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RESEARCH PAPER

VEHICULAR EMISSION LEVELS AND RISK ASSOCIATED WITH STREET HAWKERS AND TRAFFIC WARDENS IN SOME SELECTED AREAS OF ACCRA, GHANA

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ABSTRACT
Fleets of vehicles currently plying the roads in urban areas are rising steadily due to many social and economic factors. The contribution of these vehicles to air pollution due to emissions has a detrimental effect, especially on hawkers and traffic wardens who come into contact with these pollutants. Therefore, these emissions must be regulated; however, they must be measured before they can be regulated. This study determined the hazardous risks workers on the street may be exposed to in their work to promote occupational and public health. One hundred and fifty street workers on three main routes in Accra, Achimota- Neoplan, Dzorwulu-N1 and Legon-Shiashie were identified and questionnaires were administered to obtain information for risk assessment on motor vehicle emissions. A study on CO and Hydrocarbon emissions from petrol-based vehicles and opacity emissions from diesel-fueled vehicles were measured using Emission Combi Tester 6.3, Maha-Luxembourg, from vehicles that came for testing at the Drivers and Vehicles License Authority (DVLA) garage. The cars were categorized into two, based on their ages; cars manufactured before and during 1995 (old-aged) and those manufactured after 1995. The mean concentration determined for CO was 2.8% and 1.9%, hydrocarbon was 467 ppm and 215 ppm and the opacity was 49.2% and 27.8% for old aged cars and cars manufactured after 1995, respectively. The study showed that emissions from old-aged cars were generally higher than those manufactured after 1995. The average daily dose was also higher for street vendors than for traffic wardens. The hazard quotient revealed extreme risks for these workers due to exposure to the emissions. Therefore, regulating vehicle emissions and increasing air pollution awareness is crucial.

Keywords: Vehicle, Air Pollution, Workers, Traffic Supervisor

INTRODUCTION

Transport is the forte for local trade and industrialization as it is an integral tool in the economic cycle. For this purpose, the Ghana government seeks innovative ways to maximize the transport sector to promote economic growth (Angnunavuri *et al*., 2019). Vehicles are the most convenient means of transportation for most developing countries as they are readily accessible, affordable and comfortable. The fleet of vehicles increases annually; as of 2015, the number of registered vehicles in the country was 1,952,564, about six times higher than the 342,492 vehicles in 1997 (Sati & Dare, 2022). More cars are being imported into the country due to prosperity, over-population and the poor public transport system, especially in urban areas. Several efforts have been made to preserve, sustain and repair environmental air quality because the transport area is one of the major anthropogenic causes of environmental pollution, especially in developing countries (Ackom, 2016). Vehicular emissions are influenced by driving patterns such as fuel type and quality, traffic congestion, age of vehicles and poor regulations. Contaminated air is the primary cause of human health effects, especially among pregnant women and children (Adeyanju, 2018). To make ends meet, most street vendors in Accra (the capital city of Ghana) spend most of their time daily on the streets. Traffic wardens are frequently present during haste hours in the mornings and evenings. Traffic congestion in Accra is mainly seen during peak hours, i.e., between seven to nine o'clock in the morning and between five to seven o'clock in the evening when workers and students move to and from their homes, respectively. Around this period, the emission level is high, evidently seen with fumes released from exhaust pipes. These sub-groups of workers are more vulnerable because of their occupations, as they are at risk of damages that may occur due to exposure to air pollutants from these emissions (Noomnual & Shendell, 2017). According to Roberto and Leslie (2014), our jobs should not affect our physical, mental, and social welfare. Air pollutants have detrimental effects on human health (Künzli, 2000). Although air pollutants may exist naturally, artificial air pollutants account for a more significant percentage of air pollution. In urban areas, emissions from motor vehicles are regarded as the primary anthropogenic source of atmospheric pollution (Caton, 2018). The pollutants released are mobile; hence, they tend to have a broader scope of distribution, increasing the number of people exposed to these toxic substances (Srivastava & Rao, 2011). These agents emitted are harmful to public health and the environment either by themselves or by compounds formed from chemical interaction with other substances (Ioannis et al., 2020). Effects such as coughing, asthma, congenital disabilities, child mortality, and cardiovascular and respiratory diseases have implications for air pollution. For this reason, assessing the level of compliance of vehicular motor emissions in the country will improve the ambient air quality, especially in urban areas, consequently reducing the risk of the hazards resulting from these pollutants. Because of that, research was undertaken to help curb this menace. The purpose was to evaluate the vehicular emission levels and determine the risk associated with Street Hawkers and Traffic Wardens in some areas of Accra-Ghana. Hence, to determine and compare the levels of Carbon Monoxide (CO) and Hydrocarbon (HC) emissions from petrol cars manufactured in and before 1995 and after 1995, because the former may not have pollution control devices so they may pollute more than vehicles produced in 1995 and beyond. It can be hypothesized that: level of CO emissions of old age vehicles is not higher than the level of CO emissions of the younger cohort or level of CO emissions of old-age vehicles is higher than the level of CO emissions of the younger cohort level of HC emissions of old age vehicles is not higher than the level of HC emissions of the younger cohort or level of HC emissions of old-age vehicles is higher than the level of HC emissions of the younger cohort Finally, the risk associated with street workers who may be exposed to these emissions. This study would help determine the effects of motor vehicle emissions on street workers in the environment. Particularly hawkers and beggars stay in heavy traffic-congested areas to make ends meet for most of their day. It was found that street workers exposed to pollutants in the air due to vehicle emissions had a significantly higher occurrence of respiratory diseases even though the emission levels were lower than the recommended limits (Choudhary & Tarlo, 2014). Also, research conducted by Safo-Adu et al. (2014) concluded that the estimated risk values for Lifetime Lung Cancer for tollbooth workers were far greater than the permissible threshold values given by the World Health Organization (WHO) and the United States Environmental Protection Agency (EPA). This study would help determine the hazardous risks workers on the street may be exposed to in their work to promote occupational and public health. Accra was selected for this study because it is one of the major urban areas in Ghana and the tools for measuring vehicular emissions were available and accessible.

MATERIALS AND METHODS

Study area

Accra is the regional city of the Greater Accra Region and the capital city of Ghana. It spans an area of about 226 km^2 and has an estimated urban population of about 2.6 million as of 2023. For this research, three main routes in Accra were used to assess the risk exposure: high vehicular traffic congestion, high presence of hawkers and traffic wardens. The routes were the Achimota-Neoplan, the Dzorwolu – N1, and the Legon-Shiashie. Dzorwulu-N1, Legon-Shiashie and Achimota lie within the Accra Metropolis, situated at 5°33′N 0°12′W and cover an area of about 71 km^2 (Figure 1). It is inhabited by almost 284,124 people, making it Africa's thirteenth-largest metropolitan district. This district harbours the capital city of Ghana, Accra, which is also the official administrative part of the country. The study area is both occupational and residential. The various routes understudy had traffic lights and intersections.

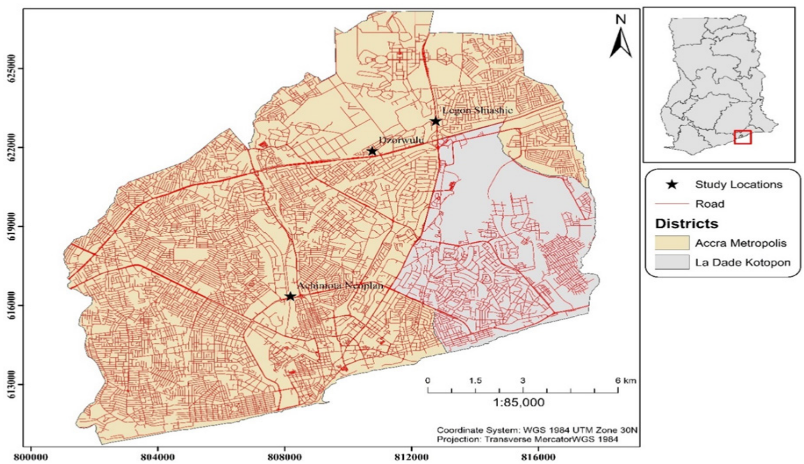

Fig. 1: Map of the study area

Design of research instrument

Data collection

The number of hawkers during the survey was unknown and the number of vehicles that plied the route was averagely over 400 daily. In order to attain the aim and objectives of this work, structured questionnaires were administered to 150 people, 50 from the three routes, to obtain information from some workers to assess the risks associated with their work. Four traffic wardens were present on each route. All Wardens were sampled; however, two complained of respiratory illness and thus could not be used for the estimation.

Because the population of hawkers was unknown; thus, the sample size was derived by computing the number of respondents needed divided by the response rate. 125 respondents were needed because it represented more than 10 % of the total population and also, this number of people could be conveniently sampled in terms of time and money (Table 1.0).

Sample size=(number of respondents needed×100)/(Expected % response rate)=(125×100)/90

138.9=139 subjects

Random and purposive sampling were applied in this research. The survey took two weeks, from 12 to 26 March 2021.

Table 1.0 : Pattern of questionnaire distribution

Occupational Group	Number of Questionnaires to distribute
Traffic Warden	10
Hawkers	140
TOTAL	150

Sample collection

The study focused on vehicles that came for testing at the Driver and Vehicle License Authority (DVLA) garage located at Trade-fair and Labadi. This was the only available testing center with a functional analyzer during the study period. Two hundred cars from the garage were conveniently sampled and used for this study. Based on the fuel types, petrol and diesel, 50 cars manufactured during and before 1995 and 50 cars manufactured after 1995 were used for each type. The experiment was conducted according to established ethical guidelines, and consent was obtained from the participant. The Humanities and Social Sciences (HuSSREC) of Kwame Nkrumah University of Science and Technology approved this research. The study complies with all regulations relating to research, including experimentation on human subjects via interviews.

Analysis

Tests were carried out using the Emission Combi Tester 6.3, Maha-Luxembourg. It was performed using GS ISO 3929:2003 and GS ISO 11614: 2018 as a guide for Carbon monoxide (CO) and Hydrocarbon emissions for petrol-based cars and opacity for diesel-based vehicles.

Quality Control

The tests to determine the errors of the instrument were carried out under rated operating conditions. Before the tests started, the instrument was adjusted according to the routine adjustment procedure described in the manufacturer's operating instructions. After the device had warmed up, the error curve was accordingly determined. The oxygen channel was tested for zero reading and span reading using a reference gas without oxygen (only CO and HC). The reference gases were supplied at the probe at ambient pressure. The observed errors were within the maximum permissible errors on initial verification for each measurement. The air-tightness of the system was checked by performing a leak check as described in the manufacturer's operating instructions. HC residues with the procedure described in the manufacturer's operating instructions were also checked for the activation of the low gas flow device and the low flow lockout by restricting the gas flow supplied to the probe while sampling ambient air was checked. The response time of the channels was also checked.

Precautions for all tests

The following precautionary measures were taken before and during the analysis: calibration was done prior to the tests, the working area was a firm, horizontal surface, the working area was not directly exposed to rain or sunlight, interfering vibration, a corrosive and/or polluted atmosphere which might have influenced the measurement results, or electromagnetic interference that might have influenced measurement results.

Normal Conditioning of Vehicle

Warming Up

Before the test, the engine was made to attain normal thermal conditions, i.e., the temperature reached by the engine and its drive-line after running at least 15 min. under normal urban traffic conditions over a minimum of 5 km. A minimum lubricant temperature of 353 K in the sump or the lubricant reservoir was achieved.

Test conditions

- The vehicle was placed on a substantially horizontal site.
- The sampling probe was inserted at least 300 mm into the exhaust outlet pipe. Where the exhaust pipe shape did not allow such insertion, an exhaust extension pipe was provided.

Determination of carbon monoxide and hydrocarbon emissions for vehicles without exhaust treatment systems

Vehicles manufactured before and during 1995 were assumed to be without exhaust emission treatment systems. Each vehicle was warmed up and the analyzer scale was selected. The vehicle was then left to idle speed. The analyzer was put into measurement mode and the probe was inserted into the exhaust pipe. The minimum and maximum values were selected in not more than 30 s. The mean of the values was calculated.

Determination of carbon monoxide and hydrocarbon emissions for vehicles with exhaust treatment systems

Vehicles manufactured after 1995 were assumed to have exhaust emission treatment systems. Each vehicle was warmed and then an analyzer scale was selected. The vehicle was left to accelerate at idle speed at 2000 min^{-1}. The analyzer was put into measurement mode and the probe was inserted into the exhaust pipe. The minimum and maximum values were selected in not more than 30 s. The mean of the values was calculated.

Determination of opacity

According to the manufacturer's specification, the vehicle was warmed up and then left to accelerated idle speed. The analyzer was put into measurement mode and the probe was inserted into the exhaust pipe. The design was such that under steady-state (SS) operating conditions, the measuring chamber was filled with smoke of uniform opacity, except for fringe effects. The minimum and maximum values were selected in not more than 30 s. The mean of the values was calculated.

Statistical analysis

The normality test on the data was analysed using the Shapiro-Wilk test. Analysis of Variance (ANOVA) XLSTAT 2022 analyzed data at $\alpha = 0.05$. The Duncan test compared means; the difference was considered significant at $p < 0.05$. To determine critical values for comparisons between means.

Human risk assessment

Average daily dose

Based on the exposure level and duration, the risk of these pollutants was calculated to evaluate whether people exposed to the agent are at levels that would harm health. The risk assessment method developed by the United States (US) Environmental Protection Agency (EPA) was used to calculate the potential dose of contaminants from inhalation. The Average Daily Dose (ADD) expressed in mg/kg.day is given by;

$$ADD = Cair \times InhR \times ET \times EF \times ED/BW \times AT \quad (1)$$

Where:

ADD = Average daily dose (mg/kg-day), Cair = Concentration of contaminant in air (mg/m^3), InhR = Inhalation rate (m^3/hour), ET = Exposure time (hours/day), EF = Exposure frequency (days/ year), ED = Exposure duration (years), BW = Body weight (kg), AT = Averaging time (days) (25 years for non-carcinogens, 70 years for carcinogens)

The exposure level was determined separately for each pollutant. The assumptions made for the calculation were that the main source of CO, HC and opacity is automobile emissions, and the exposure route is inhalation. Other exposure routes were not considered, and maximum concentrations of pollutants were used to calculate risk, EF = 231 days and 251 days for traffic wardens and hawkers, respectively (365-(no. of absent days x 52), InhR = 0.7 m^3/hr for adults, 1 % vol =10,000 ppm, 1 mg/m^3 = 0.001 ppm, RfD for CO = 50 mg/m^3 (OSHA, 2009).

Hazard quotient

The Hazard Quotient (HQ) for non-cancer toxic risk was calculated by dividing the average daily dose by a reference dose (RfD) (Man *et al*., 2010) :

$$HQ = ADD/RfD \quad (2)$$

The reference dose (mg/kg/day) estimates the maximum permissible risk on the human population through daily exposure, considering a sensitive group during a lifetime.

Cancer risk, R, is given by:

$$R = CDI \times P \quad (3)$$

where P is the cancer potency of pollutant (µg/m^3)–1 and CDI is the chronic daily intake dose (mg/m^3)

HI ≤ 1 indicated no adverse health effects and HI > 1 indicated likely adverse health effects (Guney *et al*., 2010); Zheng *et al*., 2020).

RESULTS

Sample distribution

One hundred twenty-six (126) questionnaires were analyzed out of the 150 administered. This represented 84% response, with the majority of them being Hawkers. Twenty-four percent (24%) of the targeted population could not respond because they could not take the time to do so. Below in Table 1.1 is the categorized presentation of the questionnaires.

Table 1.1: Sample Distribution concerning occupation

Occupation	Frequency	Percentage (%)
Traffic Wardens	7	5
Hawkers	119	79
Unresponsive Traffic Wardens	3	2
Unresponsive Hawkers	21	14
Total	150	100

Demographic structure

The demographic information obtained included the age, weight, number of work hours and days, symptoms of respiratory and eye diseases and how frequently these symptoms occur for both workers. Of the number that responded, the youngest Traffic warden was twenty-three (23) years while the oldest was forty-three (43) years. Hawkers' ages ranged from seventeen (17) to forty-one (41) years. The weight varied from 63 to 83 kg for traffic wardens and 55 to 108 kg for hawkers. Whereas the traffic wardens spent 4 hours at their job, Hawkers worked between 6 to 8 hours daily. Notwithstanding, traffic wardens were present all days of the week except during their 30 days' annual leave, while most hawkers took a day off weekly and about ten off days on average in a year to rest or travel. All workers agreed to have symptoms of respiratory and eye diseases nevertheless, traffic wardens reported that these symptoms were not regular. The average values/response for the population's characteristics is shown in Table 1.2.

Table 1.2: Demographics of traffic wardens and hawkers

Variable	Traffic warden	Hawker
Age (years) (Mean ± S.D)	31.7±6.5	28.3±6.4
Weight (kg) (Mean ± S.D)	74.1±7.6	73.5±11.9
Duration of work in a day (hours)	4	7
Duration of work in a week (days)	7	6
Leave days (days)	30	10
Respiratory symptoms (coughing, sneezing, running nose)	Yes	Yes
Frequency	No	Yes
Symptoms of eye diseases	Yes	Yes
Frequency of eye diseases	No	Yes

Motor vehicle emissions

Out of the 200 cars (both private and public) measured, the emission levels for the three primary pollutants under study differed. Some recorded higher values for the same year category, whereas others recorded lower levels. For CO emissions, 1.8% was recorded as the least for cars manufactured before and during 1995 (old-aged cars) and 1.2 % for cars produced beyond 1995. Likewise, a percentage of 4.7 and 3.1 were recorded as the highest emission level for both cars, respectively. Hydrocarbon emissions for old cars ranged between 190 and 970 ppm, with cars manufactured beyond 1995 ranging from 130 to 380 ppm. For diesel-fueled vehicles, opacity emissions from vehicles manufactured before 1995 varied between 29 % and 73 %, while cars made after 1995 ranged between 17% and 52%. The average concentration of the different pollutants is shown in Table 1.3.

Table 1.3: Concentration (mean± SD) of CO, HC and Opacity

Pollutant	Vehicles manufactured before 1995	Vehicles manufactured after 1995
CO (%)	2.82± 0.65	1.92± 0.40
HC (ppm)	466.80 ± 164.26	215.20 ± 50.11
Opacity (%)	49.16 ±11.08	27.82 ± 7.79

CO, Hydrocarbons and Opacity emissions from vehicles manufactured in and before 1995 and those produced after 1995 showed a significant difference ($p < 0.05$) between the levels. Similarly, for vehicles manufactured in and before 1995, there were significant differences ($p < 0.05$) between all the emissions. This observation was similar to cars manufactured after 1995 ($p < 0.05$).

Level of compliance

The emission level requirements in GS 1219: 2018 were compared with the emission levels measured for the various pollutants to find the number of vehicles that complied with the Ghana standard. Out of the 50 cars measured for opacity emissions for old-aged cars, only 34 complied, thus giving the lowest compliance percentage at 68. In contrast, hydrocarbon emissions for the same year group and number of vehicles (50) recorded the highest at 96 %. The specific compliance levels as shown in Table 1.4 below.

Table 1.4: Percentage Compliance to GS 1219: 2018 {n=50}[#]

Pollutant	Vehicles manufactured before 1995 (%)	Vehicles manufactured after 1995 (%)
CO	90.00±0.67	94.00±0.86
HC	96.00±2.21	92.00±3.41
Opacity	68.00±0.91	92.00±0.87

[#] {n} is the total number of cars tested for each pollutant)

Estimation of exposure risk

The average daily dose based on the average age, weight, work hours and workdays were calculated for both workers. Hydrocarbon recorded the least exposure level at 0.7 (10^3 mg/kg.day) and 1.1 (10^3 mg/kg.day) for traffic wardens and hawkers, respectively. In comparison, opacity emission showed the highest exposure level at 710.4 (10^3 mg/kg.day) and 1133.6 (10^3 mg/kg.day), as presented in Table 1.5. The hazard quotient was lower for Traffic Wardens relative to Hawkers.

Table 1.5: Risk Exposure Analysis for Traffic Wardens and hawkers

Pollutant	Average Daily Dose (10^3 mg/kg/day)	Hazard Quotient
	Traffic wardens	
CO	40.8	816
HC	0.7	-
Opacity	710.4	-
	Hawkers	
CO	65.0	1300
HC	1.1	-
Opacity	1133.6	-

There was no significant difference between the risks associated with both groups of workers ($p>0.05$).

DISCUSSION

Generally, the emissions for old cars were higher than those produced after 1995. This could result from effective car maintenance, allowing efficient fuel burning in these vehicles. Carbon monoxide (CO) emission was higher for vehicles manufactured during and before 1995 than those manufactured after 1995 after testing at the Drivers and Vehicle License Authority (DVLA) garage. The lower emission level of cars manufactured after 1995 could be due to faultless or perfect emission control devices and lower mileage accumulation than old cars (1995 and before). The percentage compliance of vehicles to the Ghana Standard for Motor Vehicle Emissions limits, GS 1219: 2018, was 90 and 94 for old-aged cars and cars produced after 1995, respectively. However, the mean for both categories was below the respective 3.5% and 2.5% recommended levels per the CO emission requirements provided in the standard. Between the emissions measured for petrol-based cars, CO emissions were higher. Only 10% of CO in the atmosphere is not attributable to emissions from motor vehicles (Pal, 2015). Hydrocarbon (HC) emission was the least recorded during the tests. The mean concentrations for old-aged cars and cars produced after 1995 were 466.80±164.26 ppm and 215.20±50.11 ppm, respectively. The difference in emission levels for the two categories was similar to the trend of CO emission where the level was higher for the old-aged cars; nonetheless, 96% of old-aged cars tested complied with the emission requirements, whereas 92% (4% less) of vehicles manufactured after 1995 were within the specified limits. Opacity emissions for old-aged vehicles were almost twice higher than those measured for vehicles produced after 1995 for diesel-based vehicles. The mean concentrations were 49.16±11.08% and 27.82±7.79%, respectively. Opacity emission was more elevated in old-aged cars than in vehicles manufactured after 1995. Suspended particulate matter is an important emission that usually does not meet standard requirements (Kumar *et al*., 2020). This was evident with opacity emissions from old-aged vehicles recording the lowest level of compliance at 68%. On the other hand, 92% of vehicles produced after 1995 conformed to the requirements The average daily dose (ADD) calculated for the various pollutants was higher because of the high concentrations of emissions measured. The high concentrations resulted from the vehicles' tail-pipe measurements rather than other sources (dust particles, air, and soil) as seen in other studies (Ilyas *et al*., 2010; Essumang *et al*., 2006; Li *et al.,* 2013) to determine the presence of these pollutants. As these pollutants are discharged from the exhaust, they diffuse into the atmosphere and disperse over a large area, reducing their concentration. Nevertheless, hawkers may be positioned in locations where they may be exposed to undiluted pollutants discharged in heavy traffic situations. The ADD (10^3 mg/kg.day) determined was highest for opacity emissions, followed by CO and HC. For Traffic Wardens, the ADD (10^3 mg/kg.day) calculated was 40.8, 0.7 and 710.4 for CO, HC and opacity emissions, respectively. ADD (10^3 mg/kg.day) for hawkers, on the other, was greater; 65, 1.1 and 1133.6 were determined for CO, HC and opacity emissions. Although the concentrations for both groups were the same, the exposure time and exposure frequency differed. Consequently, the ADD indicated that hawkers were more exposed to motor vehicle emissions than traffic wardens. Similarly, HQ calculated for CO emission was lower for traffic wardens than for street hawkers. HQ calculated for traffic wardens and street hawkers were 816 and 1300, respectively. HQs could not be determined for opacity and HC emissions because there is no literature value for Reference Dose (RfD) and cancer potency. With HC in particular, literature has been viewing more into the individual HC compounds such as butane and not the total HC. That notwithstanding, the ADD calculated for these pollutants was high; thus, these levels could be detrimental over time. Research by Kisku *et al*. (2013) showed that street workers developed health effects symptoms such as burning eyes and watery eyes due to motor vehicle discharges. Ojolo *et al.,* (2007) also reported that health implications such as sleepiness from heavy eyes, catarrh, and headaches result from exposure to higher levels of emissions from motor vehicles. Notwithstanding, their responses showed that these signs were not recurrent. This could be due to the shift they take during work, thereby reducing the level of exposure. Response from Hawkers also indicated similar respiratory and eye problem symptoms; however, these signs were frequent, unlike the Traffic Wardens. Research conducted by Amegah and Jaakkola, (2014) also showed a relationship between sellers on the street and lower birth weight of recent babies during pregnancy compared to babies of pregnant mothers who did not work on the streets.

CONCLUSIONS AND FUTURE PERSPECTIVE

The mean concentration of Carbon monoxide (CO) was higher than hydrocarbon (HC) emissions for vehicles that use petrol as fuel. Opacity was measured for diesel-fuelled vehicles and the mean concentration level was the highest for all three types of pollutants. Additionally, for all the motor vehicle emissions measured, vehicles manufactured after 1995 recorded lower levels than those produced before 1995. Old-aged cars showed the lowest compliance level for opacity emission; however, for HC discharges, this category of vehicles showed the highest level of conformity to the limits specified in the Ghana Standard for Motor Vehicle Emissions (GS 1219, 2018). The risk assessment also indicated that street workers were more exposed to these emissions than traffic wardens. Similarly, the former is more vulnerable to likely adverse effects from CO than the latter group of workers. Other methods of measuring only motor vehicle emissions in the environment may be employed in future studies to know the accurate contribution of these emissions to air pollution. Also, measuring the emissions in traffic situations may give a better view of the impact of air pollution and its effects on public health. Next, further studies could examine the individual pollutants, particularly with the total Hydrocarbons, to ascertain exactly what chemical compounds these workers are exposed to. Finally, as the number of vehicles continues to increase and these groups of workers especially do not have much control over where they work, more awareness should be created for them as well as drivers and all citizens to ensure that they take the necessary steps to protect themselves from exposure to these pollutants.

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