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Agreement:	NO 003/C/FND/05

Ambient Air Pollution Screening Study Dakar 2005

October - December 2005 and January 2006

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Contents

Page

1 Introduction

The Norwegian Institute for Air Research (NILU) was asked by the Conseil Exécutif des Transports Urbains de Dakar (CETUD) for support in establishing a Central Laboratory with an Air Quality Management System for Dakar. This project is part of the component entitled as "Amelioration de la qualité de l'air en milieu urbain" (QADAK) of the "Programme d'Amélioration de la Mobilité Urbaine" (PAMU) operated by the Conseil Exécutif des Transports Urbains de Dakar (CETUD).

A screening study of air pollution in Dakar was performed between October 2005 and January 2006. The main objective was to collect background information for designing a permanent air quality monitoring programme for the area in the future.

Passive samplers of NO_2, SO_2, VOC and O_3 were located at about 50 selected measurement sites in Dakar city and in surrounding suburban areas. The passive sampling of SO_2, NO_2 and O_3 was performed during October and the samplers were exposed for 4 weeks. The passive samplers of VOC were exposed over 3 to 7 days, depending on the location, in the beginning of October. A new campaign of O_3 sampling was carried out in January 2006, due to problems with the analysis from the sampling in October.

A sequential sampler for suspended particles (PM_{10} and $PM_{2.5}$) and a CO monitor were located in a busy street in the city centre. The measurements of PM_{10}, $PM_{2.5}$ and CO at this main station were carried out from 5 October 2005 to 2 January 2006. Some samples of PM_{10} and $PM_{2.5}$ were analysed further to get some knowledge on the chemical composition of the particulate matter in Dakar. The following chemical analyses were taken:

- Trace elements such as lead (Pb), cadmium (Cd), vanadium (V) and arsenic (As), Copper (Cu), Zink (Zn), Chromium (Cr), Nickel (Ni), Cobalt (Co);
- Analysis of elemental (EC) and organic carbon (OC)
- Water-soluble components like sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), nitrate (NO_3), sulphate (SO_4), ammonium (NH_4) and chloride (Cl), which gives an indication of the sea salt contribution to the formation of particles and of some anthropogenic sources.

Parallel and in addition to the sampling programme presented above, short term data were collected in selected areas of the city during a campaign lasting from 3 to 7 October 2005. The short-term samples included PM_{10}, VOC and CO. Measurements were undertaken in different microenvironments during the screening period. The aim with this study was to identify background concentrations and potential hotspots.

This report has also been submitted in French (NILU OR 58/2006).

2 Design of the screening study

The background for the design of the screening study is the identification of main emission sources and areas of highest impact of pollution, as well as existing air

quality data and meteorological data (Guerreiro, C et al., 2005a and Guerreiro, C et al., 2005b).

The sites were selected from three main criteria:

- Measure in different microenvironments (e.g. street canyon, road side, urban background, industrial area, regional background etc);
- Selection of components to measure at the different microenvironments depending on emission sources;
- Prevailing wind directions for the campaign period.

2.1 Emission sources

The most important industrial areas and areas with heavy traffic have been identified. From the identified emission sources, the most important sources in Dakar appear to be ground level sources.

On a general basis it seems that traffic jams on some of the main roads produce high emissions of CO. High traffic density on the main roads also lead to large emissions of NOx and particles. The general activities in the city seem to produce high background levels of suspended particles. The industrial areas, especially located in the eastern part of the city (e.g. Grands Moulins area) causes emissions of PM, SO_2, VOC and NOx.

2.1.1 Compounds and indicators

A number of air pollution indicators have been selected to identify the air quality level in Dakar. The selections of components to measure in the different microenvironments have been decided by the presence of the local emission sources. A list of typical indicators is presented in Table 1 below.

Table 1: Air pollution indicators measured in various microenvironments.

Station type/Microenvironment	Components
Regional background	NO_2, SO_2, PM_{10}, O_3
Industry	NO_2, SO_2, VOC, O_3, PM_{10}
City centre	NO_2, SO_2, O_3, PM_{10}, $PM_{2.5}$, CO, VOC
Traffic/street canyon	NO_2, SO_2, O_3, CO, VOC, PM_{10}
Urban background	NO_2, SO_2, O_3
Suburban	NO_2, SO_2, O_3

Ozone is a secondary pollutant formed by chemical reactions in the atmosphere. Measurements of ozone, especially in the background air, are essential for understanding the formation of NO_2 in the city.

2.2 Meteorological conditions

Climatologically data (from weather forecast models and observations) shows that the prevailing wind direction in Dakar is from around north. The wind directions in

October, November and December are mainly from north, north-northwest and north-northeast. Most of the samplers are therefore, if possible, located south of the main emission sources. Major part of the samplers was located along traverses perpendicular to the prevailing wind. The sampling programme has been designed along five traverses as far as feasible.

The meteorological data during the sampling period was collected at CERER (CERER, personal communications). Ten-minute averages of wind speed, wind direction and temperature were collected at a 15 m meteorological mast. Based on the 10 minutes values, hourly averages have been calculated and used in the analysis. Meteorological data for three different sampling and monitoring periods are evaluated individually.

2.2.1 Wind speed and wind directions

During the screening studies in October the prevailing wind direction was from north and north-northwest. The wind speed during 82 % of the time was less than 2 m/s. Only 0.4 % of the wind speed was above 4 m/s (Figure 1).

In average, the prevailing wind direction for the three months October until December gives the same picture as the annual average (Appendix D). The wind directions are mainly from north and north-northeast. Wind speed less than 2 m/s is observed in 63% of the time (Figure 1).

The meteorological condition during the measurement period seems to be representative for general wind conditions.

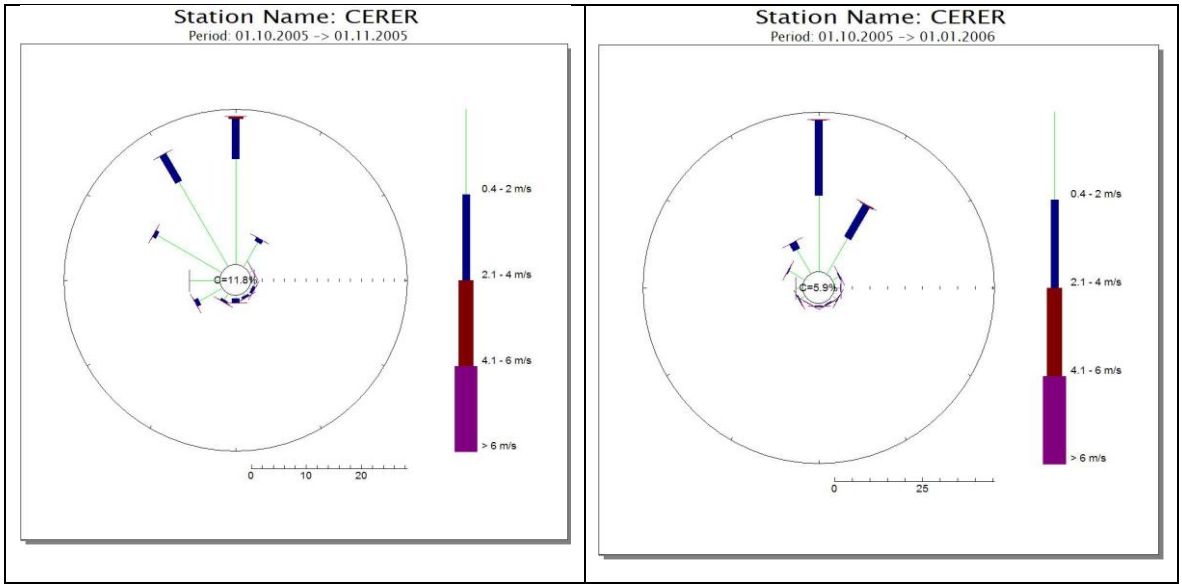

Figure 1: Calculated wind frequency distribution (wind rose) a) October 2005 and b) from October including December 2005.

Measurements of stability or turbulence have not been available for the screening period. As expected, during nighttimes the wind speed is very low in average (Figure 2). With low wind speeds and assuming clear sky and heat radiation from the surface, stable meteorological conditions are expected to have occurred during night. The wind speed conditions during daytime give an indication of neutral or unstable conditions and a well-mixed atmospheric boundary layer. On the average, the highest wind speed is measured in late afternoon.

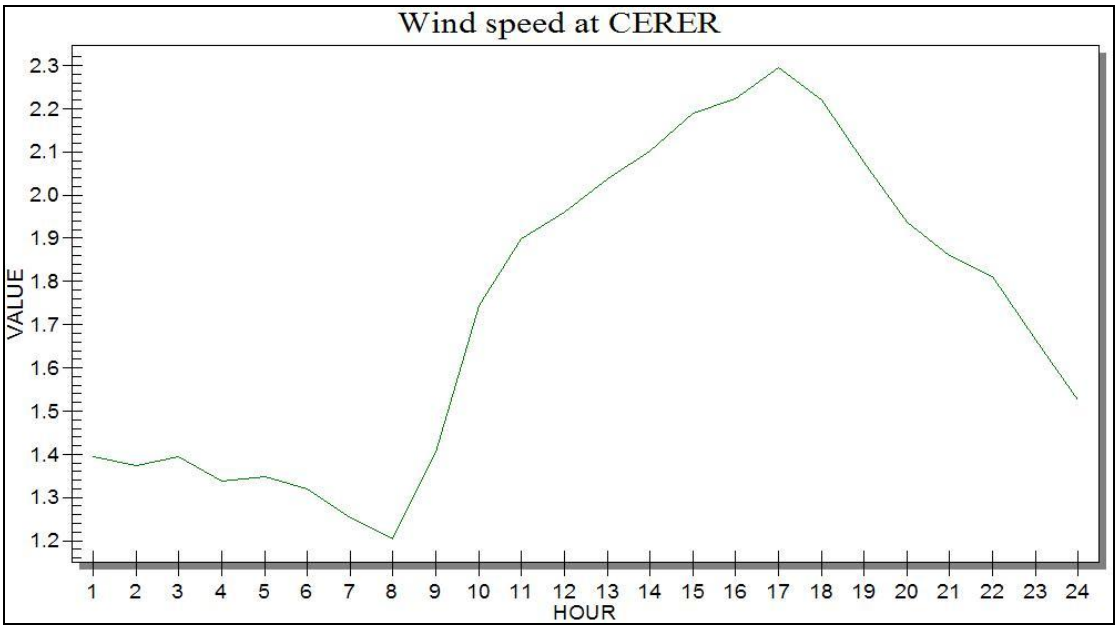

Figure 2: Calculated diurnal variations from October 2005 including December 2005.

3 Instruments and samplers

3.1 The SO_2, NO_2 and O_3 passive samplers

A sensitive diffusion sampler for sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3) in ambient air has been developed by the Swedish Environmental Research Institute (IVL) (IVL, 2006). This method has been used in several investigations to undertake a screening of the spatial concentration distribution.

The sampler includes an impregnated filter inside a small plastic tube. To avoid turbulent diffusion inside the sampler, the inlet is covered by a thin porous membrane filter (as shown in Figure 3). Gases are transported and collected by molecular diffusion.

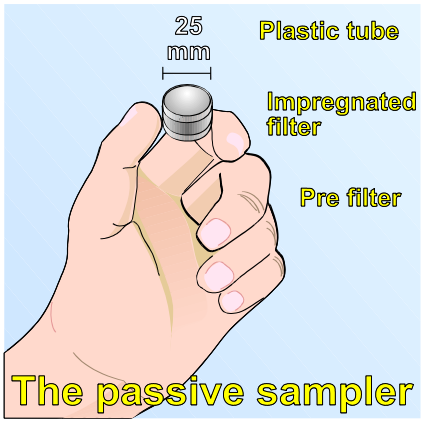

Figure 3: The passive sampler.

It should be emphasised that samplers provide time-integrated concentrations with continuous time coverage with the averaging time determined by the period they are exposed to ambient air (which can be daily, weekly, monthly, etc.).

The sampling technique is based on the property of molecular diffusion of gases. The gas molecules diffuse into the sampler where they are quantitatively collected on an impregnated filter or an absorbent material with a solution specific to each pollutant measured. Thus they achieve a time-integrated (or average) concentration. No electricity, pumps or other supporting equipment are needed.

After exposure the samplers are returned to NILU where concentrations of SO_2 are determined as sulphate by ion chromatography. NO_2 is determined by spectrophotometry. The O_3 samplers are analysed at IVL.

3.2 The Volatile Organic Components (VOC) samplers

The VOC samples are taken on adsorption tubes filled with Chromosorb or Tenax TA. Samples can be taken either by passive sampling (diffusive sampling) or active sampling (pumped sampling). The analysis is done by NILU using thermo desorption followed by GC-MS analysis. Standardised Perkin Elmer adsorption tubes are used. The method is carried out according to CEN/DIN norms (CEN/TC 264) and widely used as a standard measurement technique for monitoring BTEX and VOC levels in European cities. The accuracy of the method is better than +/- 10 %.

3.3 The PM samplers

3.3.1 SEQ47/50

The instrument used for daily monitoring PM_{10} and $PM_{2.5}$ is a sequential gravimetric sampler. The instrument is of type SEQ47/50. The sequential sampler is designed for outdoors use at all temperatures and environmental conditions. This measurement technique is a European Commission reference method. The air sample is drawn through the inlet (one inlet for each fraction) head by a vacuum pump, and the particles are trapped on a filter. The instrument holds 15 filters, which are automatically changed after 24 hours exposure. The filters are weighed before

exposure and re-weighed after exposure by NILU. Corresponding concentrations of PM_{10} and $PM_{2.5}$ are calculated based on the airflow and weight.

3.3.2 Dust trak

For the short-term measurement of PM_{10} in different microenvironments in the urban area, TSI's DustTrak Aerosol Monitor (8520) was used. The DustTrak is a portable, battery-operated laser photometer. The light emitted from the laser diode is scattered by particles drawn through the unit in a constant stream; the amount of light scatter determines the particle mass concentration based on a calibration factor. The instrument has a mass resolution of ±0.1% or 1 μg m^{-3} (whichever is greater) and a detection range of 0.1–10 μm ($PM_{0.1–10}$) (TSI, 2003). The DustTrak detects potential problems with airborne contaminants such as dust, smoke, fumes, and mists.

Comparison of measured PM_{10} concentrations with various instruments indicates that the accuracy of the dust track is dependent on the calibration of aerosol for different optical depth.

3.4 The CO sampling and monitoring

A TSI Q-trak has been used to measure hourly CO concentrations and short-term measurement of 1minutes averages. The instrument is calibrated by TSI according to NIST- standard. Presisjons Teknikk AS in Norway, performs yearly maintenance and calibration of the instrument used.

4 Air quality limit values

National Air Quality Standards have been developed for Senegal (NS 05-062, 2003). The results from the screening study are evaluated and compared with these standards. Comments on the results are also given regarding some selected international limit values and guidelines (EU, 1999; WHO, 2000).

4.1 Air quality limit values – SO_2

SO_2 is among the “classic” air pollutants, which have been shown to represent a human health risk, as well as risk to ecosystems, when occurring in high enough concentrations.

The man made SO_2 results from the combustion of sulphur, containing fossil fuels (principally coal and heavy oils). The industry, traffic and other combustion processes using sulphur content fossil fuels are the dominant sources.

A summary of the SO_2 standard for Senegal, limit values from the European Commission (EU, 1999) and the guidelines from the World Health Organisation (WHO, 2000) are given in Table 2.

Table 2: Air quality standard, limit value and guideline for SO_2 ($\mu g/m^3$).

Effect	Averaging period	Senegal (standards)	EU (limit values)	WHO (guidelines)
	10 min			500 µg/m^3
Health	1 hour		350 µg/m^3 (1)	
Health	24 hour	125 µg/m^3	125 µg/m^3 (2)	125 µg/m^3
Ecosystems (*) Health (**)	Calendar Year	50 µg/m^3 (**)	20 µg/m^3 (*)(3)	50 µg/m^3 (**)

4.2 Air quality limit values – NO_2

The environmental effects of NO_2 include human health effects, material damage and ecosystem effects caused by the air concentration, and deposition of nitrogen compounds.

Emissions of nitrogen oxides arise mainly from anthropogenic combustion sources. The main anthropogenic sources are mobile and stationary combustion sources.

The NO_2 standard for Senegal, limit values from the European Commission (EU, 1999) and the guidelines from the World Health Organisation (WHO, 2000) are given in Table 3.

Table 3: Air quality standard, limit values and guidelines for NO_2 ($\mu g/m^3$).

Effect	Averaging period	Senegal (standards)	EU (limit values)	WHO (guidelines)
Health	1 hour	200 µg/ m^3	200 µg/m^3 (4)	200 µg/m^3
Health	Calendar Year	40 µg/m^3	40 µg/m^3 (5)	40 µg/m^3

4.3 Air quality limit values – PM_{10} and $PM_{2.5}$

Airborne suspended particulate matter (PM) can be either primary or secondary in nature. Primary particles are emitted directly into the atmosphere either by natural or anthropogenic processes, whereas secondary particles have a predominantly man made origin and are formed in the atmosphere from the oxidation and subsequent reactions of sulphur dioxide, nitrogen oxides and VOCs. The most significant of the

[1] Not to be exceeded more than 24 times a calendar year.
[2] Not to be exceeded more than 3 times a calendar year.
[3] The limit value should not be exceeded for a calendar year nor a winter season.
[4] Not to be exceeded more than 18 times a calendar year. The limit values is to be met by 1January 2010.
[5] The limit value is to be met by 1 of January 2010.

sources are traffic, power plants, combustion sources (industrial and residential), industrial fugitive dust, loading/unloading of bulk goods, mining activities, human-started forest fires and, in some local cases, non-combustion sources such as building construction and quarrying. The main natural sources of airborne particulates are sea spray and soil resuspension by the wind. In addition, Saharan dust and volcano emissions can also be important natural sources of particles.

The EU limit values (EC, 1999) and the standards for Senegal are given in table Table 4. For PM_{10} the standards for Senegal are much higher the EU limit values.

WHO does not give a limit for $PM_{2.5}$ as investigations indicate health effects down to the zero exposure level.

Table 4: Air quality standards, limit values and guidelines for PM_{10}.

Effect	Averaging period	Senegal (standards)	EU (limit values)	WHO (guidelines)
Health	24 hour	260 µg/m^3	50 µg/m^3 (6)	-
Health	Calendar Year	80 µg/m^3	40 µg/m^3	-

The European Commission has not any limit values for $PM_{2.5}$, but the U.S. EPA standard is 15.0 µg/m^3 as the annual average and 65 ug/m^3 as daily average value for ambient $PM_{2.5}$.

4.4 Air quality limit values – CO

Carbon monoxide, or CO, is a gas that is formed when carbon in fuel is not burned completely. The largest source for carbon monoxide (CO) is road transport and the highest ambient CO concentrations are found near traffic in cities where congestion occurs. The ambient CO standard for Senegal the European Commission limit values (EC, 2000) and the World Health Organization guidelines (WHO, 2001) are given in Table 6.

[6] Not be exceeded more than 35 times a year.

Table 5: Air quality standards, limit values and guidelines for CO.

Effect	Averaging period	Senegal (standards)	EU (limit values)	WHO (guidelines)
Health	15 minutes			100 mg/m^3
Health	30 minutes			60 mg/m^3
Health	1 hour			30 mg/m^3
Health	8 hours		10 mg/m^3	10 mg/m^3
Health	24 hours	30 mg/m^3[7]		

4.5 Air quality limit values – VOC (Benzene)

Benzene is a (hazardous) volatile organic compound (VOC) and air quality limit values and guidelines are given for benzene (EC, 2000). The major source of benzene in air in urban areas is from gasoline, which contains a certain amount of benzene. The benzene source is partly from vehicle exhaust, partly from the handling of gasoline in pumping stations.

Table 6: Air quality standard, limit values and guidelines for benzene.

Effect	Averaging period	Senegal (standards)	EU (limit values)	WHO (guidelines)
Health	Calendar year	-	5 µg/m^3 [8]	

4.6 Air quality limit values – O_3

Ozone and other photochemical oxidants are formed by the action of short-wavelength sun radiation on nitrogen dioxide (NO_2). In the presence of volatile organic compounds (VOCs), the equilibrium favours the formation of higher levels of ozone. 8 hours running average limit value (EC, 2004) and guideline (WHO, 2001) are given for O_3 for protection of human health.

Table 7: Air quality standard, limit values and guidelines for O_3.

Effect	Averaging period	Senegal (standards)	EU (limit values)	WHO (guidelines)
Health	8 hour		120 µg/m^3 [9]	120 µg/m^3

[7] The standard should not be exceeded more the once a year.
[8] The limit value is to be met by 1 January 2010
[9] 120 µg/m^3 not to be exceeded on more than 25 days per calendar year averaged over three years.

4.7 Air quality limit values –trace elements

Combustion of fossil fuels, non-ferrous metal, iron and steel industry are the most important anthropogenic sources to trace elements. Due to the negative health impact, limit and target values and guidelines are established for some of the elements (Table 8) (EC, 1999; EC, 2004; WHO, 2001).

Table 8: Air quality standard, limit values and guidelines for trace elements.

Effect	Component	Averaging period	Senegal (standards)	EU	WHO (guidelines)
Health	Lead (Pb)	Calendar year		0.5 µg/m^3 (**)	
Health	Arsenic (As)	Calendar year (***)		6 ng/m^3 (*)	
Health	Cadmium (Cd)	Calendar year (***)		5 ng/m^3 (*)	5 ng/m^3
Health	Nickel (Ni)	Calendar year (***)		20 ng/m^3 (*)	

* Target value
** Limit value
***For the total content in the PM_{10} fraction averaged over a calendar year.

5 Sampling sites in Dakar

The overall goal selecting sampling sites in Dakar was to obtain a general picture of the air quality levels in Dakar. This screening study represents the basis for designing a permanent air quality-monitoring programme for Dakar. The sampling sites should also be selected to identify impacts from different air pollutant sources.

One common way of classifying sampling sites are by area types (urban, suburban, rural) and according to sources (traffic, industrial, background) dominating the air pollution levels at the sampling point. Traffic sites could be classified regarding location of the sampler in the traffic environment e.g. road-side (RS) and street canyon (SC). Rural areas could be subdivided upon distance from major sources and source areas and are generally categorized into: near-city background, regional and remote background stations.

The sampling sites were selected according to the criteria mentioned in section 2 and classified according to area and source types. The samplers were located downwind from the emission sources in areas where impacts would be expected. Normally the samplers were located along traverses perpendicular to the prevailing wind. The screening programme was designed to cover five traverses (Figure 4).

Passive samplers were located in about 50 different measurement points in the city and in the surrounding suburban area (Figure 4). SO_2 and NO_2 were measured at all

sites, O_3 at 10 sites and VOC at 8 sites (4 sites using passive sampling and 4 sites using active sampling). A regional site, hotspot areas (traffic and industry sites) and a site downwind the city were selected to map a picture of the O_3 levels in Dakar. The O_3 sites were selected from three main criteria, namely to measure the regional background concentration levels, to identify the O_3 contribution to NO_2 generation in the city and to evaluate the generation of O_3 due to chemical reactions with VOC, NOx, etc. in the urban area. VOC sites were selected for evaluating contribution from potential single sources (refinery and the hydrocarbon tanks) and traffic. Various traffic hot spots were selected to measure VOC levels from transport activities.

A permanent station in the city centre was selected to make a more extensive measurement of the air quality level in Dakar. This site was located in a busy street canyon in the city centre on a balcony on the first floor approximately 5 m above ground level. The concentration level at this site is expected to be representative for the level people are exposed to in the urban centre of Dakar.

Sequential sampling of suspended particles (PM_{10} and $PM_{2.5}$), CO monitoring and passive sampling of NO_2, SO_2 O_3 and VOC were preformed at this site. The PM sampling and CO monitoring was carried out from the beginning of October until the beginning of January. NO_2, and SO_2 sampling were carried out in October, O_3 in January 2006 and VOC sampling during the first two weeks of October.

The sites and the microenvironments selected are described in Appendix A, and a map displaying the site locations is presented in Figure 4.

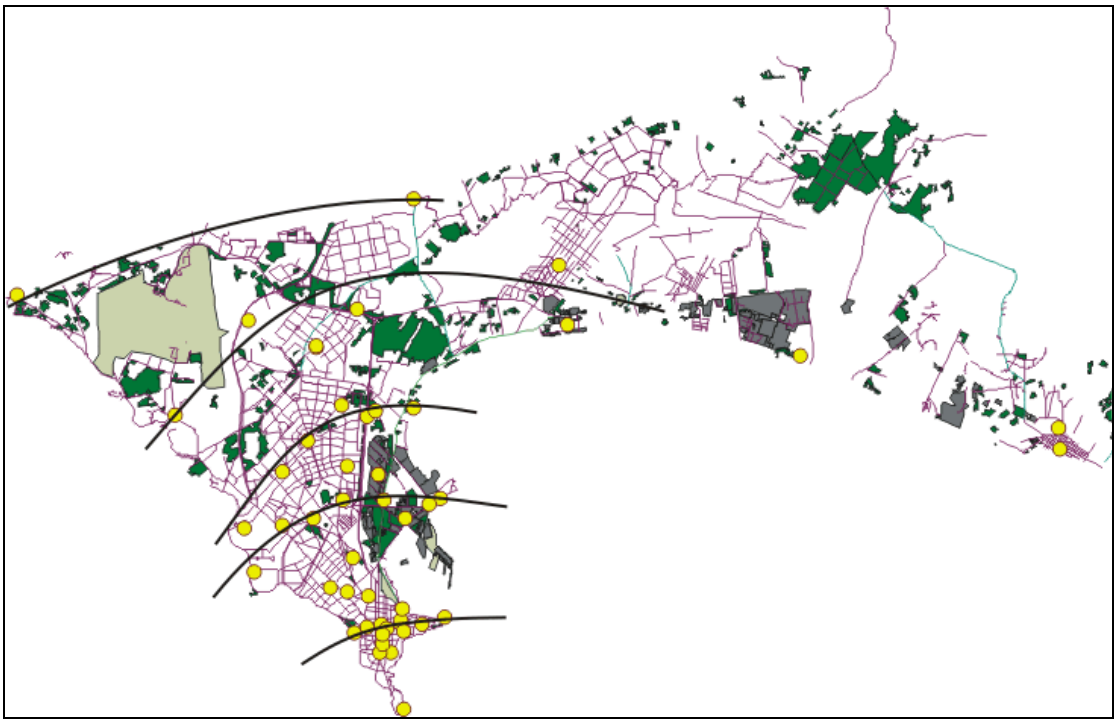

Figure 4: Geographical distribution of the sampling sites in urban and suburban area of Dakar.

Parallel and in addition to the sampling programme presented above, short term data for PM_{10}, VOC and CO were collected in selected areas of the city during a campaign lasting from 3 to 7 October 2005. One of the objectives for this was to identify background concentrations and potential hotspots.

6 Measured concentrations

Based on the assumption that monthly averages are representative for the long term average (section 2.2), monthly values of SO_2 and NO_2 concentrations have been collected and compared to annual standards and limit values. 8 hours running average concentrations of CO have been calculated based on hourly monitored concentrations and evaluated against 8 hours average limit values. Measured daily PM_{10} concentrations are evaluated against daily air quality standard and guideline values. Measured concentrations of benzene have been evaluated against annual limit values, based on the assumption that the dispersion conditions for the data collection period are representative for long term averages.

6.1 NO_2 sampling

The passive samplers were analysed at NILU. The NO_2 concentration levels are presented in Figure 5 and the geographical distribution are given in Figure 6.

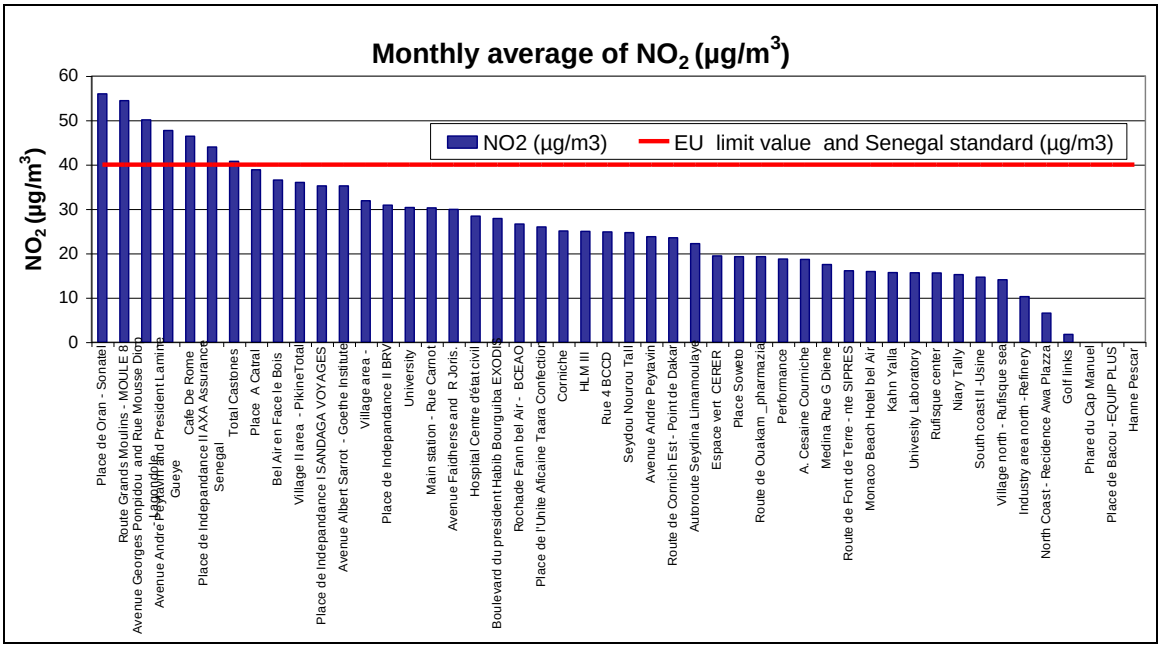

Figure 5: Concentrations of NO_2 measured by passive samplers in October 2005 (no value means missing sample).

The annual NO_2 standard for Senegal and the EU limit value are both 40 ug/m^3. This threshold value is defined to protect human health. The monthly averages exceed the yearly NO_2 standard at seven sites. The maximum concentration sampled was 56 µg/m^3 and the average measured concentration is 27µg/m^3. All the exceedances are measured at traffic sites and in street canyons. The emission sources, which are mainly traffic, will be more or less constant over the year. Based on the assumption that the meteorological conditions during the field campaign period are representative for long term average, it is expected that exceedances will occur on a yearly basis at traffic hot spot sites. The NO_2 concentrations measured during the preliminary screening study preformed in June (Guerreiro et al., 2005a) are approximately at the same levels as the concentrations measured in October. At some sites there is a difference in measured concentration level for the two field campaign periods. One reason for this may be different impact on micro scale due to different measurement period. Similar concentration levels were measured during a field campaign in 2004 (Ndiaye S.A., 2005, personal communication). Based on the monthly results, it is expected that hourly limit values will be exceeded in traffic hot spot areas.

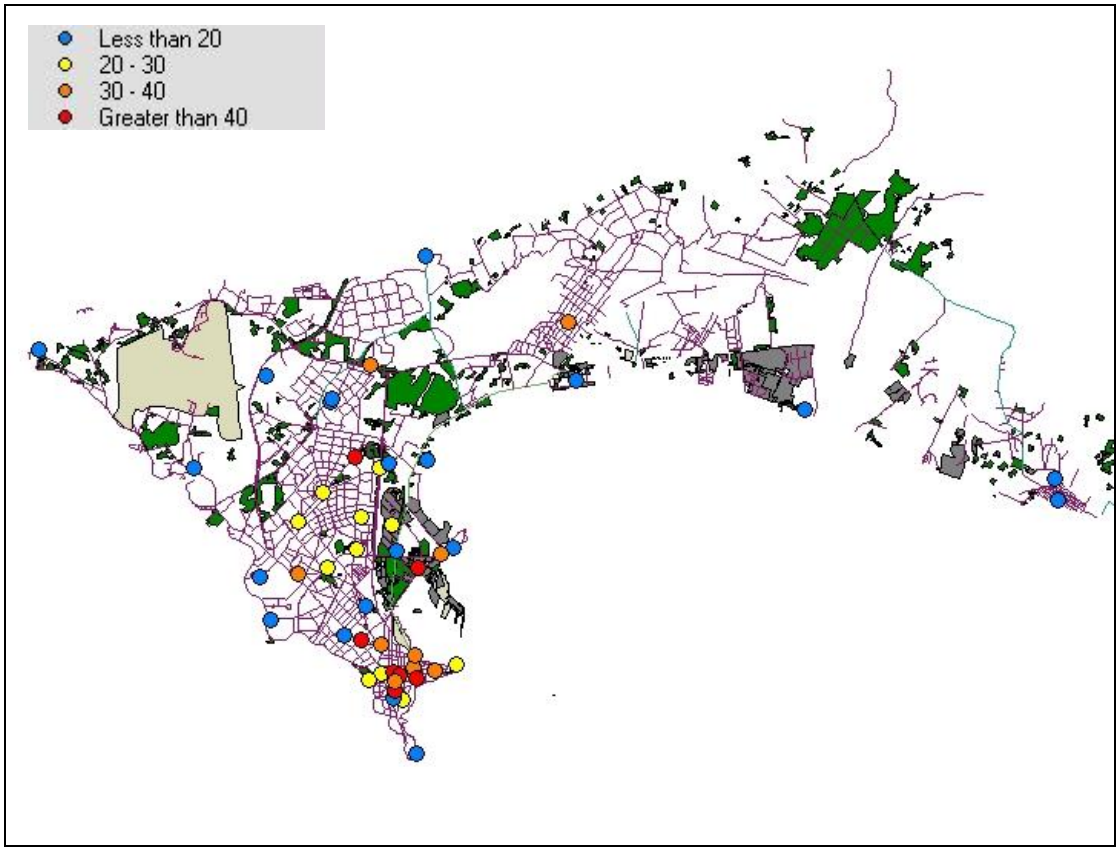

Figure 6: Geographical distribution of NO_2 concentrations measured by passive samplers in October 2005.

6.2 SO_2 sampling

The passive SO_2 samplers were analysed at the chemical laboratory at NILU. The monthly SO_2 concentration levels are presented in Figure 7. A map displaying the geographical distribution is given in Figure 8.

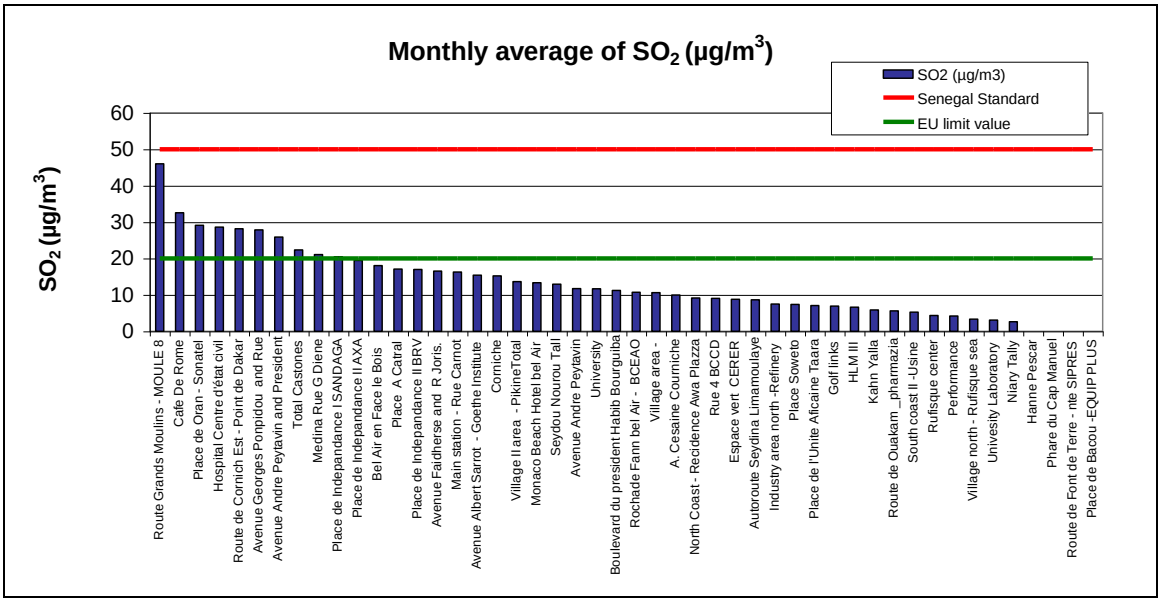

Figure 7: Concentrations of SO_2 measured by passive samplers in October 2005 (no value means missing sample).

The annual SO_2 standard for Senegal and the WHO guideline is 50 µg/m^3. This guideline is to protect human health. Based on the assumption that the monthly averages are representative as long-term averages, the SO_2 concentrations are compared to annual standard and yearly values. The monthly averages of SO_2 did not exceed the Senegal standard and the WHO guideline (50 µg/m^3). Exceedances of the EU limit value (20 µg/m^3) for protection of ecosystems are measured at both industrial sites and traffic sites (Figure 7, Figure 8). The maximum SO_2 concentration measured was 46 µg/m^3 at Route Grands Moulins. The highest impact was measured in the industrial area, as expected. The average concentration level was 13 µg/m^3. Comparisons with the results from the preliminary screening preformed in June 2005 (Guerreiro et al., 2005a) and during a field campaign in 2004 (Ndiaye S.A., 2005, personal communication) indicate that the SO_2 levels are approximately the same for all studies.

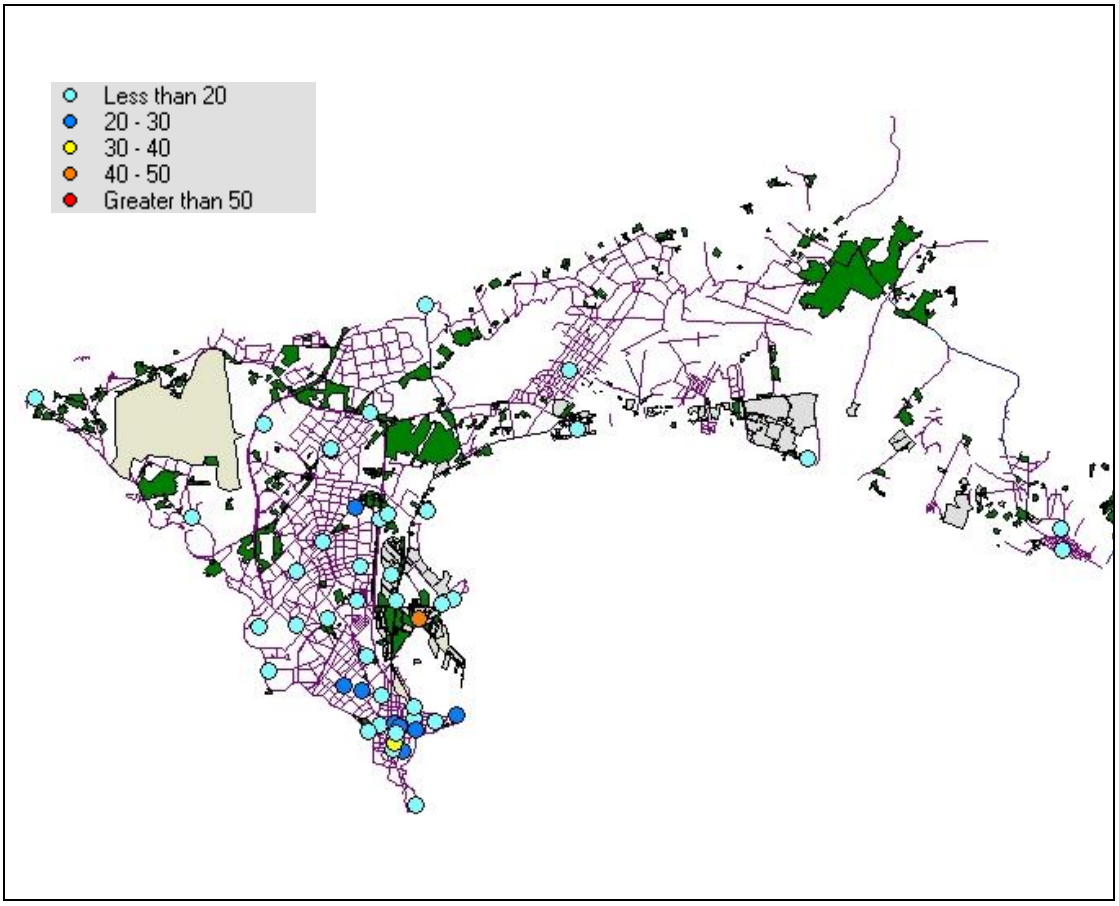

Figure 8: Geographical distribution of SO_2 concentrations measured by passive samplers in October 2005.

6.3 O_3 sampling

Ground-level ozone (O_3) is not emitted directly into the atmosphere, but is a secondary pollutant produced by reaction between nitrogen dioxide (NO_2), hydrocarbons and sunlight. Because of the time required for chemical processing, ozone formation tends to be downwind of pollution centres. Nitrogen oxide (NO), however, destroys ozone to form nitrogen dioxide (NO_2). For this reason, ozone levels are not as high in urban areas, where high levels of NO are emitted from vehicles and other emission sources, as in rural areas.

The two weeks concentration averages of O_3 at nine sites in Dakar are presented in Figure 9.

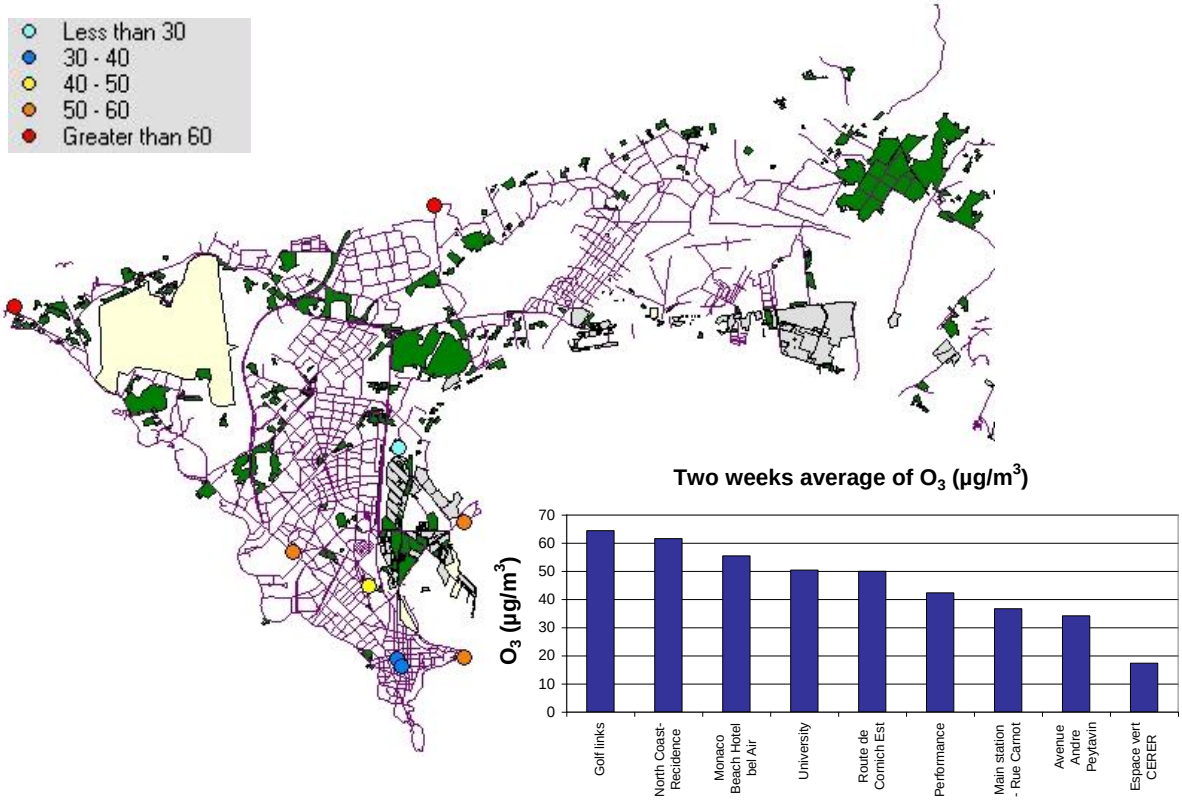

Figure 9: O_3 concentrations measured by passive samplers in January 2006.

The highest O_3 concentrations measured are more than 60 µg/m^3 as two weeks averages at the regional background sites. The lowest O_3 concentrations are measured in heavy traffic areas, close to the highway and in the city centre. The ratio between the measured concentration of O_3 at the regional site and the heavy traffic areas is 3.8. This indicates that the local NO emission sources consumes a lot of the regional O_3 to generate NO_2.

The formation of O_3 will mainly be downwind the city area on a regional scale do to the chemical reaction time.

6.4 CO monitoring

The source for ambient CO concentration is mainly traffic. High concentrations of CO might be expected in street canyons during traffic jam. Situations of high CO concentrations are often linked to rush hour traffic and the generation of CO occurs primarily while cars are idling. The site selected to measure CO is therefore a street canyon site. It is important to bear in mind that the height of the measurements was about 5 meters from the ground, where the CO emitted by the traffic has already mixed well with the air. CO concentrations closed to the source are higher and people

standing or walking on the sidewalk are exposed to greater CO concentration levels compared to measurements 5 m above ground level.

8 hours running averages of CO have been calculated and compared to EU limit value and WHO guideline. Measured CO concentrations at Rue Carnot did not exceed the EU limit value /WHO guidelines, nor the daily CO standard for Senegal which is 30 mg/m^3.

Calculation of diurnal variation of CO indicated the highest concentration occurs during rush hours. The hourly maximum is below the limit value and guideline.

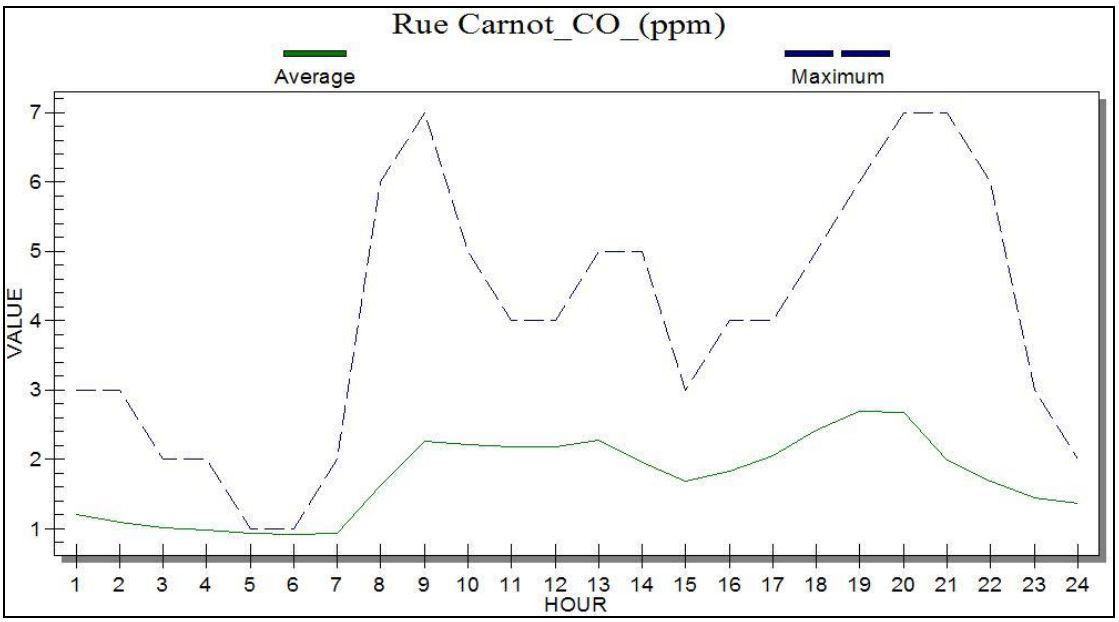

Figure 10: Diurnal variation of CO (average and maximum) measured at Rue Carnot in October including December 2005.

Some short-term measurements of CO undertaken in Dakar during the field campaigns in October 2005 show that the concentrations ranged from 3 to 27 mg/m^3.

The highest concentrations were measured along busy streets with traffic jam. One minute average concentrations measured along two streets of Dakar are presented in Figure 11.

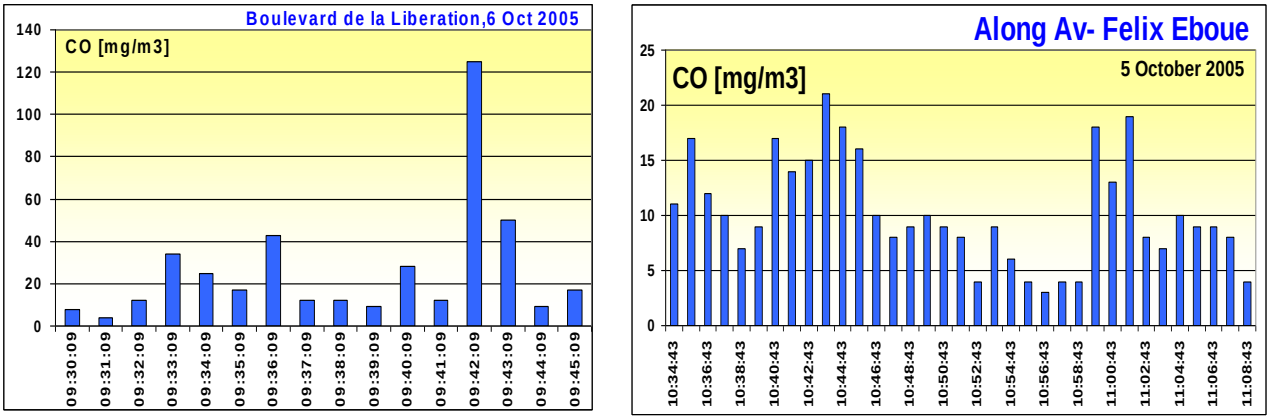

Figure 11: Minute average concentrations of CO (mg/m^3) measured along two streets on 5 and 6 October 2005.

One minute CO concentrations reached in a few cases more than 120 mg/m^3. These short-term measurements indicated that CO limit values might be exceeded in some hot spots area near roads.

6.5 VOC

Sampling of VOC was performed at 8 sites to evaluate the contributions from industrial potential sources as well as traffic hot spots. 4 samples were collected using passive sampling (diffusive sampling) and at 4 sites active sampling (pumped sampling) were performed. The adsorption tubes were exposed in 3-7 days using passive sampling and approximately 1 hour using active sampling.

6.5.1 TVOC

The total Volatile Organic Component (TVOC) concentration ranged from 31 µg/m^3 to 359 µg/m^3 (Figure 12). The highest and fairly large concentrations are measured at industrial sites (refinery and Route Grands Moulins) (Figure 12). The dominating VOC components, however, are different at the two sites. At Grands Moulins the VOC components related to traffic dominate (e.g. benzene), while at the refinery VOC components related to industrial activities dominate.

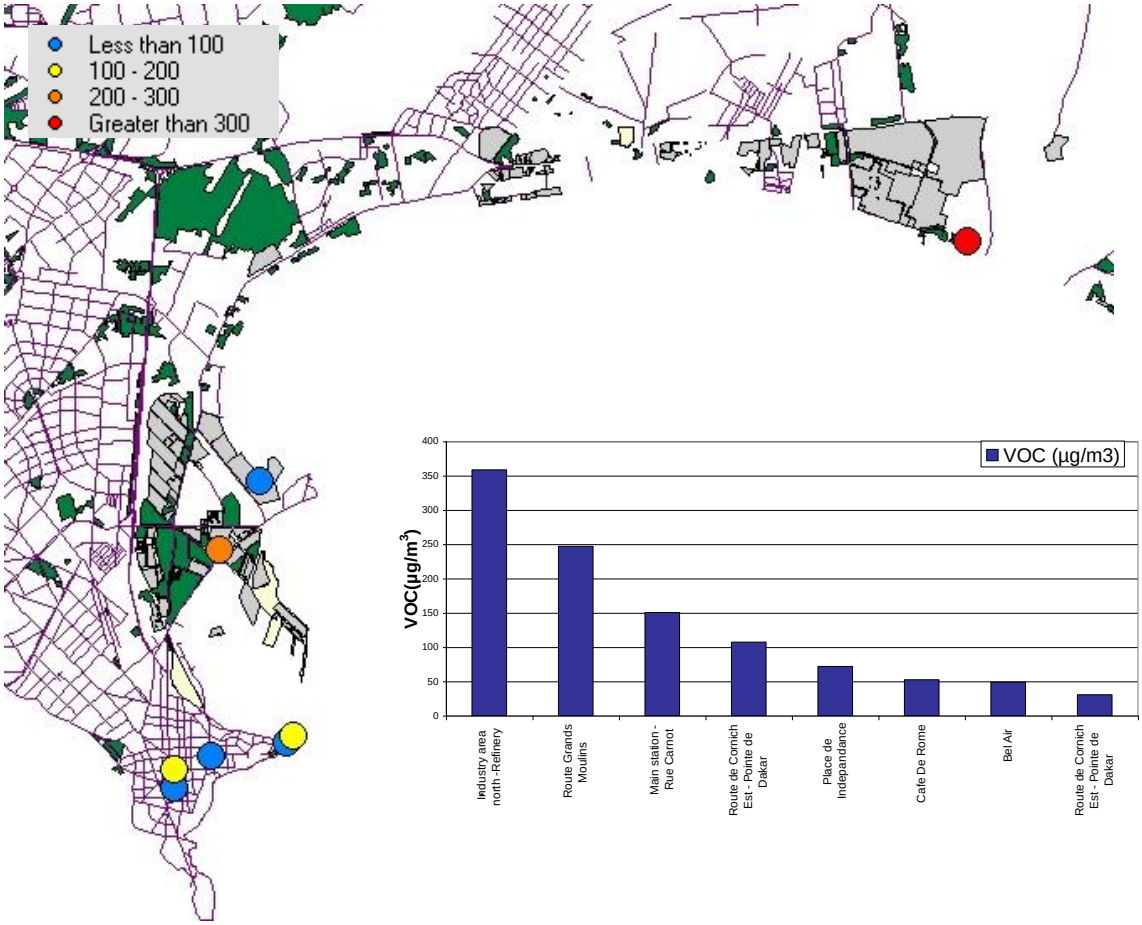

Figure 12: Concentrations of VOC (µg/m^3) measured by passive and active sampling in October 2005

6.5.2 Benzene

The measured concentrations of the volatile organic component benzene have been compared to the yearly limit value. At three locations, all traffic sites, the annual EU limit value of 5 µg/m^3 was exceeded (Figure 13). The highest value measured (at Route Grands Moulins) was 20 µg/m^3, which is 4 times the yearly limit value.

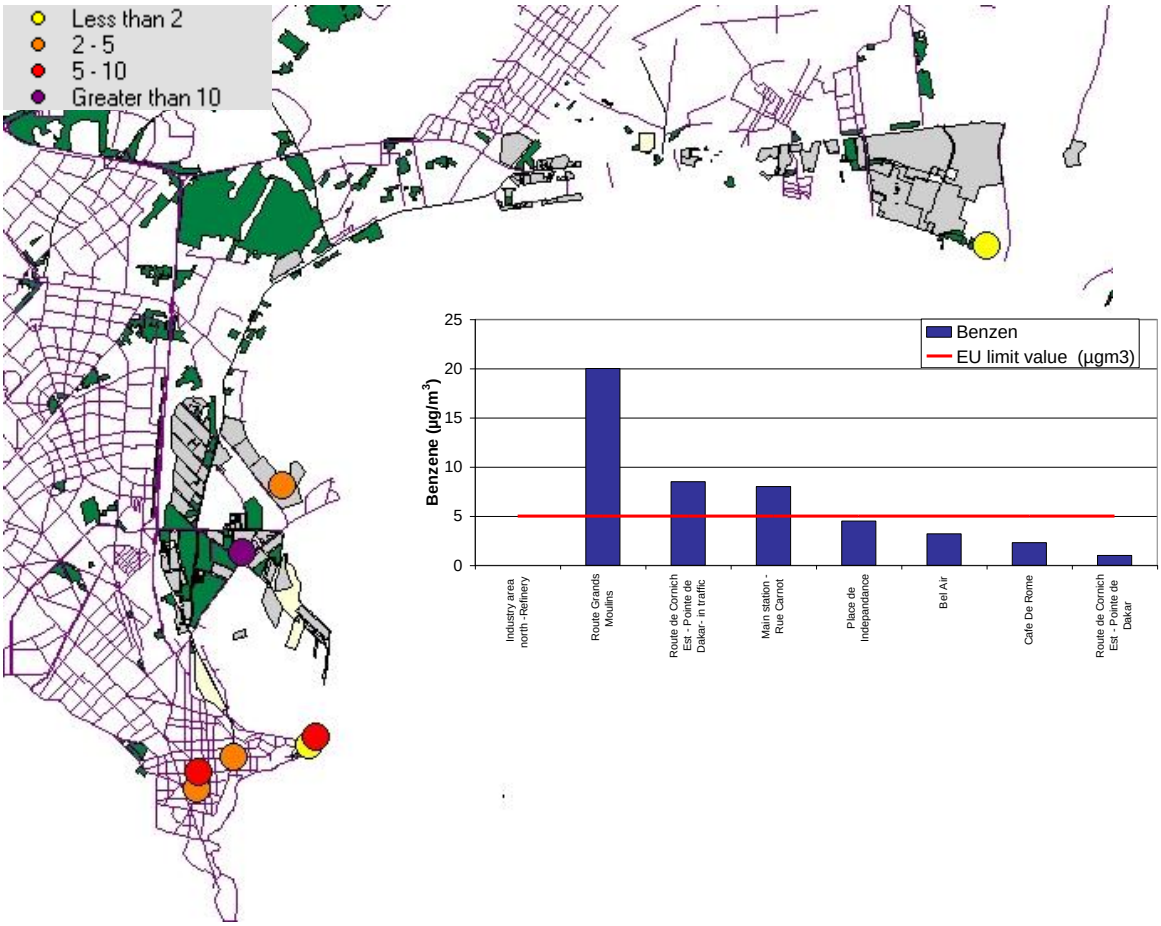

Figure 13: Concentrations of benzene (µg/m^3) measured by passive and active sampling in October 2005

6.6 Particulate matter

Daily values of suspended particles (PM_{10} and $PM_{2.5}$) were measured in a busy street in the city centre using a sequential gravimetric sampler. PM_{10} and $PM_{2.5}$ were not measured simultaneously, but in separate periods. In addition, short term values (10 minute averages) of PM_{10} were measured in industrial areas, traffic sites and regional background areas of the city, from 3 to 7 October 2005, using a portable aerosol monitor.

6.6.1 PM_{10}

The daily concentrations of PM_{10} measured at Rue Carnot exceed the Senegal standard once during the sampling period. However, the daily EU limit value was exceeded every day of the sampling period. The PM_{10} values range from 52 to 338 µg/m^{3,} with an average value of 133 µg/m^3

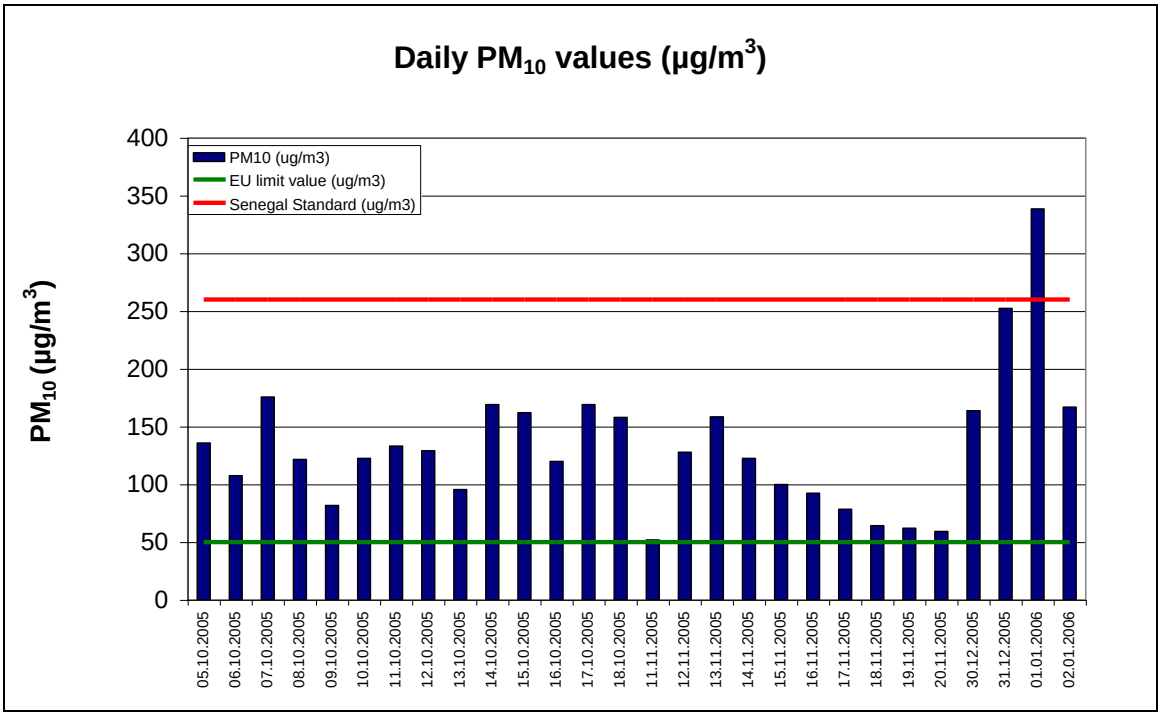

Figure 14: Daily concentrations of PM_{10} measured by sequential samplers at Rue Carnot from October 2005 to January 2006.

The PM_{10} short-term field measurements ranged from 160 to 300 µg/m^3 in most of the city area (Figure 15). The highest 10 minutes concentration measured was more than 1000 µg/m^3, on the sidewalk of a busy street.

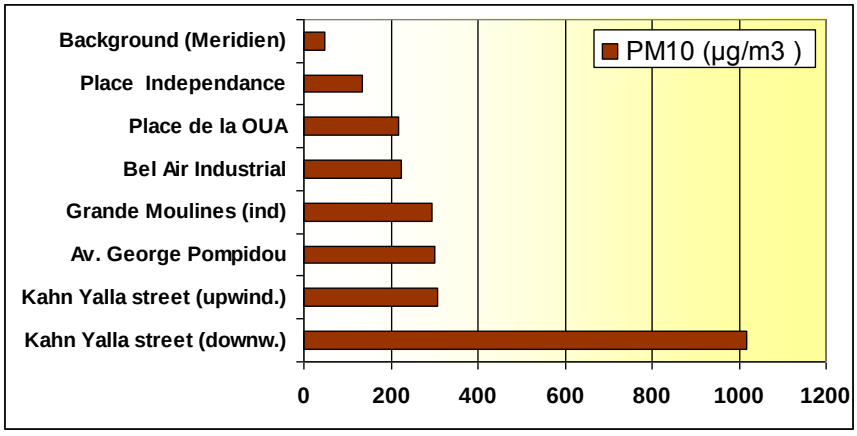

Figure 15: Average concentrations (different averaging times) of PM_{10} (µg/m^3) measured at different sites during the field campaigns in Dakar 3 to7 October 2005.

Generally high concentrations were measured in the industrial areas of Dakar. A 50-minutes average concentration measured nearby Grand Moulins was 388 µg/m^3. Close

to the industrial areas in Bel Air, 10 minutes averages of PM_{10} ranged from 200 to 300 $\mu g/m^3$, indicating general high levels of PM_{10} in the industrial area.

At two traffic sites, Avenue Georges Pompidou and Rue 4, BCCD, 10-minutes averages of PM_{10} were 301 $\mu g/m^3$ and 280 $\mu g/m^3$, respectively. Measurements conducted on both upwind and downwind side of traffic at one of the main streets in Kahn Yallah showed high 10 minutes averages. On the upwind side of the street the PM_{10} concentration was 308 $\mu g/m^3$, while on the downwind side of the street the concentration was 1017 $\mu g/m^3$.

As an indication of urban background concentrations PM_{10} measurements were carried out in the middle of the park area at Place de l'Independence and night-time measurements at the second floor of the Café de Rome hotel in the city centre of Dakar (Bd de la Republique). Ten-minute concentrations (morning hour) at Place de l' Independence ranged between 120 and 160 $\mu g/m^3$ and night time concentrations at Café de Rome ranged from 20 to 100 $\mu g/m^3$.

PM_{10} measurements were also conducted at regional background site, Meridien hotel and in the Yof area. Typical concentrations here were about 40-60 $\mu g/m^3$. This was surprisingly high, and indicates that the background air moving into the Dakar area from northeast had a fairly high "natural" burden of particles.

The daily average measurements conducted at Rue Carnot as well as the short-term average measurements performed in various microenvironments and areas of the city indicate high values of PM_{10}. PM_{10} concentrations in the urban areas of Dakar are therefore expected to exceed international limit values. Short-term averages in the hot spot areas generally raged from 100 to 300 $\mu g/m^3$ and the daily averages of PM_{10} from October to January at the main station all exceeded the EU limit value of 50 $\mu g/m^3$.

These measurements indicate that the PM_{10} level around in hot spots areas of Dakar may be high enough to represent a health problem.

6.6.2 $PM_{2.5}$

The daily $PM_{2.5}$ measurement ranged from 23 $\mu g/m^3$ to 62 $\mu g/m^3$, with an average value of 38 $\mu g/m^3$. This is less than the US-EPA daily $PM_{2.5}$ standard of 65 $\mu g/m^3$. WHO does not give a limit for $PM_{2.5}$ as investigations indicate health effects down to the zero exposure level.

On the average, $PM_{2.5}$ is approximately one third of the PM_{10} level, which indicates that a large amount of PM_{10} is coarse fraction (particles with diameters between 2,5 and 10 µm).

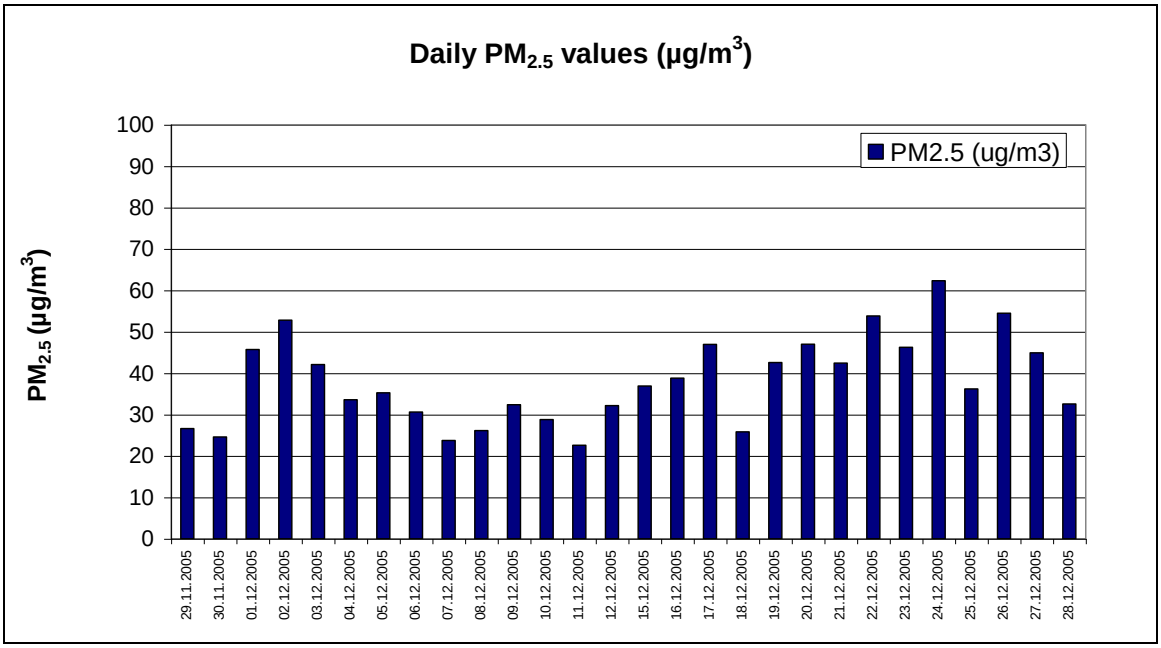

Figure 16: Daily concentrations of PM_{25} measured by sequential samplers at Rue Carnot in November-December 2005.

6.6.3 Inorganic pollutants

Element analysis using ICP-MS (Inductively Coupled Plasma Mass Spectroscopy) (NILU, 2006) has been preformed on 8 selected filters (4 PM_{10} filters and 4 $PM_{2.5}$ filters). The filters were selected based on weight (the filters with most particles were analysed) and to cover the whole measurement period. Therefore, one filter each week of the measurement period was selected to eventually identify some trend in concentrations. The average concentration has been calculated to evaluate the contribution of trace elements to the average PM concentrations and to evaluate if any guidelines are exceeded. The average concentrations of 6 of the 10 trace elements analysed (the most toxic ones and aluminium), i.e. lead (Pb), cadmium (Cd), vanadium (V), nickel (Ni), arsenic (As) and aluminium (Al), are shown in Figure 17 for the PM_{10} filters and in Figure 18 for the $PM_{2.5}$ filters.

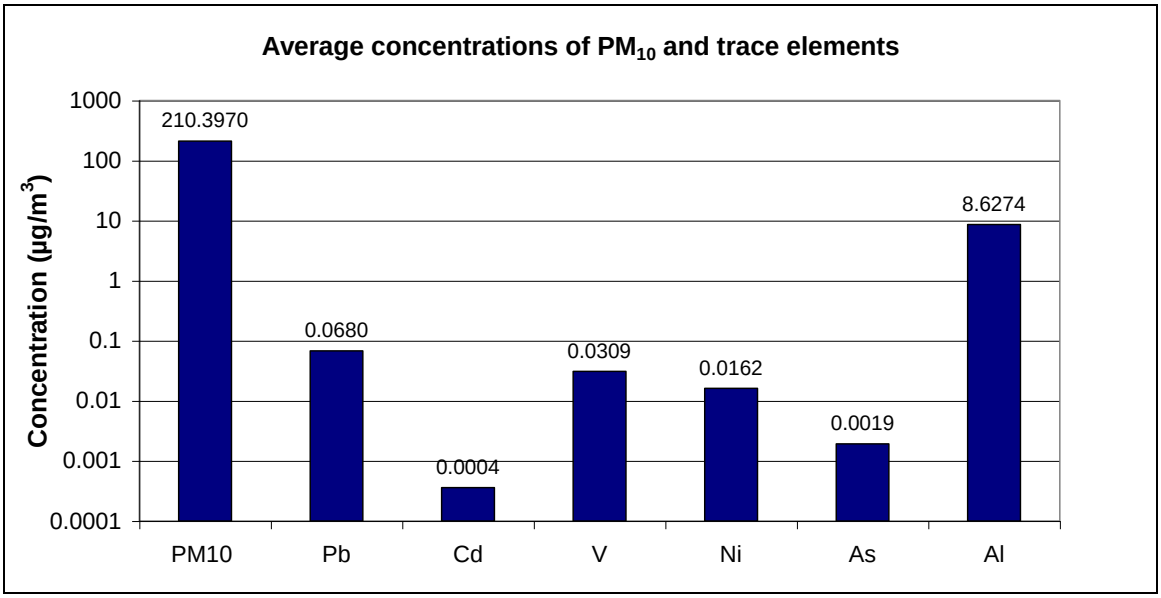

Figure 17: Average concentration of PM_{10} and of 6 trace elements of four selected filters.

The analysis identified no exceedances of EU limit values (EU, 2004; EU, 2001) nor the WHO guidelines (2001) for none of the elements tested (Appendix B). Both for lead (Pb) and cadmium (Cd) the average concentration of the filters analysed were far from of the yearly limit and target values, respectively. The average concentration measured for arsenic (As) was approximately 1/3 of the EU limit value. For nickel (Ni) however, the average concentration was 4/5 of the EU target value.

The average percentage of all 10 trace elements analysed on the PM_{10} filters is 4 %, where aluminium is the dominating element (Figure 17), which is an important component of mineral dust. The except for aluminium the trace elements are approximately only 1 per thousand of the measured PM_{10} concentration. For the $PM_{2.5}$ filters, 2 % of the mass is trace elements, and again aluminium is the main contributor.

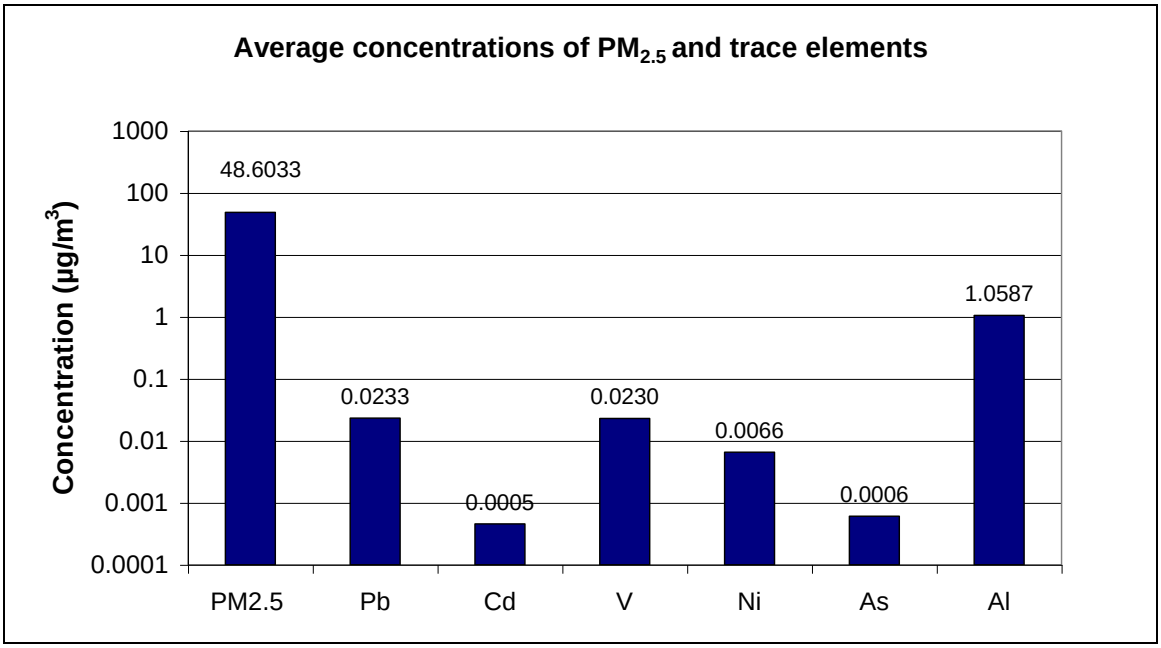

Figure 18: Average concentration of $PM_{2.5}$ and of 6 trace elements of four selected filers.

No significant trend in concentration of lead has been observed. However, the concentrations of lead are small, which indicates that lead-gasoline was practically fazed out at the time of this screening study.

6.6.4 Total carbonaceous matter (TCM)

The selected PM_{10} and $PM_{2.5}$ filters were also analysed to identify the content of elemental (EC) and organic carbon (OC). Thermal Optical Transmission, correcting for charring during analysis, was used to determine elemental and organic carbon. The content of total carbonaceous matter (TCM) was estimated based on the EC/OC analysis. The TCM content of the PM_{10} filters was on the average 17 % of the total mass ranging from 7 % to 23 % (Table 9).

Table 9: Percentages of total carbonaceous matter (TCM) of the PM_{10} and $PM_{2.5}$.

Date	TCM of the PM_{10} filters (%)	Date	TCM of the $PM_{2.5}$ filters (%)
07.10.2005	17	02.12.2005	39
17.10.2005	20	09.12.2005	68
13.11.2005	23	17.12.2005	76
01.01.2006	7	24.12.2005	54

The average concentration of TCM of the $PM_{2.5}$ filters analysed was 59%. Maximum TCM was 76%.

The EC/TC ratios were on the average 35.7 % for PM_{10} and 30.4 % for $PM_{2.5}$ for the samplers analysed. As described in literature (Seinfeld and Pandis, 1998), an EC/TC ratio ranging from 28 % to 38 % can be expected in areas where a mixture of emission

from gasoline cars and diesel cars is the dominant source. The EC/TC ratios calculated correspond well with those expected for mixed emissions from diesel and gasoline, thus, it could be speculated that emissions from vehicular traffic could be the dominant source of carbonaceous material in PM.

The TCM content and the EC/TC ratio of the $PM_{2.5}$ samples indicate that the main contributors to $PM_{2.5}$ were combustion sources.

6.6.5 Water-soluble components

Sea salt and other water-soluble components were also expected to contribute to the PM concentrations in Dakar due to the proximity to the Atlantic Ocean and anthropogenic sources. The PM_{10} and $PM_{2.5}$ filters were analysed using ion chromatography to identify the content of sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), nitrate (NO_3), sulphate (SO_4), ammonium (NH_4) and chloride (Cl) (Appendix C).

Table 10: Percentages of water- soluble components of the PM_{10} and $PM_{2.5}$.

Date	Water soluble components of the PM_{10} filters (%)	Date	Water soluble components of the $PM_{2.5}$ filters (%)
07.10.2005	24.1	02.12.2005	13.4
17.10.2005	19.2	09.12.2005	19.1
13.11.2005	15.6	17.12.2005	13.5
01.01.2006	11.3	24.12.2005	12.2

The average percentage of water-soluble components was 18% for PM_{10} and 15% for $PM_{2.5}$ indicating that a substantial part of the PM particles in Dakar are water-soluble.

On the average, the contribution from nitrate, sulphate and ammonium is 4.7% for PM_{10} This components origin mainly from anthropogenic sources (Appendix C), 12.9 % of PM_{10} are sodium, potassium, magnesium, calcium and chloride, which mainly originate from natural sources (Appendix C). For $PM_{2.5}$, on the other hand, the contribution from the anthropogenic and natural sources are both 7.3%. This result indicates that water-soluble components from natural sources contribute more to PM_{10} than anthropogenic sources. For water-soluble components in $PM_{2.5}$, however, the anthropogenic sources contribute as much as the natural sources.

6.6.6 Summary of the chemical analysis of PM concentrations

Based on the analysis of trace elements, analysis of elemental and organic carbonaceous matter as well as analysis of water-soluble components, the contributions to the total measured PM concentrations have been calculated. For the PM_{10} filters the contribution of the components analyzed explained between 24% and 44 % of the total PM_{10} concentrations measured. (Figure 19)

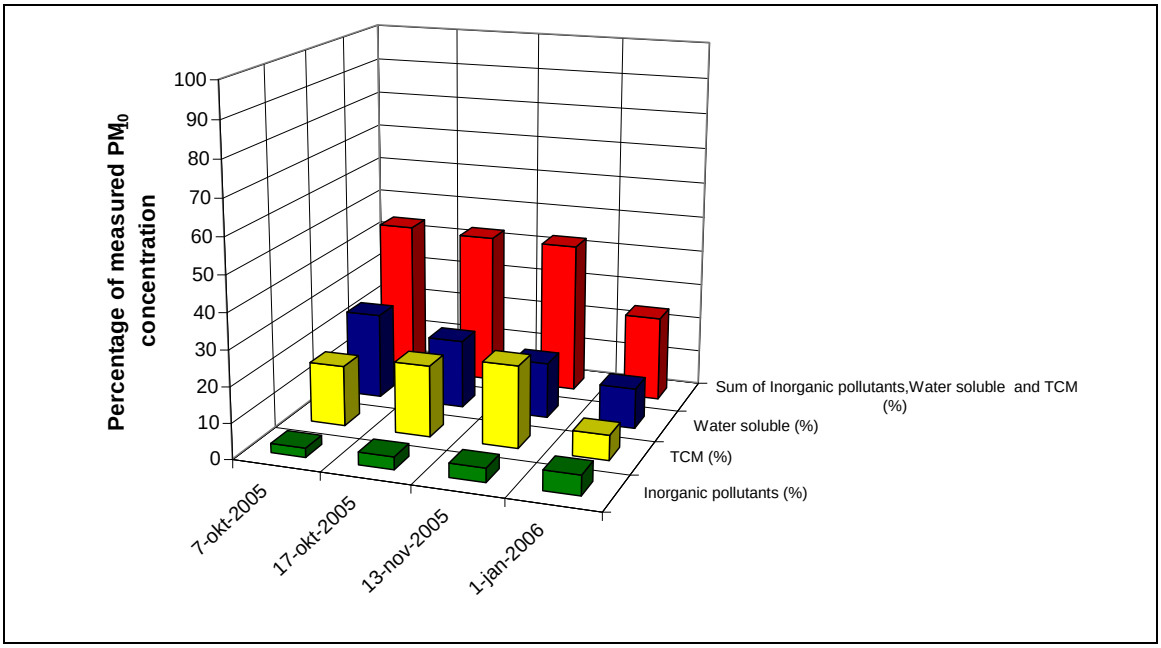

Figure 19: Percentage of inorganic pollutant, water-soluble components and total carbonaceous matter (TCM) of PM_{10} concentration measured.

For PM_{10}, the water-soluble components and TCM contribute approximately with 20% each to total PM_{10} levels in average. The analyses performed identify only aluminium (Al) contents of the mineral dust. Important components of mineral dust as silicon (Si) and not-water-soluble calcium (Ca), have not been analysed. Based on the results it is assumed that a large content of the coarse fractions (PM_{10} –$PM_{2.5}$) of the PM_{10} concentrations were soil dust.

For $PM_{2.5}$, however, the contribution of the trace elements, TCM and water-soluble components to the total $PM_{2.5}$ range between 57 and 91% in the analysed filters (Figure 20), with an average of 76%. TCM was the dominating composition of $PM_{2.5}$, corresponding in average to 59% of the total $PM_{2.5}$ concentrations. The water-soluble compounds contribute approximately with 15% to the total $PM_{2.5}$ concentrations. This indicates that a large amount of the $PM_{2.5}$ origins from combustion sources.

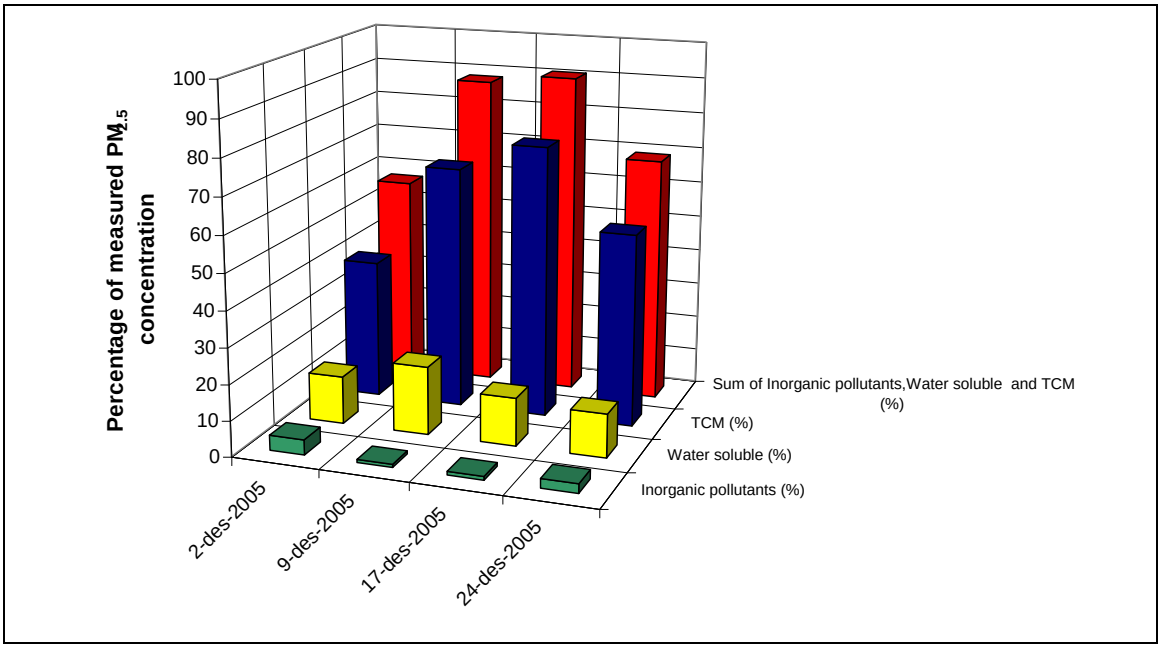

Figure 20:Percentage of inorganic pollutant, water-soluble and total carbonaceous matter (TCM) of PM_{10} concentration measured.

7 Discussion and conclusion

Based on this screening study, air pollution in Dakar seems to be related to traffic and in some cases industry. The main air pollution problem in Dakar is identified to be suspended particulate matter. The measured 24-hour averages of PM_{10} are 2 to 7 times the international standard levels and limit values were exceeded every day during the sampling period. The short-term averages (10 minutes to 1 hour) of PM_{10} in hot spot areas generally raged from 100 to 300 µg/m^3, indicating that the PM_{10} concentrations in these areas of Dakar are also expected to exceed daily international limit values.

The $PM_{2.5}$ levels in Dakar were also relatively high compared to concentration levels observed in other urban areas in the world. The average $PM_{2.5}$ concentration in the 4 weeks sampling period was 38 µg/m$^{3.}$ A large fraction of the $PM_{2.5}$ has been found to be carbon species, which indicates that $PM_{2.5}$ originated from combustion sources.

Element analysis of lead (Pb), cadmium (Cd), vanadium (V), Nickel (Ni) and arsenic (As) identified no exceedances of EU limit and target values and WHO guidelines for any of the elements tested. The average content of the 10 trace elements analysed was 4 % and 2 % on the selected PM_{10} and $PM_{2.5}$ filter, respectively. Aluminium (Al) was the dominating element, which is an important component of mineral dust.

The analysis of Total carbonaceous matter (TCM) in PM_{10} and $PM_{2.5}$ sampled at the permanent station in the city centre indicate:

- A large content of soil dust in PM_{10}, mostly in the particles with diameters between 2,5 and 10 m (coarse fraction);

- The main sources of $PM_{2.5}$ are combustion sources.

The analysis of the water-soluble components also shows that anthropogenic contribution is of importance, especially for $PM_{2.5}$.

The maximum monthly average of NO_2 concentration measured was 56 µg/m^3 and the average measured concentration for all sites was 27 µg/m^3. Based on the assumptions that the meteorological conditions in the field campaign period were representative for a long-term average, exceedances of the annual standard were observed at 7 traffic sites.

The monthly average SO_2 concentrations did not exceed the WHO guideline or the Senegal standard for annual averages. The SO_2 concentrations seem to be relatively low in the city, except in the industrial areas. However, the preliminary screening performed in June indicated that the limit values might be occasionally exceeded in the city centre of Dakar.

The hourly values of CO measured from October until December 2005 in a street canyon at about 5 meters above ground indicate no exceedances of limit values or standards. However, short-term measurements of CO in traffic (at about 1 meter above ground) showed high concentrations during traffic jam.

The annual EU limit value for benzene of 5 µg/m^3 was exceeded at 3 of the 8 sites investigated. The highest value measured, was 20 µg/m^3, which is 4 times the yearly limit value.

This screening study will be used as the main support for designing a permanent air pollution monitoring programme for Dakar.

8 References

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Appendix A

Site classifications and components

Table 11: Site classifications and components measured at the selected screening sites in urban and suburban area of Dakar.

		Area types	Sources	Component measured			
ID	Site/name			SO2	NO2	O3	VOC (passive)
1	Hospital Centre d'état civil	U	T	X	X		
2	Place Soweto	U	T	X	X	X	
3	Cafe De Rome	U	T-SC	X	X		X
4	Avenue Andre Peytavin	U	T	X	X		
5	Avenue Andre Peytavin and President Lamine Gueye	U	T	X	X		
6	Phare du Cap Manuel	R	B	X	X	X	
7	Place de Indepandance I SANDAGA VOYAGES	U	T	X	X		
8	Place de Indepandance II BRV	U	T	X	X		
9	Place de Indepandance II AXA Assurance Senegal	U	T	X	X		
10	Avenue Albert Sarrot - Goethe Institute	U	T	X	X		
11	Route de Cornich Est - Pointe de Dakar	R	I/B	X	X	X	X
12	Avenue Faidherse and R Joris.	U	T	X	X		
13	Place A Catral	U	T	X	X		
14	Place de Oran - Sonatel	U	T	X	X		
15	Medina Rue G Diene	SU	T/B	X	X		
16	Performance	SU	B	X	X	X	
17	University	SU/U	T-RC	X	X	X	
18	Seydou Nourou Tall	SU	T	X	X		
19	Rochade Fann bel Air - BCEAO	U	T	X	X	X	
20	Place de Bacou -EQUIP PLUS	U	I	X	X		
21	Route Grands Moulins - MOULE 8	U	I	X	X	X	
22	Boulevard du president Habib Bourguiba EXODIS	SU	T	X	X		
23	Place de l'Unite Aficaine Taara Confection	SU	B	X	X		
24	Autoroute Seydina Limamoulaye	SU	B	X	X		
25	Espace vert CERER	U	B	X	X	X	
26	Route de Ouakam _pharmazia	SU	B	X	X	X	
27	Route de Font de Terre - nte SIPRES	R	B-NCA	X	X		
28	Meridien Golf court	R	B- REG	X	X	X	
29	North Coast - Recidence Awa Plazza	R	B- REG	X	X	X	
30	South coast II -Usine	SU	I	X	X		
31	Industry area north -Refinery	SU	I	X	X	X	X
32	Village north - Rufisque sea	U	B	X	X	X	
33	Avenue Georges Ponpidou and Rue Mousse Diop - Lagondole	U	SC	X	X		
34	Village area -	U	T	X	X	X	
35	Village II area - PikineTotal	U	T	X	X		
36	Main station - Rue Carnot	U	SC	X	X	X	X
37	A. Cesaine Courniche	SU	B	X	X	X	
38	HLM III	SU	B	X	X		
39	Rue 4 BCCD	SU	I	X	X		
40	Total Castones	U	T	X	X		
41	Corniche	U	B	X	X		
42	Rufisque center	SU	**B**	X	X		
43	Hanne Pescar	SU	I	X	X	X	
44	Monaco Beach Hotel bel Air	U	I	X	X	X	
45	Bel Air en Face le Bois	U	I	X	X		
46	Niary Tally	SU	B	X	X	X	
47	Kahn Yalla	SU	T	X	X	X	
48	Univesity Laboratory	SU	B	X	X		
49	Hotel de Rome 3 etg	U	B	X			

Abbreviations: urban (U), suburban (SU), rural (R)(Regional=REG, NCA=Near City Area), traffic (T) (street canyon(SC) road side (RS)), industrial (I), background (B)

Appendix B

Analysis of trace elements

Table 12: Concentration and percentage of analysed trace elements in PM_{10} ($\mu g/m^3$)

	Percentage	PM10 concentration	Sum of metals	Pb	Cd	Cu	Zn	Cr	Ni	Co	V	As	Al
	%	(µg/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)
07.10.2005	2.6	175.66	4527.47	70.66	0.27	35.60	107.31	33.37	27.04	2.22	19.09	1.32	4230.60
17.10.2005	3.5	169.00	5950.84	70.68	0.33	22.37	74.65	19.96	12.94	2.72	33.78	1.71	5711.70
13.11.2005	3.9	158.46	6223.63	55.62	0.58	27.12	74.14	14.13	9.98	2.78	25.70	1.28	6012.30
01.01.2006	5.6	338.47	18816.82	75.20	0.26	31.83	58.20	27.48	14.88	5.48	45.09	3.40	18555.00
Average	**3.9**	**210.40**	**8879.69**	**68.04**	**0.36**	**29.23**	**78.58**	**23.74**	**16.21**	**3.30**	**30.92**	**1.93**	**8627.40**

Table 13: Concentration and percentage of analysed trace elements in $PM_{2.5}$ ($\mu g/m^3$).

	Percentage	PM2.5 concentration	Sum of metals	Pb	Cd	Cu	Zn	Cr	Ni	Co	V	As	Al
	%	(µg/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)	(ng/m3)
02.12.2005	4.2	52.78	2230.23	12.11	0.28	5.15	23.62		3.93	0.68	13.97	0.69	2169.80
09.12.2005	0.9	32.37	276.58	10.83	0.20	3.07	19.03		8.52	0.34	26.99	0.50	207.10
17.12.2005	1.0	46.94	485.19	19.80	0.32	6.54	25.06		5.61	0.37	18.84	0.56	408.10
24.12.2005	2.6	62.32	1604.35	50.55	1.03	17.46	43.84		8.23	0.71	32.14	0.70	1449.70
Average	**2.2**	**48.60**	**1149.09**	**23.32**	**0.46**	**8.06**	**27.89**		**6.57**	**0.52**	**22.99**	**0.61**	**1058.68**

Appendix C

Analyses of water soluble components

Table 14:Concentration and percentage of water-soluble components in PM_{10}.

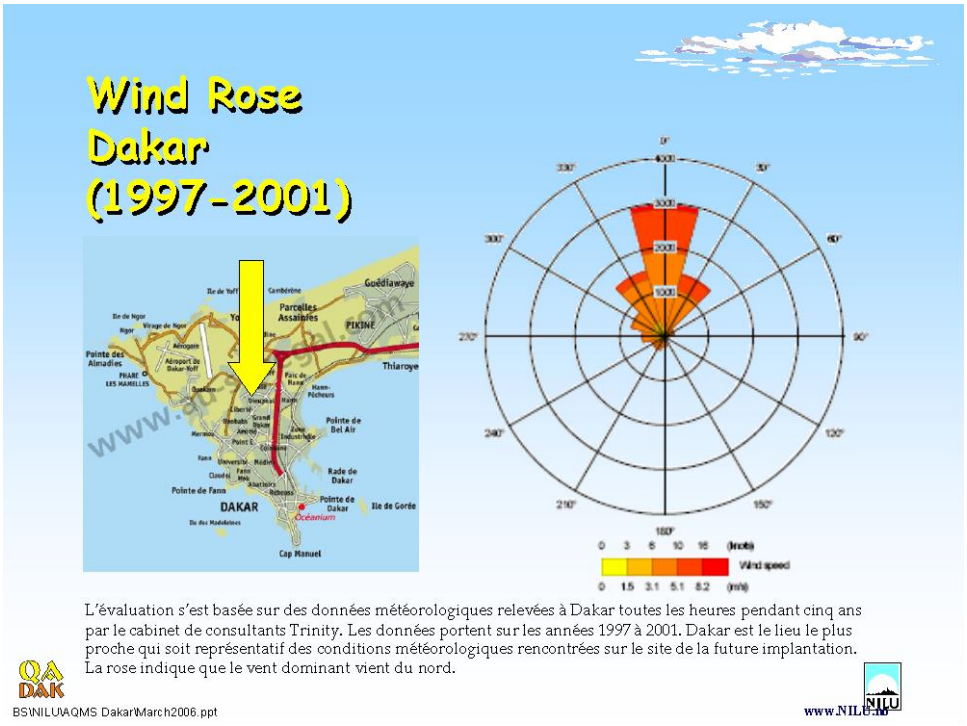
	PM10	Cl	Na	K	Mg	Ca	NO3	SO4	NH4	Sum natural sources Cl,Na,K,Ca and Mg	Sum anthropogenic sources NO3,SO4, NH4	Total water soluble	Percentage natural sources Cl,Na,K,Ca and Mg	Percentage anthropogenic NO3,SO4, NH4	Percentage water soluble
	(µg/m3)	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3	%	%	%
07.10.2005	175.7	6.27	5.25	0.55	0.88	14.88	3.31	10.95	0.31	27.8	14.6	42.4	15.8	8.3	24.1
17.10.2005	169.0	6.93	5.19	0.49	0.82	11.91	2.64	4.44	0.07	25.3	7.2	32.5	15.0	4.2	19.2
13.11.2005	158.5	5.26	3.84	0.62	0.59	9.44	1.29	3.44	0.24	19.7	5.0	24.7	12.5	3.1	15.6
01.01.2006	338.5	5.66	3.61	2.30	0.93	15.46	1.51	8.58	0.26	28.0	10.4	38.3	8.3	3.1	11.3
Average	**210.4**	**6.03**	**4.47**	**0.99**	**0.80**	**12.92**	**2.19**	**6.85**	**0.22**	**25.2**	**9.3**	**34.5**	**12.9**	**4.7**	**17.6**

Table 15:Concentration and percentage of water-soluble components in $PM_{2.5}$.

	PM2.5	Cl	Na	K	Mg	Ca	NO3	SO4	NH4	Sum natural sources Cl,Na,K,Ca and Mg	Sum anthropogenic sources NO3,SO4, NH4	Total water soluble	Percentage natural sources Cl,Na,K,Ca and Mg	Percentage anthropogenic NO3,SO4, NH4	Percentage water soluble
	(µg/m3)	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3	%	%	%
02.12.2005	52.8	1.03	1.27	0.32	0.17	1.85	0.58	1.72	0.13	4.6	2.4	7.1	8.8	4.6	13.4
09.12.2005	32.4	0.32	1.03	0.25	0.10	1.04	0.58	2.50	0.37	2.7	3.5	6.2	8.5	10.7	19.1
17.12.2005	46.9	0.09	0.83	0.33	0.09	1.26	0.71	2.72	0.30	2.6	3.7	6.3	5.5	7.9	13.5
24.12.2005	62.3	0.77	0.75	0.73	0.12	1.58	0.55	2.83	0.27	4.0	3.6	7.6	6.3	5.9	12.2
Average	**48.6**	**0.55**	**0.97**	**0.41**	**0.12**	**1.43**	**0.60**	**2.44**	**0.27**	**3.5**	**3.3**	**6.8**	**7.3**	**7.3**	**14.6**

Appendix D

Wind rose Dakar (1997-2001)


Wind Rose
Dakar
(1997-2001)
Parcelles Assainies
PIKINE
Thiaroye
Pointe des Almadies
Pointe de Bel Air
Rade de Dakar
Pointe de Fann
DAKAR
Pointe de Dakar
Ile de Gorée
Cap Manuel
Océanium
Wind speed
L'évaluation s'est basée sur des données météorologiques relevées à Dakar toutes les heures pendant cinq ans par le cabinet de consultants Trinity. Les données portent sur les années 1997 à 2001. Dakar est le lieu le plus proche qui soit représentatif des conditions météorologiques rencontrées sur le site de la future implantation. La rose indique que le vent dominant vient du nord.
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ABSTRACT
A screening study of air pollution in Dakar was performed between October 2005 and January 2006. Passive samplers of NO_2, SO_2, VOC and O_3 were located at about 50 selected measurement sites in Dakar city and in surrounding suburban areas. A sequential sampler for suspended particles (PM_{10} and $PM_{2,5}$) and a CO monitor were located at one site in a busy street in the city centre. Parallel and in addition to the sampling programme presented above, short term data of PM_{10}, VOC and CO were collected in selected areas of the city. The main objective with this study was to collect background information for designing a permanent air quality monitoring programme for the area in the future.

NORWEGIAN TITLE

KEYWORDS		
Air quality monitoring	Air quality assessment	Senegal

ABSTRACT (in Norwegian)

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