Original research article

Evaluation of the impact of motorcycles in urban transport on air pollution: case of Douala city in Cameroon

ABSTRACT

Aims: The aim of this work is to evaluate the impact of motorcycle taxis on air pollution for the particular case of Douala city in Cameroon.
Study design: A sample of motorcycle taxis drivers and an exhaust gas analyzer were used to better understand this area of activity then to obtain the different amounts of pollutants emitted by these motorcycles in different traffic situations.
Place and Duration of Study: Douala urban community, National Advanced School of Public Works, and Energy, Water and Environment Laboratory of National Advanced School of Engineering (University of Yaounde I) between February 2017 and June 2018.
Methodology: We used the statistical data concerning the motorcycles in circulation in the transport sector between 2009 and 2013 in Cameroon, estimated at 233,799. Using these statistical data, the correlation of the evolution of motorcycles in circulation in the transport sector was established. Measured atmospheric pollutants, for motorcycles exhausts, were carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxide (NOx) and hydrocarbon (HC).
Results:
A survey of 500 motorcycle taxis, to better understand this area of activity, revealed that 58% of motorcycles used were acquired prior to release, 56% had less than 5 years old and 95% consume gasoline. The survey also revealed that 64% of motorcycles operating in urban transport had a tax power of between 6 and 7 HP. The different amounts of pollutants, emitted on a sample of 45 motorcycle taxis, followed that in slow traffic in urban areas (5 km/h), CO (depending on their aging condition) was emitted between 0.40 and 3.02 g/kg; the Euro 3 standard on motorcycle emissions recommends a limit of 1 g/kg. For HC and NOx, the maximum values recorded in the same traffic situation were 0.62 g/kg and 3.10×10^{-3} g/kg respectively; values were within the limits set by the same standard, namely 0.8 g/kg and 0.15 g/kg respectively. The statistics available between 2007 and 2011 revealed an almost linear evolution of the "motorcycle" phenomenon in urban centers in Cameroon, making it possible to estimate close to 647,000 motorcycles put into circulation between 2007 and 2018.
Conclusion: Traffic situation, aging of the motorcycles and nature of the fuel revealed their influence on the emissions of pollutants by motorcycle taxis. These results are a useful tool to monitor the air pollution levels caused by motorcycles in urban transport.

Keywords: Atmospheric pollution; motorcycle taxis; pollutant concentrations; polluting gas emission; urban transport

1. INTRODUCTION

Numerous studies have been conducted on air quality, with improvements in cities in developed countries in recent years [1]. In contrast, significant air quality deficiencies were observed in tropical countries [2]. However, the increase in the urban population coupled with the rural exodus in developing countries makes it interesting to accentuate studies related to air pollution in the cities of these countries [3]. Air quality may be better in developed countries than in large tropical cities [4]. Levels of air pollution in developing countries in Asia and Latin America are among the highest in the world [1].

This increase of air pollution in large urban centers of developing countries was attributed to the steady increase in urban traffic, and secondly to the increase in industrial and economic activities and the burning of biomass by the population. In these daily activities [2]. Transport is the main source of pollutant emissions because, in addition to the rapid growth in the number of vehicles and motorcycles, there is a large number of poorly maintained engines and poor quality fuel [5]. Other factors explain the significant emissions of pollutants by the transportation sector such as pavement maintenance, its condition (dry or wet) and traffic jams [6] (Begum et al., 2008). In Africa, for example, with the growth of cities, transport is growing rapidly, especially private transport, which is growing in order to make up for the inadequacy of public transport. These private transports hardly respect the rules of environmental protection, with the consequence of a rather localized impact on the quality of the air.

In Brazil, in 2004, the concentrations of airborne particles, due to vehicle emissions in tunnels, were higher than those measured in other cities of the world [7]. In addition, 75% of the NOx present in the air in Mexico City and Santiago, in 2006, were due to transport [8]. This significant air pollution had adverse effects on human health, the environment and biodiversity, as well as climate change ([9], [10]). Mortality from air pollution affects many people. Air quality in cities is an important issue that affects people's living conditions. Several studies have been conducted in tropical countries in relation with pollution. Work has been done to gain knowledge about the sources of air pollution in order to limit their effects on human health [11].
In addition, several studies have been made on global warming linked to air pollution on a global scale with important economic consequences ([12], [13], [14], [15]). Many researchers and international institutions have given particular attention to the issue of transport in the major cities of sub-Saharan Africa. The work that has been done shows the importance given to this problem. They have developed reflections on the forms of transport, including the integration of the popular sector into urban transport systems ([16], [17], [18]). Some studies focused on the various complementary or competitive modes that are adapted to the nature of the traffic and meet the users' requirements [19].

Accelerated urbanization on the periphery has become a kind of engine for the transport system, as the uncontrolled increase in distances in the city increases the need for motorized travel. In the current context of urban transport in Sub-Saharan African cities in general, and the cities of Cameroon in particular, dominated by accelerated urbanization and a significant lack of road infrastructure, motorcycle taxis generally provide access to any point of the town, because of their great flexibility, whereas public transport plays their full role only in a radius close to stopping points.

It is, however, difficult today to advance a figure on the number of motorcycle taxis operating in Cameroon. Between 2007 and 2011, 269,625 motorcycles were registered in Cameroon and put into circulation [20]. Estimates ranged from 40,000 to 50,000 motorcycle taxis, according to the official figure, in Douala city of Cameroon [21]. Research has amply demonstrated the problem of urban air quality, linked, inter alia, to transport. However, studies have not been carried out to our knowledge on the quantification of pollutants of motorcycle origin in the cities of Sub-Saharan Africa. Our work focused on the contribution to the quantification of pollutants of motorcycles on air pollution for the case of Douala city.

2. MATERIAL AND METHODS

2.1 Material

The equipment used in this work consists of a Tronic Test G750/A type exhaust gas analyzer. It measures carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbon residue (HC), oxygen (O_2) and nitrogen oxides (NOx) present in the exhaust gases and deduce the factor λ which characterizes the quality of carburation. The response time is 6 s with automatic reset. Figure 1 shows the device used for the measurements of the various characteristic quantities of the exhaust gases from motorcycles in Douala city.

Fig. 1. Device used for measurement of exhaust gases from motorcycles

2.2 Method

The five most important exhaust components, namely carbon monoxide, carbon dioxide, hydrocarbons, oxygen and nitrogen oxides, are found in the emissions of each gasoline engine. The relationship of these gases to each other is largely dictated by the state of the engine and the quality of the combustion, which itself depends on the preparation of the mixture, the ignition, the mechanical condition of the engine and its condition instant work. In order to get closer to the real conditions of driving motorcycles in Cameroon, the motorcycles sample chosen for this study was subject to very specific criteria.

2.2.1 Sample of Motorcycles

Three parameters were taken into account, in our work, for the choice of the representative sample to be analyzed:

- the type of fuel used;
- the distance traveled since the first use (mileage);
- the number of years of use of the motorcycle.

2.2.2 Experimental protocol

Once the motorcycle started, we waited about 15 minutes to allow the engine to reach its equilibrium regime (minimum oil temperature 60 °C). The tip of the measurement probe was then inserted at least 30 cm into the end of the exhaust pipe in accordance with the instructions in the exhaust gas analyzer's operating instructions. We then proceeded to select the type of fuel that results in the lighting of a red light at the fuel selection on the analyzer's operating interface.

Our experiments on the measurement of gaseous pollutants have taken into account the conditions of circulation of the motorcycles by varying the speed from 0 km/h in a plugged state or congestion (figure 2) to 70 km/h in traffic on the urban motorway.

Fig. 2. Congestion phenomenon at the Ndokoti tunnel – Douala city

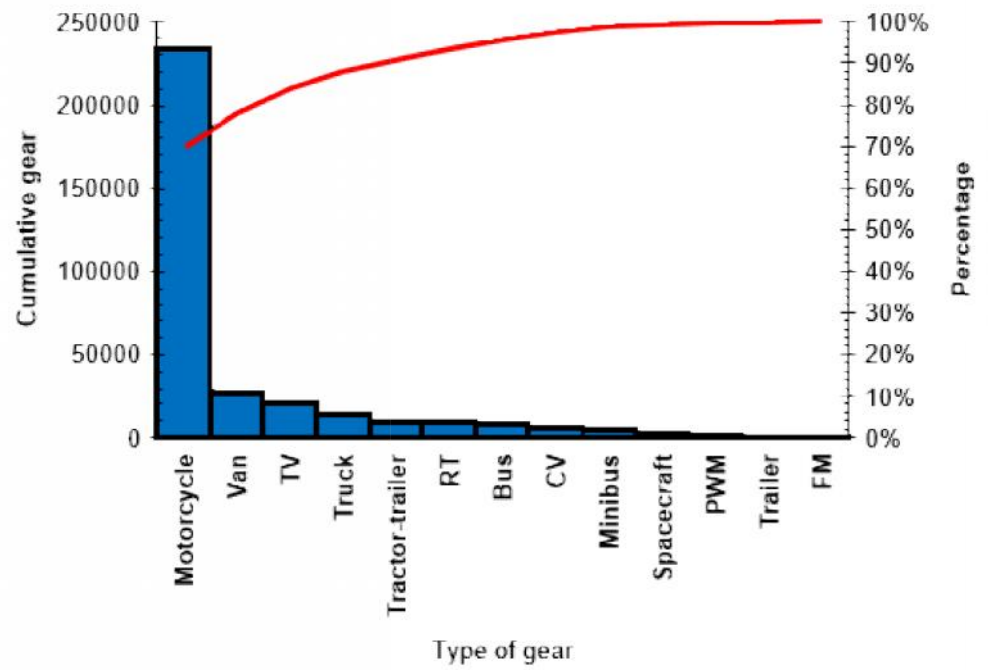
2.2.3 Quantification of pollutants

The quantities of gaseous pollutants were measured according to the experimental protocol described previously. Values of carbon monoxide, hydrocarbons, nitrogen oxides and carbon dioxide were provided by the exhaust gas analyzer in PPM (parts per million) and g/kg. The final value selected was an average value obtained after 3 tests, lasting 60 s each, for each motorcycle of the sample selected, each displacement speed and each type of gas where measured.

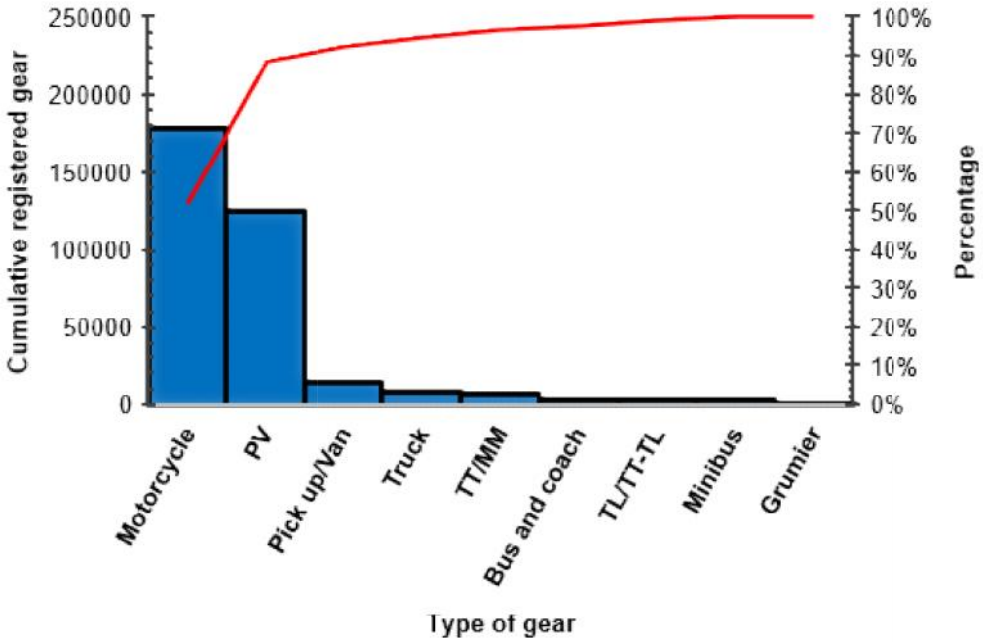
2.2.4 Data source

The concentration of the gaseous pollutants studied in this work was estimated using the data obtained with the "Tronic Test G750/A" exhaust gas analyzer. In total, 500 motorcycle taxis operators accepted an interview about their trade. But only 45 of them, precisely 40 motorcycles using gasoline and 5 using adulterated fuel, had agreed to use their engines for the experimental support of this work; the condition imposed was compensation for loss of earnings of up to FCFA 3,000 per motorcycle engaged in the operation.

Figure 3a shows the distribution of the total number of vehicles in circulation in the transport sector in Cameroon between 2009 and 2013 with 70 % representing motorcycles [20]. According to the same source, Figure 3b illustrates the distribution of the cumulative number of gears registered in the transport sector in Cameroon between 2007 and 2011 with 52 % for motorcycles. It should be noted that many motorcycles went into hiding and went into service without registration. This shows to a sufficient extent the importance of the phenomenon "motorcycles" in the transport sector in this country thus justifying the interest to bear on its impact related to air pollution.



(a) Distribution of cumulative number of gear in circulation in Cameroon between 2009 and 2013



(b) Distribution of cumulative registered gear in circulation in Cameroon between 2007 and 2011

Fig. 3. Distribution of gear in the transport sector in Cameroon

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Evolution of motorcycles in circulation in Cameroon

According to data from the National Institute of Statistics [20], Figure 4 illustrates the evolution of motorcycles, registered between 2007 and 2011, circulating in the transport sector in Cameroon. The same figure shows that these data can be estimated from a linear model with a correlation coefficient R^2 = 0.96. Assuming that this curve keeps the same trend until 2018 and beyond, we can use this model to estimate the evolution of motorcycles in circulation over years. This hypothesis was justified by the fact that no political initiative was undertaken to fundamentally address the problems of public traffic in cities and the state of urban roads. With this model we estimated about 646,600 motorcycles put in circulation in Cameroon between the period of 2007 to 2018. However, the extent of the phenomenon "motorcycle" like "motorcycle taxi" in the urban centers of Cameroon dates from 1990 because of the popular demonstration where taxis were not allowed to circulate on working days, the economic crisis had led to the dumping of many workers in the street seeking conversion to another easily accessible activity and finally the collapse of the urban transport in common company. That is to say the number of motorcycles in circulation in Cameroon is so far well above the estimation made between the period of 2007 to 2018.

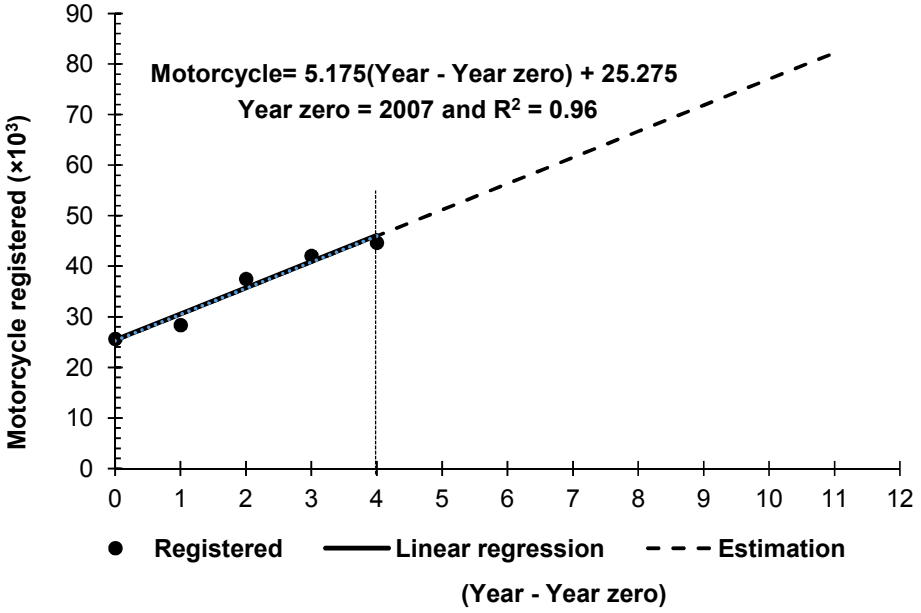


Fig. 4. Evolution of motorcycles in circulation in the transport sector in Cameroon

3.1.2 Characteristics of motorcycles in circulation in Douala

Our work focused on a sample of 500 motorcycles. Figure 5 presents some of the most relevant results obtained from the drivers of the motorcycle taxis interviewed. We observe in Figure 5a that the acquisition of motorcycles leaving the factory dominated by 8% on used motorcycles. This trend is largely due to imports of motorcycles of Chinese origin at very affordable costs. It is in the same vein that motorcycles in operation, less than 5 years ago, remained the majority (Figure 5b). Figure 5c shows that 95% of motorcycles in circulation consumed gasoline and 5% use a fuel known as "adulterated" fuel (a mixture of super fuel with kerosene to reduce cost) officially banned by the Cameroonian legislation. Regarding the tax power of these motorcycles, illustrated in Figure 5d, it was spread over a very varied range with a predominance between 6 and 7 HP. The age of the motorcycles, their states and the nature of the fuel used necessarily had an influence on their effect of pollution of the ambient air. In addition, surveys conducted on this sample of 500 motorcycles taxis drivers revealed that each driver travelled an average of 50 km per day.

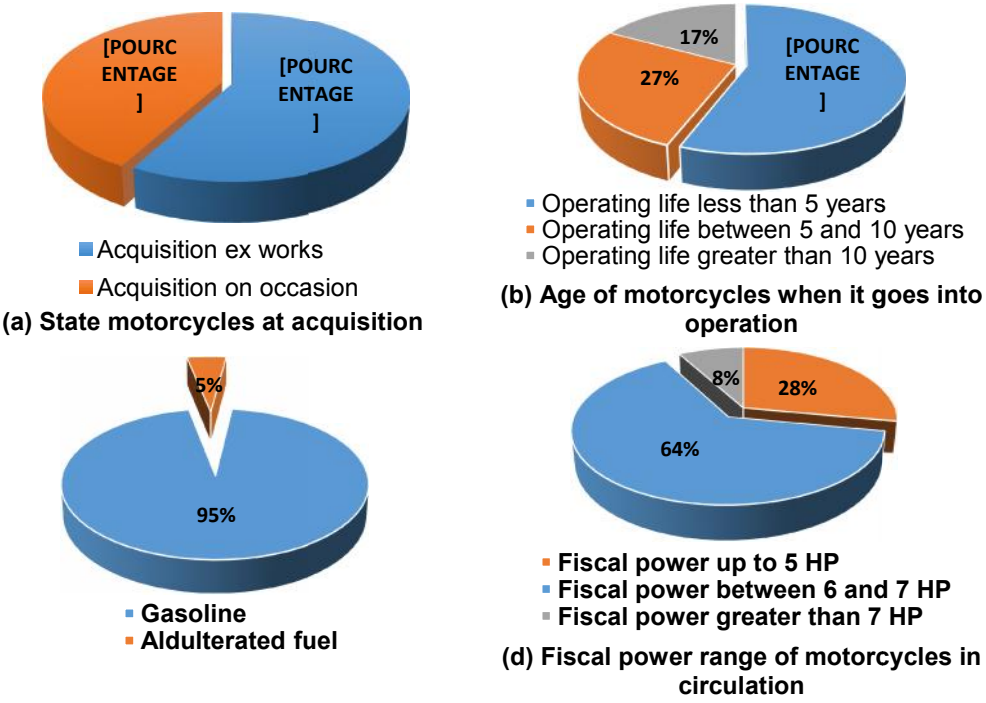
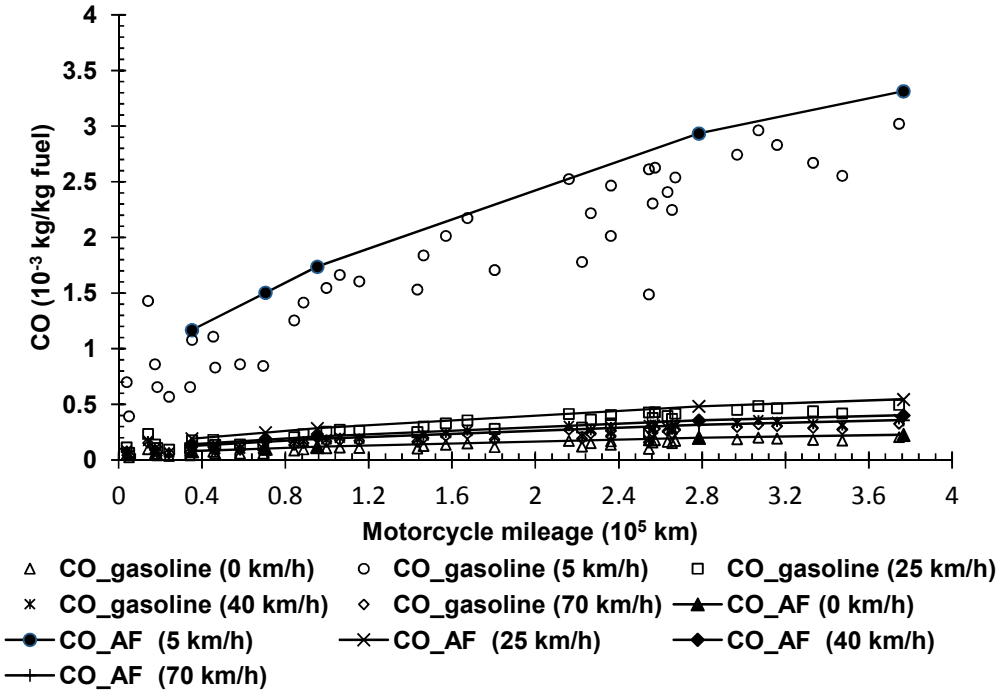


Fig. 5. Some characteristics of motorcycles in circulation in Douala city

3.1.3 Pollutant measurements related to motorcycles in circulation in Douala

The different experimental values of carbon monoxide (CO), hydrocarbon (HC), oxides of nitrogen (NOx) and carbon dioxide (CO_2) were obtained at speeds of 0 km/h, 5 km/h, 25 km/h, 40 km/h and 70 km/h on a sample of 45 motorcycles taxis. Figures 6 to 9 respectively show the emissions, in the atmospheric air, of CO, HC, NOx and CO_2 depending on the mileage. The mileage (distance already travelled by the motorcycle) reflects the aging of the motorcycle and consequently the decline in engine efficiency. These results also took into account the influence of the fuel type.



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198 **Fig. 6. Influence of the circulation rate on the emission of carbon monoxide**
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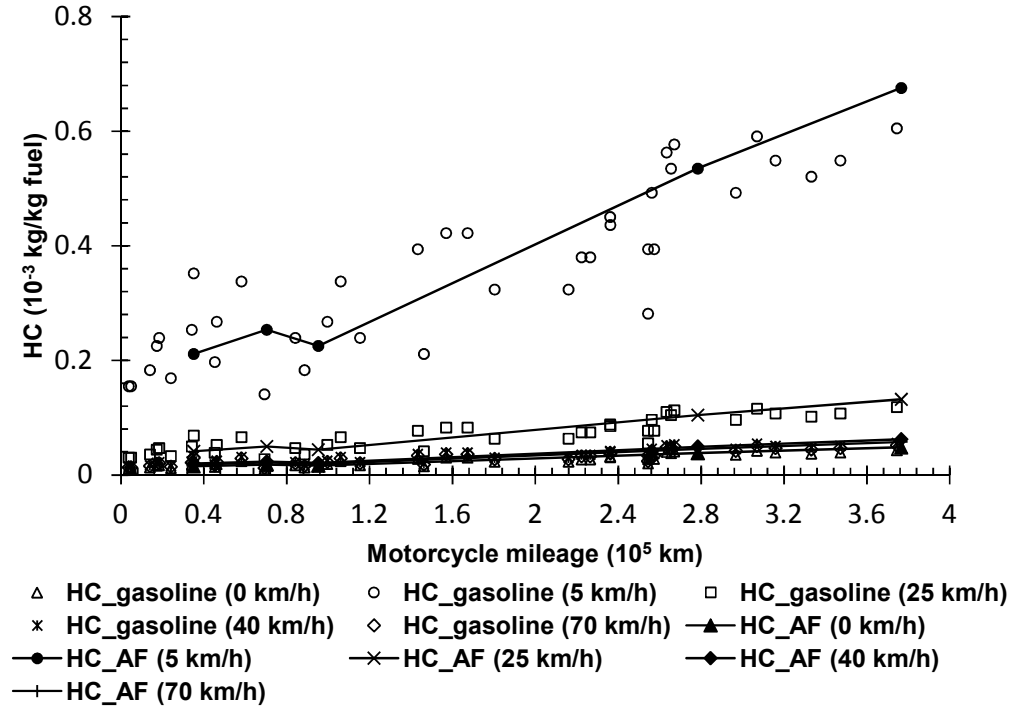

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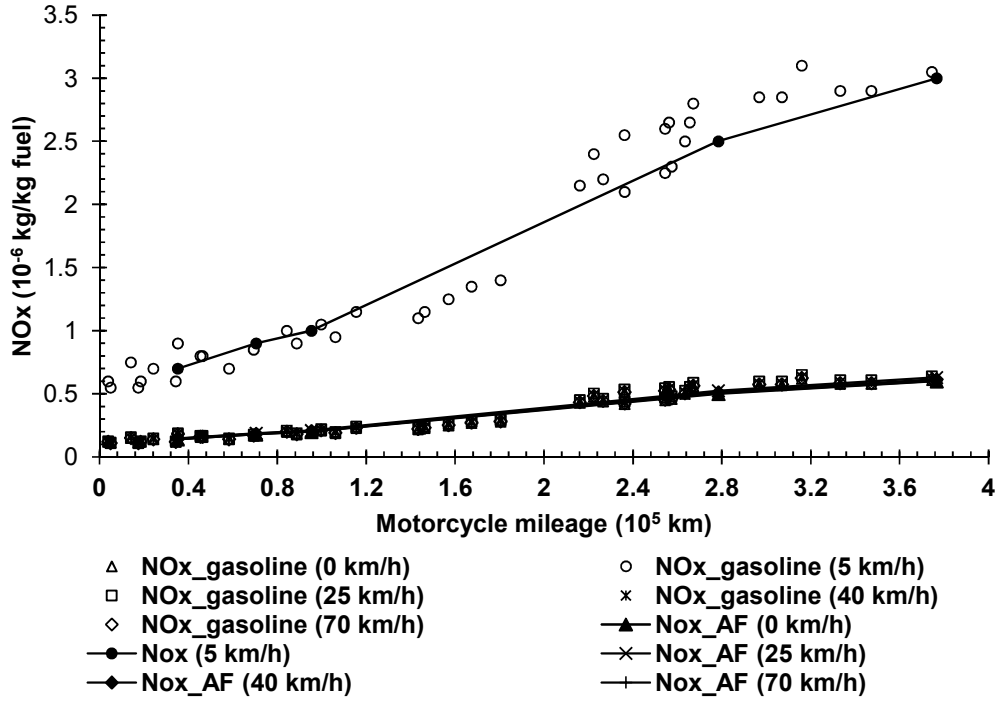
203 **Fig. 7. Influence of the circulation rate on the hydrocarbon emission**



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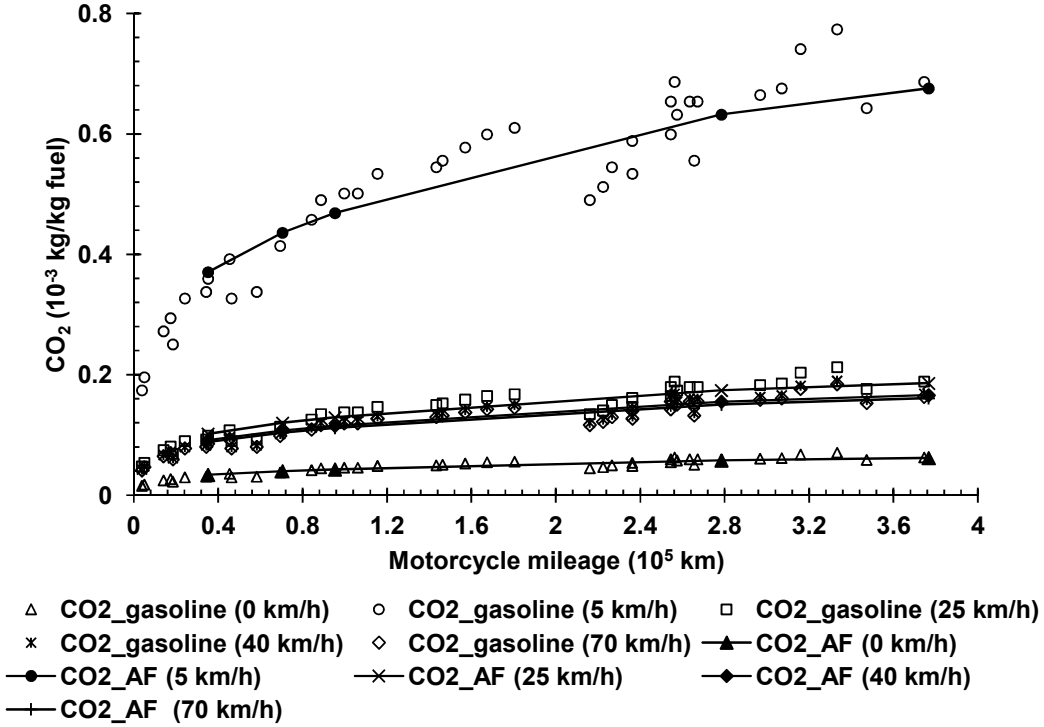
206 **Figure 8: Influence of the circulation rate on the emission of nitrogen oxides**



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209 **Figure 9: Influence of the circulation rate on the emission of carbon dioxide**
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211 **3.2 Discussion**
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213 **3.2.1 Influence of the speed of circulation on the emission of gaseous pollutants**
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Figures 5 to 8 show that the emissions of gaseous pollutants by the motorcycles, in the same state of aging, depend on the speed of circulation. We noted particularly high emissions at the traffic speed of 5 km/h, reflecting the situation of recurrent congestion in metropolitan areas in Sub-Saharan Africa in general and in Douala city in particular. This can be explained by a solicitation of the motorcycle motor at its highest speed (speed first). Differences in pollutant emissions remained relatively moderate at normal circulation rates for carbon monoxide, hydrocarbon and carbon dioxide. On the other hand, emissions of nitrogen oxides varied little at these speeds. In addition, this polluting gas has the lowest emission rates of the four gases measured. Finally, we note that the lowest emissions are recorded at zero speed; which was predictable from the moment the motorcycle motor runs at its lowest speed with low fuel consumption. In the regime under congestion conditions (5 km/h), the maximum carbon monoxide emission was 3.02 g/kg approximately 3 times the limit value (1 g/kg) recommended by the Euro 3 standard for emissions from motorcycles [22]. This result illustrates the discomfort experienced by the countries of Sub-Saharan Africa, particularly with regard to the standards for importing transport equipment. The majority of these machines were from second hand, sometimes dating back more than 20 years. The maximum hydrocarbon emission, in the same regime, was 0.62 g/kg, which was less than the limit value (0.8 g/kg) recommended by the same standard. For nitrogen oxides, the maximum emission in this regime is 3.10×10^{-3} g/kg less than 0.15 g/kg recommended by the Euro 3 emission standard for motorcycles.

3.2.2 Influence of mileage on the emission of gaseous pollutants

Figures 5 to 8 show that the emissions of gaseous pollutants by motorcycles increased with the mileage index, reflecting their state of aging. These results were predictable as engine efficiency decreases with operational year and maintenance quality. In Cameroon, preventive maintenance is not in the habits of the users of transport vehicles in general and in particular the sector of motorcycles which escapes completely to a relevant regulation of the administration. The maintenance is essentially curative. To this must be added the poor state of the road infrastructure which contributed significantly to the wear of these machines.

3.2.3 Influence of the nature of fuel on the emission of gaseous pollutants

Motorcycles operating in the public transport sector in Douala consumed mainly gasoline. A small fraction (5%) however uses an adulterated fuel. Figure 5 shows that in a congestion situation (5 km/h), the carbon monoxide emissions of motorcycles consuming adulterated fuel were greater than those of motorcycles consuming gasoline. The precise composition of this fuel is not known to allow interpretation. For hydrocarbon emissions, nitrogen oxides and carbon dioxide, values fluctuated around the same averages for both types of fuel.

4. CONCLUSION

Given the inadequacy of public transport and poor road conditions, public transport by motorcycle both inside and around the major metropolitan areas of Sub-Saharan Africa in general was an alternative must. The occupation of space by motorcycle taxis in the immediate environment of users in Douala city - Cameroon, should be analyzed in terms of utility and ease of travel. Our work has measured the rate of gaseous emissions, including carbon monoxide, hydrocarbon, nitrogen oxides and carbon dioxide, from the activities of motorcycles taxis in this city. The evaluations of these polluting gases have been made experimentally by placing themselves in the various traffic situations for motorcycles. It follows that the traffic constraints (congestion situation in particular), the aging (mileage) and the nature of the fuel are the main pollution factors. We suggest that, to preserve air quality, one must rethink and better organize urban transportation by acting on all the factors of the system: traffic, condition of vehicles, road conditions, fuel quality. Well thought out legislation should be considered for effective management with the dual aim of satisfying urban mobility while reducing the pollution rate associated with this mobility.

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ABBREVIATIONS

AF: Adulterated Fuel
CV: Commercial vehicle
FM: Public work machinery
PV: Particular vehicle
PWM: Public work machinery
RT: Road tractor
TL/TT-TL: Trailer/Tractor-trailer
TT/MM: Tractors/Mechanical machinery
TV: Tourism vehicle