ASSESSMENT OF CARBON MONOXIDE (CO) EMITTED BY EXHAUST GASES FROM MOTOR VEHICLES IN THE CENTER REGION OF CAMEROON

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ABSTRACT

This work evaluates the contribution of motor vehicles in the emission of carbon monoide (CO) in Cameroon and particularly in the central region. To achieve this, a sample is first defined (20800 vehicles classified between the categories of passenger cars and light commercial vehicles using petrol and diesel respectively), afterwards data collection is done. Then, a mathematical model is developed, which made it possible to estimate the quantity of CO emitted by the vehicles categories (PETROL VT, DIESEL VT, PETROL LCV, DIESEL LCV) according to EURO anti-pollution standards (1,2,3,4,5a,5b,6b,6c). The passenger and light commercial vehicles belonging to the EURO 1 antipollution standard are the most polluting in the central region. Their emission limit values per kilometer are respectively 3011 and 3043 mg/km. The diesel passenger vehicles of to the EURO 6c anti-pollution standard are the least polluting in CO, its limit value per kilometer is 503 mg/km. The progression slope of CO emitted by different vehicles is greater than 1.2. A Part of CO emitted in the central region of Cameroon comes from the displacement of motors vehicles. The CO amount near to the reference limits per kilometer is that of vehicles belong to the antipollution standard 5a, 5b, 6b and 6c. The public authorities are invited to prohibit the importation of motor vehicles manufactured before 2011.

Keywords: Estimation of the quantity of CO, Emission of CO, category of vehicle, reference limits per kilometer, prohibition of importation.

1- INTRODUCTION

During the last decades, the fight against environmental pollution has become a major challenge for most countries across the globe. Several summits (cops 21, 22, 23, 24, 24,25, 26) bringing heads of state have been organized in order to adopt appropriate strategies to fight against environmental pollution. various reasons can explained this environmental situations in particular the 21st century enthropogenics activities which have contributed to pollution and global warming with an increasing temperature 1880 to 2012 and from 1951 to 2015. theses increasing temperature are respectively 0.85°C and 0.73°C (Valérie Masson-Delmotte, 2013). and the world will face to many unavoidable climate hazards over the next two decades with global warming of 1.5°C (2.7°F). (GIEC, 2022). The main anthropogenic sectors responsible of pollutant emissions are transport (road and non-road), residential/tertiary, industry, energy (electricity production, district heating, etc.), wastes treatment (storage and incineration) and agriculture. Several works have shown that road traffic is the main source of pollution in urban areas, particularly with the emissions of pollutants such as carbon monoxide (Pétros, Z., 1997; Mahamadou M. Z. et al, 2020), the particles and NO_X but also unregulated pollutants such as soot carbon (BC), BTE_X (benzene, toluene, ethylbenzene, and xylenes), alkanes and carbonyl compounds (formaldehyde, acetaldehyde, hexanal, etc.). which have harmful effects on human health and the environment (Sydbom et al., 2001; Lewtas et al., 2007), and which can be secondary precursors of particles. Some authors have rated the quantity of chemical pollutants in transport (Mama et al. 2013 and Karima BOUSSOUARA, 2010); others have proven that certain atmospheric pollutants have heavy impacts on crops and ecosystems, including a weakening of organisms and a sharp slowdown in the growth of agricultural crops during a period of prolonged exposure to ozone (ATMO ARA, 2019; Anne-Flore COSSERON, 2012). Patrick Bultynck et al. (2003) hawe studied the air quality in some cities of African countries such as Cameroon, Senegal, Ivory Coast etc. to demonstrate the contribution of transport in environmental pollution. In order to limiting polluting emissions from road traffic the European Union (EU) has imposed emission limits for regulated pollutants [particles by mass and number . (PM and PN), nitrogen oxides (NO_X), carbon monoxide (CO), hydrocarbons (HC)] called EURO anti-pollution standards and which are increasingly strict with each implementation of a new standard (Simon MARTINET, 2020). The emission of these pollutants can be determined through several methods, in particular approaches based on vehicle testing on a test bench (Edwin ZAM, 2012 and Isabelle CAPLAIN, 2005), on measurement equipment on board a vehicle. vehicle (Isabelle CAPLAIN, 2005), measurement techniques following another vehicle (Institut Carnot, 2020) and in-situ measurements of pollutant concentration in a road tunnel at the side of the road as demonstrated by MARTINET in 2020 in his work entitled "In-situ estimation of the emission factors of road traffic pollutants". In view of the above, it is important to emphasize that the increased use of motor vehicles in transport and more particularly in the central region of Cameroon contributes to the degradation of the environment through its polluting emissions.

To this end, it is important for developing countries and Cameroon in particular to set up cheapers strategies to estimate the quantity of the emissions exhaust gas pollutants. It is in this perspective that we deemed it appropriate to contribute to the evaluation of this pollutant by estimating the quantities of CO emitted by vehicles in the center region – Cameroon. It is in this perspective that we deemed it appropriate to contribute to the evaluation of this pollutant by estimating the quantities of CO emitted by vehicles in the center region - Cameroon. by developing a mathematical equation and grouping the vehicles by category and according to EURO anti pollurtion standards (1,2,3,4,5a,5b,6b,6c).

The central region is one of the most developed regions of Cameroon which has such a dense vehicle fleet.

2- MATERIALS AND METHODS

2-1-VEHICLE FLEET OF THE CENTER REGION PRESENTATION

The vehicle fleet of the Center region – Cameroon studied consists of private vehicles (also called passenger vehicles) and light commercial vehicles (vans, minibuses, etc.). These vehicles are classified according to the EURO anti pollurtion standards (1,2,3,4,5a,5b,6b,6c). (Table 1).

Table 1: Emission standard for passenger/passenger motor vehicles and light commercial vehicles. [16]

Standard	Commissioning of vehicles	Approval of new types
EURO 1	1st january 1993	1er july 1992
EURO 2 (cars)	1st january 1997	1st january 1996
EURO 2 (light commercial vehicles)	1st october 1997	No approval
EURO 3	1st january 2001	1st january 2000
EURO 4	1st january 2006	1st january 2005
EURO 5a	1st january 2011	1st september 2009
EURO 5b	1st january 2013	1st september 2011
EURO 6b	1st january 2015	1st september 2014
EURO 6c	1st january 2018	1st september 2017
EURO 6d – Temp	1st january 2019	1st september 2017
EURO 6d	1st january 2021	1st january 2020

The classification according to the EURO anti-pollution standards is opted in relation to the parameters of first entry into service of these vehicles. In these different standards the reference emission thresholds are imposed.

2-2- FLEET VEHICLE DATA COLLECTION

Data on the vehicle fleet in the Center region – Cameroon are provided by the Ministry of Transport. A sample of 20800 vehicles divided into 10400 private vehicles (i.e. 5200 using petrol and 5200 using diesel) and 10400 light commercial vehicles, including 5200 in petrol and 5200 using diesel as an energy source.

2-3- COLLECTION OF DATA ON DISTANCES TRAVELED BY MOTOR VEHICLE

The annual distances traveled by the vehicles in Table 2 are obtained from the vehicle technical inspection centers in the Center region – Cameroon.

Table 2: Distances traveled by the different categories of vehicles according to the EURO anti-pollution standards.

EURO	Annual distance traveled in kilometers of PETROL VTs	Annual distance traveled in kilometers of DIESEL VTs	Annual distance traveled in kilometers of PETROL LCVs	Annual distance traveled in kilometers of DIESEL LCVs
1	$3,0545.10^{8}$	$7,87.\ 10^{4}$	$3,75.\ 10^{4}$	$3,73.\ 10^{4}$
2	$1,6083.\ 10^{8}$	$3,35.\ 10^{4}$	$2,27.\ 10^{4}$	$3,49.\ 10^{4}$
3	$9,6161.\ 10^{7}$	$8,66.\ 10^{3}$	$1,88.\ 10^{4}$	$4,08.\ 10^{4}$
4	$2,5816.\ 10^{8}$	$1,41.\ 10^{4}$	$3,00.\ 10^{4}$	$5,69.\ 10^{4}$
5a	$1,8057.\ 10^{9}$	$1,20.\ 10^{4}$	$3,81.\ 10^{4}$	$1,45.\ 10^{5}$
5b	$2,7288.\ 10^{11}$	$1,03.\ 10^{5}$	$3,31.\ 10^{4}$	$1,90.\ 10^{5}$
6b	$2,9780.\ 10^{9}$	$1,44.\ 10^{5}$	$5,09.\ 10^{4}$	$1,53.\ 10^{5}$
6c	$9,4370.\ 10^{8}$	$9,4370.\ 10^{8}$	$2,00.\ 10^{4}$	$2,00.\ 10^{4}$

These distances are classified according to the vehicle category according to the EURO anti-pollution standards (1,2,3,4,5a,5b,6b,6c).

2-4- CO ESTIMATION

The method consists in first making a statistical arrangement of the vehicles of vehicle fleet by category of vehicles, age, and anti-pollution standard using the Excel spreadsheet. Then, these data are calculated using a mathematical model dependind on the emission factors contained in table 3.

Table 3: Exhaust emission factors for passenger cars and light commercial vehicles ($EF_{(i,j,k)}$) (Valérie Masson-Delmotte, 2013)

Type	Technology	CO(g/km)	
Units		VT	LCV
Petrol	Euro 1	3.41	8.82
	Euro 2	1.67	5.89
	Euro 3	1.50	5.05
	Euro 4	0.53	2.01
	Euro 5	0.53	1.30
	Euro 6 a/b/c	0.53	1.30
	Euro 6 d – temp	0.53	1.30
	Euro 6 d	0.53	1.30
Diesel	Euro 1	0.414	0.577
	Euro 2	0.296	0.577
	Euro 3	0.089	0.473
	Euro 4	0.092	0.375
	Euro 5	0.040	0.075
	Euro 6 a/b/c	0.049	0.075
	Euro 6 d – temp	0.049	0.075
	Euro 6 d	0.049	0.075

The quantity of CO emitted through the exhaust gas is deduced by the model (a) below (a) below:

$$\boldsymbol{E_{i,j}} = \sum_{k=1}^{kn}(\boldsymbol{N_{j,k}}.\boldsymbol{M_{j,k}}\,.\boldsymbol{EF_{i,j,k}}) \quad \text{(a)}$$

With:
E(i,j) = Emission of pollutant i [(in milligrams)] of vehicle category j ;
j= “Vp: passenger car / VT: passenger vehicles, LCV: light commercial vehicles and PV: heavy vehicles”;
i =CO;
N(j,k) = Number of vehicles in the regional fleet of category j and emission anti-pollution standard k
k=EURO (1, 2, 3, 4, 5a, 5b, 6b, 6c);
M(j,k) = Total annual distance (in km) traveled by all vehicles of category j and emission anti-pollution standard k;
EF(i,j,k)= Specific emission factors (in g/vehicle) at the pollution control standard of pollutant i for vehicle category j and pollution control standard k.

3- RESULTS AND DISCUSSIONS

3-1- DISTANCES TRAVELED BY MOTOR VEHICLES

Table 2 presents the annual distances traveled by PETROL VT, DIESEL VT, PETROL LCV and DIESEL LCV vehicles according to the Euro anti-pollution standard and their ages. It emerges from the analysis of the said table that, PETROL VT vehicles of the EURO anti pollution standard 5b have done more annual distances (2.7288. 1011 km) compared to other vehicles of other standards. The vehicles in the VT DIESEL category of the EURO 3 standard covered less annual distance (8.66. 103 km). One observation emerges, vehicles in the VT PETROL category have done more distance, i.e. 29,428,001,000 km compared to the other categories (DIESEL VT, PETROL LCV and DIESEL LCV).

3.2. CO ESTIMATION

The tables 4, 5, 6 and 7 present the quantity of carbon monoxide CO emitted per kilometer by vehicles categorie (VT PETROL, VT DIESEL, LCV PETROL, and LCV DIESEL) and according to EURO antipollution standards (1, 2 , 3, 4, 5a, 5b, 6b and 6c).

Table 4: Quantity of CO emitted by PETROL VTs

EURO	Number of PETROL VTs	Annual distance traveled in kilometers	Emission factor	Emission limit per km (mg/km)	Reference limit emission (mg/km)	Emission obtained with the formula in grams
1	650	$3,0545.10^{8}$	3.41	3011	2700	$9,1971 .10^{7}$
2		$1,6083. 10^{8}$	1.67	2403	2200	$3,8647 .10^{7}$
3		$9,6161. 10^{7}$	1.50	2397	2200	$2,3050 .10^{7}$
4		$2,5816. 10^{8}$	0.53	1206	1000	$3,1134 .10^{7}$
5a		$1,8057. 10^{9}$	0.53	1101	1000	$1,9881. 10^{7}$
5b		$2,7288. 10^{11}$	0.53	1187	1000	$1,1717. 10^{10}$
6b		$2,9780. 10^{9}$	0.53	1156	1000	$3,4425. 10^{8}$
6c		$9,4370. 10^{8}$	0.53	1099	1000	$1,0356. 10^{8}$

Table 5: Quantity of CO emitted by DIESEL VTs

EURO	Number of DIESEL VTs	Annual distance traveled in kilometers	Emission factor	Emission limit per km (mg/km)	Reference limit emission (mg/km)	Emission obtained with the formula in grams
1	650	$7,87. 10^{4}$	0,414	2975	2720	$2,34211. 10^{11}$
2		$3,35. 10^{4}$	0,296	1201	1000	40283476300
3		$8,66. 10^{3}$	0,089	708	640	6123995597
4		$1,41. 10^{4}$	0,092	583	500	8214614746
5a		$1,20. 10^{4}$	0,04	550	500	6585341548
5b		$1,03. 10^{5}$	0,04	547	500	56571433848
6b		$1,44. 10^{5}$	0,049	509	500	73096322013
6c		$9,4370. 10^{8}$	0.53	503	500	237649,2754

Table 6: Quantity of CO emitted by PETROL LCVs

EURO	Number of PETROL LCVs	Annual distance traveled in kilometers	Emission factor	Emission limit per km (mg/km)	Reference limit emission (mg/km)	Emission obtained with the formula in grams
1	650	$3{,}75.\ 10^4$	8,82	3043	2720	$1{,}14217.\ 10^{11}$
2		$2{,}27.\ 10^4$	5,89	1101	1000	25022767821
3		$1{,}88.\ 10^4$	5,05	710	640	13373706221
4		$3{,}00.\ 10^4$	2,01	578	500	17301689013
5a		$3{,}81.\ 10^4$	1,3	543	500	20805761114
5b		$3{,}31.\ 10^4$	1,3	546	500	18200000000
6b		$5{,}09.\ 10^4$	1,3	511	500	26182306838
6c		$2{,}00.\ 10^4$	1,3	506	500	10155104111

Table 7: Quantity of CO emitted by DIESEL LCVs

EURO	Number of DIESEL LCVs	Annual distance traveled in kilometers	Emission factor	Emission limit per km (mg/km)	Reference limit emission (mg/km)	Emission obtained with the formula in grams
1	650	$3{,}73.\ 10^4$	0,577	2803	2720	$1{,}05921.\ 10^{11}$
2		$3{,}49.\ 10^4$	0,577	1011	1000	35786112884
3		$4{,}08.\ 10^4$	0,473	653	640	27331671973
4		$5{,}69.\ 10^4$	0,375	567	500	32740886509
5a		$1{,}45.\ 10^5$	0,075	534	500	7882815307
5b		$1{,}90.\ 10^5$	0,075	521	500	10057786158
6b		$1{,}53.\ 10^5$	0,075	511	500	7915113357
6c		$2{,}00.\ 10^4$	1,3	505	500	10135034736

The values of CO emitted per kilometer for VT PETROL, VT DIESEL, LCV PETROL, and LCV DIESEL for 650 vehicles are respectively 3011; 2975; 3043; 2803mg/km. The Figures 1, 2, 3, and 4 present the CO estimation curves for 5200 vehicles according to the EURO anti-pollution standards belonging to each category of vehicle.

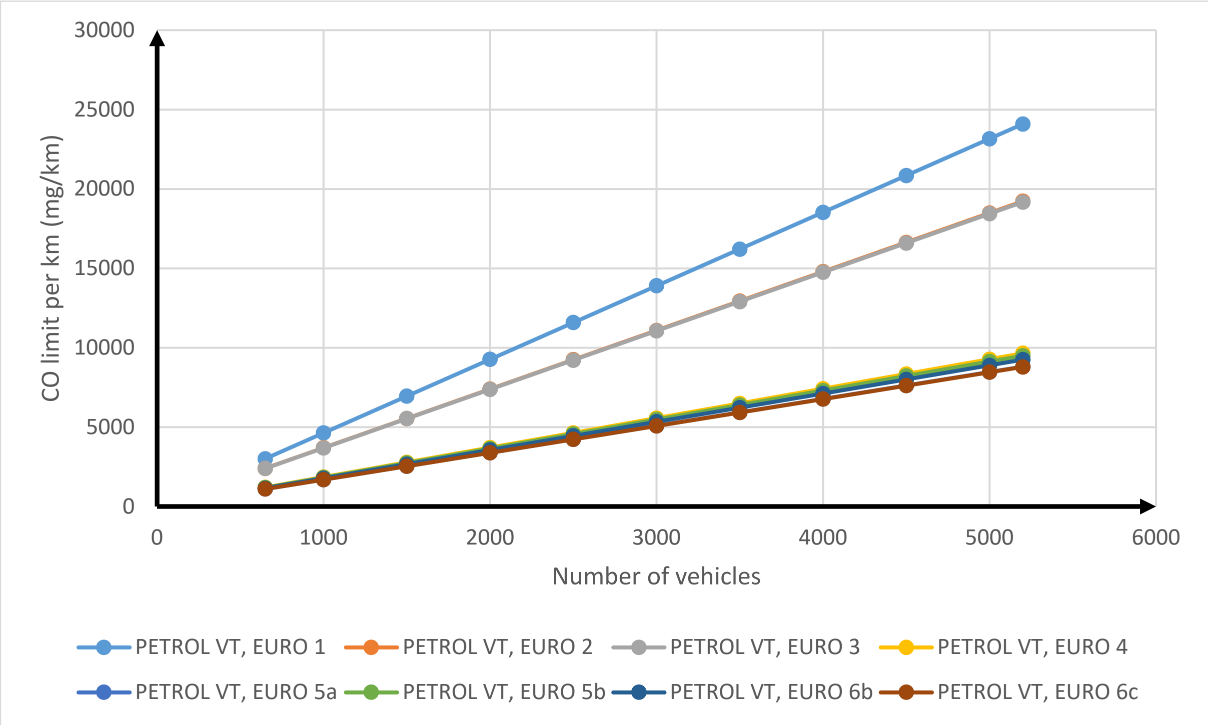

Figure 1: Quantity of CO emitted per km (mg/km) for VT PETROL

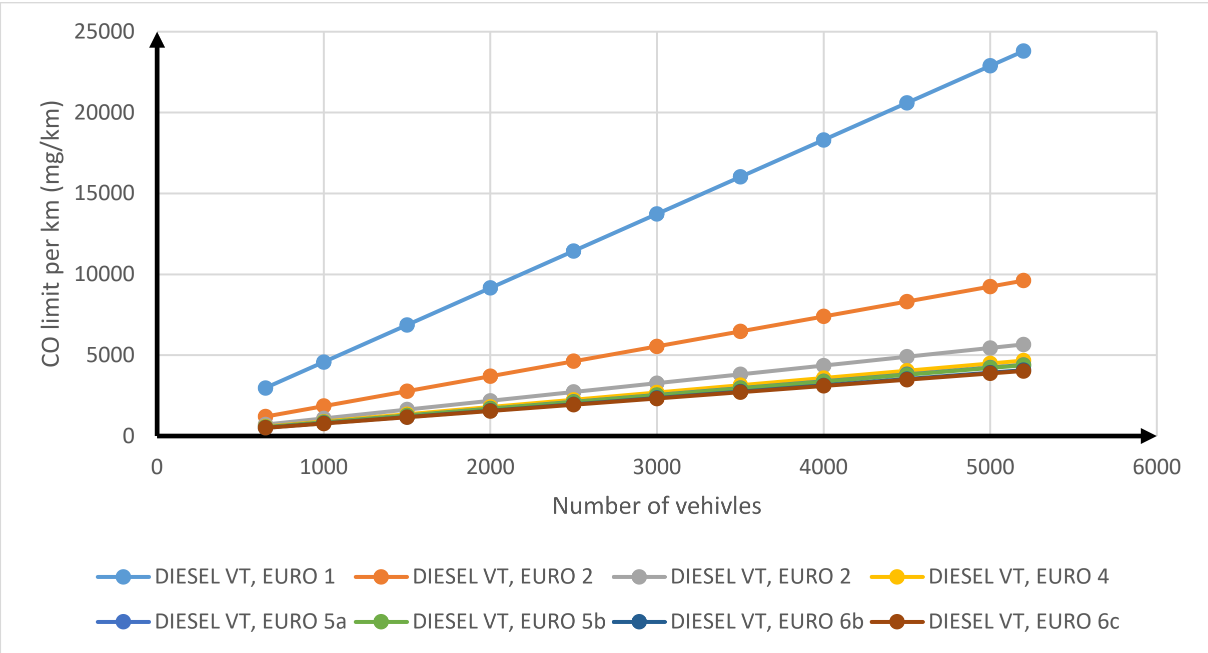

Figure 2: Quantity of CO emitted per km (mg/km) for VT DIESEL

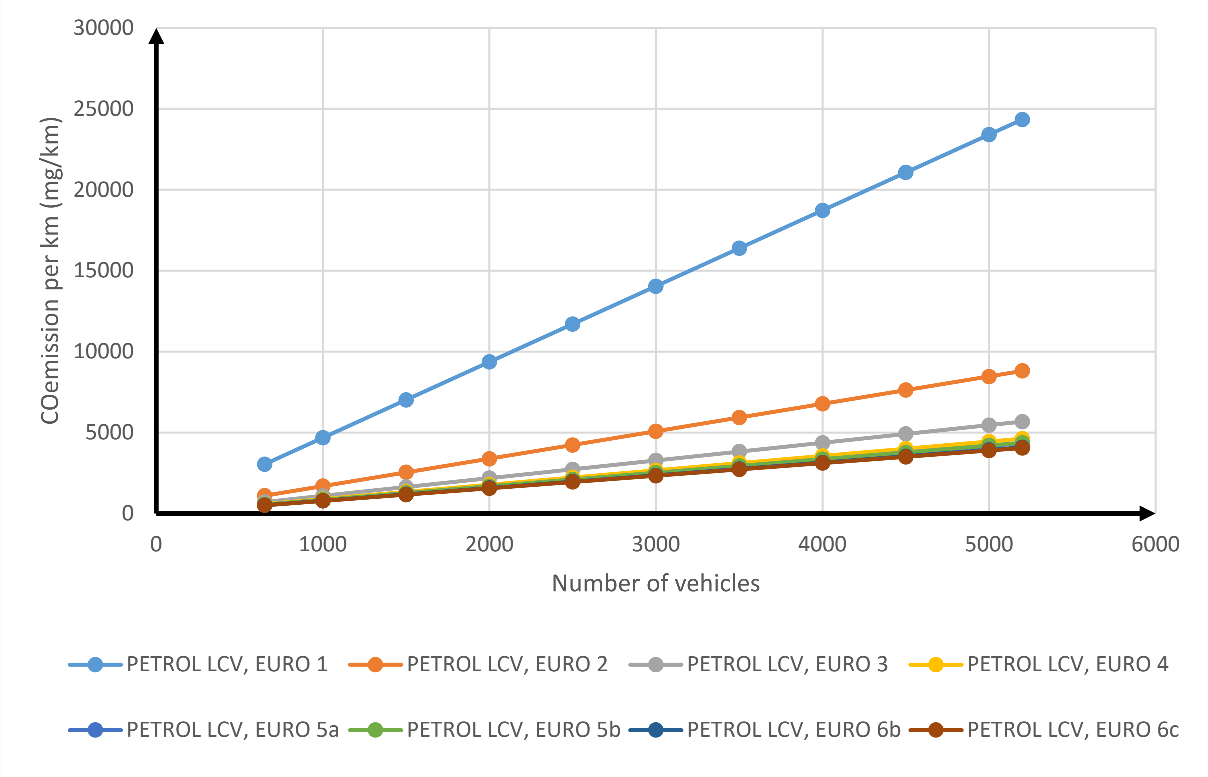

Figure 3: Quantity of CO emitted per km (mg/km) for LCV PETROL

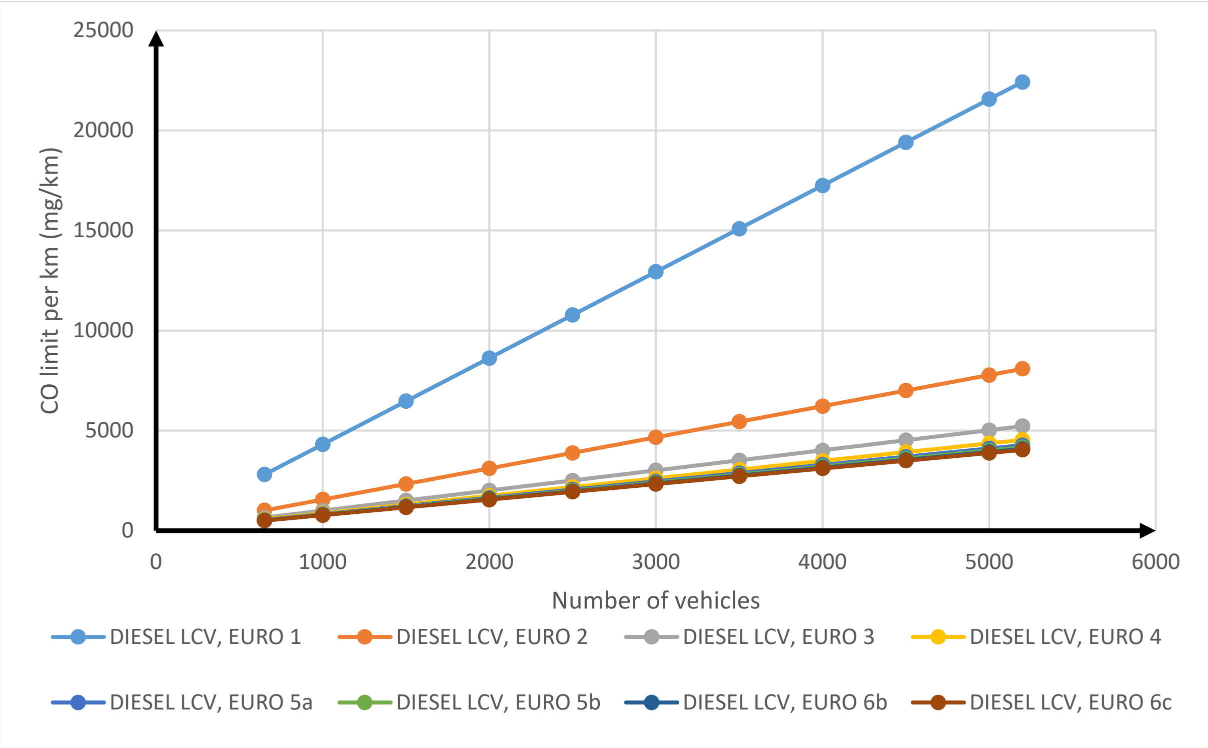

Figure 4: Quantity of CO emitted per km (mg/km) for LCV DIESEL

With regard to the different slopes of these figures contained in table 8, we see that the slope change in CO emissions from gasoline-powered light commercial vehicles (LCVs) belonging to the EURO 1 anti-pollution standard (slope = 4.68), is higher than the others.

Table 8: Slope of CO emitted straight lines

EURO	Slope VT PETROL	Slope VT DIESEL	Slope LCV PETROL	Slope LCV DIESEL
1	4,63	4,57	4,68	4,31
2	3,69	1,84	1,69	1,55
3	3,68	1,08	1,09	1
4	185	0,89	0,88	0,87
5a	1,69	0,84	0,83	0,82
5b	1,82	0,84	0,84	0,8
6b	1,77	0,78	0,78	0,78
6c	1,69	0,77	0,77	0,77

This means that the evolution of CO emissions from PETROL LCVs is faster than the others. With regard to the said figures, a projection made on the vehicles of the car fleet of the central region, shows that the emission of CO by type of antipollution standard and category of vehicle will be multiplied by 1,2. vehicles (VT DIESEL, LCV PETROL and LCV DIESEL) belonging to EURO 6c, will emit less CO with regard to their slope (slope = 0.77). The CO limit values per kilometer emitted by these vehicles presented in tables 4, 5, 6 and 7 are slightly higher than the reference limit value (Simon MARTINET, 2020). The annual distance done in kilometers has a huge influence on the amount of CO emitted. With regard to the values of CO emitted by the various EURO anti-pollution standards, PETROL VTs are the most polluting in the central region, this confirms the idea that petrol vehicles emit more CO compared to diesel vehicles (Paul DEGAUBERT, 1992). The Vehicles emitting a few CO belong to the EURO 6c anti-pollution standard (cars with approximately four (04) years of service). DIESEL VTs belong to the EURO 6c anti-pollution standard are the least polluting in CO, their maximum value per kilometer is 503 mg/km. In view of the different values of CO emitted, we can say that the CO emission of the center region of Cameroon originating from exhaust gases is nothing but a consequence of the movement of motor vehicles. With regard to the tables 4, 5, 6 and 7, the quantity of CO close to the reference limits per kilometer belongs to the antipollution standard 5a, 5b, 6b and 6c. To limit CO emissions, the public authorities are invited to prohibit the importation of motor vehicles manufactured before 2011 and to increase the rigor of technical inspections of motor vehicles.

CONCLUSION

At the end of the analysis, PETROL VTs and LCVs belong to the EURO 1 anti-pollution standard emit more CO than the others. The amount of CO emitted in the central region of Cameroon from exhaust gases comes mainly from the deplacement of motor vehicles. In order to contribute effectively to the fight against environmental pollution, local public authorities are invited to take more measures aimed at encouraging Cameroonians to import vehicles belonging to Euro pollution standards (5a, 5b, 6b, 6c).

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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