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Agreement:	NO 003/C/FND/05

Passive sampling of SO_2 and NO_2 in ambient air in Dakar

Preliminary study, June 2005

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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 for designing a monitoring network will be preformed during the second mission. During the first mission, in May-June 2005, some passive samplers were located at 5 different sites in Dakar city to give the first indication of the ground level concentrations.

This report has also been submitted in French (NILU OR 39/2005).

2 The passive samplers

A sensitive diffusion sampler for sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) in ambient air has been used in several investigations to undertake a screening of the spatial concentration distribution.

The sampler was developed by the Swedish Environmental Research Institute (IVL) and has been used in several cases by NILU. 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. Gases are transported and collected by molecular diffusion.

The samplers are very easy to manufacture. For example, the samplers used by NILU are produced from commercially available 50 mm long polypropylene tubes. The tubes are cut to the desired length and then fitted with a solid cap containing the impregnated filter at one end, and an open cap containing the anticonvection mesh/membrane at the inlet end (as shown in Figure 1).

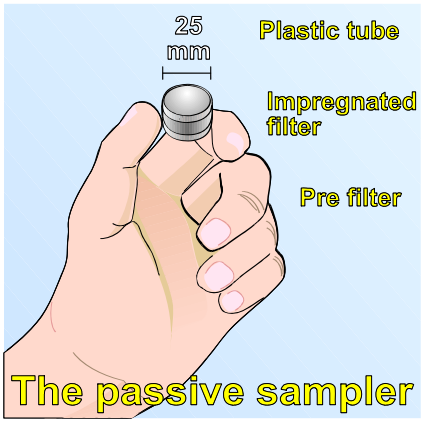

Figure 1: The passive sampler.

All components, except the impregnated filter can be reused. They have many other advantages as well for use in the field. For example they are small, light (~2 g), and require no electricity.

It should be emphasised that they 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.). They are obviously not well suited for monitoring temporal variations over short time intervals, or for detection of individual peak values, or when real time measurements are needed.

2.1 The basic principle

The sampling technique is based on the property of molecular diffusion of gases, hence the term passive (also referred to as diffusive) sampling. The gas molecules diffuse into the sampler where they are quantitatively collected on an impregnated filter or an absorbent material. Thus they achieve a time-integrated (or average) concentration. No electricity, pumps or other supporting equipment are needed.

If the sampling efficiency is sufficiently high, then the sampling rate can be calculated from the cross sectional area perpendicular to the transport direction and the distance that the gas has to diffuse using Fick's first law of diffusion.

To work properly (and quantitatively) it is essential that the transport occurs solely by molecular diffusion and that no gas is lost to the walls of the sampler. Under these conditions then the sampling rate, and thus the concentration range of the sampler, is directly proportional to its cross sectional area and inversely proportional to its length.

Inorganic gases are absorbed by chemical reaction on a filter impregnated with a solution specific to each pollutant measured. The reaction product, which is washed out of the filter prior to analysis, is specific to the particular gas in question. When

species do not react sufficiently fast with other chemicals (e.g., organics) they are instead trapped on an absorbent material. Such gases are then desorbed from the adsorbent during analysis.

2.2 Uptake rates and analyses

The uptake rate is only dependent upon the diffusion rate of the gas. The collection rate is 31 *l*/24h for SO_2 and 36 *l*/24h for NO_2.

For SO_2 the measuring ranges are approximately 0,1-80 ppb for a sampling period of one month. The corresponding range for NO_2 is 0,02-40 ppb. The passive samplers are assembled and made ready for use at NILU. After exposure the samplers are usually returned to NILU where concentrations of SO_2 are determined as sulphate by ion chromatography. NO_2 is determined by spectrophotometry.

The average concentration at the measurement site over the time period that the sampler is exposed to ambient conditions is determined by chemical analysis of the filter. Analysis consists of removing the impregnated filter and leaching the reaction product, typically using de-ionised water. The leachate is then analysed using an appropriate analytical technique. The highest concentration that can be measured depends on the amount of sorbent on the impregnated filter. This is typically estimated by the stoichiometric amount of the impregnate reduced by a safety factor (typically a factor of 2).

The lower detection limit of the samplers is determined by the use of blanks. As soon as a filter is impregnated it will begin to measure ambient levels. A filter kept in the laboratory will measure laboratory levels, while field blanks will measure the integrated exposure during the transport and storage periods.

The samplers are impregnated shortly before sent to the field, samplers labelled for batch number, a few filters checked immediately, and then filters identified for lab and field blanks. The laboratory blanks are stored in the lab and periodically tested. The field blanks are kept in their containers and accompany the samplers to the field and are returned after the filters are exposed. The field blanks are analysed along with the exposed samples. The concentrations determined from the exposed filters are then corrected using the blanks. The lower detection limit is commonly defined as 2 to 3 times the standard deviation of the blanks. The repeatability of the results is quantified and checked by use of duplicate samples.

3 Sampling sites in Dakar

Passive samplers were used to measure NO_2 and SO_2 concentrations at selected sites in Dakar. The aim with this study was to identify the levels of NO_2 and SO_2 in different microenvironments of the city (e.g. road side, urban background, industry area etc).

The different site and the environments are described in Table 1, and the map in Figure 2 gives a picture of the spatial distribution of the sampling sites selected for Dakar.

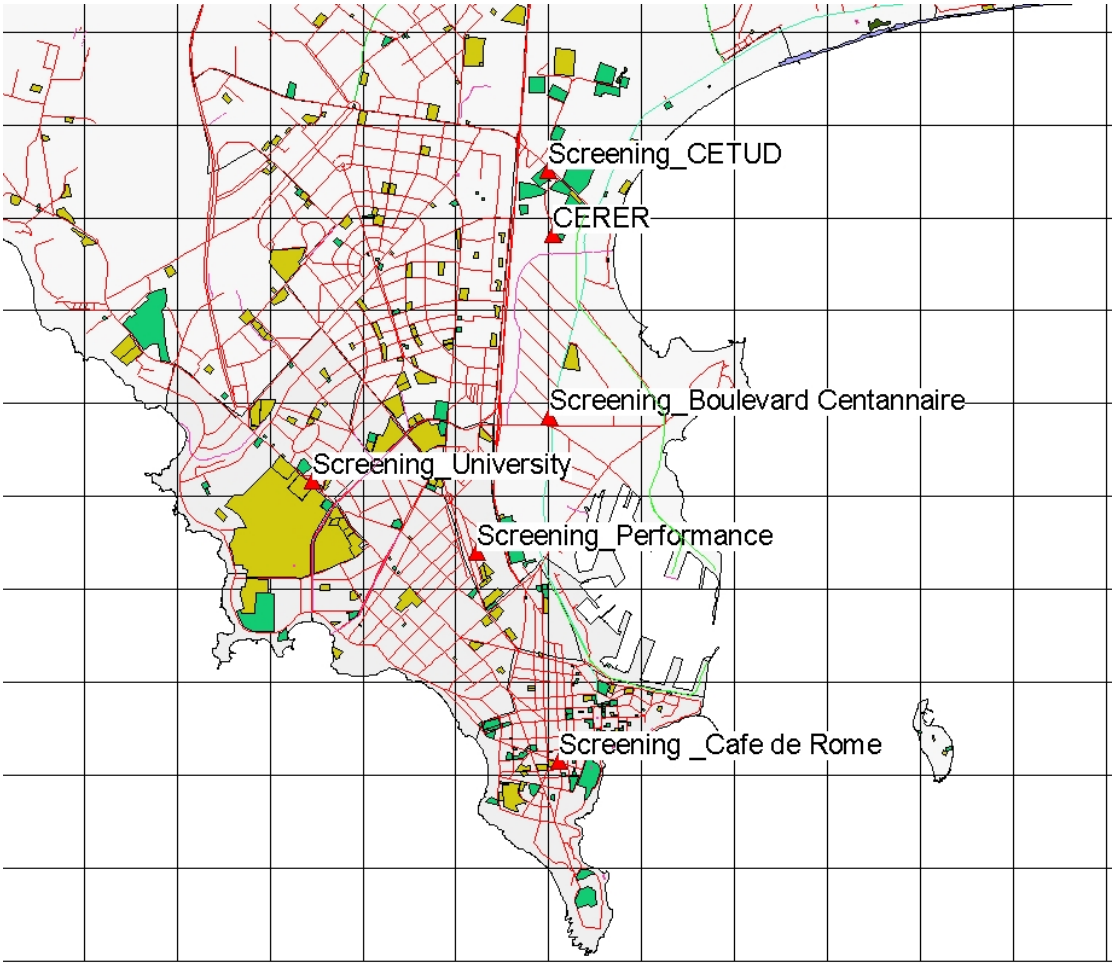

Figure 2: Location of sampling sites.

Table 1: Sampling sites for SO_2 and NO_2 passive samplers.

Site name (position)	UTM coord.		Station type	Main emission sources	Number of samplers		Comments
	X	Y			SO_2	NO_2	
Café de Rome	237606	1622665	Urban/ Traffic	Traffic	1	1	The samplers were located approximately 3 m above road level and 3–4 m from the pavement. Traffic /street canyon station.
CETUD	237496	1629018	SubUrban/ - Traffic	Traffic	1	1	The samplers were located approximately 3 m above ground and closed to the pavement. The road is heavy traffic
Universitetet	234956	1625670	Road side	Traffic	1	1	The samplers were located at a approximately 3 m above the ground level at the corner of a shop closed the pavement.
Boulev Centannaire	237503	1626358	Industry/ traffic	Industry/ traffic	1	1	The sampler was located approximately 3 m above ground and 4 m from the roadside closed to barrier.
Performances	236722	1624905	Urban backgroun d	Traffic	1		The samplers were located close to the pavement 2 m above ground level on a fence. Open build area.
TRAFFIC			In traffic	Traffic		1	Sampling is preformed while driving or walking in traffic.

4 Air quality limit values

The air quality limit values for SO_2 and NO_2 from the European Commission (EU, 1999) and the guidelines from the World Health Organisation (WHO, 2000) are given in Table 2 and Table 3.

Table 2: Air quality limit values and guidelines for SO_2.

Effect	Averaging period	EU	WHO
	10 min		500 µg/m^3
Health	1 hour	350µg/m^3[1]	
Health	24 hour	125 µg/m^3[2]	125µg/m^3
Ecosystems	Calendar Year and winter	20µg/m^3	50µg/m^3

Table 3: Air quality limit values and guidelines for NO_2.

Effect	Averaging period	EU	WHO
Health	1 hour	200µg/ m^3[3]	200µg/m^3
Health	Calendar Year	40µg/m^3[4]	40 µg/m^2

[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] Not to be exceeded more than 18 times a calendar year. The limit values is to be met by 1 of January 2010
[4] The limit values is to be met by 1 of January 2010

5 Measured concentrations

The passive samplers are analysed at NILU and the results are presented in Table 4.

Table 4: Measured ground level concentrations, averaged over the sampling period.

Sampling period				Sampling period	Site name	Average Concentrations	
From:		To		Days	Position	µg/m^3	
date	hr.	date	hr.			SO_2	NO_2
31.5.05	0800	7.6.05	0830	7.0	Café de Rome	60	68
31.5.05	0830	7.6.05	1405	7.2	CETUD	30	40
1.6.05	0907	7.6.05	1745	6.4	Universitetet	19	28
1.6.05	0930	7.6.05	1725	6.3	Boulev Centannaire	14	21
1.6.05	1400	6.6.05	1500	5.0	Performances	5	
1.6.05	1200	1.6.05	1430	0.1	In traffic		344

6 Discussion and conclusion

The sampling period was between 5 and 7 days. If the weather and dispersion conditions during the field trial period are representative for the average meteorological conditions, the concentrations measured are also an indication for the long-term average concentrations in Dakar.

During the campaign period meteorological data was not available. Manually observations were, however, preformed every day. Generally, the dispersion conditions were good with relatively high wind speeds.

The weekly concentrations ranged from 5 to 60 µg/m^3 SO_2 and from 21 to 68 µg/m^3 for NO_2. Similar concentration levels were measured during a field campaign in 2004 (Ndiaye S.A., 2005, personal communication). The air pollution levels are comparable with levels measured in other polluted cities in the world, like Ho Chi Min city in Vietnam (Sivertsen et al., 2005).

The SO_2 concentrations are close to or exceed the EU limit value on long-term average at three of the five stations. Only at Café the Rome the SO_2 concentration is above the WHO guideline.

For NO_2, the long- term average WHO guideline was exceeded on two of the four stations. The concentration level measured while in traffic was approximately 75% higher than the hourly EU limit value.

The concentration levels were highest at Café De Rome. This indicates that the most polluted areas might be in the street canyons with high traffic. There are probably other street canyons that are more polluted. As expected the lowest concentrations are at the urban background station.

The preliminary study indicates that Dakar city is highly polluted since relatively high concentrations are measured under good dispersion conditions.

7 References

EU (1999) Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogens, particulate matter and lead in ambient air. *Official Journal of the European Communities*, L163, 29.6.1999, pp.41-60.

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

Sivertsen, B. ,Thanh, T.N and Willoch, H. (2005) Ho Chi Minh City Environmental Improvement Project. Air Quality Monitoring Component. Mission 6, Status report (MR1-2), Station audits, design reference laboratory and training. Kjeller (NILU OR 38/2005).

World Health Organization (2000) Air quality guidelines for Europe. 2nd. ed. Copenhagen, WHO Regional Office for Europe (WHO Regional Publ., European Series, 91).

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ABSTRACT
The Norwegian Institute for Air Research (NILU) is supporting the Conseil Exécutif des Transports Urbains de Dakar (CETUD) in establishing a Central Laboratory with an Air Quality Management System for Dakar. During the first mission, in May-June 2005, some passive samplers were located at 5 different sites in Dakar city to give the first indication of the levels of NO2 and SO2 in different microenvironments of the city (e.g. road side, urban background, industry area etc). This preliminary study indicates that Dakar city is highly polluted since relatively high concentrations are measured under good dispersion conditions.

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ABSTRACT (in Norwegian)

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A Unclassified (can be ordered from NILU)
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