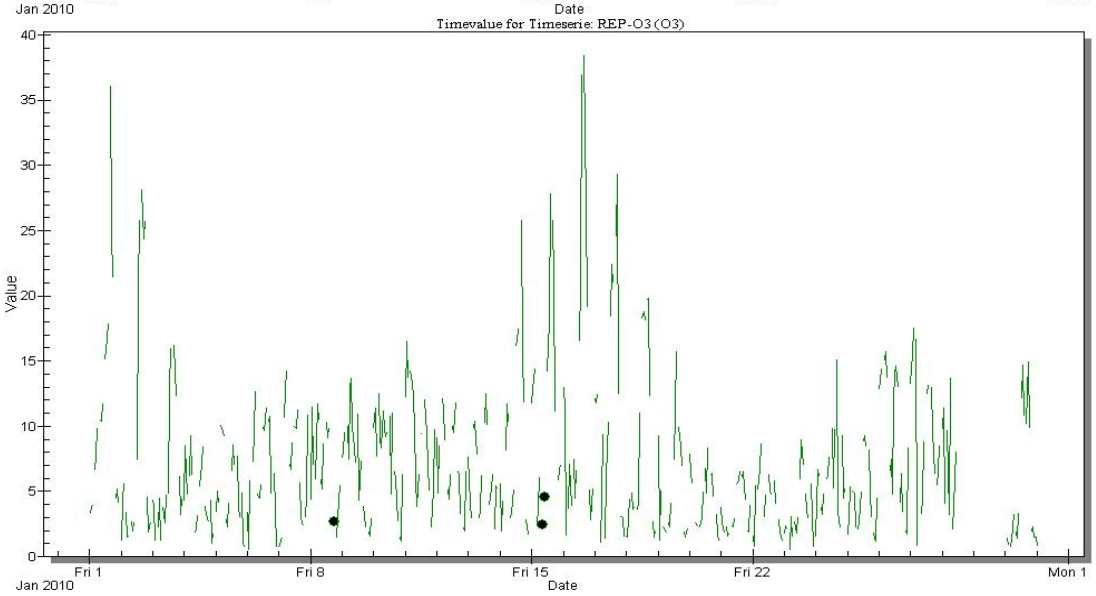
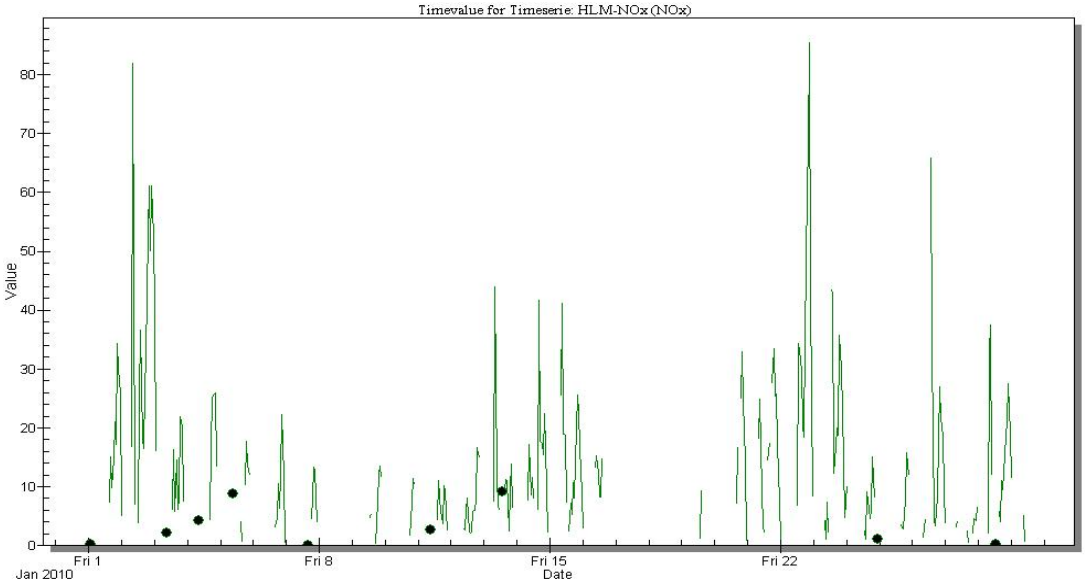
Date


Timevalue for Timeserie: REP-O3 (O3)
Value
40
35
30
25
20
15
10
5
0
Fri 1
Jan 2010
Fri 8
Fri 15
Fri 22
Mon 1
Date

HLM4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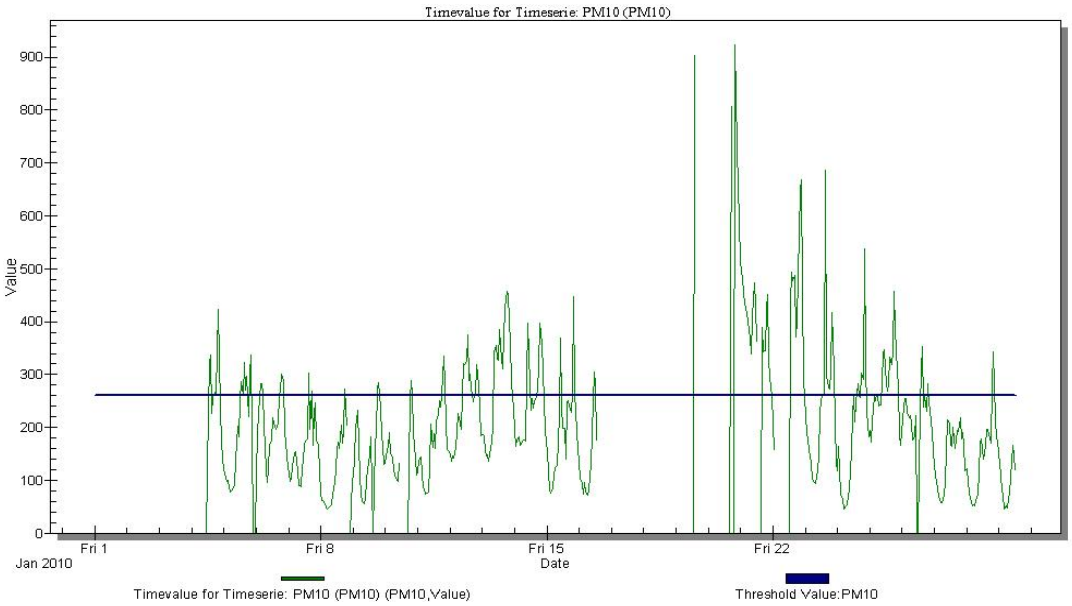
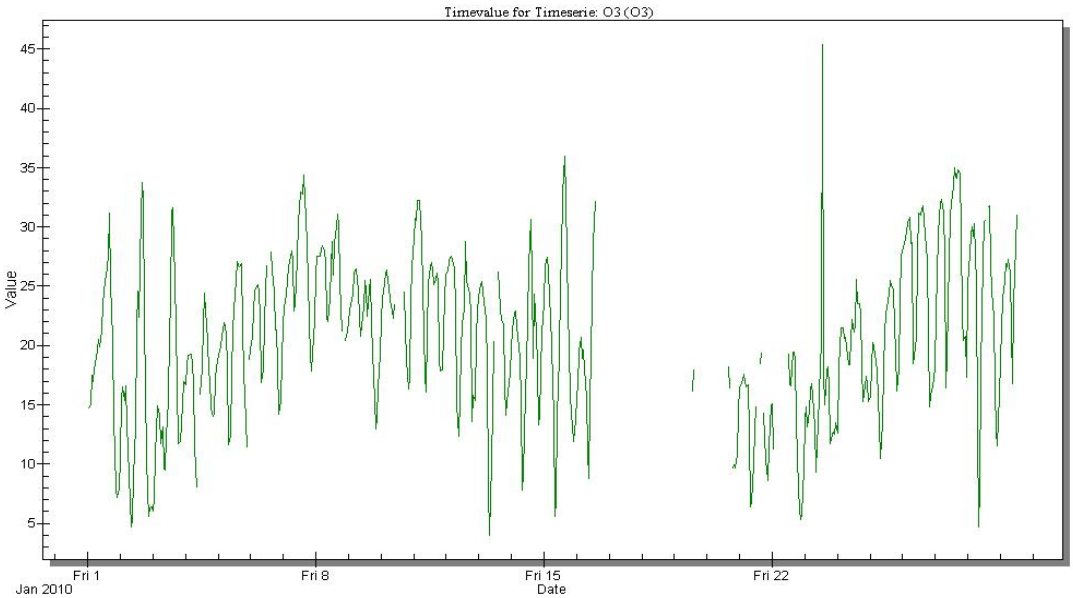
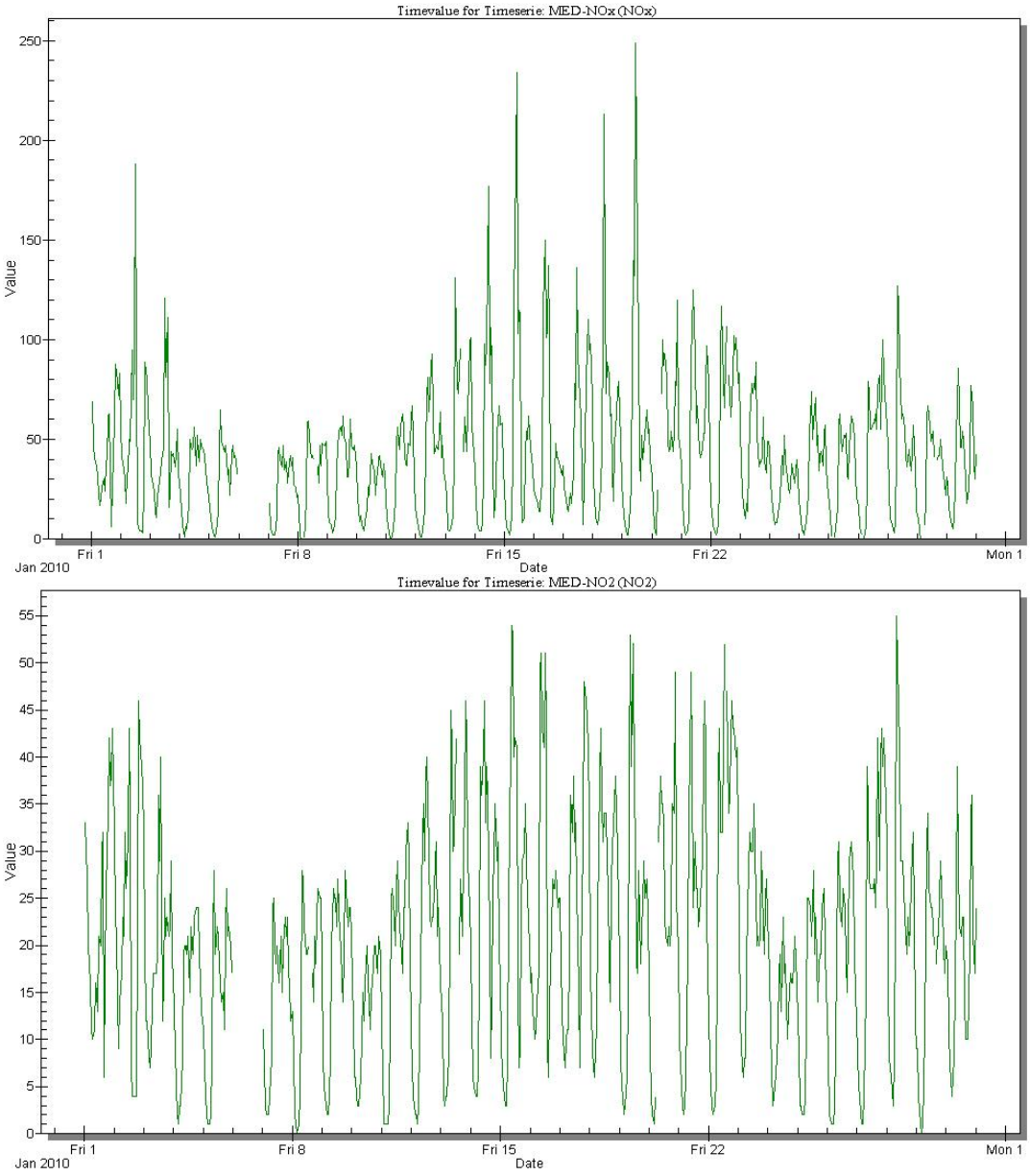
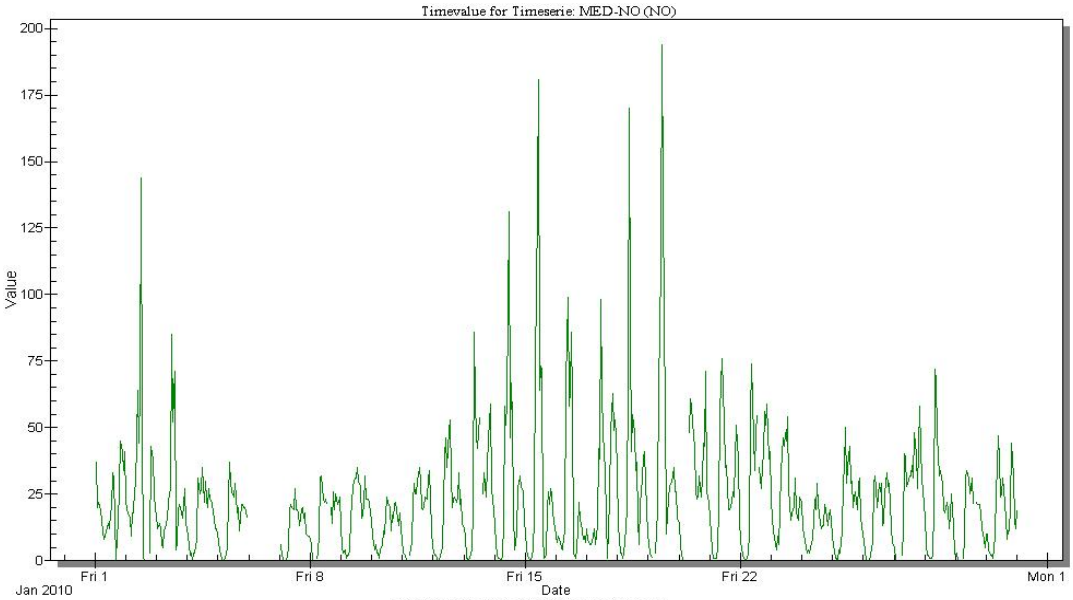
Value
Fri 1
Jan 2010
Fri 8
Fri 15
Fri 22
Date


Timevalue for Timeserie: PM10 (PM10)
Value
Fri 1
Jan 2010
Fri 8
Fri 15
Fri 22
Date
Timevalue for Timeserie: PM10 (PM10) (PM10,Value)
Threshold Value:PM10


Timevalue for Timeserie: O3 (O3)
Value
Fri 1
Jan 2010
Fri 8
Fri 15
Fri 22
Date

Médina


Timevalue for Timeserie: MED-NOx (NOx)
Value
250
200
150
100
50
0
Fri 1
Jan 2010
Fri 8
Fri 15
Date
Fri 22
Mon 1
Timevalue for Timeserie: MED-NO2 (NO2)
Value
55
50
45
40
35
30
25
20
15
10
5
0
Fri 1
Jan 2010
Fri 8
Fri 15
Date
Fri 22
Mon 1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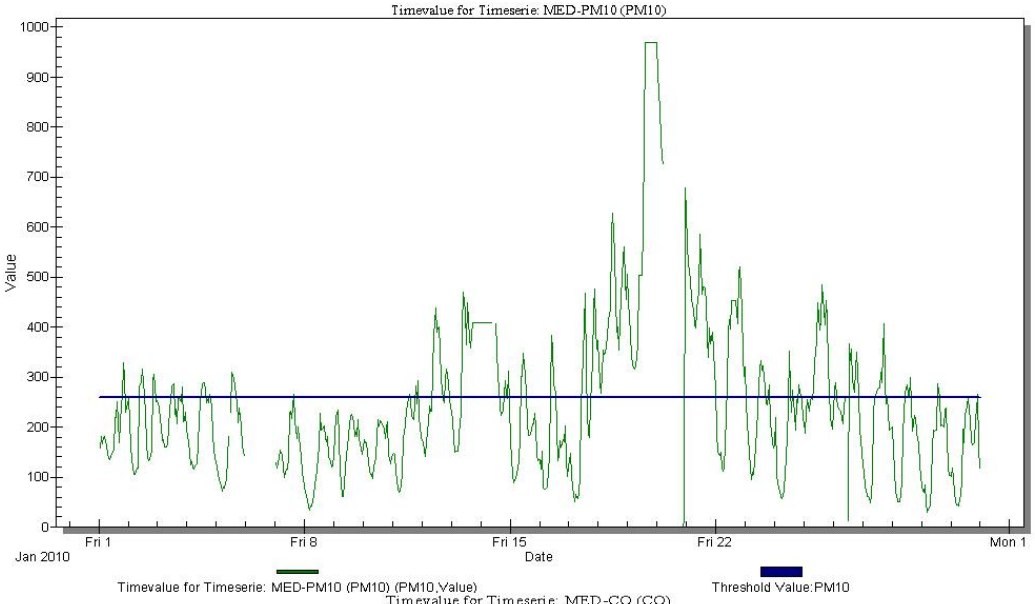
Jan 2010
Fri 1
Fri 8
Fri 15
Fri 22
Mon 1
Date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Value
Jan 2010
Fri 1
Fri 8
Fri 15
Fri 22
Mon 1
Date
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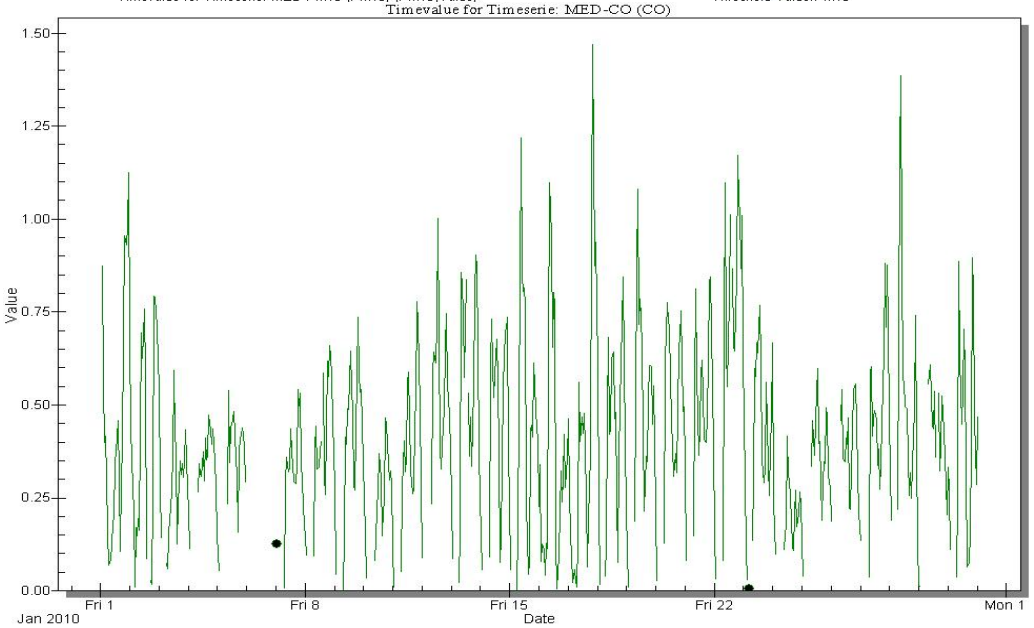
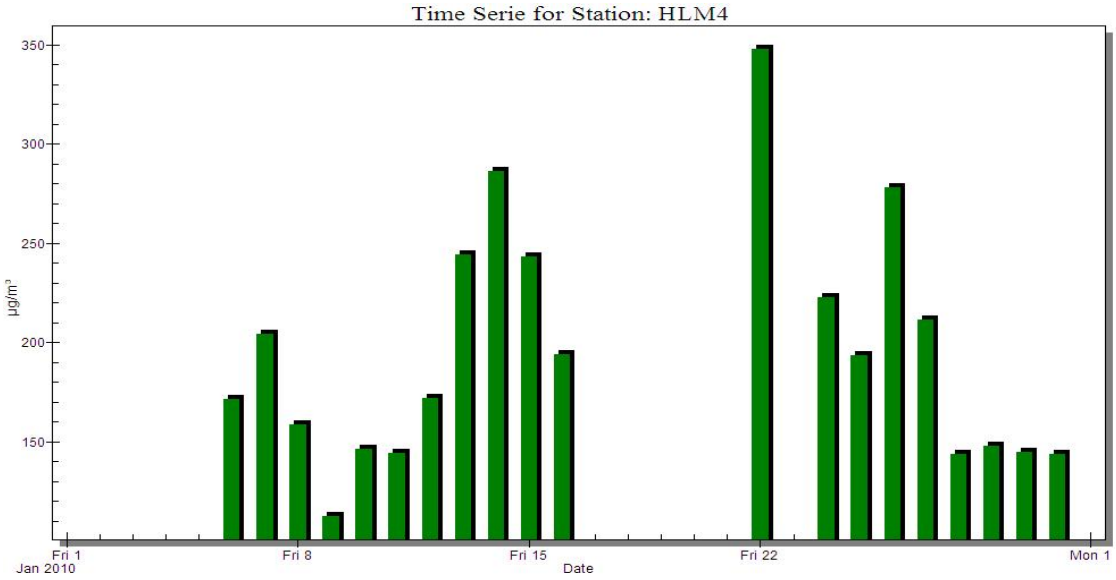
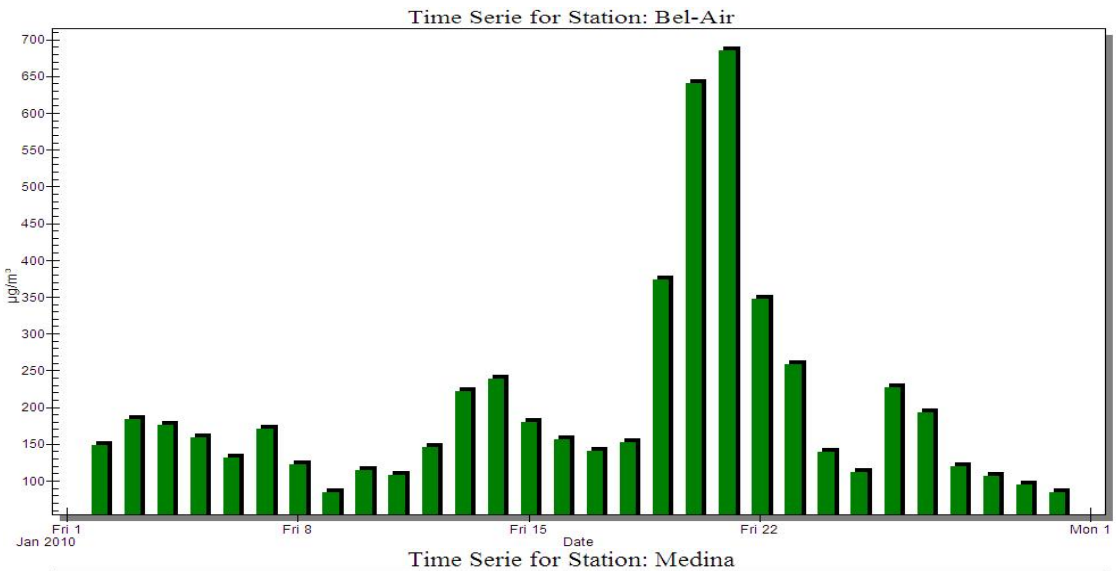
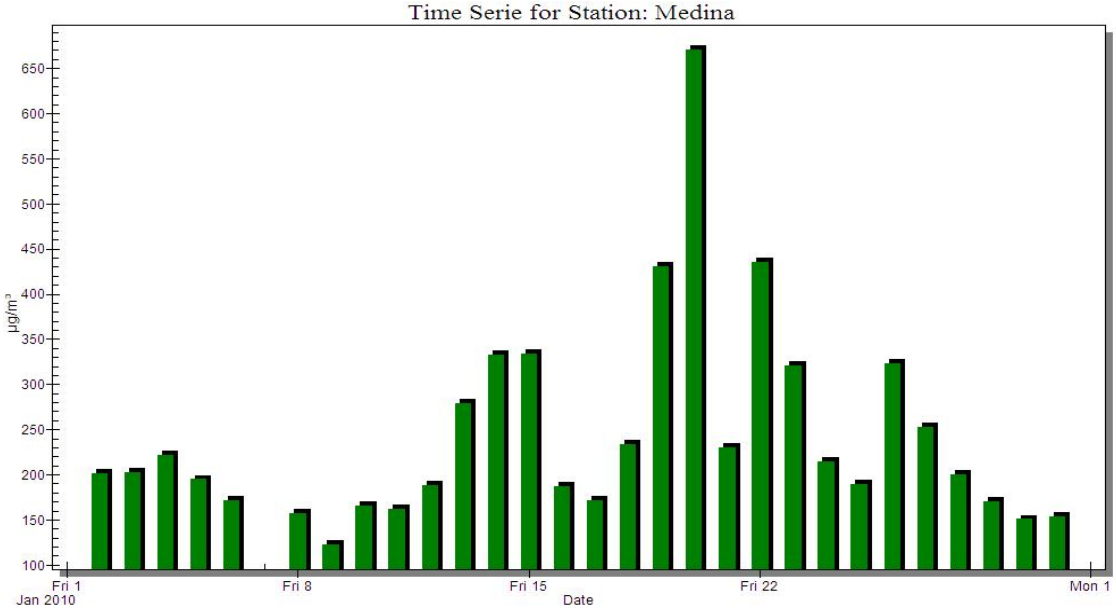
Threshold Value:PM10


Timevalue for Timeserie: MED-CO (CO)
Value
Jan 2010
Fri 1
Fri 8
Fri 15
Fri 22
Mon 1
Date

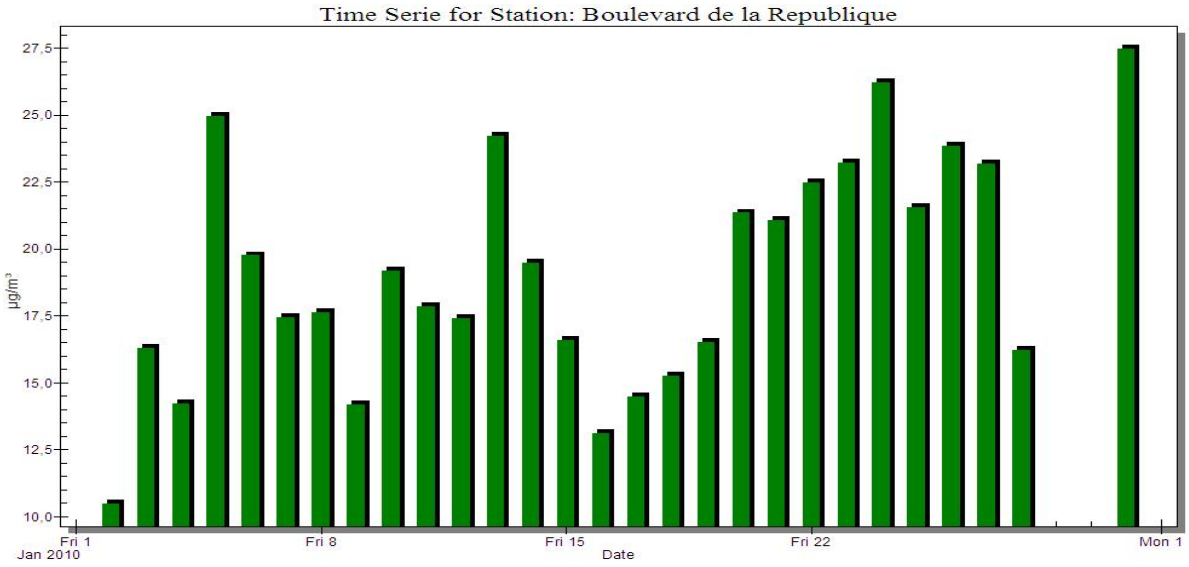
2 Twenty four hours aggregated PM_{10} concentrations

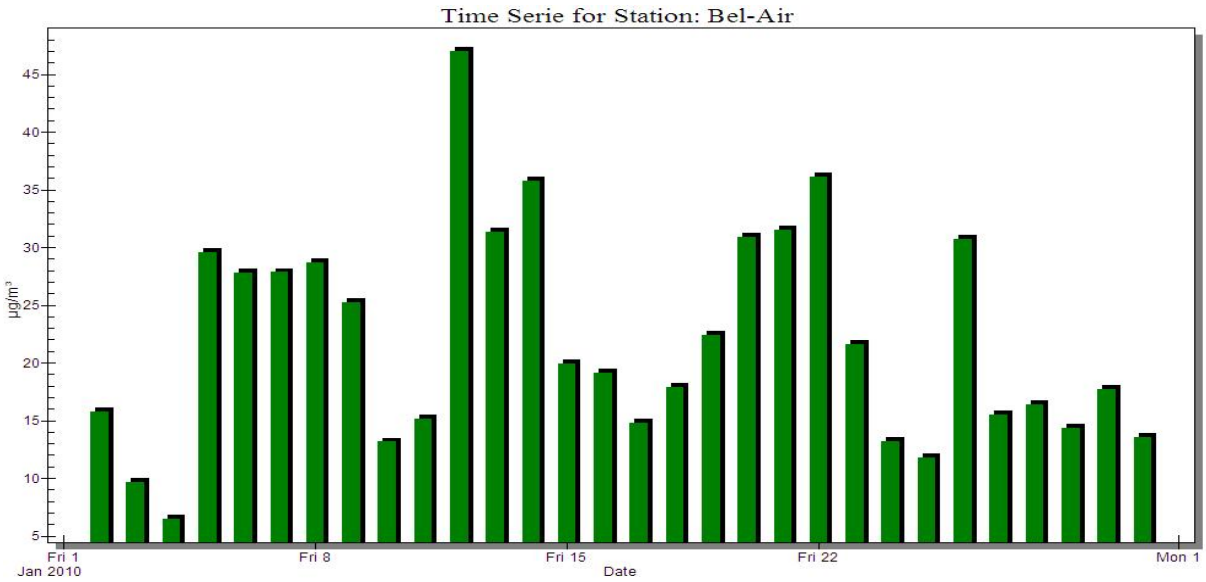






3 Twenty four hours aggregated SO_2 concentrations





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AUTHOR(S) Bjarne Sivertsen, Abdoulaye Ndiaye and Mbaye Diop	CLASSIFICATION * A
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Senegal

ABSTRACT
The current report on air quality in Dakar has been based on measurement data from five (05) air quality monitoring stations operating in Dakar for the month of January 2010. The data have been evaluated by the Air Quality Management Center (CGQA) assisted by NILU. The data was quality controlled and prepared as a basis for the statistics presented in this report. Air pollution in Dakar is dominated by suspended particles in the air. The main sources are linked to dust from traffic, industries and desert. Generally there is frequent exceeding of the national limit values for particulate matter measured as PM10.

NORWEGIAN TITLE

KEYWORDS		
Air quality monitoring	Air Quality Reporting	Dakar

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C Classified (not to be distributed)

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