Air Pollution linked to Road Traffic: Assessment of Carbon Monoxide (CO) Emissions in Zinder City, Niger Republic

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Abstract
Massive importation of used vehicles into many African cities couple with the use of fuel of questionable quality is of concern and source of most African cities atmospheric pollution. This work focuses on air pollution cause by Carbon Monoxide (CO) linked to vehicle traffic in Zinder, Niger Republic. The research conducted hourly measurement of traffic proximity and CO concentration with digital meters and mobile multi-gas detector BH-4 and established the existance of correlation between traffic flow and deterioration in air quality. The daily profiles show two peaks (11 am-1pm and 6 pm-9pm) with CO values of 40 ppm ; which is well above the WHO standard of 30 ppm. The field measurements were subjected to linear model, in which the Coefficient of determination ($R^2 = 0.634$) indicates that more than 63% of the variance in the level of CO is explained by road traffic and weather conditions.

Keywords: Zinder, Air pollution, Carbon monoxide (CO), Traffic.

1. Introduction

Preserving the quality of the atmosphere has today become a global economic, legal, Health and Environmental issue. Air quality is essential to the quality of life. Like Water and Earth, Air is vital (Vennin, 2000). Air pollution, a matter of major global concern, is a concept that appears to be polymorphic over the long time and varies according to technological developments and the perception of its harmful effects on society. It does not date from yesterday, but as early as the 13th century, when a Royal edict prohibited the use of coal for domestic use as long as sessions of parliament lasted; any failure to observe this provision led to a trial, the out come of which could be fatal (Florian et al., 2015).

Thus, as early as 1967 the Council of Europe (CEC, 1991) defined atmospheric pollution as resulting from " the presence of a foreign substance in the Air or a significant variation in the proportions of its components which may, given current scientific knowledge, cause a harmful effect, create a nuisance or a gene". It is therefore a complex issue bringing together meteorological factors and various air contaminants which may be of a physical, chemical or biological nature, responsible for toxic, allergic or infectious effects; according to the work of (Quénel et al., 2003).

1950s were a decisive turning point in the Countries of the North with regard to the social problem of air pollution marked by a series of major episodes, in particular the London Smogs which allowed the adoption of " Clean Air Act " (Logan, 1953). Since then studies have been undertaken and policies to reduce emissions have been implemented culminating with the signing of the Geneva Convention on long-range trans-boundary air pollution in 1979 and the creation of the European Environment Agency in 1990.

On the other hand, in African countries, air pollution is poorly characterized because very few studies have been carried out in this direction. air quality monitoring in cities of Sub-Saharan Africa (SSA) is practically non-existent and without any real text regulating Pollutant emissions forcing their populations to breathe toxic air spewed out by the exhaust pipes of traffic automobile (Camara, 2014 ; Fourn et al., 2006).

The work of Assamoi et al. (2010) revealed that in West Africa, due to the reduction in public transport and/or their obsolescence, there is an increase in the vehicle fleet with second-hand vehicles aged over ten years on average. The same study underlined that, for economic reasons,

there is an upsurge in the fleet/use of motocycles with two-stroke engines, mostly using adulterated fuel oïl, which is cheaper but can cause 10 to 30 times more pollution of organic particles.
Research by Pétros (1997) highlighted that in African Capitals, gaseous and particulate pollution mainly results from automobile traffic, domestic fires and, to a lesser extent, industrial emissions.
The first efforts in SSA countries to improve air quality started in late 1990s with actions to eliminate lead in gasoline which was implemented in 2005, thanks to the initiative Program on Air Quality in Sub-Saharan African Cities financed by the World Bank within the framework of the Sub-Saharan Africa Transport Policy Program (SSATP - Urban Mobility Component) and the 'Global Air Quality Initiative coordinated by the World Bank Institute in 1998. This was the first program to stop the degradation of urban air quality linked to emissions from motor vehicles, and by far the leading source of urban air pollution in Africa (Patrick et al., 2003). The initiative, thanks to subsequent funding for studies, had effects at three levels: in the partner cities (Dakar in 1998, Ouagadougou in 1999, Cotonou in 2000 and Douala in 2002), at the Sub-Regional level and at the Regional level. A fifth study, financed under an operational program of the transport section of the World Bank, was carried out in Abidjan in 2001. Among the many results of these studies, we can cite the organization of national follow-up seminars, scientific publications, production of a video documentary "Leaded Gasoline, a Silent Threat`` available in English and French, development of the Sub-Saharan Africa Air Quality Initiative website in June 2001: www.worldbank.org/cleanair.
The main objective of this work is the Quantitative Evaluation of Carbon Monoxide (CO) by highlighting the role played by vehicles in the emission of this gaseous pollutant : As presented in the daily and weekly Profile of CO Air Pollution in the city of Zinder.

2. Materials and Methods

2.1. Study Zone

Zinder City, Capital of the Region, is located in the East-Central Part of Niger Republic on the National Road n ° 1 ; 917 km East of the Capital Niamey and 700 km West of Lake Chad in cross roads of 2 major international axes: the Trans-Sahelian oriented from West to East and the Trans-Saharan oriented from South to North. According to the National Institute of Statistics (INS) estimates, its total population in 2020 would be 431,149 inhabitants distributed in the five communal districts of the city, with an average density of 712 inhabitants / km^2.
The region's economy resides primarily on agriculture entreprises (Crop Production & livestock production), and other business ventures such trading and transportation. Because of its favourable location, Zinder is home to Niger Republic only Oil Refinery, and various SMIs that are into hide & Skin and food processing.

2.2. Choice of Measurement Sites

The measurements were taken in high traffic areas of the city. For Comparative analysis, test site was chosen at the outskirts of the city, far from automobile Pollution.
The Sites are :
- The Optical Light of the Tribune ;
- The Optical Light of the Post Office ;
- The Nagari Crossroads;
- The Optical Light of the *Dole* Market;
- The Optical Light of the Municipal Stadium ; and

- University of Zinder (as the Comparative Analysis).

2.3. *Presentation of measurement equipment*

The measurements were conducted by the use of Mobile Multigas Detector BH-4 which measures gas concentrations in the air using cells. This portable electronic detector uses electrochemical probes to monitor Methane (CH_4), Oxygen (O_2), Carbon Monoxide (CO), Hydrogen sulfide (H_2S) and combustible Gases with lower limits of explosiveness (LEL).

Electrochemical cells are sensors fitted with several electrodes, depending on the concentration of the gas, a reagent delivers a modeled electrical signal. Each cell reacts to a particular chemical component. As the device is often used in harsh environments, it is IP65[1] certified, which means it is completely protected from dust, low pressure jets of water in all directions, and It is really a very high precision device. The detector is factory calibrated therefore operational upon receipt, however, when the need for re-calibration/calibration arise, it is quite simple and can be done with just several clicks of a button (www.metrics.com).

The average hourly traffic flow (cars and Motorcycles) is counted with digital counters. On each site, a counters were used to monitor the number of cars, another to count the 2 and 3 wheels (*motocycle*) to carry out so-called 'Traffic Proximity' measurements.

2.4. Data Collection and Processing

The site measurement took place between march and june 2018, basically, the measurements of CO and the flow of Road Traffic. On each sites, hourly measurements of the concentration of Carbon Monoxide and the number of vehicles, namely cars and motorcycles (2 wheels and tricycles) that passed. For the vehicles, the forward direction as well as backward direction were recorded and total number computed. For the CO measurement, we took 3 to 5 readings per hour and the average value computed and recorded.

In order to compile the Results of the daily and weekly profiles, each of the 5 sites (with exception of the control site) an average of 3 weeks of follow-up visits was undertaken. Also, as part of the study, we hypothesized that certain climatic parameters can influence the diffusion and/or dilution of pollutants. The hypothesized parameters are ; Minimum and Maximum Temperatures, Relative Humidity and Average Meridian Wind Speed, thus, their daily values were obtained from http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP-NCAR/.CDAS-1/.DAILY

The effect of road traffic on CO concentration is examined through a linear model. We assume that on any given day, the level of CO in the atmosphere is determined by the number of cars and motorcycles / tricycles in circulation and the prevailing weather conditions. The model specification is as follows:

$$co_t = \alpha_0 + \alpha_1 veh_t + \alpha_2 moto_t + \alpha_3 Tmax_t + \alpha_4 Tmin_t + \alpha_5 him_t + \alpha_6 vitm_t + \alpha_6 vitm_t^2 + \varepsilon_t$$

with :

- co_t is the average CO concentration in ppm per hour of day t;
- veh_t Represents the average number of cars per hour recorded on day t
- $moto_t$ Corresponds to the average number of motorbikes per hour recorded on day t;

[1] Certification for the protection index of the device

- $Tmax_t$ and $Tmin_t$ respectively represent the maximum and minimum temperatures (in ° C) felt on day t;
- him_t is the relative humidity (%) recorded on day t;
- $vitm_t$ Represents the mean meridian wind speed (m / s) wind of the day t
- ε_t Corresponds to the error term of the model. It is assumed to be white noise, distributed according to a normal law with zero mean and variance σ^2 ;
- $(\alpha_0, \alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6)$ are the coefficients of the model.

The parameters of the model $(\alpha_0, \alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \sigma^2)$ are estimated by the method of least squares. The coefficients, α_1 and α_2 make it possible to assess the impact of road traffic on the level of CO concentration.

3. Results

3.1. Analysis of the impact of road traffic on CO emissions

The system put in place during data collection makes it possible to analyze CO emissions per hour and depending on the day of the week. In this section, we present the daily and weekly profile of atmospheric CO Pollution from the sampling sites.

3.1.1 Daily profile of CO emissions

Air pollution is mainly linked to human activities, the intensity of which varies depending on the time of day. Automobile CO emissions would then be expected to follow the same dynamic.
In the case of the study areas, the average amount of CO released into the atmosphere per hour during a day is given in Figure 1. It shows that, the highest level of atmospheric pollution occurs at 1:00 p.m. At this time, the concentration of CO in the air exceeds 40 ppm; which is much higher than the WHO standard of 30 ppm representing a threshold of toxicity for human Health.
The air quality also remains very poor between 10 a.m. and 11 a.m ; 1 p.m. to 2 p.m. and between 6 and 9 p.m. During these periods, the CO concentrations also represent a danger for the Health of the populations because they often exceed the threshold of 30 ppm.
The comparison between the daily profile of pollution and that of road traffic seems to indicate the existence of a link between deterioration in air quality and the flow of vehicles in circulation. In fact, the periods for which the CO concentrations in the atmosphere are particularly high correspond, in general, to peak hours. By way of illustration, between 10 a.m. and 11 a.m the time interval when the level of pollution exceeds the WHO tolerance threshold, road traffic is the most important of the day with a flow of more than 300 cars and 2000 motorcycles.
On the other hand, the lowest pollution levels are recorded from 11 p.m. with virtually non-existent CO emissions. During this period, the flow of cars and motorcycles barely reaches a quarter of that observed at peak hours.

3.1.2. Weekly Traffic Profile

Figure 2 gives the number of car and motorcycles in circulation at the intersections (Crossroads) studied. The weekly profiles therefore, represent the daily average values for each day of the week during the study period. This angle of analysis makes it possible to highlight the periodicities of CO pollution events over the week. We notice that vehicle traffic increases gradually from thursday to sunday with a peak on saturday. But for two and three wheelers (motorcycles), the traffic remains almost stationary especially on working days with a peak on thursday.

The level of pollution also varies depending on the day of the week. It is weaker at the beginning of the week but grows steadily on other days to reach its maximum on weekends. Thus, in a typical week, saturday and sunday represent the days when the air quality is the worst, with CO concentrations above the WHO guidelines (Figure 2).
As in the case of the daily profile, the level of pollution seems in part to be linked to road traffic. In fact, the average number of vehicles traveling on weekends is higher than that on other days.

3.1.3. Linear model of road traffic on atmospheric CO concentration

The results of the estimate are shown in Table 1. The coefficient of determination (R^2 = 0.634) indicates that over 63% of the variance in the level of CO concentration is explained by road traffic and weather conditions. Of the eight (8) estimated coefficients, 3 are significantly different from 0 at the 5% level. These are the coefficients associated with the number of vehicles and the meridian wind speed.
The number of cars therefore affects the atmospheric concentration of CO. In fact, 100 additional cars in traffic increase the average CO concentration by 11.48 ppm. On the other hand, the number of motorcycles does not have a significant effect on CO emissions at the 5% level. For climatic variables, only the meridian wind speed has an influence on the level of CO in the atmosphere. The effects of all the variables used in the models are given in Table 2. It appears that a unit increase in the meridian wind speed induces an increase in the CO concentration of 3.54 ppm.

4. Discussion

The results of this study show that air pollution is a reality in Zinder, particularly local pollution linked to road traffic. Studies on this type of pollution in West African Cities are very rare, even if they experience significant air pollution problems linked to the uncontrolled increase in the size of the cities, the number of urbanized areas and the increasing trend, demographic, manufacturing activities and poorly organized road traffic system (Ndong, 2019). The CO-related pollution recorded in Zinder in this work is the result of the movement of car and motorcycles because at the control site which is far from traffic, the CO concentration is zero ppm all day. Several studies corroborate our results regarding the effect of amplifying the level of gaseous pollution such as CO by traffic flow.
This is the case of the results of AllAfrica (2015) which revealed that 72.76% of the registered vehicle fleet in Senegal estimated at more than 400,000 vehicles, all series combined circulate in the capital Dakar, which explains the level of pollution of the city. Apart from the number of vehicles in circulation, their age is also an aggravating parameter as underlined by studies by the Air Quality Management Center (CGQA, 2017) which have shown that the majority of Dakar's car fleet, the largest city in Senegal, is mainly composed of dilapidated vehicles with old and inefficient combustion technologies, which would result in significant air pollution from a fleet of old vehicles. The work of Alcède et al. (2003) approaching in the same direction has shown that Brazzaville, capital of the Congo, has become one of the most Polluted cities in Central Africa due to the fumes released by second-hand cars massively imported from Europe and Asia that run on adulterated gasoline.
Compared to the hours of peak pollution, the work of Mama et al. (2013) on monitoring carbon monoxide at certain crossroads in Cotonou (Benin) gives results similar to ours with peaks of pollution around 12 noon and at the start of the night. with threshold values also exceeding the

WHO standard. In Developed Countries, Pollution levels can vary during the day, for example during morning or evening peaks in traffic (ATMO France, 2014). The influence of road traffic on CO levels is inevitable, but extensive studies have proven that beyond traffic, the maximum hourly pollution levels depend on the interaction of several parameters, contextual and environmental related to the land use planning and transport, including issues such as town planning, road design, traffic and public transport regulations, as well as demographic, topographical, economic and social considerations (Venzia, 1977).

Regarding the weekly profile, against all expectations, peaks in traffic and pollution are recorded on weekends, while Zinder Market day is Thursday. This can be explained by the fact that weddings that are celebrated on weekends attract large processions and create a festive atmosphere with a lot of come and go. This result diverges from the reality of developed countries where, overall, Pollution levels are slightly lower on weekends, especially on sundays due to Store closures (ATMO France, 2014).

The results of our model using field data across 8 parameters showed overall good predictive capacities, despite the quality of the input data (especially the method of counting the traffic density) which is very limiting (archaic method).

The works of Brauer et al. (2003) and Ryan et al. (2007) have shown that regression models constitute methods allowing a better understanding of the proximity Pollution linked to traffic while remaining close to reality. They therefore provide elements to guide public action in terms of air quality management. These arguments justify the use in several studies of linear models (single or multiple) especially in the case of comparative studies (Goyal et al.,2006). However, the results of these models cannot be directly transposed from one locality to another given the specificities in terms of buildings, urbanization, vehicle fleet and lifestyle (especially modes of travel) which can be observed (Host, 2012).

The fact that certain parameters do not have a significant effect on CO emissions at the 5%. Threshold (number of motorcycles, for example) can be interpreted by the choice of model and parameters. Considering the ratio (cars / motorcycles) and a hybrid model, the influence of the traffic as a whole could be more palpable from the point of view of the physical interpretation of the results. Indeed, according to Anda (2017), given that the dynamics of air pollution is non-linear; to achieve convincing results it is better to use a hybrid model, that is to say a linear part and a nonlinear part.

5. Conclusion

This study have showed the importance of focusing on Air Pollution in Developing Countries. Although this pollution is a topical issue because of Health and Environmental risks, very little research has been carried out in Sub-Saharan African Countries. Thus, this study, through measurements of the flow of traffic and the concentration of Carbon Monoxide, has made it possible to highlight the weight of local air pollution which is increasingly the subject of attention in our cities.

Zinder, like other large Cities in Sub-Saharan Africa needs an Air Quality Monitoring Mechanism, in order to identify pollutants as well as sources of emissions, which would subsequently allow to guide research, but also communication and action in this area. But these challenges can only be met by setting up a global convention on air pollution, and consequently supporting developing countries to reduce this pollution and its impacts, whether the sources are domestic or urban , regional or cross-border.

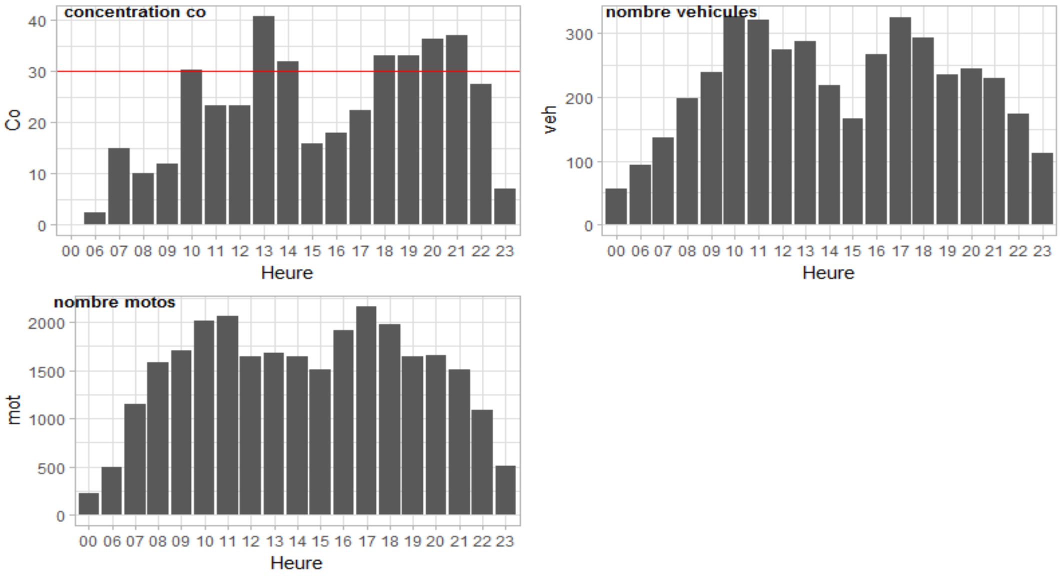

Figure 1 : Daily profile of CO emissions

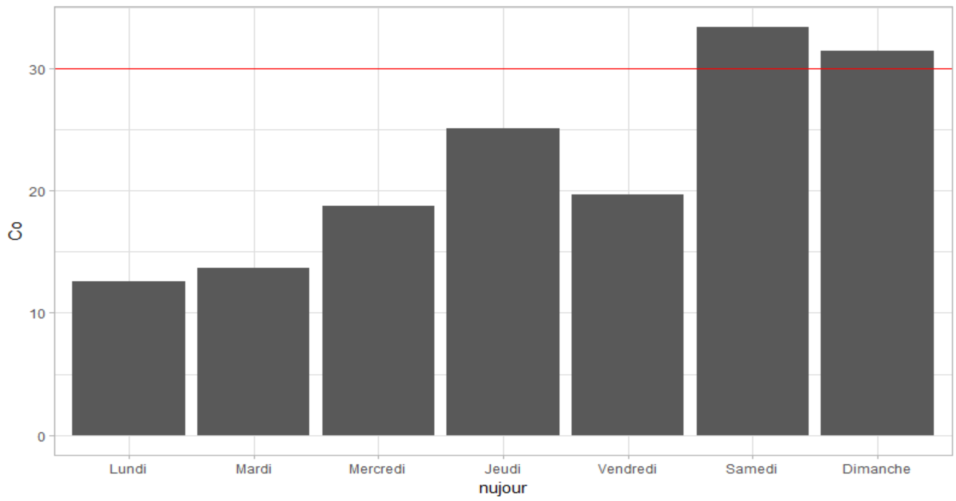

Figure 2 : Weekly profile of CO emissions

Table 1: Model estimation results

	Coefficient	Standard deviation	t-Student	P-value
α_0	-18,718	40,812	-0,459	0,648
$\boldsymbol{\alpha_1}$	**0,115**	**0,024**	**4,698**	**0,000**
α_2	-0,002	0,006	-0,307	0,760
α_3	0,935	0,661	1,414	0,163
α_4	0,655	0,959	0,683	0,497
α_5	-0,484	0,591	-0,819	0,416
$\boldsymbol{\alpha_6}$	**16,263**	**3,557**	**4,573**	**0,000**
$\boldsymbol{\alpha_7}$	**2,502**	**0,725**	**3,449**	**0,001**
R^2 = 0,634 ; $R^2 adjusted$ =0.5875 ;				

Table 2: Marginal effects of the explanatory variables on CO concentration

Variable	Marginal effect	Standard deviation	t-Student	P-value
hum	-0.4844	0.5913	-0.8191	0.4127
moto	-0.0017	0.0056	-0.3067	0.7591
Tmax	0.9350	0.6614	1.4137	0.1575
Tmin	0.6552	0.9591	0.6832	0.4945
veh	**0.1148**	**0.0244**	**4.6984**	**0.0000**
vitm	**3.5388**	**1.8023**	**1.9635**	**0.0496**

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