International Journal of Environment and Pollution Research
Vol.10, No.1 pp.28-44, 2022
Print ISSN: 2056-7537(print),
Online ISSN: 2056-7545(online)

Study on Factors Influencing Exhaust Emission Levels in Five Major Cities in Ghana

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Citation: Seth T. K. Dzokoto, Charles Atombo, Maurice M. Braimah and Abdul-Rahaman Issahaku (2022) Study on Factors Influencing Exhaust Emission Levels in Five Major Cities in Ghana, *International Journal of Environment and Pollution Research*, Vol.10, No.1 pp.28-44

ABSTRACT: *Road transport exhaust emissions represent the main sources of atmospheric pollution in urban areas, due to the growing number of vehicles and travelled distances. The study examined determinants of exhaust emission levels based on vehicle engine type and vehicle age and fuel type used at city level. This study adopted an explorative and descriptive research design. The study areas were Accra, Kumasi, Tema, Takoradi and Tamale. An exhaust Gas Analyzer was used to collect exhaust emissions from sample of 1,000 vehicles. The data was analyzed using Analysis of variance (ANOVA) and regression to explain the significance of the emissions. The result shows that vehicles older than year 2000 have a 23% to 25% chance of increasing emission pollution compared to cars newer than 2006. Fifteen percent of the sample indicated that the type of fuel contributes to a significant amount of exhaust emission. Comparatively, emissions of CO_2, HC and CO from petrol engines are much higher in terms of value than the diesel engines. However, diesel engine produces high NOx compared to petrol engines. Vehicles in Accra and Kumasi produce more emissions than those of other cities. As means of mitigation measure, the regulatory bodies should enforce stringent emission legislation and regulation.*

KEYWORDS: exhaust emission, exhaust gas analyzer, Ghana, urban areas, vehicle engine type

INTRODUCTION

Despite technological improvements in internal combustion engines, pollutant emissions by vehicles are still responsible for high levels of air pollution in urban areas. In recent years particulate emissions have given rise to particular concern due to their detrimental effects on human and environmental health (Gerlofs, 2009). Vehicular exhaust gas pollution is a major contributor to global warming (UCS, 2014). In the United States (US) alone, it is estimated that, cars and trucks emit carbon dioxide and other greenhouse gases, which represent about onefifth of the United States' total global warming pollution (Braimah, 2012). Greenhouse gases are gases that usually trap excessive heat (than needed) in the atmosphere, and cause worldwide temperatures to rise at the earth's surface. They also keep and balance the temperature of the earth's surface and atmosphere in spaces without greenhouse gases and so preventing those parts of the earth from being covered with ice. However, Green (2018) reported that excessive burning of fossil fuels, such as gasoline and diesel, has caused a substantial increase in temperature on the earth's surface by 0.6 degrees Celsius.

The effects of car exhaust pollution are widespread, affecting air, soil and water quality. For instance, Nitrous oxide contained in exhaust gases contributes to the depletion of the ozone layer, which shields the Earth from harmful ultraviolet radiation from the sun. Sulfur dioxide and nitrogen dioxide mix with rainwater to create acid rain damages crops, forests and other vegetation as well as buildings (Braimah, 2012).

In terms of combustion pollution from vehicles, spark-ignition (SI) engines are a major source of urban air pollution (WHO, 2016). The engine exhaust is the source of nitrogen oxides and carbon monoxide emissions (Swatlz, 2014). The exhaust reactors and catalytic converters provide substantial additional reductions in emissions before the exhaust gases enter the atmosphere. While nitric oxide (NO) and nitrogen dioxide (NO_2) are grouped together as NOx emissions, NO is the only oxide of nitrogen produced in significant quantities inside the engine. It is formed in burning and burned gases. According to Guo et al., (2014), the chemistry of NO formation in gas phase mixtures of O, N, C, and H has been extensively studied in shock tubes, stirred reactors and flames. However, the formation of the post-flame gases is generally much more important under typical SI engine conditions. Therefore, the study aims to examine the determinants of exhaust emission levels based on fuel type used for vehicles with Ghana as a case study.

The Driver and Vehicle Licensing Authority (DVLA), plays a huge role in ensuring that exhaust gas pollution and emissions from cars are controlled in Ghana (EPA, 2007). The type of fuel cars uses and carbon dioxide cars emit are among the determinate of tax rate. When the vehicles are first registered, the DVLA and other regulatory bodies check the emission status of the car before being allowed on the streets. The findings from this study can, therefore, serve as a guiding tool for emission regulatory bodies to put measures that will reduce emissions levels.

LITERATURE REVIEW

The number of studies examining the main sources of atmospheric pollution is increasing steadily. Some of these studies have identified road transport exhaust emissions as the main sources of atmospheric pollution in urban areas. Focusing on vehicular emission in urban areas in Beijing, Hao et al. (2000) used a mathematical dispersion model, meteorological and emissions distribution data to simulate the vehicular pollutant concentration distribution. The authors observed that more emission pollutants are produced during decelerating, acceleration and idle in concentrated traffic conditions. Supporting the findings of Hao et al. (2000), Shukla and Alum (2010) evaluated the relationship between traffic flow and vehicle emissions and different speeds under dynamic urban traffic conditions in Delhi and found that high emissions rates occurred during acceleration, but contrary, vehicle emissions were low when the vehicle was idling. In another study, Nejadkoorki et al. (2008) developed three modelling components using a Loose-Coupling approach to estimate road traffic CO_2 emissions on a street-by-street basis for an urban area in Norwich. According to the authors, about 85% of the total CO_2 emissions in urban areas were from main roads and only 15% were from minor roads. Moreover, the authors found that Cars contributed 72.5% of all CO_2 emissions and 41% were attributed to the off-peak periods. These authors suggested improving road systems can mitigate air pollution from vehicles.

Other researchers have focused on examining the relationship between vehicle type, Fuel quality and emission pollution**.** Using a remote sensing device (RSD) Smit et al (2021), generated emission samples to assess the performance of the light-duty vehicle (LDV) and light-commercial vehicles (LCVs) in Australia. According to the researchers, on average, 4% of diesel cars aged between 1–5 years have smoke factor values. The authors recommended the adoption of Euro 6d vehicle emission standards and EU fuel quality requirements as soon as possible. Similarly, Rhys-Tyler et al 2011 also used roadside remote sensing absorption spectroscopy techniques and Automatic Number Plate Recognition for vehicle identification in London to examine the level of exhaust emission based on vehicle class, fuel type, and Euro emissions standard. The authors noted that from Euro 1 onwards, petrol cars displayed a significant reduction in pollutants. Moreover, they observed that Euro 2 diesel cars emit higher rates of NO than either Euro 1 or Euro 3 standard diesel cars. Moreover, Carslaw et al. 2019 summarized findings from research that used vehicle emission remote sensing measurements in the UK and found that new diesel cars and light commercial vehicles are associated with high amounts of NO_2/NOx. According to the authors, the amount of absolute NOx and NO_2 Euro 6 vehicles emitted has decreased substantially and the amount of NO_2 decreases as the vehicle mileage increases.

Studies on the impact of fuel quality on air pollution have received attention at the country level. For instance, Yue et al. (2015) observed that fuel quality standards and fuel supply management in China have long been an impediment to improved air quality. As part of the mitigation measures, they highlighted the importance of upgrading fuel quality to reduce pollutant emissions and introducing competition as well as enforcing the transition period for improved fuel introduction. The study of Ayetor et al (2021) evaluated the state of road vehicle emissions to ascertain compliance with local and international standards in Ghana and Rwanda and found that even some new vehicles failed the emission tests while almost all the diesel cars tested failed the international standard. The authors blamed the air pollution induced by vehicles emission on poor fuel quality, aged vehicles and lack of mandatory roadworthy emission tests. They recommended the implementation of Euro 4 standards for both fuel and new vehicle standards.

In an attempt to find appropriate intervention measures to mitigate air pollution, studies have focused on reviewed approach to suggest mitigation strategies. Jin et al (2010) conducted a review on vehicle emission and atmospheric pollution in China and provided insight into the circumstances and causes of vehicle air pollution. The authors observed that vehicle emission has contributed significantly to air pollution in cities. Besides, the authors suggested that the development of a combined approach including regulatory innovation in vehicles, fuel, and roads is the effective remedy to break the impasse between air pollution and the automobile thriving. In another study, Ong et al (2011) used COPERT 4 model to conduct a review on emissions. The researchers observed that passenger cars are the main cause of CO_2, N_2O and CO emissions, while motorcycles are the main cause of hydrocarbon (HC) emissions. The study further revealed that light-duty vehicles and heavy-duty vehicles are the main contributors of particulate matter. From a technical point of view, the authors proposed promoting the use of public transport coupled with fleet renewal and natural gas vehicles as an effective strategy to reduce emissions and fuel consumption. Using a top-down model and the bottom-up model Zhang et al. (2019) reviewed the measurement of carbon emission from road traffic and summarized the main factors that affect the traffic carbon emissions. The author advocated the implementation of traffic mitigation measures from economic, technical, and administrative aspects to minimize vehicle emissions. Finally, Zhu etal. (2021) used panel data regression models to quantify the growth of local emissions and found significant reductions in the average hourly growth rates of air pollutants in heavily industrialized cities. As a means of mitigating the emission growth rate, the author suggested the advancement of the fuel emission standards and added that every local car be made to be off the road one day per working week. From the above studies it is clear that the intervention measures suggested are quite different and factors such as geographical location is a significant determinants. This points to the fact that the study on emission pollution is very relevant and still not exhaustive. However, the study on emission in Africa continent is scarce and majority of such studies have been conducted in developed countries.

MATERIALS AND METHODS

Study Area

Research has shown that in highly-populated urban areas, road transport is often a major local source of ambient air pollution, in particular contributing significantly to nitrogen dioxide (NO_2) concentrations. Road transport also impacts negatively on ecosystem and noise levels. Due to the continuing increase of motor vehicles, human health and the environment have been severely impacted. This study was therefore conducted in the five major cities in Ghana where there is an increase in traffic flow causing traffic congestion and hence excessive emission of exhaust gases. The five cities are: Accra, Tema, Takoradi (southern belt), Kumasi (middle belt) and Tamale (northern belt) which were carefully selected to cover the southern, middle and the northern part of Ghana. The study was conducted in five (5) major cities of Ghana. These were Accra, Tema, Takoradi Tamale and Kumasi. These are major cities in Ghana with a large number of vehicles.

Equipment and materials
To gather data from various selected vehicles, there was the need to use specific and precise materials and equipment. Table 1 shows the details of the equipment and materials used in testing the vehicles for emission factors and values needed for the study. It is important to note the same instrument was used in all cities.

Table 1 Equipment and Materials

NO	EQUIPMENT AND TOOLS	NO	MATERIALS
1	SV-5Q Automotive Exhaust Gas Analyzer with accessories	**1**	Fuel
2	HP Laptop with NOVA Exhaust gas Analyzer 7460 series installed software	**2**	Engine oil

Sources of data
This research was implemented through the use of descriptive and quantitative research tools. A multi-stage sampling technique was employed in the selection of vehicles, towns and Auto garages for the experiment. Creswell (2017) defined multistage sampling as a sampling method that divides the population into groups (or clusters) for conducting research. In the first instance, purposive sampling was used to select five cities across Ghana. These included; Tamale, Kumasi, Accra, Takoradi and Tema. The locations of viable auto garages were also sampled through snowballing. After the areas of study have been identified, the simple random sampling technique was used in the second stage to select prospective vehicles, thus vehicles which have been brought to the garages for repair or maintenance work. According to Stevenson (2012), simple random sampling helps due to the fact that anyone is chosen entirely by chance and each member of the population has an equal chance of being included in the sample.

Sample Size
To determine the appropriate sample size of the registered auto garages to be selected as a study site, snowballing sampled technique was used. Through the snowballing sampled technique we identified 416 registered auto garages among the selected cities. Based on 416 registered garages,

the minimum statistically acceptable sampling size of 200 auto garages had been selected through the use of the formula proposed by Krejcie and Morgan (1970) as shown in equation (1). According to them.

$$\frac{X^2NP(1-P)}{d^2(N-1)+X^2P(1-P)} \quad \text{eqn. [1]}$$

Variables:

The respective variables have been given their explanations below.

S = required sample size

X^2 = table value of Chi -square for 1 degree of freedom (df) at desired

confidence level (3.841)

N = The population size = 416

P = The population proportion (Assumed to be 0.5 since this would provide the

maximum sample size)

d = the degree of accuracy expressed as proportion (0.05)

From the information above;

$$\frac{3.841(416)(0.5)(1-0.5)}{(0.05)^2(416-1)+(3.841)(0.5)(1-0.5)}$$
$$= \frac{399.464}{1.99775}$$
$$= 199.9$$
$$= 200$$

The sample size was then distributed proportionally to the Cities depending on the number of viable and registered garages present in each Metro. The distribution has been segmented into the various areas as shown in Table 2. Thus, the sample size distribution of the garages has been segmented into metropolitan cities with the highest number going to Accra, followed by Kumasi, Tema, Takoradi and Tamale with 48, 44, 41, 38 and 29 respectively. In each garage, an emission test was conducted on 5 vehicles. In total, an emission test was conducted on 1000 vehicles.

Table 2: Sample Size distribution

NO	Metropolitan Cities	Population of garages	Sampled garages	Vehicles sampled
1	Kumasi	91	44	220
2	Takoradi	80	38	190
3	Accra	100	48	240
4	Tema	85	41	205
5	Tamale	60	29	145
	Total	**416**	**200**	**1000**

Vehicle physical inspection

All 1000 vehicles selected for the emission test were subjected to a thorough check in order to verify the specifications of the engine and ensure that they were in good working conditions. The checks were carried out on exhaust leaks on the exhaust manifolds, the cooling system for water levels, and the lubrication system for engine oil levels. All kinds of vehicle emission control technology incorporated into the engine were also identified and located appropriately. For example, gasoline vehicles with three-way catalytic converters, diesel vehicles with oxidation catalysts, exhaust gas recirculation devices, electronic, conventional type of fuel injection and ignition system applications were rectified for the application of the right parameters.

Emissions testing procedure

Figure 1 shows the emission test procure. The MODE key was pressed to display the measurement screen (CO, HC, CO2 and NO_X) along with the date and time display. After the display of the emission, the probe of the Exhaust Gas Analyzer was placed in the exhaust system of the engine to collect gases. The major components of the gases measured include; Carbon Monoxide (CO), Oxides of Nitrogen (NOx), Hydrocarbons (HC's) and Carbon dioxide (CO_2). Different analytical techniques were adopted to measure the volume concentrations of exhaust emission. Before measuring the gases, each vehicle engine was run for 5 minutes to ensure that the engine warmed up. Each sampled vehicle was tested at idle speed.

The calibration and the calculation of emission results in terms of engine speed, temperature and load conditions, measurement of exhaust gas concentration and other engine operating parameters were considered. An experimental specimen form was designed and used to collate the required

Vol.10, No.1 pp.28-44, 2022
Print ISSN: 2056-7537(print),
Online ISSN: 2056-7545(online)

information on parameters which were measured during the experiment in the workshop/ Laboratory for the analysis.

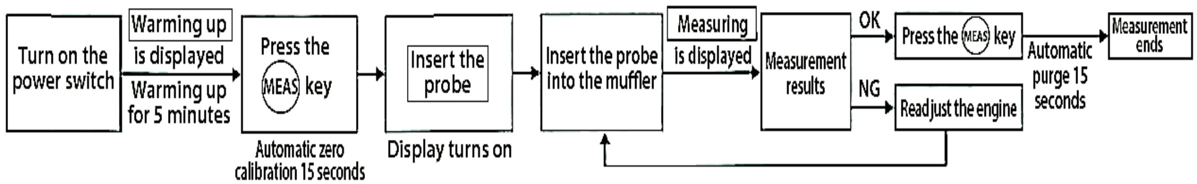

Figure 1 Emission pest procure

Data analysis

Data analysis is critical for bringing out the meaning of all the experiments and data gathered from the vehicles. This research focuses on the use of the Analysis of variance (ANOVA) and regression to explain the significance of the emissions. Two main soft-wares were used for the study; the first one was performed on primary data using GenStat PC software (version 17) and the second software was done using the Statistical Package for Social Scientists (SPSS) version 24. The Cross tabulation was also adopted in testing the significant relationship between the various engine type and vehicle age and the car ownership type.

RESULTS AND DISCUSSIONS

Descriptive features of Vehicles

The data were collected on 1000 vehicles (Table 3). The result shows that vehicle engine types had the majority of them being petrol engines (spark ignition) representing 675 (67.5%) of the sample cars, while, those cars with diesel engines (compression ignition) represented 325 (32.5%) of the sample cars for the study. In relation to car ownership type, the data gathered from the respondents (owners) and as well as observation by the researcher showed that majority 615 (61.5%) were privately owned cars (non – commercial), while, 385 (38.5%) of them were commercial vehicles (passenger cars). Within the context of year of vehicle manufacture, 515 (51.5 %) of the sampled cars range between 2000 and 2006; this was followed by 240 (24.0 %) vehicles manufactured below the year 2000 while vehicles manufactured between 2007 and 2013 numbered 205 (20.5 %). The least of the cars were cars manufactured within the period of 2014 – 2019 representing 40 (4.0%) of the sample respondents of cars selected for the study.

Table 3: Features of vehicles

		Frequency	Percentage (%)
Engine type	Petrol	675	67.5%
	Diesel	325	32.5%
Car ownership type	Commercial/Passenger	385	38.5%
	Private	615	61.5%
Car Age	Below 2000yr	240	24.0%
	2000 - 2006	515	51.5%
	2007 - 2013	205	20.5%
	2014 - 2019	40	4.0%

Cross tabulation

Table 4 shows a cross-tabulation between car engine type, car age and car ownership. The tabulation of the various features was established to inform the researcher concerning what specific features are in which category and their compositions. From the cross-tabulation between engine type and car ownership, 675 (67.5%) were those having petrol engine cars; of this, 505 (74.8%) were private cars and 170 (25.2%) were passenger cars. Of the 325 (32.5%) of the cars having diesel engines 225 (69.2%) were passenger cars and 100 (30.8%) were passenger cars. Of all the 1000 cars sampled, 605 (60.5%) were private and 395 (39.5%) were passenger cars. In the cross-tabulation, majority (505 0r 50.5%) were those who have private cars and use petrol engine type. In all, majority of the private/personally owned cars were petrol engines, while, the majority of commercial cars were diesel engine types.

Table: 4 Cross-tabulation on Engine type, Car age and Car ownership type

		Car ownership type			
		Passenger	Private	*p (sig.)*	Pearson Chi-Square
Engine type	Petrol	170	505	.000	39.604[a]
	Diesel	225	100	.000	37.699
Car age	below 2000yr	40	200	.000	77.600[a]
	2000 - 2006yr	420	95	.000	79.297
	2007 - 2013yr	175	30	.000	53.498
	2014 - 2019yr	40	0	.000	77.600[a]

Table 4 further presents the result obtained concerning car age and car ownership cross-tabulation. It has been shown that majority (420, 81.5%) of the cars were passengers' cars and manufactured within the period 2000 – 2006; this was followed by 200 (83.3%) cars which were private cars and manufactured within a period earlier than the year 2000. Thus, 175 (85.4%) cars were manufactured within the years 2007 – 2013 and were passenger cars. The least number of the cars (30, 14.6%) were private cars manufactured between years 2007 – 2013, while, none of the private cars were manufactured between 2014 and 2019.

Chi-square test

Using the 95 percent confidence level, cross-tabulation analyses were conducted to examine the relationship. The estimated chi-square test statistic in each case was compared with the critical chi-square value to make a judgment on a significant relationship. Tables 4 show the results of the cross-tabulation analysis examining the relationships between car ownership and engine type. Taking into consideration the 5% level of significance and the critical chi-square value of 3.84, the estimated chi-square values of "petrol engines" and "diesel engines", were higher than the critical value indicating that the purpose for which a car is used and engine type is statistically associated and dependent of each other. Therefore, the null hypothesis was rejected. In accordance with previous results, this means that diesel engines are more likely to be used for passenger cars car (Tong et al., 2000) and petrol engine is mostly used for private. This implies that the proportion of cars that use diesel engines is significantly different from the proportion of cars that used petrol engines. This result supports the findings of a previous study (Tong et al., 2000).

Similarly, the results on the relationship between car age and car ownership indicated that the chi-square test statistics were higher than the critical value, suggesting that the purpose for which a vehicle is used depended on the age of the car. Thus, the null hypothesis of independence was rejected. Largely, the age of a car significantly influences the purpose for which a car is used (i.e., private of passenger's car).

Determinants of Exhaust emission levels based on fuel type

The experimental tests were conducted on all the 1000 sampled vehicles in the study. Each sampled vehicle was tested at idle speed. In order to gather the necessary data, the test data were separated into vehicle fuel type usage. The emissions were collected to calculate the mean and standard deviation. The units of the Carbon Monoxide (CO) and Carbon dioxide (CO_2) measurements concentrations were in %. The Nitrogen oxide (NOx) and Hydrocarbons (HCs) measurements concentrations were in parts per million (ppm). The data gathered from the vehicle model year span from 1995 to 2019. As indicated in Table 5 the data showed Carbon dioxide (CO_2) emission composition from petrol fuel type engines had a mean (*M*) of 13.7 with a Standard Deviation (*SD) = 0.531*, while that of the Diesel engine cars was a little lower with a mean (*M) = 12.8* and SD =0.489. This indicated that there is much emission of CO_2 from petrol car engines as compared to diesel cars. From the data gathered, Hydrogen Carbon emission from petrol cars was much higher than that of the diesel cars, the data showed that the average pollutants of HC (*M = 207.99)* for petrol vehicles with a standard deviation of *SD 73.77* while that for diesel cars were 195.28 HC *ppm* for diesel vehicles with a standard deviation of *SD* = 63.11. This data clearly showed that the HC emissions from petrol vehicles were much higher than that of diesel vehicles. In relation to Carbon Monoxide (CO) emissions from Petrol, the average components from all the petrol vehicles showed that the mean (*M) = 1.76 and SD = 1.071* while that of the diesel cars showed a mean of *M* = *0.*9025 and *SD =0.112*. The data was in accordance with Mottossin (2012) who indicated that the level of Carbon Monoxide and Hydrogen carbons tend to be much higher in gasoline or petrol vehicles compared to that of diesel vehicles. In the context of Nitrogen oxide (NO_x) emissions, the vehicles using petrol had a mean (*M) = 0.55* with a standard deviation of *SD =0.543* while in comparison with diesel vehicles showed a value of mean (*M) =0 .65 and SD =0 .424* of NO_x emission for the vehicles. In a comparative analysis, the data proved that the emissions from petrol vehicles were much higher in terms of value than that of the diesel engine vehicles.

Table 5: Descriptive Statistics on Mean, Standard Deviation

Year Model	Emissions	Fuel Type			
		Petrol		Diesel	
		Mean	*Std. Deviation*	*Mean*	*Std. Deviation*
1995 – 2019	CO_2 (%)	13.700	0.531	12.79	.489
	HC (ppm)	207.99	73.77	195.28	63.11
	CO (%)	1.7600	1.071	.9025	.112
	NO_x (ppm)	0.5583	.5426	.6475	.424

The findings were in agreement with Ratcoe and Potsein (2015), that gasoline or petrol vehicle has a high concentration and emission of CO, NO_x CO_2 and HC in the atmosphere compared to that of diesel vehicles, however, diesel vehicles release more air pollutants compared to vehicles powered by other fuel types. These results demonstrate the importance of classifying test vehicles based on fuel type with regard to calculating the amount of air pollution caused by different fuels. Also, as agreed on by Robinson and Mateo (2015), while diesel fuel contains slightly more carbon (2.68kg CO_2/litre) than petrol (2.31kg CO_2/litre), overall CO_2 emissions of a diesel car tend to be lower. On average, this equates to around 200g of CO_2/km for petrol and 120g CO_2/km for diesel. But, as pointed out by Moneoy and Quartey (2015), diesel vehicles produce higher nitrogen oxides (NO_x)

such as toxic nitrogen dioxide (NO_2), nitrous oxide (N_2O) and nitric oxide (NO), which are harmful to humans than petrol vehicles.

Determining the city with the highest emissions thresholds

The Table 6 consist of two categories of emission effect rankings: ANOVA and Regression Analysis. The former had the Mean and SD for the various emission in the cities. From the ANOVA test, there was more emissions coming from Accra which shows an overall average of 36.8 emissions comprising of: CO_2 = 10.212, $p = 0.05$; HC = 135.11, $p = 0.05$; NO_x = 0.412, $p = 0.05$ and CO = 1.511, $p = 0.05$; followed by that of Kumasi with 34.9 and comprised of CO = 9.012, $p = 0.05$; HC = 129.21, $p = 0.05$; NO_x = 1.421, $p = 0.05$ and CO = 0.231, $p = 0.05$. Comparatively between the two cities with the highest emissions generation, vehicles in Accra produced 5.2% more emissions than that of Kumasi. Tema also generated 27.80 emissions comprising CO_2 = 8.521, $p = 0.05$; HC = 101.14, $p = 0.05$; NO_x = 0.192, $p = 0.05$ and CO = 1.351, $p = 0.05$ while Takoradi generated 22.4 emissions, comprising CO_2 = 7.211, $p = 0.05$; HC = 81.18, $p = 0.05$; NO_x = 0.191, $p = 0.05$and CO = 1.121, $p = 0.05$ and Tamale had an emissions generation of 29.4 which was made up of CO_2 = 8.912, $p = 0.05$; HC = 107.12, $p = 0.05$; NO_x = 1.281, $p = 0.05$ and CO = 0.101, $p = 0.05$. Tamale recorded much higher emissions threshold than that of Tema and Takoradi. Few of the reasons extrapolated from the data showed that most of the cars were aged and diesel car composition was also relatively higher. The data shows that Accra has the highest emissions thresholds (the emissions are about 4% higher than all the comparative cities combined). Some studies have shown that growth increases energy consumption and produces a higher level of emissions (Poumanyvong & Kaneko, 2010; Cole & Neumayer, 2004; Zhu et al, 2012). Therefore, this result could be attributed to the fact that Accra has the greater populations and emission is expected to increase.

Print ISSN: 2056-7537(print),
Online ISSN: 2056-7545(online)

Table 6: Emission Thresholds and effects of the emissions in the selected cities.

	CO_2 (%)				HC (ppm)				CO (%)				NO_x (ppm)			
	M	**SD**	***p***	***β***	**M**	**SD**	***p***	***β***	**M**	**SD**	***p***	***β***	**M**	**SD**	***p***	***β***
Accra	10.21	0.711	0.02	0.34	135.11	71.28	0.01	0.28	1.51	1.04	0.03	0.31	0.41	0.21	0.02	0.41
Kumasi	9.01	0.14	0.01	0.49	129.21	72.11	0.02	0.21	1.42	1.32	0.01	0.29	0.23	0.21	0.01	0.36
Tema	8.52	0.28	0.01	0.51	101.14	69.12	0.01	0.34	1.35	1.21	0.01	0.31	0.19	0.10	0.02	0.24
Tamale	8.91	0.41	0.02	0.28	69.12	107.12	0.02	0.29	1.28	0.39	0.02	0.28	0.10	0.21	0.01	0.21
Takoradi	7.21	0.46	0.01	0.31	81.18	49.21	0.01	0.34	1.12	0.43	0.02	0.31	0.19	0.13	0.01	0.26

In this situational analysis, we considered the regression analysis (Bivariate regression) more appropriate to identify the magnitude of impact that each emission has on the overall emissions in their respective city. The values have been conducted to ascertain the p – significant value and effects of the emissions in the various cities.
Cumulatively, CO_2 averagely *$\beta = 0.45$ ($p = 0.01$) had* more impact on the various cities, this was followed by NO_x with an average of *$\beta = 0.39$*. The least emission impact on the cities was HC averagely *$\beta = 0.34$ ($p = 0.01$)*. Specifically, taking into consideration respective cities for analysis, Accra had a higher impact from NO_x *$\beta = 0.41$* meaning cars in the cities produced more NOx during their emission tests, this was followed by CO_2 *$\beta = 0.34$* and that was HC *$\beta = 0.28$.*

Regarding emissions in Kumasi, the city had a much higher impact of emissions from CO_2 *$\beta = 0.49$ ($p = 0.01$)* which proved the test was statistically significant. This was followed by the NO_x with *$\beta = 0.36$ ($p = 0.01$)*, the least among the comparison of the emission of impact on the region was HC *$\beta = 0.21$*.

In relation to emissions in Tema, the highest impact of emission when the vehicles were tested was CO_2 *$\beta = 0.51$ ($p = 0.01$)* followed by HC *$\beta = 0.34$ ($p = 0.01$)*. The least of the emissions in the city of Tema was $NO_x = 0.24$. This showed that CO_2 emission was high in Tema. Considering the city of Tamale, it was ascertained that HC had the highest impact with *Beta = 0.29 ($p = 0.01$)*, this was followed by both CO and CO_2 with *Beta = 0.28* apiece. The least emission was NO_x *$\beta = 0.21$*.

The city of Takoradi had a higher impact of HC pollutants on emissions with *β = 0.34 (p = 0.01)* than any other pollutants. However, this was followed by CO and CO_2 with *β = 0.31 (p = 0.02 and p = 0.01)* respectively. The least of them was HC *β = 0.26 (p=0.01)*. The data clearly showed that each city had higher to lower pollutants when the vehicles were tested for emissions levels.

CONCLUSION AND POLICY IMPLICATIONS

Road transport exhaust emissions are responsible for high levels of atmospheric pollution in urban areas, due to the growing number of vehicles and travelled distances. Exhaust emissions have given rise to concern due to their detrimental effects on human health and the environment. Studies have been conducted to mitigate the increasing greenhouse gas emissions, though the intervention measures suggested are not conclusive and geographical location is a significant determinant. The study on emissions in the Africa continent is scarce and majority of such studies have been conducted in developed countries. Therefore, we examined the determinants of exhaust emission levels based on vehicle engine type, vehicle age and type of fuel used at the city level. Hence, the study serves as a guiding tool for emission regulatory bodies to put measures that will compel vehicle owners to adhere to the emission standard at both regional and country levels.

The study evidenced that vehicles older than the year 2000 have more chances of increasing emission pollution compared to cars newer than 2006. This has been crucial since the emission sensors needed to be replaced at some high number of mileages driven. A vehicle driven for so long tends to have poor emission detection systems thereby increasing the level of emission from the vehicle. It was further revealed that emission of CO_2 HC and CO from petrol engines are much higher in terms of value than the diesel engines. This means that type of fuel internal combustion engines used is a major contributor to exhaust emissions and the emission increases when petrol engines tend to outnumber diesel engines. Besides, untreated fuel contributes excessively to fuel emissions. Moreover, the findings evidenced that vehicles in heavily populated cities in Ghana (i.e., Accra and Kumasi) are more likely to produce more emissions than that in other cities.

Obviously, atmospheric pollution from vehicle emissions cannot be easily managed with a single approach. However, as a means of mitigating the emission growth rate, there should be an advancement of the fuel emission standards. Again, stringent emission legislation and regulation should be enacted by the Ghana Standard Boards in collaboration with the Environmental Protection Agency to compel vehicle owners to embrace more energy-efficient vehicle usage. Government should implement encouragement Acts such as tax rebates for vehicle owners who use environment-friendly cars and fuel. Finally, the use of electromobility public transport and natural gas vehicles could be an effective strategy to reduce emissions and fuel consumption, especially in heavily populated cities. Besides, vehicle owners should be aware of the environmental benefits of using renewable energy and innovative technology to run internal combustion engines to promote a clean environment.

The chassis dynamometer is a significant element in emissions testing. The non-availability of a chassis dynamometer did not permit certain engine parameters during the emission test. The study suggests that future research examine the effect of vehicle heating and cooling systems, and fuel efficiency on exhaust emission. This will go a long way in identifying the key antecedents of exhaust emissions and hence contribute to finding better remedies for mitigating atmospheric pollution.

Acknowledgements
We acknowledge the support of the Ho Technical University, Bolgatanga Technical University and Desert Research Institute, University for Development Studies, Ghana.

Conflict of interest
On behalf of all authors, the corresponding author states that there is no conflict of interest.

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