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Original Article

Pollution Potential of Imported Used Vehicles and Law: Towards a Working Policy for Green Supply Chain in Imported Used Vehicles to Cameroon

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Abstract - *Taking effective steps to reduce emissions of pollutants from imported used vehicles is an important policy strategy to combat climate change and maximize health and economic benefits. It is in this regard that emission concentration has been studied from imported Toyota cars at idle speed to assess their pollution potential and their compliance with existing European norms in view of proposing baseline information for a working norm in Cameroon. Data of three pollutants were collected using an AVL Ditest 5480 analyzer. Toyota vehicles were selected because they constitute the highest market share. The compiled database consists of five variables: carbon monoxide, hydrocarbons, and nitrogen oxides, and two predictors, age and mileage. The results revealed that the ages of the vehicles ranged from 3 to 19 years ($M = 12.93$, $SD = 4.639$), while the mileage ranged from 101 653 to 434 699 Km (Mean = 233 729.82, SD = 79161.37). A paired sample correlation revealed a significant relationship between age and CO emissions ($r(45) = 717$, $p = .000$), NOx ($r(45) = .571$, $p = .001$), and HC ($r(45) = .490$, $p = .001$). Mileage has a significantly higher correlation with all pollutants: CO, $r(45) = .692$, $p = .000$; HC, $r(45) = .711$, $p = .000$; and NOx, $r(45) = .703$, $p = .000$. The study provides the first evidence of emissions from imported used light-duty vehicles in Cameroon and recommended similar studies in other countries, using a variety of imported cars and pollutants so that a mitigation standard can be prioritized to maximize health and economic benefits. Meanwhile, there is a need for mandatory inspection of all newly imported used vehicles into all sub-Sahara African countries, as imported used cars and pollution seems to be intimately connected.*

Keywords - *AVL Ditest 5480 analyzer, European norms, Imported used vehicles, Working norm.*

1. Introduction

One of the greatest environmental challenges of our time is air pollution resulting from the transport sector since it is the fastest-growing source of fossil fuel carbon dioxide emissions in the world and is responsible for 24% of direct vehicular carbon dioxide (CO_2) emissions from fuel combustion [1]. Other emissions generated from fuel combustion by internal combustion engines include oxides of nitrogen (NO and NO_2, together called NOx), unburned hydrocarbons (HC), also known as volatile organic compounds (VOCs) or non-methane hydrocarbons (NMHC), carbon monoxide (CO), and particulate matter of sizes 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$), including black carbon. Particulate matter emitted by automobiles contributes to air pollution, causing negative health effects [2–3]. Increasing emissions of these pollutants from imported vehicles are contributing factors to domestic air pollution, global climate change, human health problems, and ground-level ozone formation at both regional and national scales [4].

Pollutants emitted are believed to have spatially variable radiative forcing effects on global radiation. When exposed to ultraviolet radiation, NOx can react with HCS, VOCs, and other pollutants to form ground-level ozone and photochemical smog, which can trigger asthma, cause lung diseases [5], and impair visibility. Particulate matter, on the other hand, has been linked to lung cancer [6]. At least 85% of Africa's vehicle fleet is used [7], and their emissions impact local and regional air quality.

According to the Organization for Economic Cooperation and Development (OECD), outdoor air pollution kills more than three million people worldwide each year [8]. Yet, the majority of African countries that import or assemble these vehicles lack emission standards that govern the type of emission technology that can be installed. Furthermore, the annual vehicle in-service testing regime does not require emissions testing. As a result, the population is becoming increasingly vulnerable to the harmful effects of vehicle pollutants. Setting cost-effective emission limit values for all

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vehicles, with a focus on NO_X, PM, HC (volatile organic compounds), non-methane hydrocarbons (NMHC), carbon monoxide (CO), and particulate matter 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$), including black carbon (BC), is essential.

Policymakers all over the world regulate vehicle emissions of criteria pollutants in order to improve air quality and people's health and quality of life. Many current regulations rely on type approval testing. For example, successive Light Duty Vehicle (LDV) emission standards have reduced the regulated emission intensity (g/km) of NMHC and NOx emissions by 97% in the US (Tier 1-3 in 2025), 80–85% in the EU (Euro 1-6), and 84% in China (China 1-5) [9]. Similarly, since 1988, HDV emission standards for NMHC and NOx have decreased by 95% or more in the United States [9]. To meet these standards, advanced vehicle emissions after-treatment systems such as three-way catalytic converters, lean NOx traps, selective catalytic reduction (SCR), and diesel particulate filters (DPFs) have been developed and implemented [10].

Harvard researchers discovered that light-duty vehicles, defined as cars, pickup trucks, and SUVs, accounted for a significant portion of the health burden reduced by tougher regulations on fossil fuel companies and vehicle manufacturers [11]. They further stated that as more light-duty cars are implementing energy-efficient technologies, the amount of greenhouse gas emissions per mile has decreased. In their conclusion, they stated that the regulations saved $270 billion in mortality and greenhouse gas emissions and recommended targeting light-duty vehicles since they cause a majority of both public health and climate burdens.

Although Europe has had emissions regulations since 1970, the first EU-wide standard, known as Euro 1, was not implemented until 1992, when catalytic converters were made mandatory on new cars, effectively standardizing fuel injection. Since then, a series of Euro emissions standards have been introduced, culminating in the current Euro 6, which was introduced in September 2014 for new type approvals and rolled out in September 2015 for the majority of vehicle sales and registrations [12]. The regulations, which will become increasingly stringent over time, define acceptable exhaust emission limits for new light-duty vehicles (LDV) sold in EU and EEA member countries. EU emissions standards aim to reduce the levels of harmful exhaust emissions, especially nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons (HC), and particulate matter (PM). These standards are based on mobile and stationary source emission controls and can potentially lower vehicle emissions. However, these rich countries export millions of older, dirtier vehicles abroad in a largely unregulated trade, even as they mandate cleaner cars at home.

Aside from political efforts, researchers have developed models based on the previously mentioned measurements to evaluate emissions from both manufactured and imported used vehicles over the years. For example, the US EPA and the California Air Resources Board (CARB) developed the emission factor (EMFAC) model [28], a first-generation vehicle emissions model, to predict regional inventories and projections for HC, CO, NOx, CO2, PM, SOx, a sensor system for collecting pollution data through portable sensors positioned in many points of a specific area such as the Air Quality Egg [14], and fuel consumption. The emission rate was adjusted using EMFAC based on various parameters such as vehicle type, vehicle year, pollutant type, and fuel type.

An alternative to EMFAC is the computer program to calculate the emissions from road transport (COPERT), which the European Commission developed. COPERT [15] estimates the emissions of air pollutants produced by different vehicle categories (passenger cars, light commercial vehicles, heavy-duty vehicles (HDV), buses, motorcycles, and mopeds). In COPERT 4, all major air pollutants and greenhouse gas emissions, including CO, NOx, VOC, PM, NH3, SO_2, CO_2, N_2O, and CH_4, emitted from vehicles can be estimated [12]. This model employs a significant amount of reliable experimental data compatible with different countries' statistical calibrations and parameter variables.

Some other studies have employed vehicle fuel consumption and emission models, such as the speed model and comprehensive modal emissions model (CMEM), developed by Barth et al. [16], to evaluate the emission pollutants of CO, CO_2, HC, NO_x, and PM, as well as fuel consumption. Additionally, Ahn et al. [17] proposed a microscopic model of the instantaneous vehicle fuel consumption and emission rate named the Virginia Tech Microscopic vehicle fuel consumption and Emission Model (VT-Micro) to predict the instantaneous fuel consumption and emissions for individual vehicles.

Based on data collected from 146 countries studied as of July 2020 by the United Nations Environment Program [18], Cameroon is second on the list of the top countries with the worst ambient air pollution in Africa [19], with a PM 2.5 reading of 196.7 g/m3, which is well above the World Health Organization's minimum recommendation of 10 g/m^3. She is also one of the countries in Sub-Saharan Africa with no working vehicle emission standards. As a result, quantitative data has never supported information on such vehicles' pollution potential and consequences. A thorough examination of the pollution potential of newly imported vehicles into the country could fundamentally provide support for road transportation emissions control. In this regard, this research was carried out to: characterize the budget of selected air pollutants emitted from the exhausts of newly imported cars based on experimental data, analyze the inter-norm variability of the pollutants to decipher which norm could be best adapted to minimize pollution from imported used cars in the country; Instead of using complex models, which often require difficulties in interpretation by local policymakers, this study uses simple descriptive and inferential statistics. The Toyota brand was chosen because it has the highest market share.

2. Materials and Methods

2.1. Study Area

The focus of this study is the Douala municipality (410 km²; ~ 13m a.s.l), which is the capital of the Littoral region, is located in the estuary of the Wouri River, between 4° 03' N latitude and 9° 42' E longitude. It is an industrial city and one of the fastest developing urban areas in Africa and ranks first at the national level. According to current estimates from the Douala urban council, the municipality's population is estimated to be 5,000,000 people with an average growth rate of 4.8%. The city was chosen for this study because it is the largest city in Cameroon, but also because it is Cameroon's commercial and economic capital and the entire CEMAC region comprising Gabon, Congo, Chad, Equatorial Guinea, Central African Republic, and Cameroon.

2.2. Vehicles Tested

A sample of 45 light-duty gasoline vehicles of the Toyota mark in low and high idle operation was assessed in terms of NOx, HC, and CO emissions. The vehicles were chosen from a broad range of manufacturers, mileage, and emission standards. The Toyota mark was chosen because it constitutes over 75% of the total cars in circulation.

2.3. Instrumentation

Within the framework of our study, we used the AVL DITEST 5480 emission control station, which consists of:

- A gas analyzer for vehicles with gasoline engines. Our study calibrated the emission monitoring station with the exhaust gas analyzer. The device consists of:
- Rev counter clamp: determines the engine speed. It is placed in the engine seat and connected to the spark plug cable, respecting the polarity of the current. These connections are made on the spark plug and injector of the first cylinder without forgetting to connect the ground cable on the chassis.
- Temperature sensor: Measures the engine oil temperature. It is inserted in the place of the dipstick during the measurement; before inserting the probe, we sized it to the same size as the dipstick. The temperature should be about 70 to 90°C.
- Sampling probe: It is inserted into the exhaust pipe to collect the exhaust gases and transmit them to the control station (Fig 1).

The "Diffusion Charging" measuring principle (electrical charging of particles) and the robust construction allow for fast measuring availability without consumables, an exact particle count in a short time, and continuous measurements in all-day continuous operation.

2.4. Vehicle Measurement Procedure

The measurements were taken under ambient conditions at a technical control center on a roller test bench that produces aerodynamic resistance in real time, and the exhaust emissions were collected. The tip of the measurement probe was then inserted at least 30 cm into the end of the exhaust pipe following the instructions in the exhaust gas analyzer's operating instructions. The next step was to select the type of fuel. An operator handles the vehicle for a short period and subjects it to several acceleration cycles predefined by the device to reproduce real driving cycles. The temperature is controlled during the test, allowing the variation of emissions under different conditions to be measured. The final value chosen was an average of three tests, each lasting 60 seconds, for each type of gas. To avoid the effects of cold starts, we waited about 15 minutes after starting a car to allow the engine to reach its equilibrium regime (minimum oil temperature of 60 °C); the vehicles were driven at low speeds and idled during this time before the measurements were taken. The low idle measurements were taken after the warm-up. The high idle measurements surpassed the low idle measurements. For these measurements, the gas pedal was used to keep the engine's rotational frequency (1500 ± 100 rpm) above the rotational frequency at low idle speed. A database comprising five key variables was created (Table 1).

Table 1. Description of variables

Name of the variable	Symbol	Type of variable	Measure
Mileage	X_{Mil}	Independent	Km/year
Age	X_{Age}	Independent	Years
CO	Y_{CO}	Dependent	Emissions(g/Km)
NOx	Y_{NOx}	Dependent	Emissions(g/Km)
HC	Y_{HC}	Dependent	Emissions(g/Km)

2.5. Data Analyses

Pearson's correlation coefficient, or Pearson's r [20], and linear regression (LR) models were used in this study as statistical methods. Pearson's r was used to measure the strength of the relationship between the variables. The variables were first tested for normality. Because correlation does not reveal anything about cause and effect, LR was used to fill this gap partially.

Because of their versatility and well-founded theory, LR models have been widely used in various scientific fields. However, linear regression analysis is frequently prone to noise and overfitting. The hypothesis to use the LR (Equation 1) in this study is based on the effect of the response variables (CO, HC, and NOx) on the explanatory variables (Age and mileage).

$$Y = \beta_0 + \beta_1 . X_1 + \epsilon \quad (1)$$

Where Y is the response variable, X_i is the explanatory variable, β_i is the regression coefficients, and ε is the residual error. To determine the regression coefficients, the least squares method, which is based on minimizing the sum of squared errors (SSE), as shown in Equation 2)

$$SSE = \sum_1^n (Y_1 - \hat{Y}_1)^2 \quad (2)$$

Where:

Y_i is the value of each observation, and

$\hat{Y}_i$ is the predicted value.

Theoretically, low SSE values reflect a better fit of the regression model [29]. The statistical significance of the explanatory variables and the general model was analyzed to determine the most parsimonious regression model. The analysis of the explanatory variables was performed with the t-test, while the degree of adjustment and usefulness of the proposed model was performed by evaluating the F-test, Equation. 3.

$$F = \frac{(SS_{yy} - SSE)/k}{SSE/[n-(k+1)]} \quad (3)$$

Where:

- $SS_{YY} = \sum(Y_i - \bar{Y})^2$ represents the sum of the squares of the difference in the observed data (Y_i);
- = k is the number of explanatory variables included in the model; and
- n = is the sample size.
- A paired t-test (Equation 4) was used to determine whether the mean change for pairs of the variables was significantly different from zero (null hypothesis) at a 5% significance level.

$$t = \frac{\bar{x}_d - \mu_d}{\frac{s_d}{\sqrt{n}}};\ df = n - 1 \quad (4)$$

Where,

$\bar{x}_d$ = the mean of difference in the change variable

s_d = standard deviation of the difference in change variable, and

n = the size of the sample.

- All statistical analysis in this study is performed using SPSS 20.0 analysis software.

3. Results and Discussion

3.1. Characteristics of the Sampled Vehicles

The age of the vehicles ranged from 3 to 19 years (M = 12.93, SD = 4.639). Based on the Euro norms, the vehicles were classified into four categories. O theses, 6(13.3%) were less than 5 years old and were classified as “New”, 17 (37.8%) were classified as old (between 10 and 15 years old), 8(17.8%) were classified as relatively new (between 5 and 10 years old), and 14(31.1%) were classified as very old (more than 15 years old).

Concerning mileage, the range was 333046.00Km, from a minimum of 101653.00 Km to a maximum of 434699.00 Km (Mean = 233729.82, SD = 79161.37) Km.

The skewness of mileage was found to be .442(SE = .354), indicating that the distribution was left-skewed, while the kurtosis was found to be .038(SE =.695), indicating that the distribution was more heavy-tailed compared to the normal distribution.

3.2. Characteristics of the Emitted Gases

CO concentrations ranged from a minimum concentration of 1.10g/Km to a maximum of 4.56g/Km (Mean = 2.24g/Km; SD = .892). NOx ranges from a minimum of .07g/Km to a maximum of .04g/Km (Mean = .189; SD = .097), while the hydrocarbons range from a minimum of .11 to .52g/Km (Mean = .2600; SD = .108). All pollutants show a general increase in emission trends: CO ›HC › NOx, with the increase in age (the year the car was first put into use) (Fig 2).

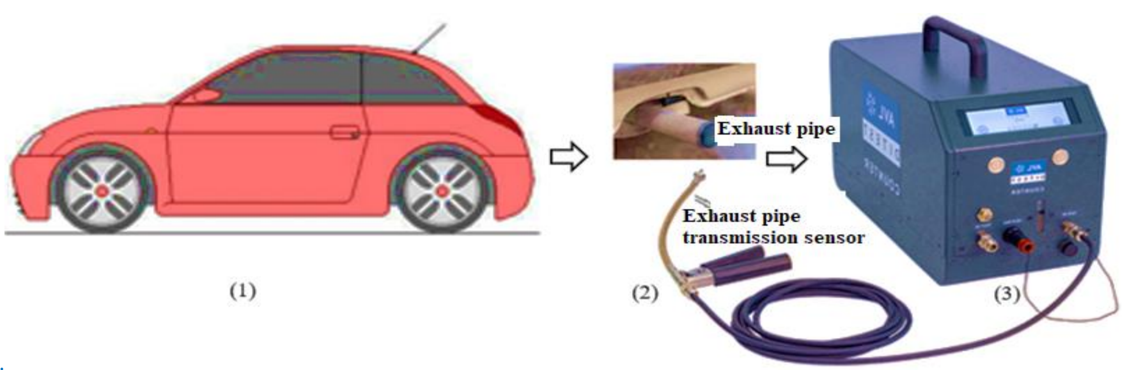

Fig. 1 Experimental setup used for calibration measurements and the assessment of gaseous emissions at low and high idle speed: (1) Test vehicle; (2) Exhaust + analyzer probe; (3) AVL DISTEST 5480 gas analyzer

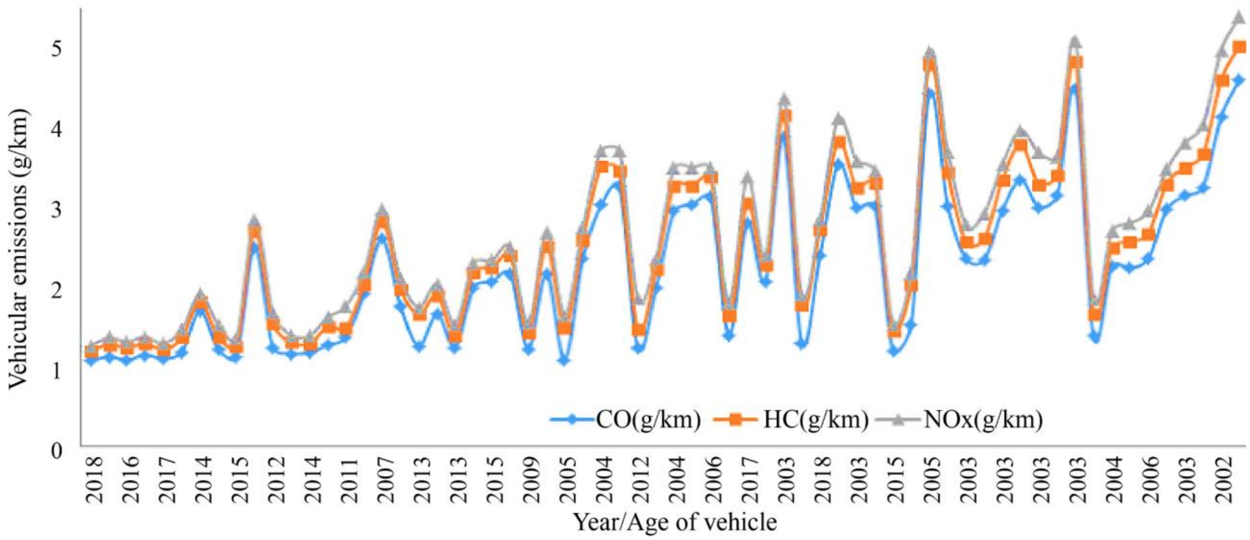

Fig. 2 Relationship between vehicular emissions and age of the car or year of manufacture: 2002 to 2018

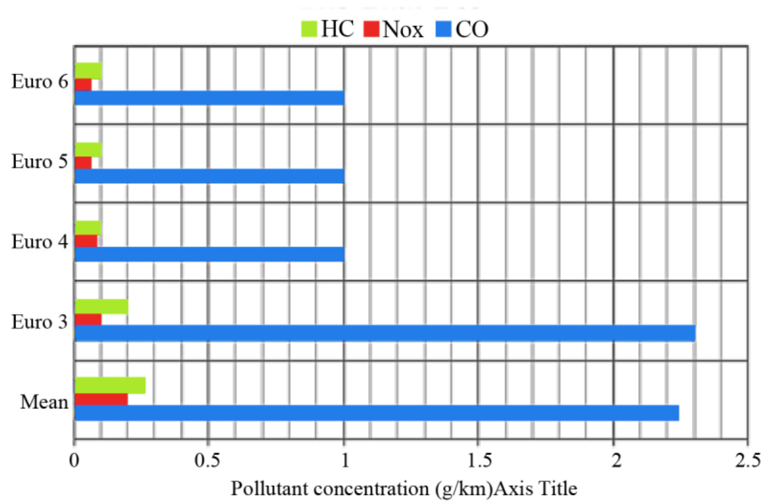

Fig. 3 Comparison of mean pollutant concentration of all pollutants with Euro norms

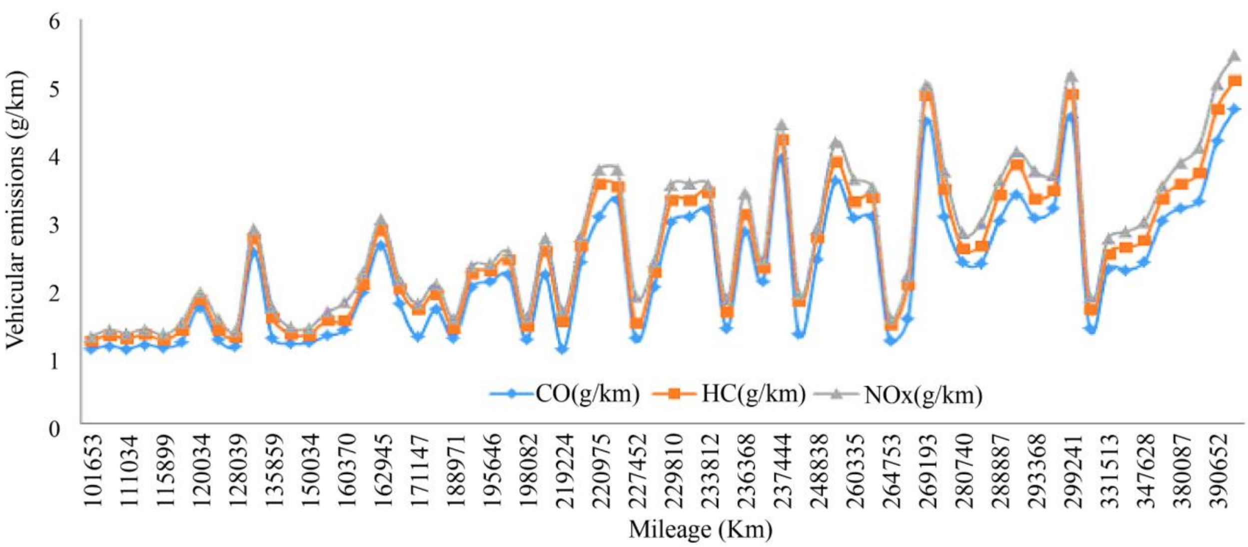

Fig. 4 Relationship between vehicular emissions and mileage of cars: 2002 to 2018

Table 2. Paired Sample Correlations of pollutants emitted from the Vehicles

Combination		N	Correlation	Sig.
Pair 1	Age & CO	45	.717	.000
Pair 2	Age & HC	45	.490	.001
Pair 3	Age & Nox	45	.571	.000
Pair 4	Mileage & CO	45	.692	.000
Pair 5	Mileage & HC	45	.711	.000
Pair 6	Mileage & Nox	45	.703	.000

The mean gaseous pollutants emissions of all gases of the forty-five selected vehicles exceeded the official limits set by all Euro norms except the Euro 3 norms, where the mean CO concentration was slightly lower (Fig 3).

When the explanatory variable was changed to mileage, similar trends were observed (Fig 4). It is worth noting here that mileage does not necessarily mean the age of a car. Many new cars have covered many more kilometers than the older ones. A paired sample correlation (Table 2) showed that while there was a strong significant correlation between age and CO emissions, r(45) = 717, p =.000, and a fairly strong with NOx, r(45) = .571, p = .001, the HCs showed a rather weak significant correlation, r(45) = .490, p = .001. In contrast, mileage showed fairly strong to strong significant correlations with all pollutants: CO, r(45) = .692, p = .000; HC, r (45) = .711, p = .000, and NOx, r (45) = .703, p =.000, suggesting that mileage could be an important explanatory variable when considering regulations that can reduce such pollutants.

According to some researchers, most vehicles older than ten years do not exhibit a strong and consistent deterioration with age for carbon monoxide and hydrocarbon emissions [22]. However, these findings suggest that mileage (not only age) should be an important factor when considering standards for importing cars into the country.

With CO as the dependent variable, the predictor age explained 51.4% of the variance, R^2 = .514, F (1, 43) =45.449, β = .137, p = .000; 95% CI [.096, .178]. Our hypothesis that the age difference would influence CO emission levels was accepted. The p-value and the F-test indicate that it is a statistically valid model that can be used for forecasting purposes. However, when the predictor was changed to mileage, the model explained 47.9% of the variance (R^2 = .479, F (1, 43) =39.515, β = .18.291E-006, p = .000; 95% CI [.000, .000]. Our hypothesis that the mileage difference would influence CO emission levels was accepted. The p-value and the F-test indicate that it is a statistically valid model that can be used for forecasting purposes. Fig 5(a-b) shows the relationships of CO emissions as a function of mileage (a) and age (b).

Carbon monoxide emissions can be due to several emission failures ranging from inadequate air intake to defective engine computer sensors.

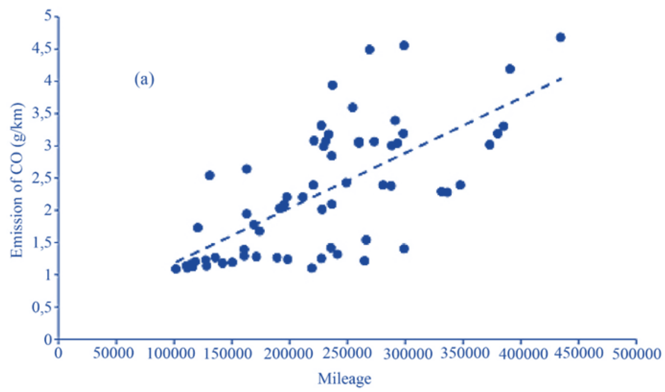

Fig. 5 (a) Relationship between CO emissions with mileage (Km)

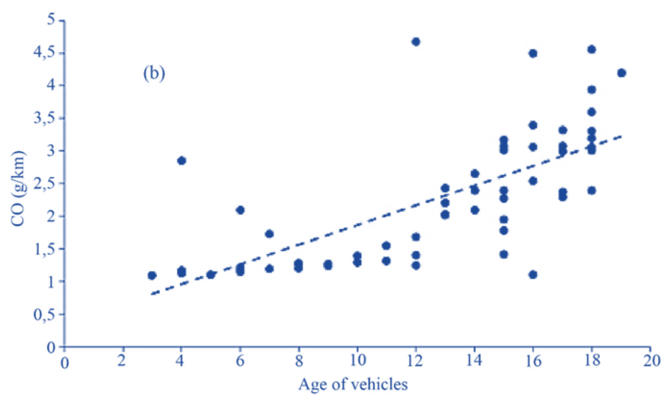

Fig. 5 (b) Relationship between CO emissions with age (years)

When the dependent variable was changed to HC, the predictor mileage explained 50.6% of the variance (R^2 = .506, F (1, 43) =44.065, p =.000) in HC emissions. It was found that mileage significantly predicted HC emission tendencies (β = .010, p = .000; 95% CI [.000, .000]). The p-value and the F-test indicate that it is a statistically valid model that can be used for forecasting purposes.

When the predictor was changed to age, the model explained 24.1% of the variance (R^2 = .241, F (1, 43) =13.620, p =.001). It was found that age significantly predicted HC emission tendencies (β = .003, p = .001; 95% CI [.005, .016]). Again, the p-value and the F-test indicate that the model is statistically valid that can be used for forecasting purposes. Fig 6 shows the relationships of HC emissions as a function of mileage (c) and age (d).

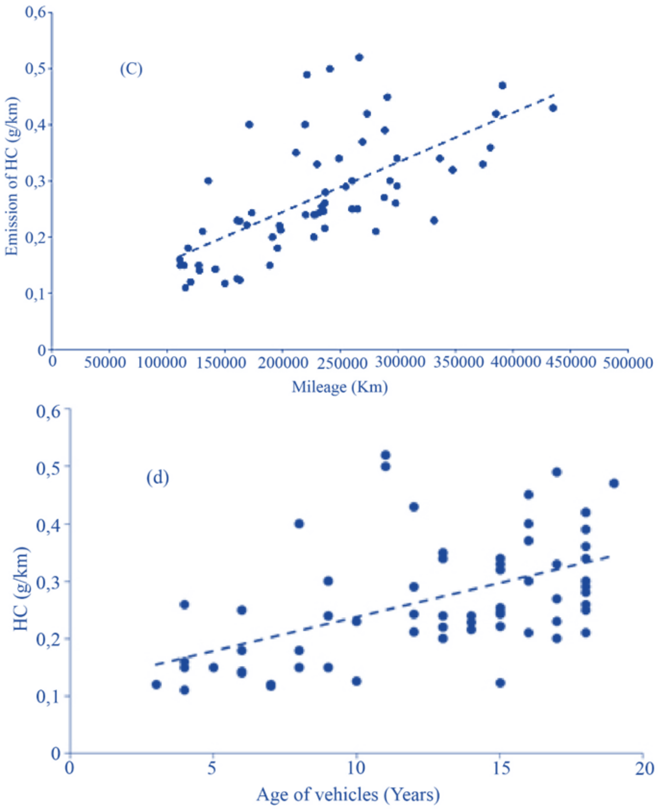

Fig. 6 Relationship between CO emissions with (c) Mileage and (d) age

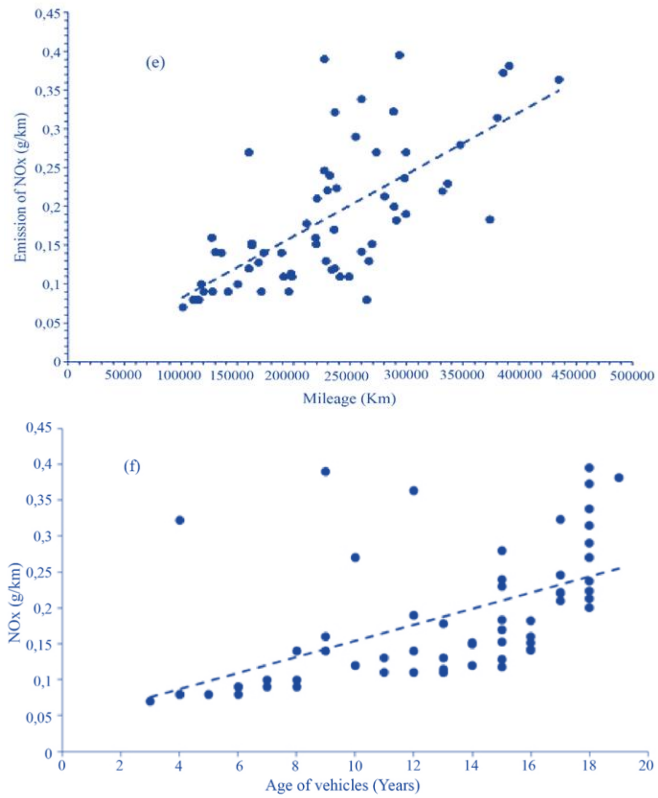

Fig. 7 Relationship between CO emissions with mileage (e) and age (f)

The result suggests the need for imported cars to be checked for engine misfiring and, where necessary, be regulated with catalytic converters as a proactive step in reducing the negative consequences of this pollutant to the atmosphere. Halderman and Mitchell [23] found that defective or worn spark plugs, defective or loose spark plug wires, defective distributor caps, incorrect ignition timing, lean air-fuel mixture, and low fuel pump pressures can all result in an engine misfire. Zuo et al. [24] added that hydrocarbon emissions could result in serious health effects and contribute to ground-level ozone concentration and smog.

Finally, with NOx as the dependent variable, the predictor mileage explained 49.4% of the variance (R^2 = .494, F (1, 43) =41.906, p =.000). It was found that mileage significantly predicted HC emission tendencies (β = .8.909E-007, p = .000; 95% CI [.000, .000]). The p-value and the F-test indicate that it is a statistically valid model that can be used for forecasting purposes.

Similarly, when the predictor was changed to age, the model explained 61.4% of the variance (R^2=.326, F (1, 43) =20.754, p =.000). It was found that mileage significantly predicted HC emission tendencies (β =.012, p =.000; 95% CI [.006, .017]). Again, the p-value and the F-test suggest that the model is statistically valid that can be used for forecasting purposes. Fig 7 shows the relationships of NOx emissions as a function of mileage (e) and age (f).

We infer from the above analyses that the models with mileage as an explanatory variable are e more parsimonious than those with age as the explanatory variable. Correlation analyses revealed similar conclusions, suggesting that when considering working standards for importing secondhand or used cars into the country, more emphasis should be placed on mileage. This conclusion deviates somehow from that of most existing regulations as they strictly focus on the age of cars. This disparity could be the result of several parameters including but not limited to depreciation, quality of the fuel used, inadequate maintenance, and lack of in-service emission testing, inferior emission systems technology of new vehicles sold in the city. The absence of fuel and vehicle standards and the lack of working regulations and politics will have dire consequences on transport emissions.

Cleaner and more efficient vehicles can make a key contribution to a low and ultimately zero-emission transport sector. The Intergovernmental Panel on Climate Change (IPCC) report on achieving a 1.5^0C Climate Scenario in October 2018 has stated that "electric vehicles, electric bikes, and electric transit need to displace fossil-fuel powered passenger vehicles by 2035–2050 to remain in line with a 1.5^0C consistent pathway." Used vehicles play a major role in addressing some issues and achieving these targets. As per definition, used vehicles should not connote more polluting or obsolete vehicles. Promoting national and international efforts to rationalize and regulate used vehicles should not imply a ban on the used vehicle trade. Used vehicles can be cleaner and more energy efficient than new vehicles. They can even be cleaner (and safer) than new vehicles being sold in low- and middle-income countries' markets.

3.3. Relationship between Vehicles' Emission Potentials and Euro Norms

The Euro emissions standards aimed to reduce the levels of harmful exhaust emissions, mainly nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons (HC), and particulate matter (PM). Therefore, we investigated the extent to which imported used cars relate to each of the norms as the first step towards a working regulation for imported used cars in the city and the country in general. Our findings revealed that, of the 45 randomly sampled Toyota cars, none (0%) respected either the Euro 1 or Euro 2 norms, 19 (42.2%) were in the Euro 3 norm category, 13 (28.9%) fell in the rank of the Euro 4 norm category, 6(13.3%) fell in the category of the Euro 5 norm category, while 7(15.6%) fell in the category of the Euro 6 norm (Fig 8).

In terms of pollutant concentrations (g/Km), most of the old/very old vehicles were strongly associated with the Euro 3 and Euro 4 norms, while most of the new and relatively new vehicles were strongly associated with the Euro 5 and Euro 6 norms (Fig 9)

A cross-tabulation of age category vs Euro norm category revealed that all cars, 6(13.3%) that were classified as new were of the Euro 6 norm category. For the relatively new, 2(25%) were in the Euro 4 category, while the rest 6(75%) were in the Euro 5 category. On the other hand, of the 17 cars that were classified as "Old", 5(21.4%) were of the Euro 3 category, 11 (64.7%) of the Euro 4 category, while only 1(5.9%) were of the Euro 6 category. All the very old cars, 14(100%), were of the Euro 3 norm category.

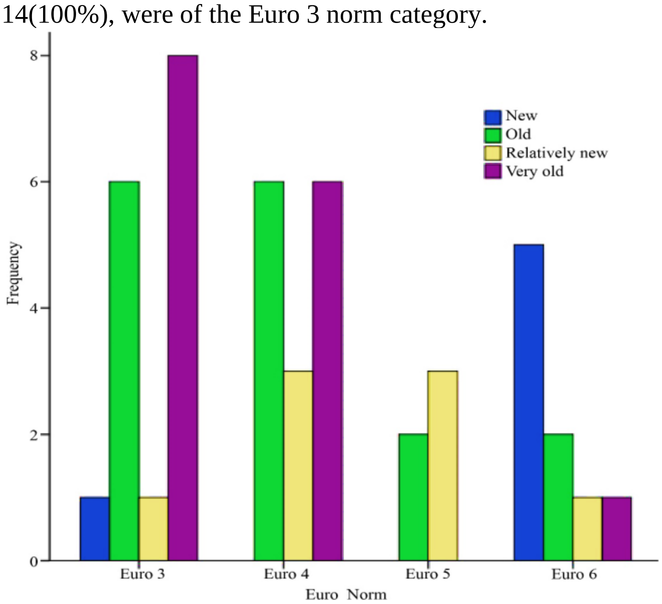

Fig. 8 Relative compliance of imported used cars with Euro norms

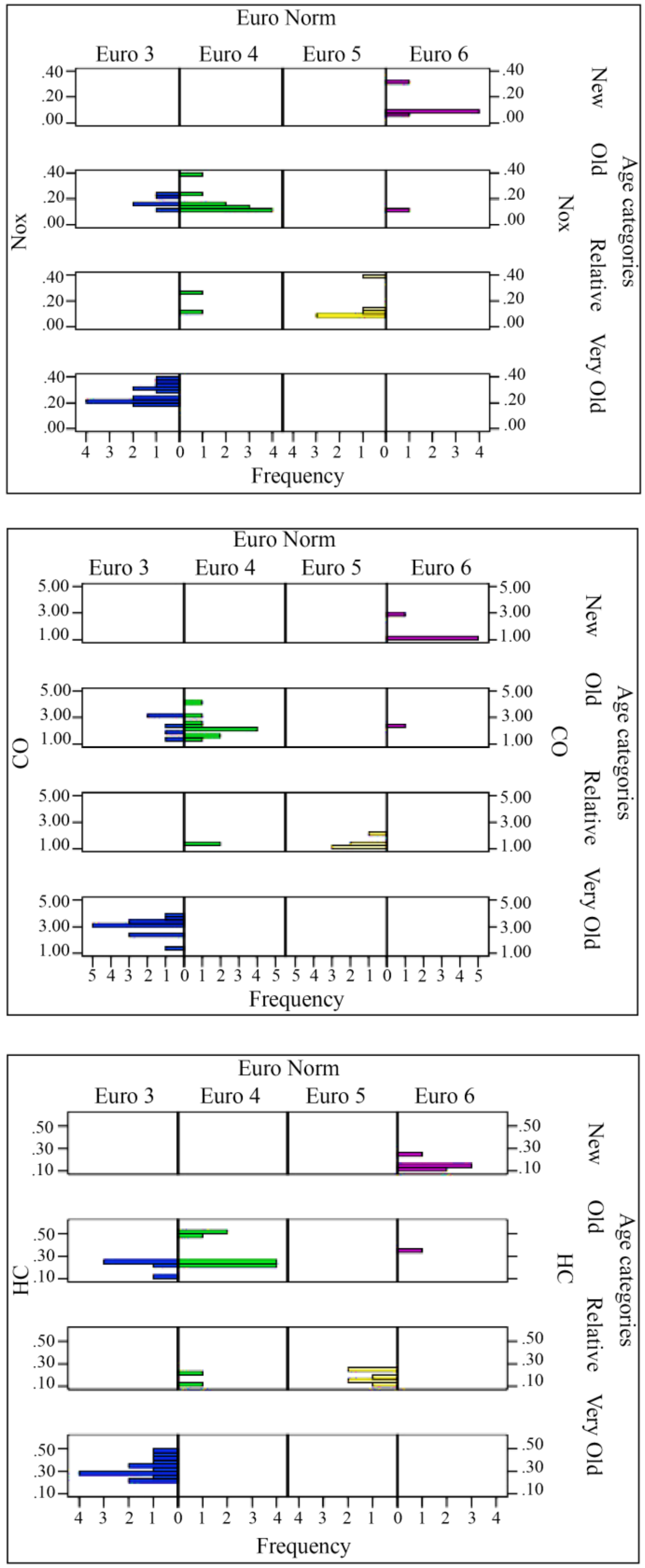

Fig. 9 Relationship between age categories and Euro norms (Relative ="Relatively new")

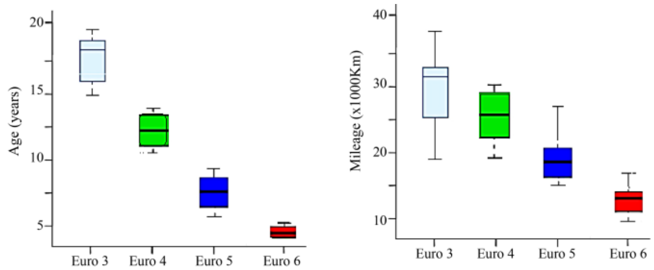

Fig. 10 Relationship between age (a) and mileage (b), with Euro norms

Similar results were obtained when the explanatory variable was changed to mileage categories: high mileage (200 000 – 300 000 Km), like the very high mileages (≥ 300 000 Km) vehicles, were strongly associated with Euro 3 and Euro 4 norms, while the moderately high mileage (< 200 000Km) vehicles were strongly associated with Euro 5 and Euro 6 norms (Fig 10).

On the whole, most of the new cars relate to Euro 6 norms, most of the relatively new cars relate to Euro 5 norms, and most of the old and very old cars relate to the Euro 3 and Euro 4 norms. A chi-square test of independence was performed to examine the relation between the age categories of the cars and their compliance with different Euro norms. The relationship between these variables was significant, X2 (9, N = 45) = 90.75, p = .001, suggesting that the age category of imported cars and Euro norms depend on each other. A further statistical analysis was carried out to investigate the relationship between each pollutant and the different Euro norms. The results portray a decreasing emission rate as we shift from Euro 3 to Euro 6 standards for all pollutants (Fig. 11a, b, & c).

We infer from the above analyses that cars with the highest emissions are associated with Euro 3 & 4 norms, while those with the least emissions are associated with the Euro 6 norms.

Given that most of the imported cars are of the Euro 3 and 4 characteristics, suggesting that the city of Douala should be highly polluted. Euro 3 was in place for five years, from 2001 to 2005. The result was a cumulative reduction of NOx (–22%), NMVOC (-65%), and CO (-60%). The results of Euro 4 implementation (2006–2010) were a cumulative reduction of transportation pollutants for SOx (-88%), NOx (-41%), NMVOC (-80%), and CO (-76%). After Euro 5 and Euro 6 implementation from 2011 to 2015, there were further significant signs of progress made in transport pollution reductions. Compared to 1990, the transport emissions of NOx, NMVOC, and CO had reduced by 57%, 88%, and 86%, respectively, by 2018. Table 3 presents the CO, HC, NOx, and PM vehicular emission limits and the benefits required to meet the various emission standards in Europe.

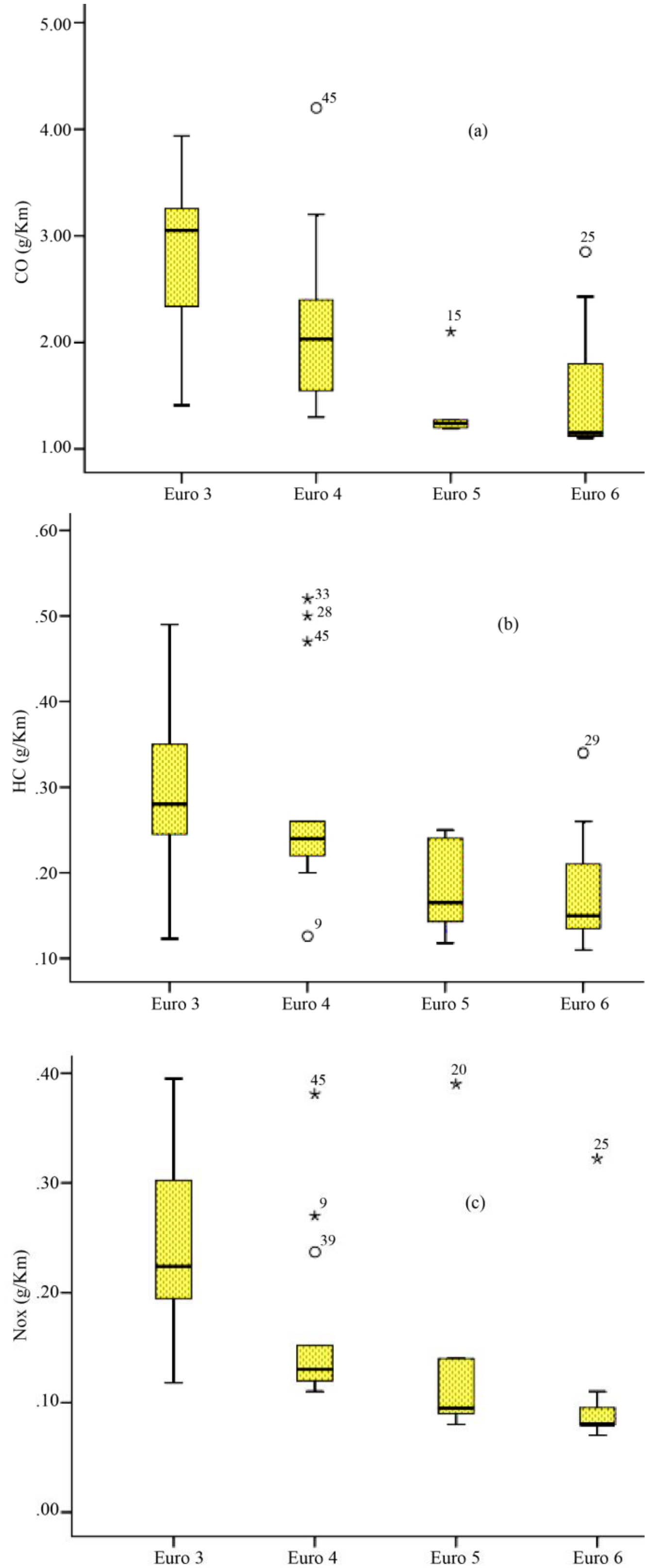

Fig. 11 Relationship between (a) CO, (b) HC, and (c) NOx emission potentials and Euro norms

Table 3. Characteristics of different Euro norms for car pollution control

Norm	Description	Limits		Benefits
		Petrol	Diesel	
Euro 2 (EC96)	Applies to all new cars registered from 1 January 1997	▪ CO: 2. 20g/km ▪ HC+ NOx: 0.50g/km	▪ CO: 1.00g/km ▪ HC+NOx: 0.70g/km ▪ PM: 0.08g/km	Different emission limits were introduced for gasoline and diesel engines, and the acceptable levels of all four major emissions were reduced across the board.
Euro 3 (EC2000)	Applies to all new cars registered from 1 January 2001	▪ CO: 2.30g/km ▪ HC: 0.20g/km ▪ NOx: 0.15g/km	▪ CO: 0.64g/km ▪ HC: 0.56g/km ▪ NOx: 0.50g/km ▪ PM: 0.05g/km	Separate limits for hydrocarbons and nitrogen oxide emissions for gasoline engines, as well as a separate nitrogen oxide limit for diesel
Euro 4 (EC2005)	Applies to all new cars registered from 1 January 2006	▪ CO: 1.00g/km ▪ HC: 0.10g/km ▪ NOx: 0.08g/km	▪ CO: 0.50g/km ▪ HC+NOx: 0.30g/km ▪ NOx: 0.25g/km ▪ PM: 0.025g/km	Significant reduction in particulate and nitrogen oxide limits in diesel engines. Diesel particulate filters (DPFs) are now standard on some new diesel vehicles, trapping 99% of particulates.
Euro 5	Applies to all new cars registered from 1 January 2011	▪ CO: 1.00g/km ▪ HC: 0.10g/km ▪ NOx: 0.06g/km ▪ PM: 0.005g/km	▪ CO: 0.50g/km ▪ HC+NOx: 0.23g/km ▪ NOx: 0.18g/km ▪ PM: 0.005g/km ▪ PM: 6.0x10 ^11/km	Diesel particulate filters (DPFs) for all diesel vehicles were announced.
Euro 6	Applies to all new cars registered from 1 September 2015	▪ CO:1.00g/km ▪ HC:0.10g/km ▪ NOx:0.06g/km ▪ PM: 0.005g/km ▪ PM: 6.0x10 ^11/km	▪ CO: 0.50g/km ▪ HC+NOx: 0.17g/km ▪ NOx: 0.08g/km ▪ PM: 0.005g/km ▪ PM: 6.0x10 ^11/km	The permissible levels of nitrogen oxides in diesel have been reduced by 67%, and a particle number limit for gasoline has been implemented.

Vehicles manufactured from 2011 were obliged to satisfy Euro 5 emission requirements [25]. The diesel engine had to be fitted with a diesel particulate filter (DPF) to trap particulate matter, a three-way catalytic converter to reduce Oxides of Nitrogen (NOx), and Hydrocarbons (HC), Exhaust Gas Recirculation technology to reduce NOx. To meet the stringent NOx limit, Euro 6 requires the technology of Lean NOx Traps (LNT).

In Cameroon, there is no working policy regulating the age of imported cars into the country, and neither is there any working policy regulating the mileage of imported cars into the country. The lack of monitoring to measure air quality and political will are hindering the effective response to contain pollution from imported used cars of all categories. As a result, the streets are littered with very old vehicles of all ages and mileage, exposing the population to the dangerous risks of environmental pollution resulting from inhaling pollutants such as PM2.5, PM10, CO, HC, and NOx.

Other studies have found that inhaled carbon monoxide emissions can combine with blood hemoglobin to reduce the oxygen-carrying capacity of the human body [26]. Long-term exposure causes heart disease, edema, severe pulmonary congestion, and nausea, to name a few side effects [27]. As a result, local governments and government agencies must develop strategies and policies to reduce emissions from the transportation sector in urban areas to enhance the overall quality of the entire community.

A participatory regulatory system wherein, on both the supply/exporters and demand/importers sides, there is pre-export and post-export verification for roadworthiness could be a way forward. However, corruption could be a major constraint to the successful implementation of such regulations.

4. Conclusion

In this study, the volume of air pollutant emissions (CO, NOx, and HC) from imported used Toyota cars were quantified and modeled. This work has been conducted on the one hand not only to raise awareness of the real effects of pollution on the environment and economy of a city but also to draw the attention of owners and maintenance services to the need to get used vehicles with an acceptable rate of pollutants (close to the regulated value). Although most regulations have focused on the age of cars, our results revealed that the mileage of vehicles is an important variable structuring pollutant emissions from vehicles that must be considered in any regulation or standard. It is further recommended that the city council of Douala puts in place a working institution and adopts a more stringent emissions standard similar to the Euro 6 emissions standard with an emphasis on mileage for its roadworthiness tests. The city authorities may also introduce clean fuel standards that ensure the correct fuels are available for these vehicles. Understanding the current barriers in the vehicle industry is necessary to develop effective and sustainable measures and policies to manage vehicle-induced air pollution not only in the city of Douala but the nation at large.

On the other hand, the complexity of highly variable traffic emission sources, variability in fuel quality, and poor road system design all call for integrated strategic control of vehicle-induced air pollution based on social participation, technological revolution, and regulatory innovation. However, our work was limited to petrol cars and did not take into consideration representative samples of all categories of petrol cars. Future research should consider representative samples of both diesel and petrol cars. Characterization of pollutants should include both particulate phase and gas-phase CO, NOx, and HCs. Other machine learning algorithms, such as neural networks, have been successfully applied to solve many optimization problems in the past. It is possible that these techniques can be used to solve the current problem if a good mapping of the problem to the appropriate network architecture is discovered. These could be interesting areas of research in the future.

Conflicts of Interest

The authors declare that there is not any conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and falsification, double publication and submission, and redundancy, have been completely observed by the authors.

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