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IN SITU MEASUREMENTS OF CO AND NOX PUNCTUAL SOURCES FORMED DURING COLD START AND IDLE ENGINE MODES IN ORAN CITY.

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Abstract
Oran, a large economic city in northwestern of Algeria, is nowadays home to a rapidly expanding urban fabric and a diversified infrastructure where socio-economic activity is increased. It distinguishes by the presence of a port, an airport, several industrial zones, several university centers, as well as various commercial and hospital structures. This results in a dense and ramified road network. Because, in Algeria, the car fleet is booming during the last decades, road traffic is one of the main sources of air pollution in Oran. The construction of hoppers, tramway lines, the extension of the city with the displacement of economic activity zones from the city center to the periphery generate a multitude of new data to be considered and updated regularly to analyze pollutant dispersion with the aim to develop cleanup strategies.

This article focuses closely on estimating pollutant quantities exhausted by vehicles which are considered to be the main sources. Measurements consist in recording the CO and NOx contents emanating from the exhaust of vehicles during their passage through the plugs during rush hours. An analysis is devoted to pollutants released during cold start engine mode. Particular interest is dedicated to the roundabouts without hoppers of the third ring road as well as to two crossings with traffic lights. The approach is inspired by several previous works on pollutant dispersion in Oran. The estimation of the pollution level is done by adding the number of vehicles per category noted at the points at mentioned times. The measurements are processed and analyzed by vehicle category and by site and correlations are determined. In the aim to a good exploitation of the results, pollutant amounts are expressed as hourly rate flows.

Key words: Punctual sources, CO, NOx, IDLE, Cold start, Traffic plan, Oran.

Nomenclature

BTPH	Société de bâtiments travaux public et hydraulique.	
C	Concentration	(%, ppm, mg/m^3)
CFD	Computational fluid dynamics.	
CI	Compression ignition	
DTWO	Direction des transports wilaya d'Oran.	
i	ind species index	
LCI.	Light compression ignited	
LSI.	Light spark ignited.	
N	Engine speed	(rpm)
SI	Spark ignition	
Vcyl	Engine displacement	(Liter)

1. INTRODUCTION

The analysis of gaseous pollutants emitted by thermal engines and spread in an urban environment requires prior knowledge of many parameters which depend on the nature of the site, weather conditions and pollutants emitted with their rates. Thus, punctual pollution source is important because it is located at the smallest spatial scale.

According to the literature (B. Sportisse, 2008; Günter et al, 2006), considering the volume percentages of the gases emitted without catalysis, it has been established that:

- ✓ Pollutant emissions volume from spark-ignition engines is about five times the volume emitted by compression-ignition engines.
- ✓ The species present in gas emitted by gasoline engines are mainly CO, followed by NOx, unburned hydrocarbons and particulate matter.
- ✓ The species present in the gases emitted by diesel engines are mainly NOx followed by sulfur dioxide, CO, Unburned Hydrocarbons and Soots.
- ✓ The amounts of NOx emitted by each type of engine are globally the same.
- ✓ The opposite behavior of NOx and soot is well known problem in diesel engines (Bencherif et al, 2009).

Just like the Algiers DC, Annaba and Skikda cities, Oran city has had since January 2008 an air pollution monitoring network. It consists of three measuring stations located three meters above the ground. The first one is located at the Hospital Center (Ex Garrison), the second one at Cherfaoui middle school (Mediouni) and the third one at the Pasteur high school (Rue de la Vieille Mosquée). These stations are connected by telephone cable to the Regional Laboratory of the Environment. The networks are automated and continuously measure oxides of nitrogen, carbon monoxide, halocarbons, ozone, sulfur dioxide and particulate matter (A. Wahid, 2011; K. Zenata, 2008; Zenata et al, 2010). The devices ensure real-time air quality measurements after dispersion of pollutant gases released by road traffic near the stations.

However, this system is not operational for a while and three stations are not enough to cover Oran city and provide inaccurate pollution estimation. The work of Zenata et al (Zenata et al, 2010) carried out a measurement campaign during November 2007, February and April 2008 in order to measure the air quality at nine sites in the Oran. CO and NOx levels are measured near the traffic flow taken one meter above the ground using a portable device between 12h-13h and 16h-17h. The measurements made during the month of April are shown in Figure (2). It is clear that the most polluted period of the day is between 12h and 13h.

A succession of recent works (Rahal 2005, Rahal et al 2011, Rahal et al 2014, Rahal 2015, Rahal et al 2018)., succeeded in representing the spatial and temporal dispersion of emissions emanating from fossil-fueled vehicles The methodology proposed and validated by Rahal et al is based on a combination between chronological analysis of satellite imagery and deterministic modeling with the EMISENS model based on vehicle counting. Rahal et al work led to the realization of polluting emissions cartography, which represents an important step in the prediction of air quality in Oran. Rahal et al associate emitted and dispersed quantity of pollutants by a linear correlation as indicated by:

$$C_i = d\, F_i + C_{0i} \qquad (1)$$

Here C_i is the average concentration of pollutant i, d is the dispersion factor, F_i is the average quantity of pollutant i emitted by the flow of vehicles and C_{0i} is the background pollution concerning the pollutant ip(10).They added that emissions should continue to increase because of the spread of the urban fabric towards east inducing mobility needs oriented mainly from the periphery to the center of the city of Oran. According to Rahal et al, the effective development of environmental policies to improve air quality depends on a good qualitative and quantitative assessment of air pollutants emitted by sources related to human activities (Rahal et al 2018).Moreover, the numerical analysis proposed by Abed (Abed et al, 2016) on the dispersion of pollutants in canyon streets illustrates à CFD application where the explicit knowledge of a source of pollution is essential for a numerical prediction of dispersion in an urban environment. However, because of the development of the urban and road fabric in addition to the car in the city of Oran, the work requires constant updates. In fact, in the current situation, no real estimate of point source pollution is available, hence the motivation for this study. This article aims to provide a quantification of the main pollutant species released by diesel and gasoline engines in sensitive locations in Oran. The methodology consists of measuring the CO and NOx levels released by vehicle categories with the Gunt-IMR1600 gas analyzer.

The measurements are made on different vehicle category samples according to DTWO data with a margin error of 5%. Measurement locations are taken in sensitive roundabouts of the third ring road and two crossing-roads with traffic lights according to DTWO least traffic plan of Oran city.

2. RESULTS AND DISCUSSIONS

The vehicles are sorted according to DTWO (Rahal et al, 2018) in light commercial vehicles, trucks and buses. As the vehicles are in traffic congestion areas, only the measured pollutant levels release by the engines in idle mode are to be used. In addition, particular interest will be paid to the emissions caused during cold start mode.

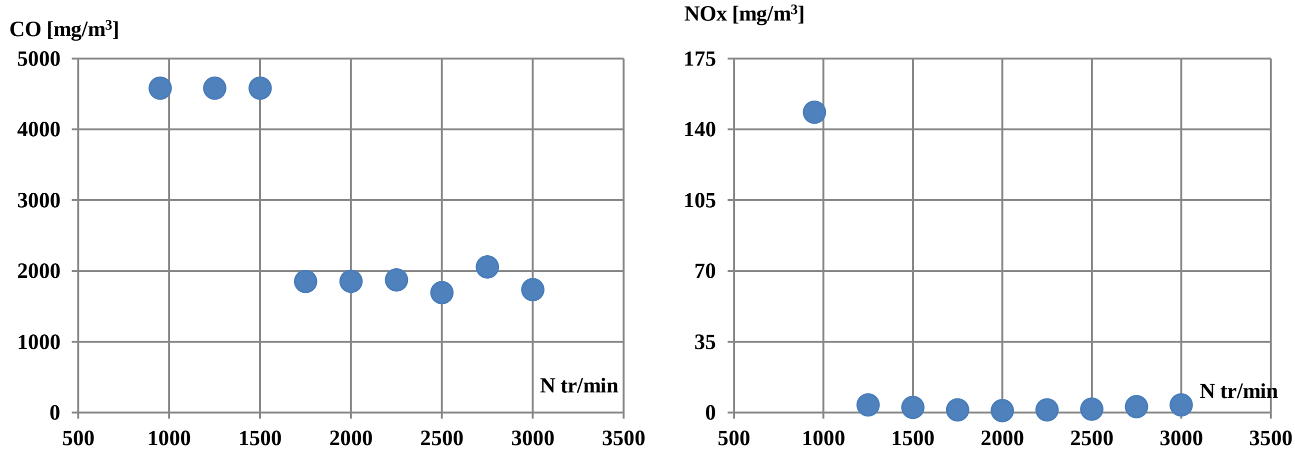

Figure1. CO and NOx emitted according to engine speed (SI engine,1,5 liter).

Curves in figure (1) represent the quantities of CO and NOx released by a gasoline vehicle with multipoint injection (Year 2013) equipped by an engine with a displacement equal to 1.5 liters and a maximum power of 75 KW at 6000 rpm. As expected, because of high fuel air ratios, CO and NOx concentrations are maximum at idle and at low speeds.

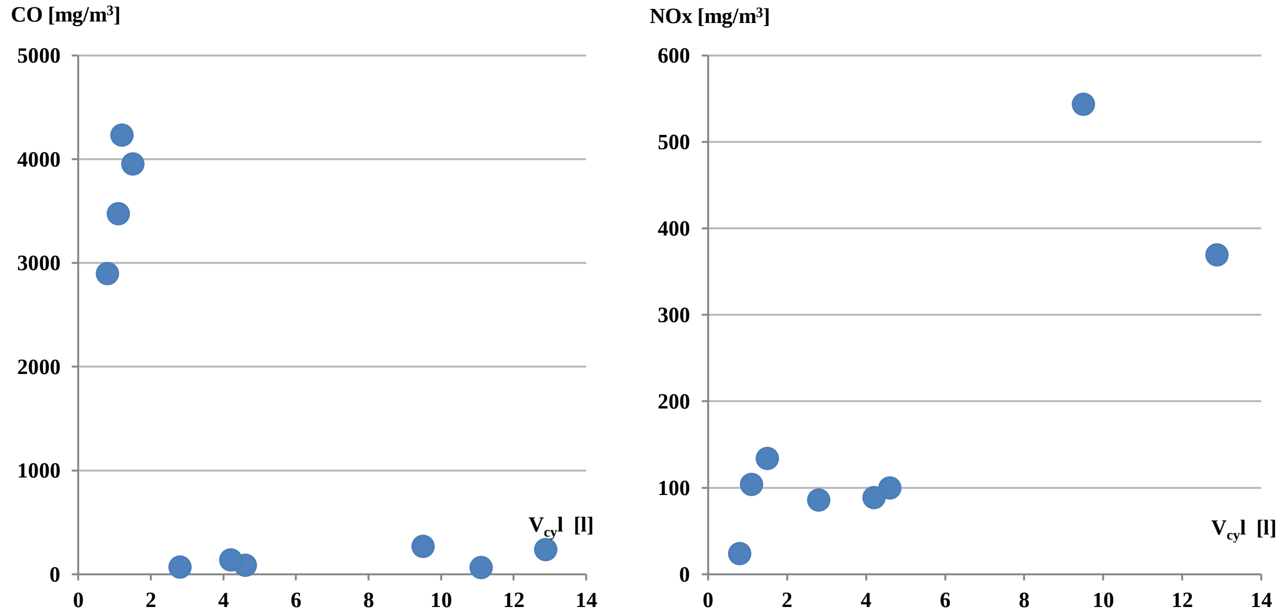

Figure 2. CO and NOx emitted VS engine displacement.

Curves in figure (2) illustrate CO and NOx amounts released by different vehicles operating at idle speed. It shows that low-capacity vehicles (gasoline vehicles) are characterized by higher carbon monoxide levels while large-displacement vehicles (diesel vehicles) are characterized by NOx levels at the exhaust. This is in perfect concordance with the results reported in the literature. Figures (3) and (4) show respectively the evolution of CO and NOx levels in cold start mode for the gasoline vehicle. Results a recorded during a measurement campaign spread over a week. The horizontal lines correspond to the average value. The amount of released CO varies between 1000 and 5000 mg/m^3 with an average value equal to 2750 mg/m^3. The amount of NOx released varies between 50 and 200 mg/m^3. Measured NOx levels tend to bunch around an average value of 125 mg/m^3.

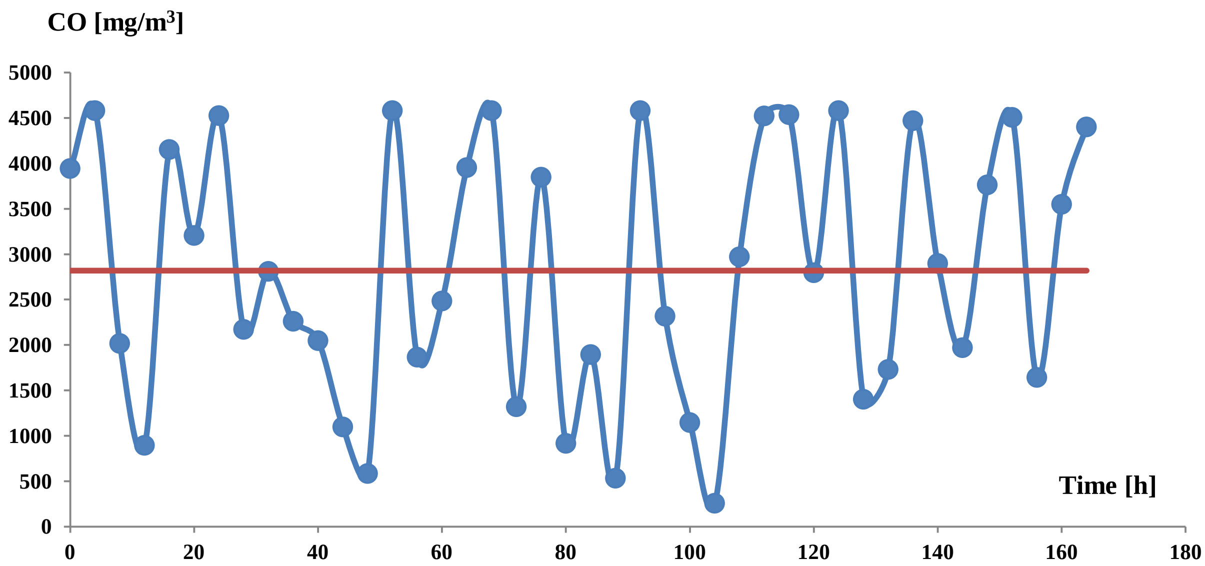

Figure 3. Temporal CO emitted evolution in cold start mode.

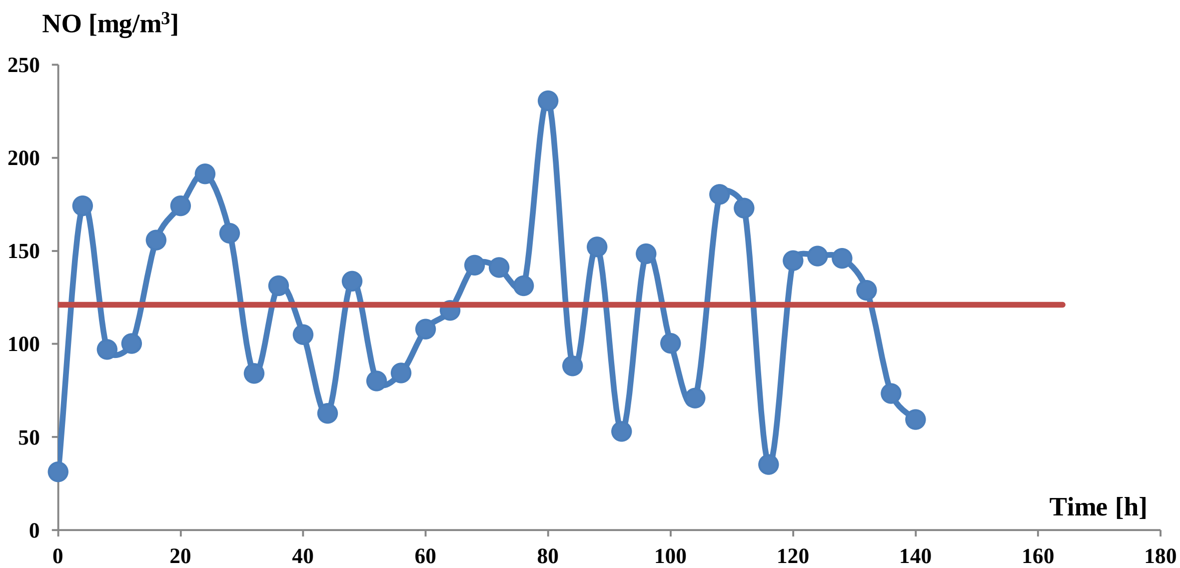

Figure 4. Cold start mode temporal NOx evolution.

Figure (5) shows variation of the NOx/CO ratio in cold start mode measured during a week. It should be noted that this ratio is of main importance for the validation of pollutant dispersion models and simulations. Despite of some singular values, the NOx/CO ratio is globally less than 0.05.

The measurement campaign is carried from the DTWO traffic plan on a fleet of vehicles consisting of light commercial vehicles, buses and trucks. The average values of the gases emitted are grouped by category in Table (1).

Table 1. CO and NOx mean concentrations.

	LSI	**LCI**	**Buses**	**Trucks**
CO mg/m^3	2760	431	88	130
NOx mg/m^3	92	223	127	304

Figure (6) represents the average levels of CO and NOx released by category operating at idle speed. We note that light gasoline vehicles release about 6 to 30 times more carbon monoxide compared to light and heavy diesel vehicles. Trucks release the most nitrogen oxide compared to other categories. We also note that the amount of NOx emitted by trucks is three times that emitted by gasoline vehicles.

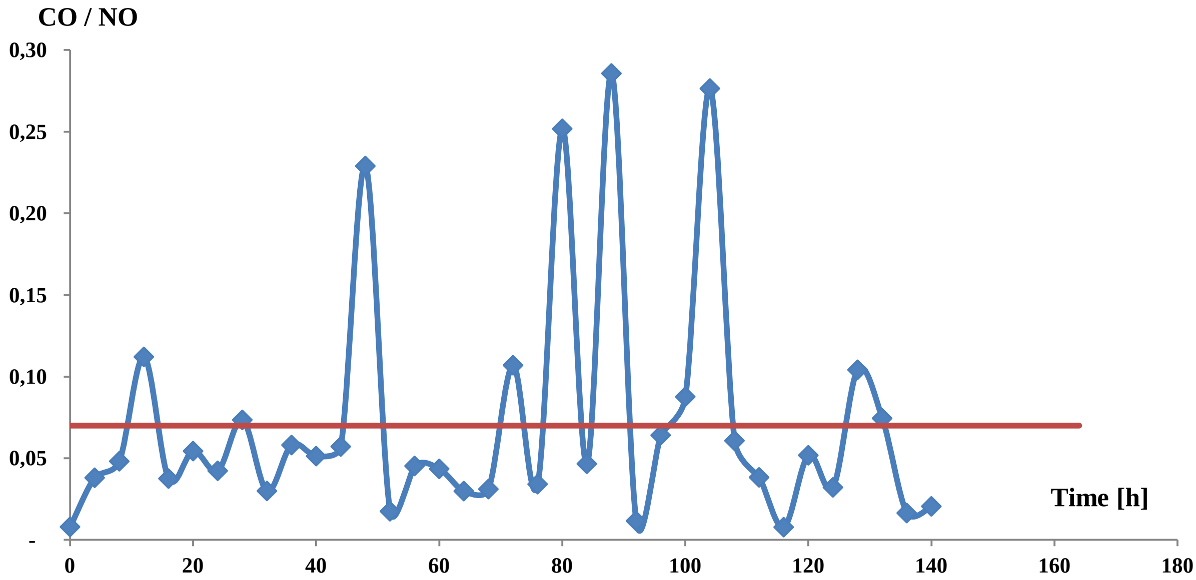

Figure 5. Cold start mode temporal NOx/CO ratio evolution.

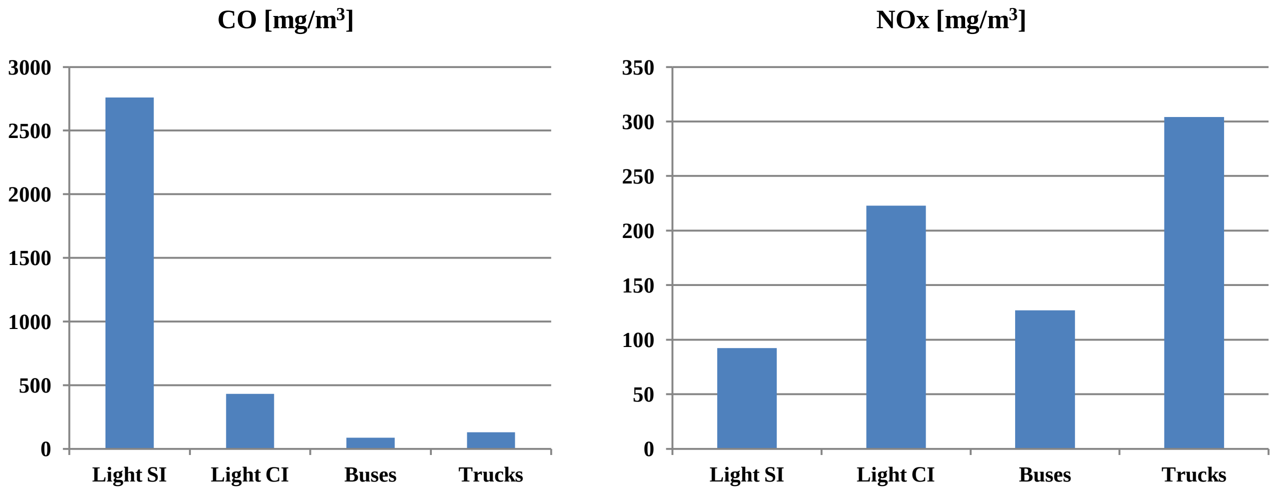

Figure 6. CO and NOx mean concentrations released by vehicle category.

Figure (7) illustrates ratios obtained by the CO and NOx released by each category, normalized respectively by those released by spark ignition and compression ignition vehicles. In order to calculate the total amounts of CO and NOx emitted vehicle counting campaign at the main roundabouts of the third ring road is carried out. Vehicle flows per hour by category and location are shown in Table (2). The columns Akid-Lotfi and Les Castors represent intersections located near the chosen ring road and in which traffic is regulated by lights.

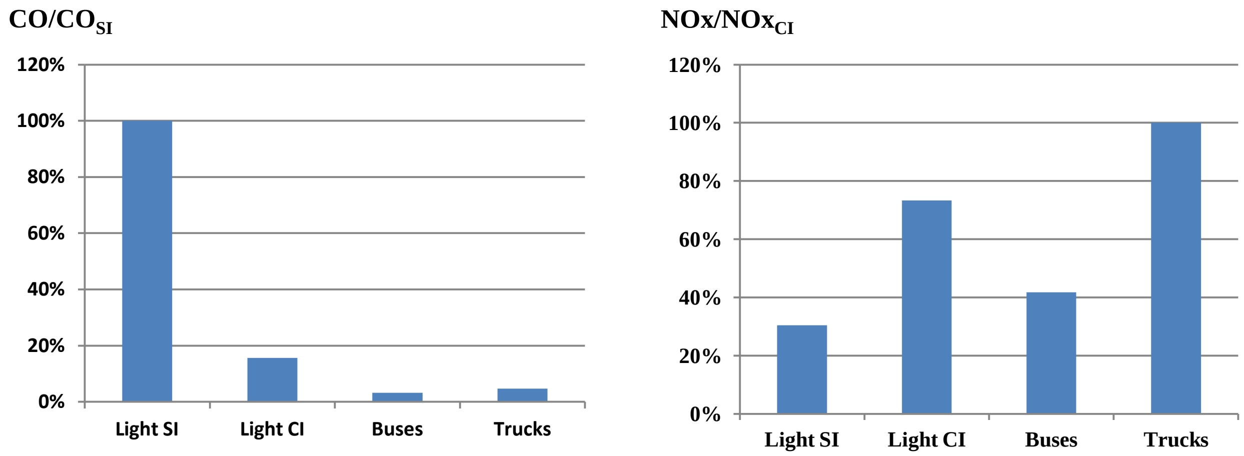

Figure 7. Normalized CO and NOx mean concentrations released by vehicle category.

Table 2 Vehicle rate per hour.

	Akid-Lotfi	Les Castors	Pépinière	El Bahia	El Morchid
LSI	7140	6120	*6150*	*7200*	*6030*
LCI	3780	2280	*2850*	*2160*	*2190*
Buses	138	162	*126*	*99*	*351*
Trucks	360	300	*1110*	*720*	*300*

Figure (8) represents one hour vehicle rate classified by category and by location (source DTWO).

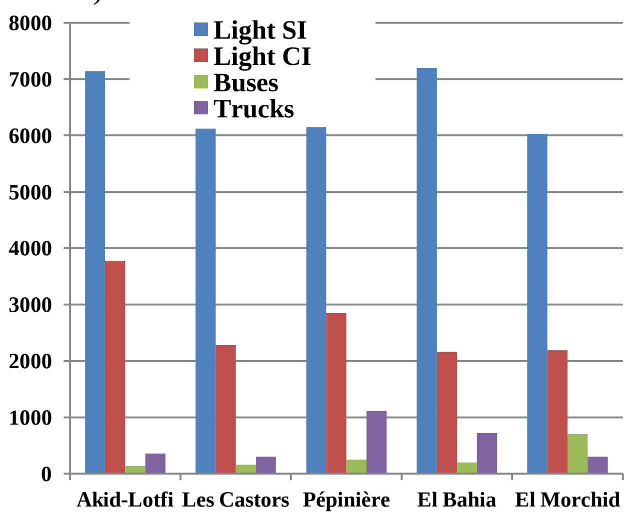

Figure 8. Vehicle rate per hour at each location.

It should be noted that the number of light commercial gasoline vehicles is very important compared to the other categories followed by diesel light commercial vehicles and then by trucks. Transport vehicles arrive in the last position. Akid-Lotfi intersection and roundabout El Bahia observe a large influx of gasoline vehicles. El Morchid roundabout records a large number of transport vehicles due to the presence of nearby bus station. Moreover, it is clear that the amount of CO released is the most important given the preponderance of the number of gasoline vehicles in the fleet. The histograms of Figures (9) and (10) illustrate the overall rates of CO and NOx released per minute by location. It should be noted that CO and NOx emitted at the source level are significantly high. Very high quantities of CO are recorded at El Bahia roundabout given the large flow of vehicles to and from the east.

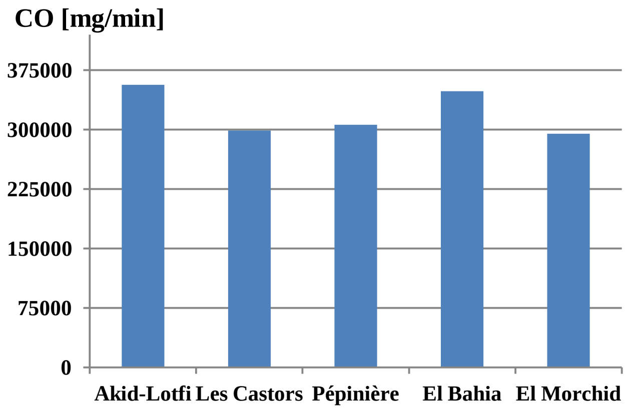

Figure 9. CO global rate by location.

Maximum amounts of CO and NOx released at Akid-Lotfi are recorded. Indeed, this site represents access to a region of extension of urban activities and development of mobility in the city of Oran.

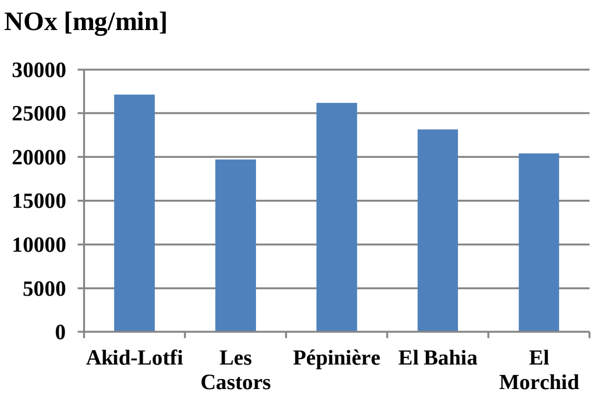

Figure 10. NO global rate by location.

A significant amount of NOx is recorded at Pépinière roundabout because of increased activity of trucks and transport with heavy traffic to the industrial area of Arzew.

3. CONCLUSION

The main purpose of this article is to fill a huge gap created by the lack of preliminary data on small scale pollution sources. In addition, the analysis presents a simple methodology capable of providing data that can be used in simulation works on the dispersion of pollutants emanating from engines in an urban environment topic. Knowing that heat engines emit a lot of harmful gases at very low speeds and during cold starts, the analysis focus on vehicle engines, congested in traffic, operating at idle speed and vehicle engines operating in cold start mode. The study focused on roundabouts and cross-roads with sensitive traffic lights at the third ring road in Oran. The measure was limited to two chemical species. Carbon monoxide and nitric oxide represent the main chemical species emitted respectively by gasoline engines and diesel engines. The measurements are carried out using a transportable probe and are carried out on three roundabouts without hopper and two very sensitive cros-roads during rush hour. Based on the results, it follows that:

1- The amount of CO released varies between 1000 and 5000 mg/m^3 with an average value equal to 2750 mg/m^3. The amount of NOx released varies between 50 and 200 mg/m^3 with a tendency to cluster around an average value equal to 125 mg/m^3. In addition to some singular values the ratio NOx/CO is globally lower than the average value recorded.

2- At idle speed, the hourly flow of gasoline light commercial vehicles is predominant compared to the other categories followed by diesel commercial vehicles, then by transport vehicles and finally by heavy duty vehicles. The intersection with Akid-Lotfi traffic lights and the roundabout El Bahia observe a very large flow of gasoline vehicles. El Morchid roundabout observe a large flow of transport vehicle due to the presence of nearby bus stations. Gasoline vehicles emit about 6 to 30 times CO than other categories. Heavy duty vehicles emit an amount of NOx three times equivalent that of gasoline vehicles. Thus, ratios of CO and NOx released levels released by each category normalized by the CO and NOx respectively by spark ignition and compression ignition vehicles are obtained. There is a huge disparity between the global CO and NOx flow rates measured at the source and those measured after dispersion. It would be interesting in perspective to determine a correlation between these two quantities. Very high amounts of CO are recorded at El Bahia roundabout given the large influx of vehicles arriving from or going to El Karma industrial zone and to the east. The maximum amounts of CO and NOx are recorded at the intersection with traffic lights at Akid-Lotfi, which is an extension of urban and commercial activities. A significant amount of NOx is noted at the Pépinière roundabout because of the passage of a large number of heavy duty and transport vehicles from or to the industrial area of Arzew.

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