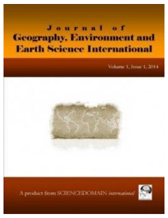

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Title of the Article: Assessment and Risk of the Impact of Air Pollution in Dakar

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study assessed the risks of air pollution in the city of Dakar. The objective is to evaluate the concentration levels of the pollutants measured in different sites of the Air Quality Management Center (CQA) of Dakar. The study took place between January and August 2013 and is divided into

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three phases or measurement campaigns. The first step consisted of continuous and real-time measurements of the different types of pollutants using automatic analysers that are specific to them in different zones, defined according to the kind of pollution (Urban, Traffic-related, or Industrial). In the second phase, the pollutants were transmitted under controlled conditions to the CGQA laboratory by varying the levels of concentrations reached for each of the pollutants studied. In the third phase, the analysis should be compared to the regulatory threshold values for health protection, which are NS-05-062 and WHO. The results showed that there is excellent seasonal variability in the concentrations of some pollutants studied, especially the suspended particles (PM10 and PM2.5). The analysis of variance revealed that the first two measurement campaigns (January-June) were the most affected by these pollutants, this is explained by a high concentration of dust in the air emanating from the North, mainly from the Sahara, which has a significant effect on recorded concentration peaks, but also due to weather phenomena during this study period. The quality of the air is appreciated through a global index for the city of Dakar. The evolution of this index shows a medium to poor air quality during the dry season (January-June) and good air quality at the heart of the rainy season (July-August).

Keywords: Assessment; air pollution; risk; impact; atmospheric particle.

1. INTRODUCTION

Air pollution is a topic that touches the quality of life of the population. In fact, there is no pollution, but atmospheric pollution. Each human activity generates pollutants in the ambient air in more or less large quantities, and these contaminants are different according to their emission source [1]. The ambient air may contain several hundred compounds present at deficient concentrations of 10 µg / m3 or in trace amounts, some of which are harmful to health or the environment [2, 3]. Sources of air pollutants can be divided into two broad categories [4]:

- anthropogenic sources
- biogenic sources

All of these contaminants can lead to atmospheric issues such as smog, ozone depletion, acid rain, ecosystem deterioration, and the greenhouse effect [5]. Industrial and demographic activities lead to the release of specific more toxic pollutants. This generates significant pressures on the integrity of the ecosystem [6].

The quality of the air is a primordial human stake. According to studies, pollution is responsible for 42,000 premature deaths per year in France [7].

Air pollution is a complex problem, because of the high diversity of sources and the nature of the pollutants emitted, and the multiplicity of places of exposure: outside air, indoor air, occupational exposures ... It is linked to numerous interactions between meteorological factors and various aero-contaminants. The latter may be of a physical, chemical or biological nature, responsible for toxic, allergic or infective effects. Air is essential for life, whatever its nature and source, it would be impossible to stop breathing even if it is polluted. This is why public authorities have identified the fight against air pollution as a priority because of its impact on the population [8].

According to the World Health Organization (WHO), diseases related to poor air quality (outside and inside) are responsible for nearly 7 million deaths in 2012. Of this total, 90% live in low- and middle-income countries. In fact, one dying in 8 in the world is linked to a disease caused by air pollution. According to the same source, this mortality is due to exposure to particles with a diameter of 10 microns or less (PM10, which cause cardiovascular and respiratory diseases, and cancers) [9].

In many parts of the world, exposure to air pollution is increasing at an alarming rate, to the point where it has become the main environmental threat to citizens [9]. According to an assessment made in 53 European countries by the World Health Organization (WHO) and the Organization for Economic Co-operation and Development (OECD) in 2012, ranging from Iceland to Kazakhstan, pollution outdoor and indoor air caused nearly 600 000 deaths per year: 482 000 for outdoor pollution and 117 200 for indoor pollution [10]. In 2008, 1.5% of the world's Greenhouse Gases (GHGs) came from Mexico City and an estimated 4,000 deaths from this urban pollution [11]. In China's big cities, it reported 750,000 premature deaths in 2007 [12].

Epidemiological studies carried out in recent years in Dakar have made it possible to correlate the link between air pollution and health risk (ranging from premature mortality to changes in the parameters of ventilatory function) [13].

According to a study. Carried out by the World Bank in 2001, the health cost related to air pollution was estimated at CFAF 30,000 / person/year, which corresponds to CFAF 63 billion per year, i.e. 2.7% of GNP (National Product Brut) from Senegal. These estimates were based on the cost associated with the increase in the mortality rate due to air pollution and the morbidity rate (bronchitis, asthma, heart disease ...) [14]. The study published by Ibrahima Ndiaye et al., Reviews the risks related to the impacts of air quality resulting from road traffic that could recur in the coming years due to the exports of ageing transport vehicles, and despite recent initiatives by the authorities [15].

The aim of this study is to assess whether the level of ambient air pollutant concentrations, such as of nitrogen dioxide (NO2), ozone (O3), sulfur dioxide (SO2), fine particles (PM10 and PM2.5), carbon monoxide (CO) are above the level of risk or not are about to measure in the city of Dakar (Senegal).

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in the region of Dakar located on the peninsula of Cape Verde and covers an area of 550 km² or 0.28% of the territory of Senegal [16]. The population of the Dakar region is estimated at 3,137,196.0 inhabitants in 2013, or nearly a quarter (21%) of the total population of the country, estimated at 13,508,715 inhabitants. Dakar is characterised by profound disparities marked by demographic and economic weights [17]. The Dakar region is the centre of economic exchange between the different neighbouring cities and concentrates 80% of the country's economic activities [18, 19]. In a sub-desert tropical zone, Dakar benefits from a coastal-type microclimate, influenced by the maritime trade winds and the monsoon [20]. The wind pattern is marked by the predominant influence of the trade wind. Its main direction varies from North-North-West to North-North-East. Rainfall is characterised by a relatively short duration of wintering, ranging between three and four months from June to October with temperatures approaching 27°C and a peak of precipitation in August (250 mm) [21].

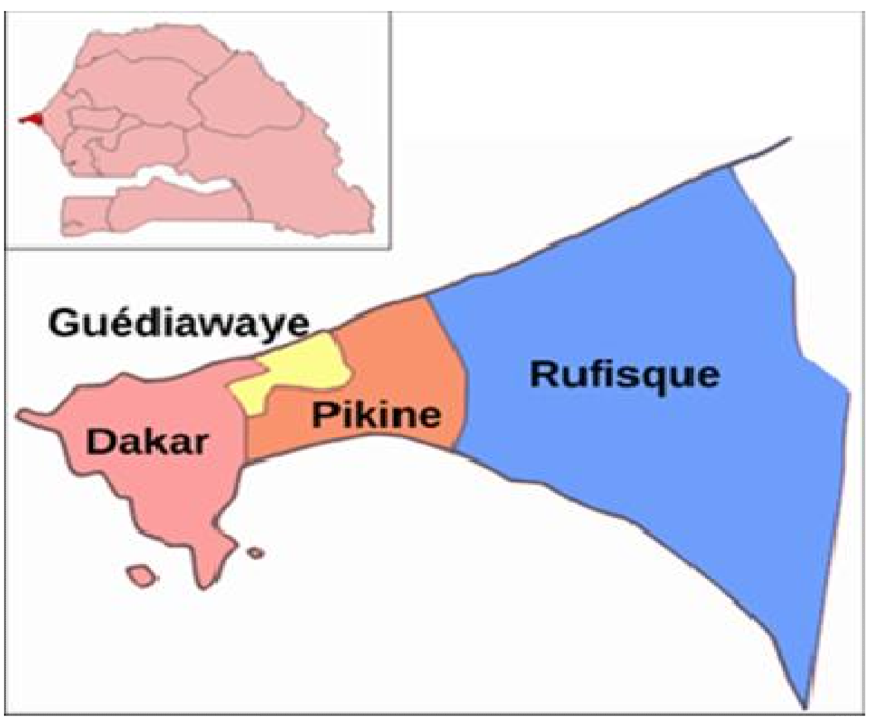

Fig. 1. Illustration of the Region of Dakar

Table 1. Description of CGQA air measurement sites

Ville	Stations	Types	Date de mise en service	Coordinates		NO_2	CO	O_3	SO_2	$PM_{2,5}$	PM_{10}
				Longitude	Latitude						
DAKAR	MEDINA	Suburbain (T.R .B)	2009	14°41'14'' N	17°26'54'' W	x	x				x
	BEL AIR	Industriel (U.I)	2009	14°40'50'' N	17°25'58'' W	x			x	x	x
	YOFF	Régional (S.R.F)	2009	14°44'51'' N	17°27'35'' W	x		x			x
	HLM	Périurbain (S.F.B)	2009	14°42'37'' N	17°26'54'' W	x		x	x		x
	CATHEDRALE	Urbain (T.R.U)	2009	14°40'14'' N	17°26'11'' W	x	x	x	x	x	x

T.R.B: Suburban Road Traffic; U.I: Industrial Urban; S.R.F: Regional Base Station; SFB: Suburban Base Station; T.R.U: Urban Road Traffic

2.1.1 Measurement site and sampling campaign

The samples were taken from five sites of the Air Quality Management Center (CGQA) located in the city of Dakar. For more than five years, the CGQA has measured concentrations of atmospheric pollutants in the ambient air throughout Dakar's agglomeration using these five fixed measurement sites (or stations) and a mobile station providing one-off measurements. These positions are equipped with a sampling head at the top of the location and automatic analysers located inside each centre, allowing the continuous and real-time analysis of the concentrations of the atmospheric pollutants taken such as the following:

- nitrogen dioxide (NO_2)
- ozone (O_3)
- sulfur dioxide (SO_2)
- fine particles (aerodynamic diameter less than or equal to 10 µm and 2.5 µm): PM_{10} and $PM_{2.5}$
- carbon monoxide (CO)

The classification of the stations corresponds to the air pollution problems encountered according to the geographical area, according to the existing measurement tools but also according to the public health concern. They may belong to urban or rural areas [22, 23]. Thus the selected stations can be distinguished in Fig. 2.

2.2 Methodology

The five CGQA monitoring stations perform continuous measurements. Measurements of concentrations, sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), aerodynamic particles less than or equal to 10 µm and 2.5 µm (PM_{10} and $PM_{2.5}$) , and ozone (O_3), are performed using automatic analyzers 24/24. In fact, the ambient air is taken by a pump and then transmitted to the analyzer by a Teflon line. Thus, in the "heart of the analyzers", the concentration of each pollutant in the air is measured according to a physicochemical technique that is specific to it.

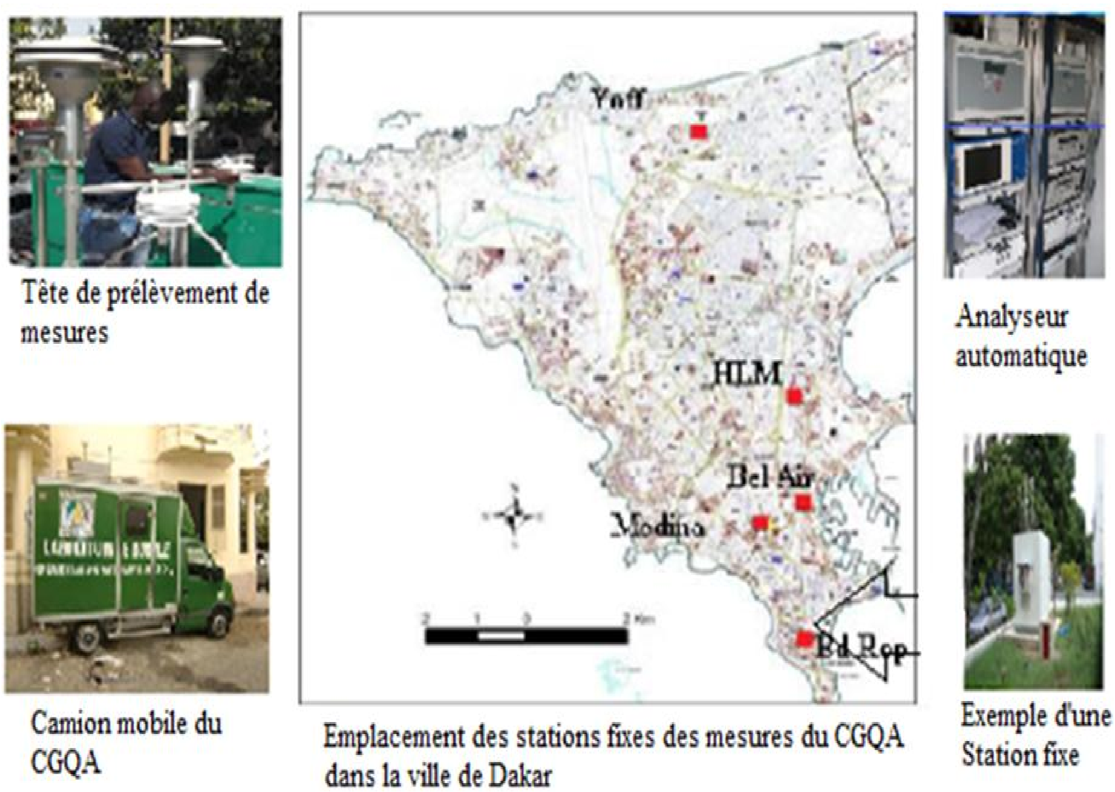

Fig. 2. Measurement Sites and CQA air quality monitoring devices (automatic analyzers, measuring station and mobile truck)

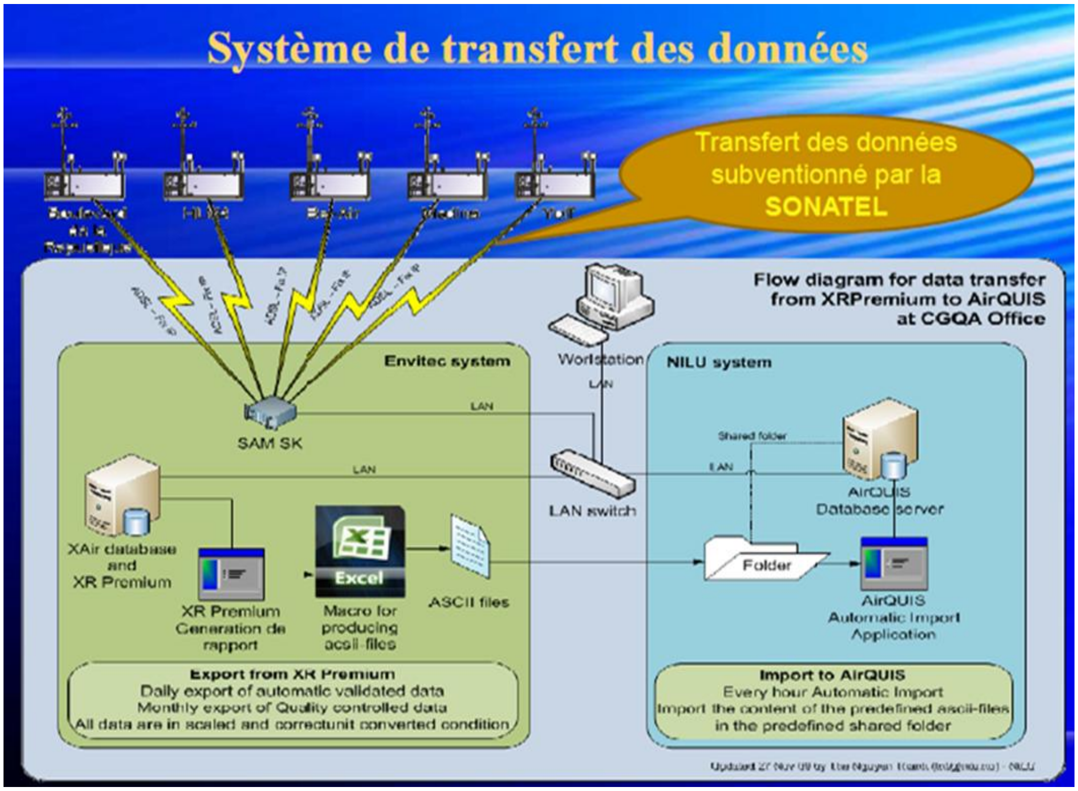

Fig. 3. Description of the chain of acquisition and dissemination of the data

These standardized methods make it possible to access target gas concentration levels with great precision corresponding to the quality objectives specified in the Senegalese directive. These stations also measure the different meteorological parameters that can have an impact on the dispersion of pollutants (temperature, humidity, wind speed, and direction). They provide air quality data for all pollutants monitored, at a concentration of 15 minutes. The data collected by the analyzer is then automatically transmitted via an ADSL connection to the central lab server located at the CQA premises. The raw data are quarter-hourly data, aggregated from measurements taken every ten seconds for SO_2, CO and NOx, and every two seconds for particles.

2.2.1 Study periods

Indeed, the study took place between January 1, 2013, and August 31, 2013, and is divided into three measurement campaigns. The first two quarters correspond to the dry season (January 1st to June 31st), while the last two months of the last quarter (July 1st to August 31st, 2013) coincide with the rainy season. The measurement results are representative of the period studied. The study is not limited to the campaign period, it also takes into account the temporal data recorded by the CGQA. This is to validate the annual representativeness of two seasonal measures per year.

Table 2. Methods of measurement

Composite	Méthodes de measure	Référence aux procédures normalisées
NO, NOx, NO_2	Chimiluminescence	CEN/EN 142111
SO_2	Fluorescence Ultraviolette	CEN/EN 142112
CO	Spectroscopie Infrarouge	CEN/EN 14626
O_3	Photométrie Ultraviolette	CEN/EN 14625
PM_{10}	Jauge radiométrique atténuation bêta	CEN/EN 12341

Table 3. Precipitation totals and mean temperatures established during the different campaigns

Campagnes de mesures	Précipitation (mm)	Température moyenne (T°C)	Vitesse de fréquence (m/s)	Direction du vent
(1) 1er Janvier -31 Mars	0.33	23	2,1 et 4/4,1 et 6	Nord-Nord-est
(2)1er Avril- 31 Juin	1mm	25	4,1 et 6/2,1 et 4	Nord-Nord -ouest
(3) 1er Juillet – 31 Aout	250	28	4,1 et 6 / 2,1 et 4	Nord-Nord-ouest

2.2.2 Meteorological data

Weather conditions play an important role in the mechanisms of air pollution because they condition the dispersion and transformation of pollutants. Thus, the direction and strength of the wind, temperature, sunshine, and precipitation are key factors. The meteorological conditions observed during the three measurement campaigns are presented in the table and are available from the observations of the HLM station (urban station). The station Helm is a station located in an urban fabric, it is influenced by the activities of the population. The stability of the air was obtained by making the difference between the temperature measured at 10 meters from the ground and that measured at 2 meters.

3. RESULTS AND DISCUSSION

3.1 Air Quality Data

The pollutants considered in this study are nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), sulfur dioxides (SO_2), aerodynamic diameter particles less than 10 micrometers (PM_{10}) and 2.5 micrometers ($PM_{2.5}$). They are measured in the 5 fixed measurement stations of the city and managed by the CGQA (table ...).

3.1.1 Nitrogen oxides (NOx)

The nitrogen oxides are measured on the five stations of the territory. The average evolution of the 8-hour nitrogen dioxide concentrations recorded is rather low for all these stations. However, they show the influence of road traffic on the measurement sites, especially at the morning point time and the evening descent time at 17:00. No exceedance of the NS-05-062 standard of 120 µg/m^3 was noted, nor that of the WHO (40 µg/m^3 annual average and 200 µg/m^3 hourly average).

3.1.2 Carbon monoxide (CO)

Carbon monoxide is continuously measured at the two urban and suburban road traffic stations at Boulevard de la République and Medina respectively. Due to the low percentage of valid, recorded data and technical problems that occurred during this campaign on the Medina site, this station was not included in the calculations. However, the maximum average concentrations observed over 8 hours, obtained at the Boulevard de la République station, were well below the limit value, defined by a standard NS-05-062 set at 30 000 µg / m^3. The maximum is obtained during the second campaign with 7.86 µg/m^3 on 14/05/2013 at 8:00: 00 min.

3.1.3 Ozone (O_3)

Ozone is measured continuously on three stations of the city of Dakar: traffic station in the urban area (Boulevard of the Republic), urban bottom station (Helm) and the Yoff regional base station. The average evolution of ozone concentrations over the study period shows no exceedance. However, there are episodes of high concentrations exceeding 45 µg/m^3 recorded at the Yoff site (bottom station) with a daily maximum of 8-hour averages of 61.7 µg/m^3 during the second campaign. No exceedance of the standard set by WHO at 100 µg/m^3 averaged over 8 hours was found, nor that of the Senegalese standard NS-05-062 set at 120 µg/m^3 was noted.

3.1.4 Sulfur dioxide (SO_2)

They are measured on three stations of the city namely: the station of the road traffic (Boulevard of the Republic), the industrial station (Bel Air) and the urban base station (Helm). During the study period, the daily average concentrations and the hourly maximum concentrations at the measurement sites of the city are very low. The highest mean concentration and maximum hourly peak concentration, respectively 18.35 µg/m^3 and 69 µg/m^3, were observed during the first campaign at the road traffic site (Boulevard de la République). These concentrations are below the threshold set at 50 µg / m^3 by the WHO for an annual concentration and the daily limit value for the protection of human health set at 125 µg/m^3 by the WHO and the Senegalese Standard. Although the limits were not exceeded, we note an influence of the release of SO_2 by the traffics on the study area because, during all the campaign period, only the station of Boulevard of the Republic presented strong peaks of concentrations.

3.1.5 Particles in suspension (PM_{10} and $PM_{2.5}$)

PM_{10}

For PM_{10}, the daily limit value set by Standard NS 05-062 (260 µg/m^3 averaged over 24 hours) experienced 130 days of exceedance at all sites (Fig. 4).

The city was sufficiently influenced during the first measurement campaign by suspended particles from northern Senegal (Sahara) and by anthropogenic discharges at the city level. On all sites, the maximum hourly concentrations were above 650 µg/m^3. Four episodes of high pollution occurred on February 3, 2013, at the Helm (suburban-urban suburbs: 860.28 µg/m^3), on February 3, 2013, in Medina (suburban road traffic: 833.04 µg/m^3), the 02 February 2013 in Bel Air (industrial urban: 831.63 µg/m^3 and finally February 02, 2013 at the Boulevard de la République (Urban traffic).

In the second season, despite a significant drop in concentrations recorded at all sites, only the industrial urban station (Bel Air) had a concentration lower than the limit set by standard NS-05-062 (260 µg/m^3: thresholds for information-recommendations and alert). The other stations: Helm, Yoff, and Medina each showed a strong peak of pollution, with very close concentrations exceeding 300 µg/m^3 respectively: April 04, 2013 (372 µg/m^3), April 02, 2013 (341 µg/m^3) and May 31, 2013 (303 µg/m^3).

During the third measurement campaign, these concentrations decreased in intensity, and this drop in concentrations coincides with the onset of the rainy or overwintering season. At each site, the PM_{10} concentrations are below the regulatory value. These indices are explained by the heavy rainfall during this period when the city was leached. From this, we can deduce that the variability of suspended particle concentrations is seasonal and strongly influenced by weather conditions.

Comparison with 2012 levels

In comparison, the 2012 PM_{10} measurement campaigns during the same period each gave significantly higher concentrations than the NS-05-062 standard, ie above 800 or even 900 µg/m^3 on average, with suburban-type (Helm and Medina), which recorded peaks of 982µg /m^3 on 07 February 2012 and 951µg/m^3 on 20 January 2012. On type sites, urban road traffic (Boulevard de la République) and urban industrial (Bel Air), the concentrations are respectively 851 µg/m^3 and 880µg/m^3.

Like this year, we noticed almost the same trend with a drop in concentrations in the second and last quarter. It should be noted that in 2012, measurements at Yoff Station showed double the exceedances compared to other sites. The recorded concentrations are interpreted in a particular way, because of its geographical situation close to the sea. Indeed, this site receives important contributions of sea salts coming from the sea which are less dangerous for the population but which nonetheless have a considerable effect on the structures. These measurements (Yoff station) cannot be compared with the other stations and are not taken into account in the graph.

$PM_{2.5}$

$PM_{2.5}$ are measured at two sites in the city, industrial urban (Bel Air) and road traffic (Boulevard de la République). However, pollution levels in $PM_{2.5}$ appear to follow the same monthly changes as PM_{10} (except for January and February). Concentrations were significant during the first two quarters, notably at Bel Air and Boulevard de la République. The value set by the WHO (25 µg/m^3) was exceeded 232 times, with average concentrations of 48.55 µg/m^3 for the first season and 27µg/m^3 for the second campaign at Bel Air. At the Boulevard de la République, the average concentrations were 56 µg/m^3 for the first season and 24.69 µg/m^3 for the second season. Two identical episodes of heavy pollution were observed on February 02, 2013 with 206 µg/m^3 on the industrial urban site (Bel Air) and 205.38 µg/m^3 on that of road traffic (Boulevard de la République).

During the last season, in view of the rainy season, the two stations experienced a drop in concentrations, which however remained high compared to the standard set by the WHO [24].

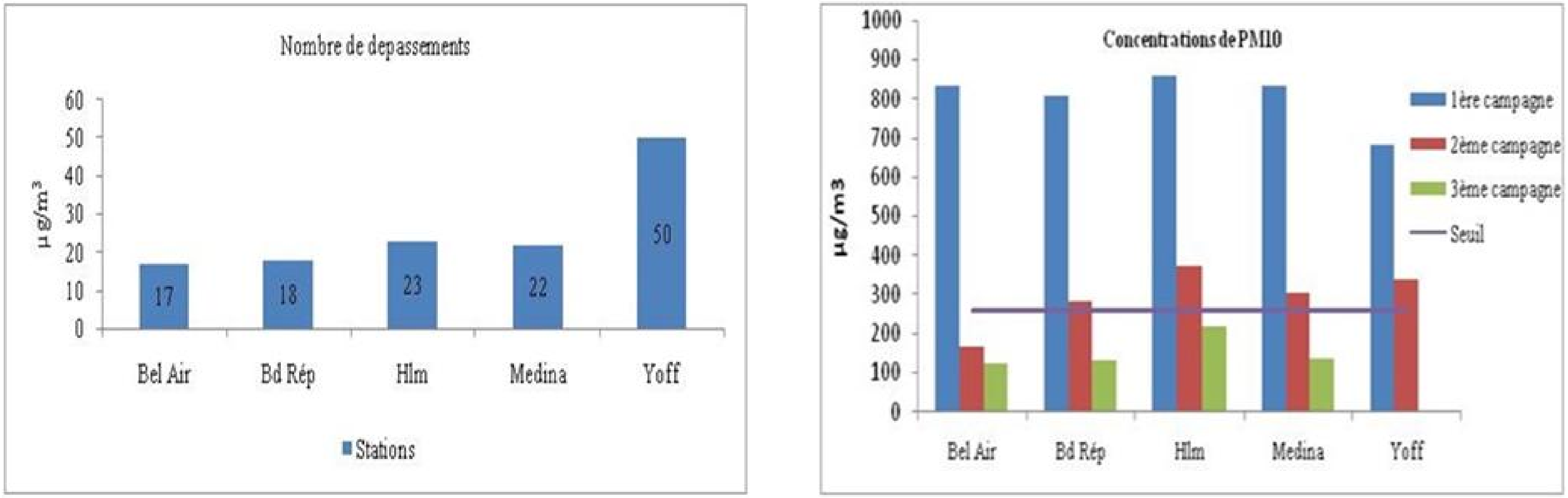

Fig. 4. Change in average PM_{10} concentrations and level of exceedances in 2013

Table 3. Average PM_{10} Concentrations

Station de mesures continues (en µg/m³)	Pourcentage des données valides	Concentrations moyennes	Concentrations horaires		Jour/mois/an de max
			Maxima horaire	Nombre de dépassement	
Bel Air	79%	189,66	831,63	17	02/02/2013
Bd. Rep.	97%	176,99	806,37	18	02/02/2013
Hlm	85%	223,67	860,28	23	03/02/2013
Medina	86%	223,00	833,04	22	03/02/2013
Yoff	31%	340,80	682,42	50	01/02/2013

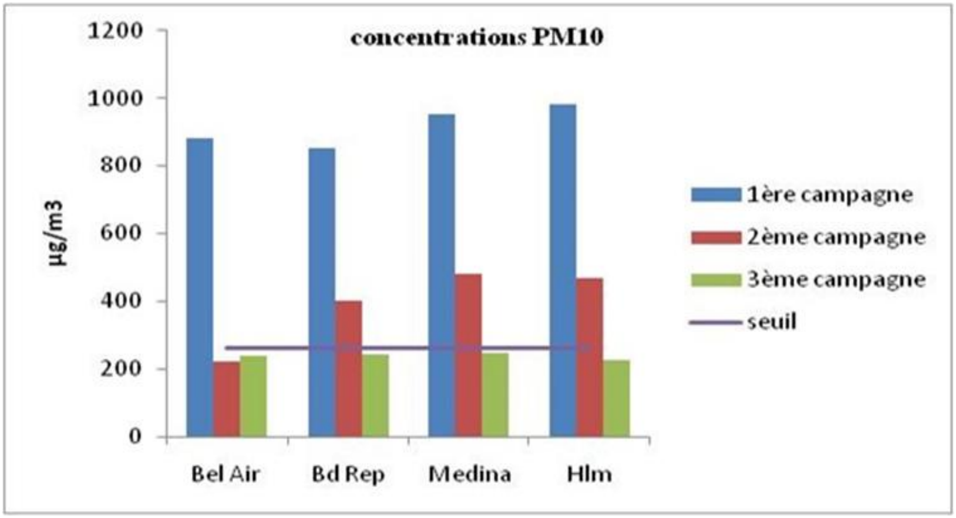

Fig. 5. Evolution of average PM_{10} concentrations in 2012

Table 4. Mean concentrations and number of $PM_{2.5}$ exceedances

Station de mesures continues (en µg/m^3)	Pourcentages de donnée valide	Concentrations moyennes	Concentrations horaires		Jour/mois/an du maximum
			Maximal horaire	Nombre de dépassement	
Bel Air	87%	34,07	206,60	128	02/02/2013
Bd. Rep.	98%	31,46	205,38	104	02/02/2013

3.2 Discussion

This study is part of the first of its kind in Dakar. First, the choice of the study area, the agglomeration of Dakar, appears relevant in terms of urbanization, sources of pollution, intercity travel, relief, geography. Firstly, the monitoring of air quality developed over the past five years by the CGQA produces data that can be used to carry out an evaluation or impact study. Weather data is also of good quality.

The second important element brought by this study is that the measurement campaign is the only representative of the period studied and takes into account only a small number of pollutants. It does not make it possible to apprehend all the genes felt, especially in terms of odors for which it is difficult to determine the pollutant responsible. Nor to quantify by sector of activities. On the other hand, it draws up an assessment of the air quality in the city of Dakar at different times of the year and makes it possible to evaluate the concentration levels of the different pollutants compared to the reference values or the NS-standard. 05-062 and WHO (Table 6).

Although the measurements of these air quality stations are reliable and precise, they have some major drawbacks: Insufficient measurement sites: the data are limited to the areas where the measurement stations were located and therefore do not totally cover the city. Lack of mobility: measurements are always made at the same geographical point. The high cost of installation and operation: the costs associated with the purchase of the various analyzers and their maintenance are high.

In this context it would be desirable to carry out sampling by passive tubes or passive samplers: this monitoring technique makes it possible to have a large number of measurement points in a given area.

In parallel, it also seems necessary to increase the number of stations and to broaden the research to other pollutants such as NMVOCs, Pb, PAHs, etc. It would be interesting if necessary, to carry out, for each type of pollutant, an Ecotoxicological Impact Assessment (EIA) as well as the inventories and cadastres of the emissions, in order to better

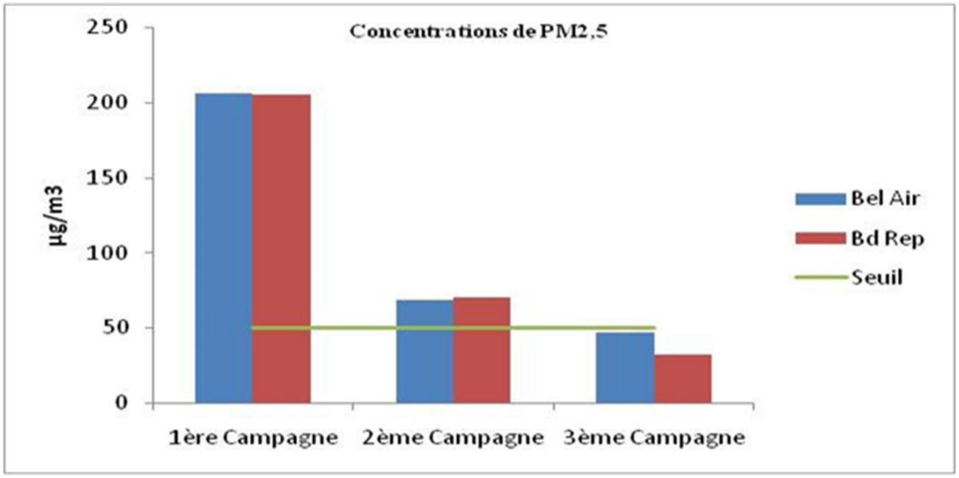

Fig. 6. Evolution of average concentrations of $PM_{2.5}$

Table 5. Regulatory value of Senegal and WHO

Pollutants	Moyenne temporelle	Valeur réglementaire (en µg/m^3)	
		Directives OMS	**NS-05-62 (Sénégal)**
Dioxyde de soufre (SO_2)	Horaire	500 (10 mn)	-
	Journalière	125	125
	Annuelle	50	50
Dioxyde d'azote (NO_2)	Horaire	200	200
	Annuelle	40-50	40
Ozone (O_3)	Horaire	150-200	-
	8 Heures	120	120
Monoxyde de carbone (CO)	Journalière	30 000	-
	8 Heures	10 000	30 000 (24h)
Particules <10µm (PM_{10})	Journalière	50	260
	Annuelle	20	80
Particules <2,5 µm ($PM_{2,5}$)	Journalière	25	-
	Annuelle	10	-

target or locate the impacted places thus making it possible to evaluate the impact of pollution on the health of sensitive populations.

This study thus makes it possible to emphasize that atmospheric suspended particulate matter levels are subject to a high seasonality with higher levels in the dry season (1st and 2nd season) than in the rainy season or wintering (3rd season). This phenomenon is explained by the increase of particulate emissions in the air or anthropogenic releases (industries, transport, domestic heating) which are at the origin of these overruns, coupled with stable weather conditions (favoring the accumulation pollutants). As their concentrations are higher throughout the campaign period, well beyond the limit set by the Senegalese standards and WHO, it would be appropriate to implement action plans with adequate measures to reduce these pollutants, which are considered high priorities for health in the future.

4. CONCLUSION AND PERSPECTIVE

This first study on air pollution in Dakar should be regarded as an exploratory study. It confirms the validity of continuous monitoring and validates the device put in place by the CGA. Even if it did not allow the fact of a health impact, nevertheless it approved to set up the first staked, to lay the first base of a reflection going in this direction. Of all the pollutants studied, only suspended particles exceeded the regulatory thresholds. Thus, it appears that the impact of air pollution on the agglomeration of Dakar is mainly related to the dust content and that it is probably not negligible. Besides, it appears important to address preventive health measures. Because it is likely that this finding is in contradiction with the perception of the health impact of the air pollution in a part of the population. Finally, future research should include a more in-depth study of the biological and physiopathological aspects involved in the impact of air pollutants on health by improving the protection of the ecosystem, intending to sustainable development.

COMPETING INTERESTS

- **Scientific benefits**

The project puts its results and tools at the disposal of POLICYMAKERS to help them formulate more effective local and national policies. Elements allowing the state authorities to take measures considered useful for an improvement of the air quality in Dakar. It will also provide health professionals with information to better advise vulnerable people and all citizens so that they can better protect their health.

- **Socio-economic impacts**

the air pollution, more particularly, the particles in suspension, are at the origin of certain pathologies as respiratory cause, cardiovascular disorder, cardiopulmonary disorder, asthma, cancer of the lungs which induce considerable economic costs for the society, expenses, covered by the care system: medical consultations, care, purchases of medicines, hospitalizations, reduction of daily activity (including work stoppage), daily allowances, premature death, ..,

It is this cost to the care system that, the study conducted by the world bank in 2001, in the city of Dakar, evaluated a total of 63 billion fca per year. to be complete, this already high level of cost would be to increase other expenses that could not be quantified (medical transport, consultations, and examinations in city medicine, impact on public buildings and historical heritage).

REFERENCES

1. Afsse. Impact sanitaire de la pollution atmosphérique urbaine; 2004.
2. Charles L. Pollution atmosphériques et santé environnementale. Quels enjeux? Quels acteurs? Quelles preventions? 2009.
3. Festy B. A propos de l'évaluation des expositions humaines d'origine atmosphérique: la necessité d'une vision globale et multipartenariale, pollution atmosphérique; 2001.
4. InVS. Impact sanitaire de la pollution atmosphérique dans neuf villes françaises, Résultats du projet Aphekom; 2012.
5. Wahida KIHAL T. Inégalité de santé, environnement de voisinage et impact sanitaire de la pollution atmosphérique"apports d'une analyse multidisciplinaire à fine échelle. Application à l'agglomération strasbourgeoise; 2011.
6. Zahra. Barakeh. Suivi de pollution atmosphérique par système multi - capteurs- méthode mixte de classification et de détermination d'un indice de pollution; 2012.
7. ADEME. Classification des stations de surveillance de la qualité de l'air; 2009.
8. Sabrina H. Contribution de la pollution Atmosphérique aux Inégalités Socio – Spatiales de Santé. Analyse écologique du risque d'infarctus du Myocarde dans l'agglomération de Strasbourg; 2008.
9. OMS. 7 million deaths annually to air pollution; 2012.
10. OCDE. Mortality risk valuation in environment, Health and Transport Policies; 2012.
11. Perrin E. Green et vert publie que la pollution atmosphérique tu 40 personnes par jrs soit au total 14 700 personnes au Mexique; 2013.
12. Bécu E. La pollution tue 750 000 personnes en Chine chaque année; 2007.
13. Diallo I. Pollution de l'air à Dakar; Sud Quotidien; 2008.
14. Banque Mondiale B. Dysfonctionnement du transport urbain et pollution de l'air à Dakar; 2001.
15. Ndiaye I. Le secteur des transports routiers au Sénégal; 2004.
16. SRSD. Situation Economique et Sociale de la région de Dakar de l'année 2007, 2008.
17. ANSD. Agence Nationale de la Statistique et de la Démographie (ANSD), Sénégal. 2013. [En ligne]. Available:http://www.recensement.sn/fr/. [Accès le 16 Avril 2013]
18. Banque Mondiale B. Situation socio-économique du Sénégal, 1ère édition. Apprendre du passé pour un avenir meilleur, 1ère éd. 2014;50.
19. Young EE. Sénégal: la zone franche industrielle et les possibilités d'une zone de développement économique. Projet de Soutien au Développement de l'Entreprise Privée; 1991.

20. CSE. Rapport sur l'état de l'Environnement au Sénégal; 2010.
21. Doumbia. Caractérisation physico-chimique de la pollution atmosphérique urbaine en Afrique de l'Ouest et étude d'impact sur la santé)(parlé des chiffres et les biomasse; 2012.
22. Mathé, et al. Surveillance de la qualité de l'air: le dispositif français (revue)// techniques de l'ingénieur. – 2009. revue// techniques de l'ingénieur, 2009.
23. Mathé F. Evolution de la classification et des critères d'implantation des stations de mesure de la qualité de l'air – participation à la réactualisation du guide de classification des stations; 2010.
24. WHO. Evaluation and use of epidemiological evidence for Environmental Health Risk Assessment. Copenhagen: WHO Regional Office for Europe; 2000.

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