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Original Research

Characterization and Quantification of Vehicular Emissions in Abuja Municipality–Implications for Public Health

***Nnenna M Ezeigwe[1], Echendu D Adinma[2,3,4], Efegbidiki L Okobia[5,6], Stephan Schwander[7,8].**

[1]Environment for Health Development Initiative (E4HDI), Abuja, Nigeria. [2]Department of Community Medicine, Nnamdi Azikiwe University Teaching Hospital, Nnewi, Nigeria. [3]Department of Community Medicine and Primary Health Care, Nnamdi Azikiwe University, Awka, Nigeria. [4]Center for Sustainable Development, Nnamdi Azikiwe University, Awka, Nigeria. [5]Nigerian Environmental Society, Abuja, FCT-Nigeria. [6]Lympson Leosentino Ireland, Republic of Ireland. [7]Departments of Environmental and Occupational Health and Justice and Urban-Global Public Health, School of Public Health, Piscataway, NJ 08854, USA.[8]Division of Global Environmental Health, Environmental and Occupational Health Sciences Institute, Rutgers University, Piscataway, NJ 08854, USA.

Abstract

Background: Air pollution from vehicular emission and other sources accounts for over seven million global deaths annually and contributes significantly to environmental degradation, including climate change. Vehicular emission is not prioritized for control in Nigeria, thus undermining public health and the Sustainable Development Goals 3, 11 and 13. This study aims to characterize vehicular emissions in Abuja municipality and quantify exhaust air pollutants of commonly used vehicles.

Methodology: Cross-sectional exhaust emissions study of vehicles in Abuja Municipal Area Council. Information on the type and age, fuel type, purchase and use category of 543 vehicles on routine Annual Road Worthiness Test at the Computerized Test Center, Abuja. Exhaust levels of CO, CO_2 HCHO and PM_{10} were measured using hand-held devices. IBM SPSS version 26.0.0.0 (2019) statistical software.

Results: Toyota brand comprised 52.5% of the vehicles. Over 80% were older than 10 years; 85.5% preowned and 87.3% used for private purposes. PMS was the dominant fuel used (91.1%). Except PM_{10}, older vehicles emitted higher levels of the measured pollutants than newer ones. The differences were significant for CO and HCHO. Diesel-fueled and commercial vehicles also emitted higher levels of CO, HCHO and PM_{10} compared to PMS-fueled and private vehicles respectively.

Conclusions: Strong regulatory policies that discourage over-aged vehicles; speedy adoption of the ECOWAS guidelines on cleaner fuels and emission limits; and coordinated implementation of effective Inspection & Monitoring programme by relevant government agencies are required to safeguard public health and the environment. We also recommend the introduction of vehicles powered by alternative energy, use of bicycles, designation of one-way traffic and pedestrian zones.

Keywords: Air Pollution; Vehicular Emissions; Public Health; Abuja Municipality

Key Message: Reducing the threats to the public's health from vehicular air pollution in Abuja municipality requires strong policy and coordinated monitoring programs for effective control.

***Correspondence:** Nnenna M Ezeigwe, Address E4HDI, Plot 3349 Lualaba Close, Maitama, Abuja, FCT, Nigeria.
E-mail: drninaezeigwe@gmail.com

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Introduction

Vehicular emissions from combustion engines are an important source of air pollution (AP), and a major global health concern that poses threat to human health and the environment.[1,2] AP is responsible for seven million deaths globally every year, mostly from non-communicable diseases.[3,4]

AP occurs when a chemical, physical or biological agent contaminates and modifies the natural atmospheric characteristics of the environment. AP can be indoor (household air pollution, HAP) or outdoor (ambient air pollution, AAP) and results from human activities such as transportation, agriculture, industrial activities and bush burning; as well as natural occurrences like volcanoes, wild fires and dust storms.[4]

Globally, the major air pollutants of concern, representing the US EPA criteria pollutants, include particulate matter (PM) in the size ranges of <2.5µm and <10 µm aerodynamic diameter ($PM_{2.5}$, PM_{10} respectively), ozone (O_3), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and volatile organic compounds (VOC) like formaldehyde (HCHO).[4,5]

A plethora of epidemiological and other studies linking AP to increased burden of communicable and especially non-communicable diseases with varying degrees of certainty[6–11] are supported by experiments that show adverse effects of PM exposure on cell functions, including oxidative stress, ultimately leading to suppression of immune responses in human blood and lung cells.[12–16] These studies show strong evidence of increased incidence, severity or worse outcomes for pulmonary diseases,[10,12,17–20] including drug resistant tuberculosis;[7,8,15,16,21] cardiovascular diseases;[9,13] lung cancer;[4] obesity;[22] cognitive impairment;[23] and psychosocial disorders.[24] The association of exposure to high levels of traffic pollution with increased body mass index (BMI) in children in Southern California[22] raises concern for early onset of NCDs such as cardiovascular diseases, diabetes, musculoskeletal disorders, as well as endometrial, breast and colon cancers.[25]

Emerging evidence from the recent pandemic indicated strong correlation of COVID-19 infection and mortality to AP in some countries,[26,27] which may have prompted the WHO to release the updated Air Quality Guidelines (AQGs)[28] which Nigeria is yet to adapt in September 2019, to reflect the deleterious impact of air pollutants at lower levels than previously thought.[29,30] Earlier in 2018 at the 8th High Level meeting on NCDs, the WHO also designated AP as a major risk factor for NCDs.[31]

Although there is marked paucity of local data in this area, the 2019 global burden of disease (GBD) estimate of DALYs attributed to AAP in Nigeria was 2339/100,000 population.[32] However, in spite of their demonstrated contribution to AP, vehicular emissions are not prioritized for air pollution control, with policy and regulatory emphasis skewed towards mitigating oil pollution.[33] Besides, relevant regulations are old, and previous studies in Nigeria found them ineffective and poorly implemented.[34,35]

Until December 2016, when vehicles older than 15 years were banned, there was no limit to the age of vehicles imported into Nigeria and vehicles emiting large amounts of smoke were a common sight on many roads.[36] Unfortunately, to date, there is no monitoring and inspection (M/I) programme in place to control vehicular emissions in Abuja. The mandatory annual road worthiness test by the Vehicle Inspection Office, a prerequisite for road worthiness certification of all vehicles in Abuja pursuant to the National Road Traffic Regulation, 2012[37], is limited in scope and applies solely on mechanical conditions. Similarly, the National Vehicular Emission Control Programme long promoted by the National Environmental Standards Regulatory and Enforcement Agency (NESREA) has not been implemented. It is also observed that there is no synergy between the two agencies in the conception and implementation of their respective programmes.

Cognisant of the need for more attention to vehicular air pollution, the ECOWAS ministers approved a stringent regional guideline that stipulates timelines for transitioning to cleaner fuels, adopted European Union emission standards, Euro 4 and set age limits for used and light duty vehicles at ten and five-years, respectively[38]. Nigeria is striving to adopt these standards.[39] The ECOWAS guideline together with the WHO AQGs have provided an opportunity for an overdue review of the NESREA Act 2018,which includes the 2011 regulations S.1 No. 20 (Control of Vehicular Emissions).[40]

Pursuant to the Health in All Policy (HiAP) recommended by the WHO for the attainment of the SDGs, vehicular emission has to be monitored and regulated. Therefore, this study aimed to characterize and quantify air pollutants emitted from vehicle exhausts in Abuja municipality.This study may contribute to needed regulatory action for effective control of AP and protection of public health in Nigeria.

Study Design and Measurements

This was a cross-sectional study involving 543 vehicles visiting the Computerized Test Center operated by the Vehicle Inspection Office in Kubwa, Abuja. Approval was obtained from the Department of Road Transport Services, Abuja prior to commencement. We deployed a purposive sampling technique such that every vehicle that came for the mandatory annual road worthiness test between the hours of 10:00 am and 3:00 pm on Tuesdays, Wednesdays and Fridays between 20th August to 6th September 2019 was included in the study. A questionnaire was used to collect information of each vehicle from the driver and vehicle records on type/model, year of production, type of fuel used- diesel or Premium Motor Spirit (PMS), acquired brand new (never been used at the time of purchase) or pre-owned (used by other persons locally or abroad prior to purchase by current user), and use status- commercial or private- prior to measurement of emissions.

To assess CO and CO_2, emissions from each vehicle, we used the HoneyWell handheld Gas Alert MicroClip XL monitor (BW Technologies, MCXL-XWHM-Y-NA, Mexico) and a portable CO_2 Meter (Shenzhen Aermanda Technologies, AZ 7755, Taiwan/China) respectively. For PM_{10} and HCHO we used IGERESS formaldehyde detector (Opustyle Technology Co. Ltd, WP 6930S, Guandong/China). All monitors were employed and calibrated in accordance with the manufacturer’s instructions.

To avoid inter-observer error, the same two research assistants were involved in the assessment throughout the project period, each performing the same task. For each test, the designated personnel drove the vehicle from the parking lot to the testing bay and left it idling while the measurements were done. One person held the devices such that the sensors were within half an inch to the exhaust pipe. This individual read out the gas values while the second person entered the values into the questionnaire.

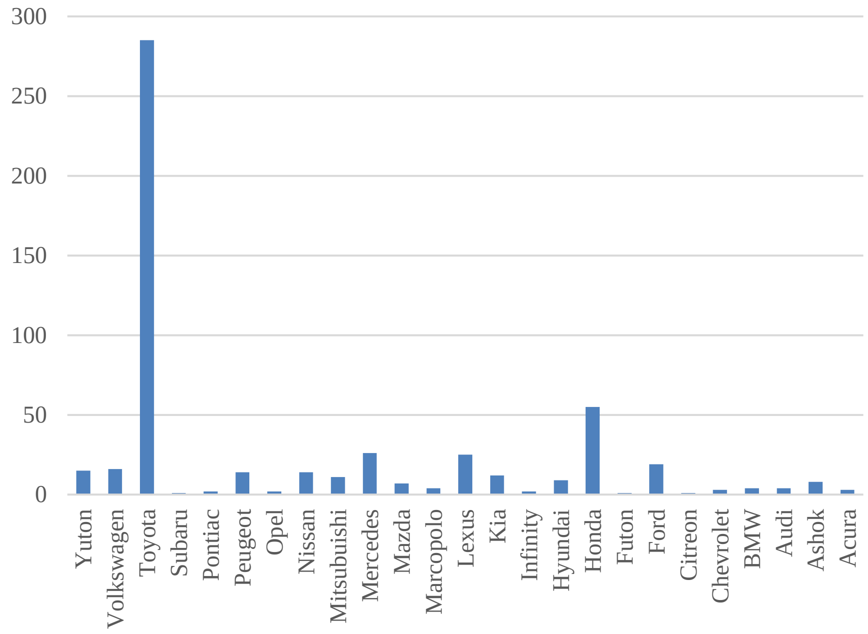
Data collected were analysed using IBM SPSS version 26.0.0.0 (2019) statistical software to obtain descriptive statistical values for the vehicle categories and the mean values for the pollutants. T-Test for comparison of means was done to obtain p values and establish significance or otherwise of the difference in the means of the pollutants for the different vehicle categories. To compare the CO data in our study with the Euro standard, as did Ibeto and Ugwu[41], we converted the mean value 76.95ppm (Table 2) using the authors’ formular: CO (g/Km) = 9.66×10^{-3} x CO (ppm) and obtained an estimated value of 0.74g/Km.

Results

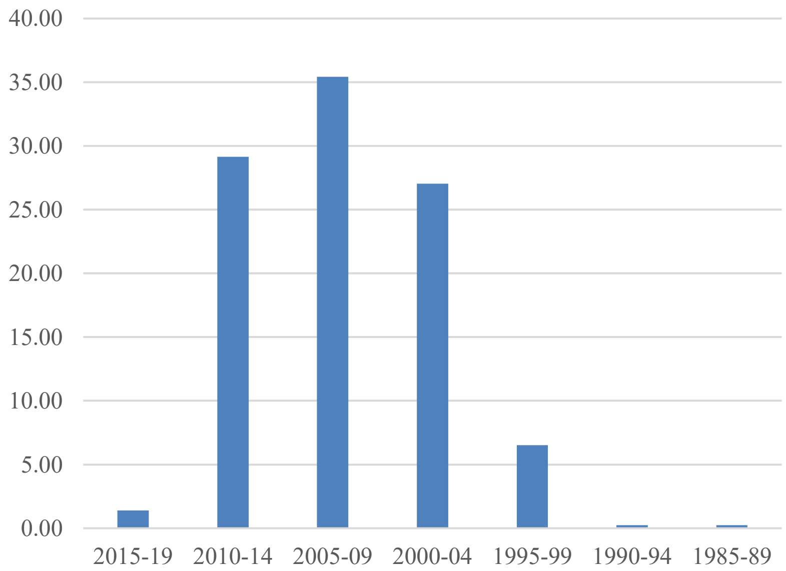
The Toyota brand was the most common vehicle with a count of 285/543, representing 52.5% Honda, Mercedes, Lexus and Ford were also among the top five brands studied. (Figure 1a). Figure 1b shows that most of the vehicles were older than 10 years.

Figure 1. Counts of vehicle by (a) Type and (b) Year of Production

(a)



(b)



The majority of the vehicles (85.5%) were pre-owned (Table 1) and PMS, which accounts for 91.9%, was the dominant fuel. Also, the majority (87.3%) were used for private purposes. The median value and interquartile range for each of the pollutants are shown in Figure 2a-d, while Table 2 and Table 3 shows the Mean Value of pollutants by all the vehicles and the mean values of pollutants by category respectively.

Table 1: *Counts of Vehicles by (a) Status at Purchase; (b) Fuel Type and (c) Use Category*

(a)

Status	Number	Percentage
Old	382	85.5
New	65	14.5
Total	447	100

(b)

Fuel	Number	Percentage
Diesel	44	8.1
PMS	499	91.9
Total	543	100

(c)

Use	Number	Percentage
Commercial	69	12.7
Private	474	87.3
Total	543	100

Table 2: *Mean Value of pollutants by all the vehicles*

	N	Min.	Max.	Mean	SD
CO (ppm)	536	0	391	76.95	80.364
CO2 (ppm)	535	4	5768	1714.28	1064.702
HCHO (mg/m3)	541	0	1.99	0.7218	0.73267
PM10 (ug/m3)	501	2	64	19.75	10.838

Generally, older vehicles emitted more pollutants, except for PM_{10} (Figure 3). This was significant when vehicles manufactured in 1995-1999 were compared with those manufactured in 2005-2009 for CO (p = 0.012; 95% CI: 8.68, 69.05); and HCHO (p<0 .001; 95% CI: 0.28, 0.86). The pattern was maintained when vehicles in 1995-1999 group were compared with the 2010-2014 group, for CO (p = 0.049; 95% CI: 0.19, 69.39) and HCHO (p<0.001; 95% CI: 0.37, 0.96).

Table 3: *Mean Value of pollutants by Category*

		POLLUTANTS			
GROUP	**CATEGORY**	**CO (PPM)**	**CO_2 (PPM)**	**HCHO (mg/m3)**	**PM10 (µg/m^3)**
All Vehicles		76.95	1714.28	0.72	19.75
Type	Toyota	74.17	1687.19	0.7	19.62
	Mercedes	71.12	1717.69	0.69	17.36
	Lexus	44.96	2160.33	0.37	16.46
	Honda	86.8	1988.19	0.82	17.89
	Ford	60.47	1625.21	0.75	24.79
Production Year	1995-1999	105.27	1779.46	1.26	20.21
	2000-2004	77.82	1584.8	0.93	20.32
	2005-2009	64.45	1615.01	0.68	19.23
	2010-2014	70.48	1822.62	0.59	23.06
	2015-2019	76.67	1469.83	0.68	24.83
Purchase Status	New	78	1696.03	0.59	24.29
	Prior-Used	72.44	1699.27	0.79	20.16
Fuel Type	PMS	73.28	1731.98	0.69	19.51
	Diesel	118.98	1516.77	1.09	36.57
Use Category	Private	72.49	1744.64	0.67	19.48
	Commercial	107.66	1509.23	1.08	23.19

Vehicles acquired brand new had lower emission levels for HCHO than those acquired pre-owned (Figure 4c). However, the difference is not significant ($p = 0.053$, *ns*). For PM_{10} (Figure 4d), vehicles purchased as brand new had significantly higher values of emission than preowned vehicles ($p = 0.015$; 95% CI: 0.80, 7.47).When compared by fuel types, all but CO_2 were significantly higher in diesel vehicles, HCHO ($p<0.001$; 95% CI: -0.62, -0.17); CO ($p<0.001$; 95% CI: -70.52, -20.87); PM_{10} ($p<0.001$; 95% CI: -25.03, -9.09) as shown in Figure 5.

Vehicles used for private purposes had lower emissions, except for CO_2, which had higher values for private vehicles. This observation was significant for HCHO ($p<0.001$; 95% CI: -0.60, -0.23); CO ($p = 0.001$; 95% CI: -55.47, -14.89) and PM_{10} ($p = .048$; 95% CI: -7.39, -0.04) (Fig. 6)

Figure 2. Values of pollutants by Type of Vehicle

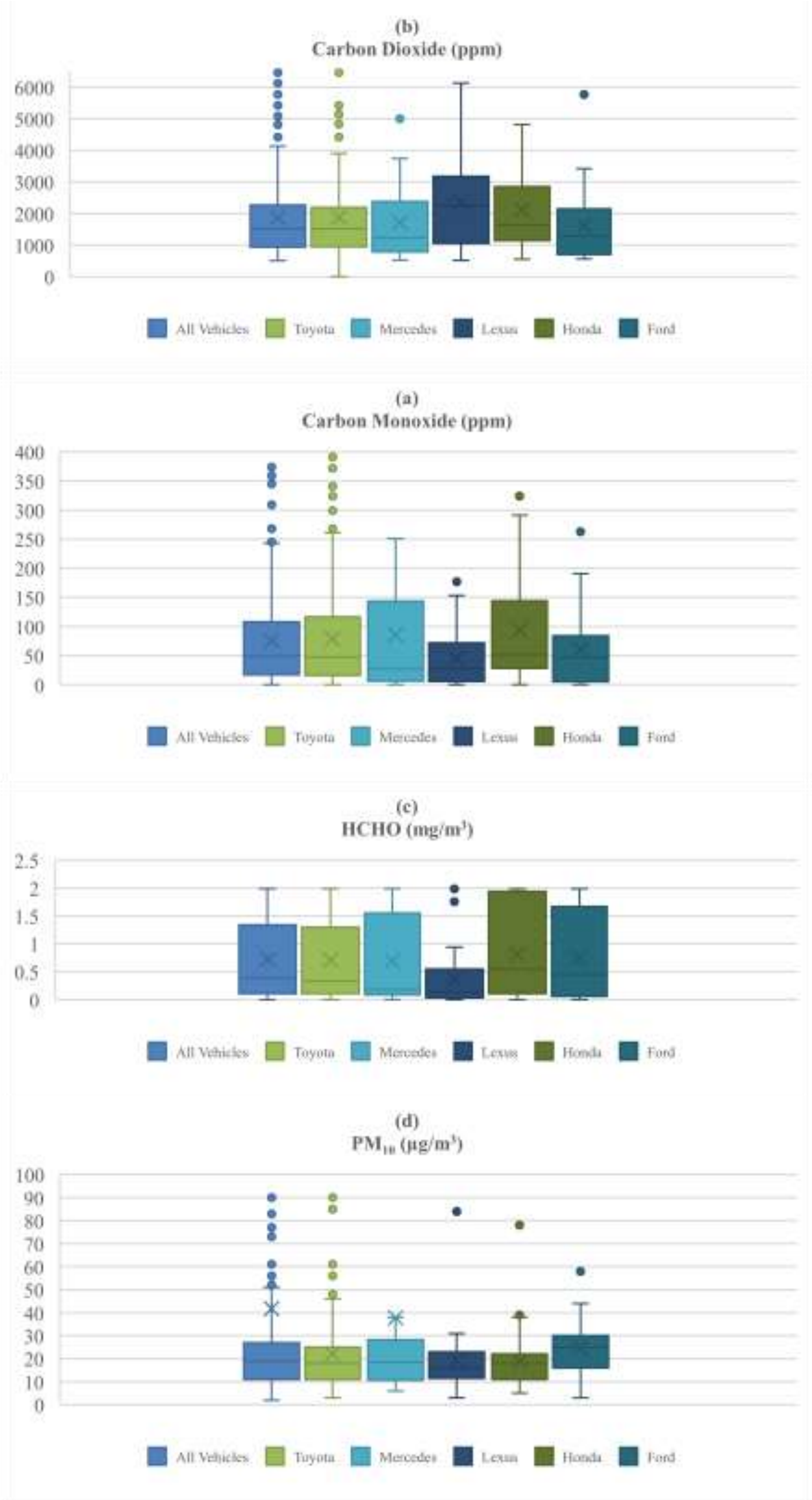


Figure 3. Values of pollutants by Year of Production

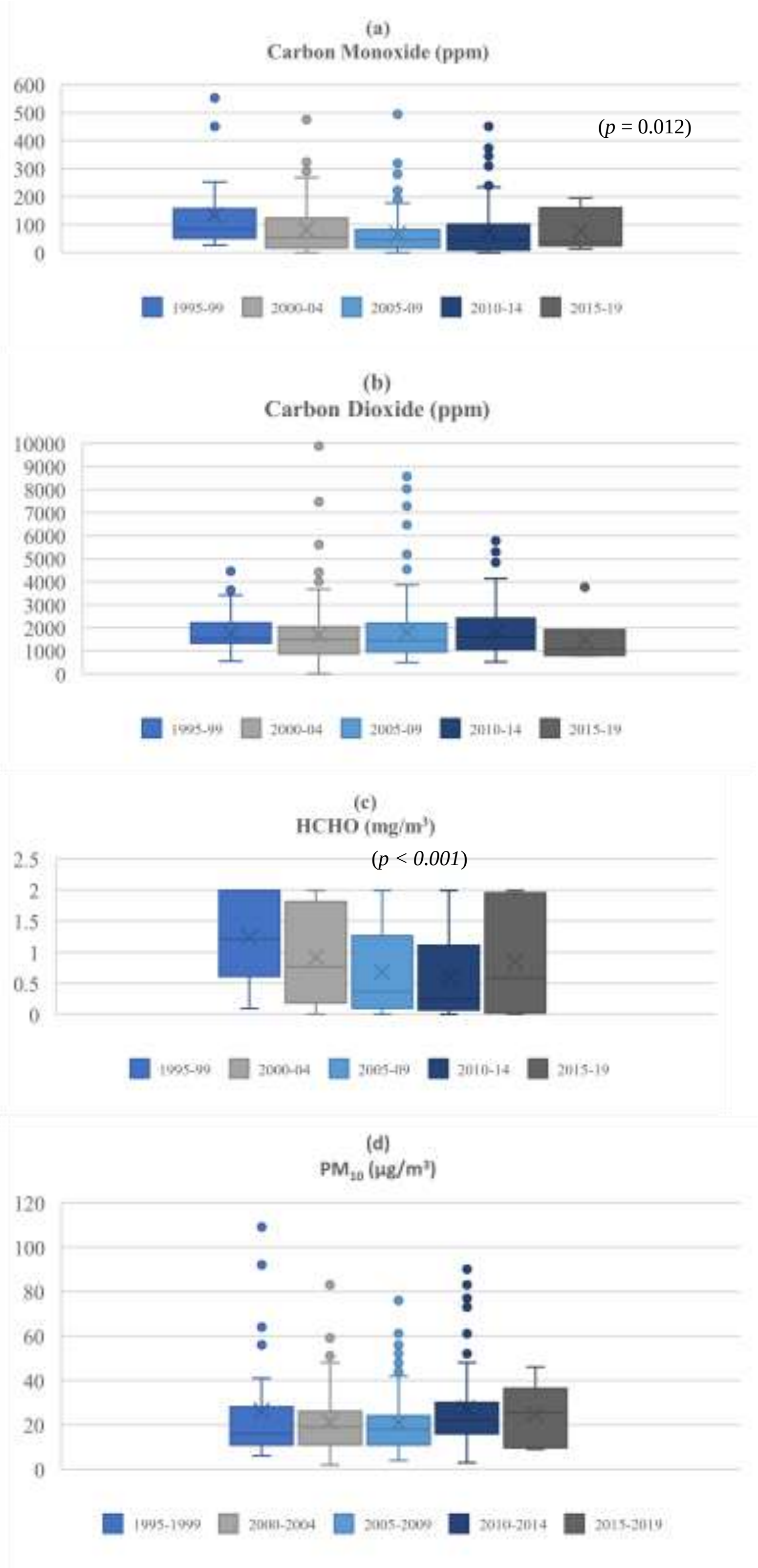


Figure 4. Values of pollutants by Status at Purchase

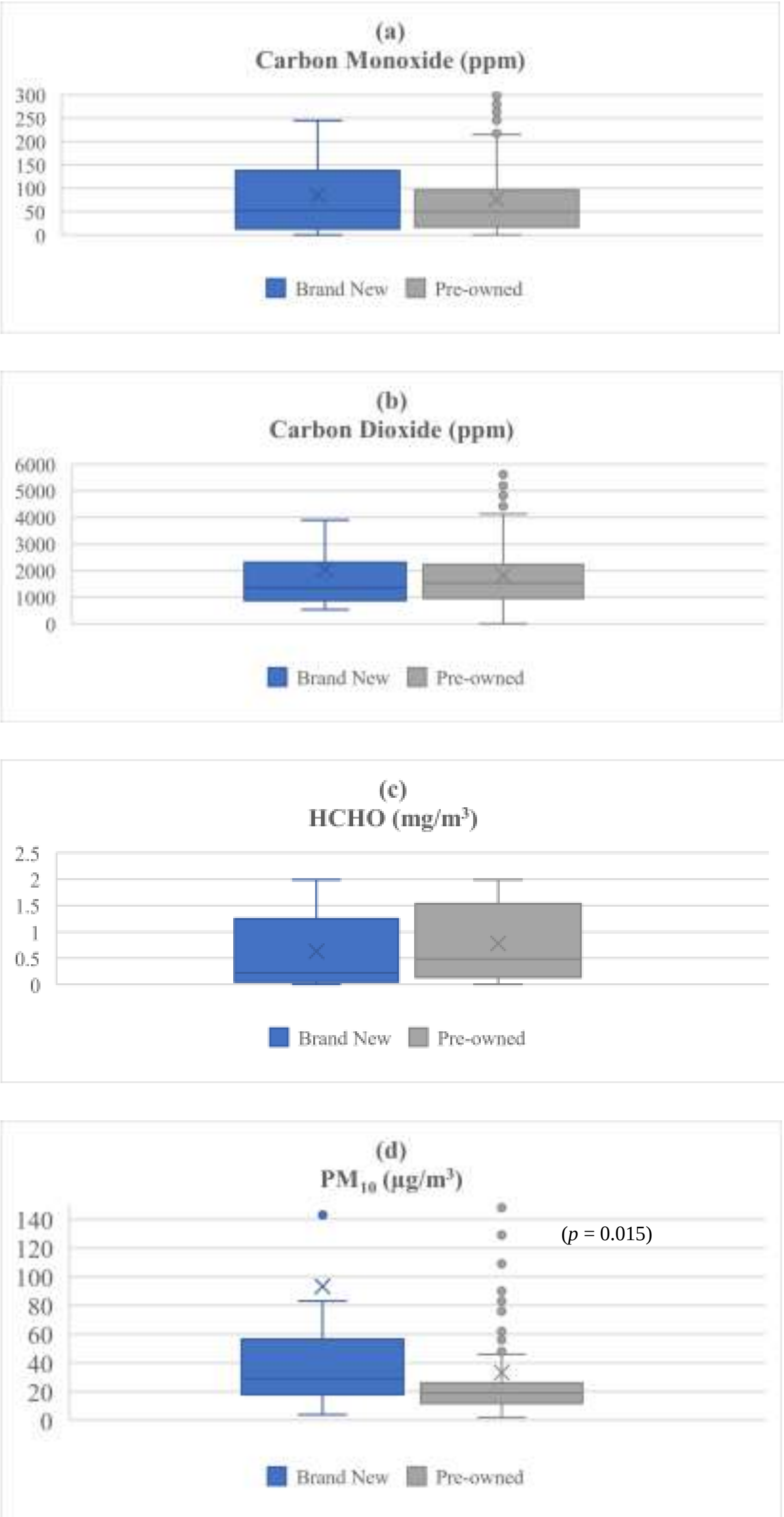


Figure 5. Values of pollutants by Fuel Type

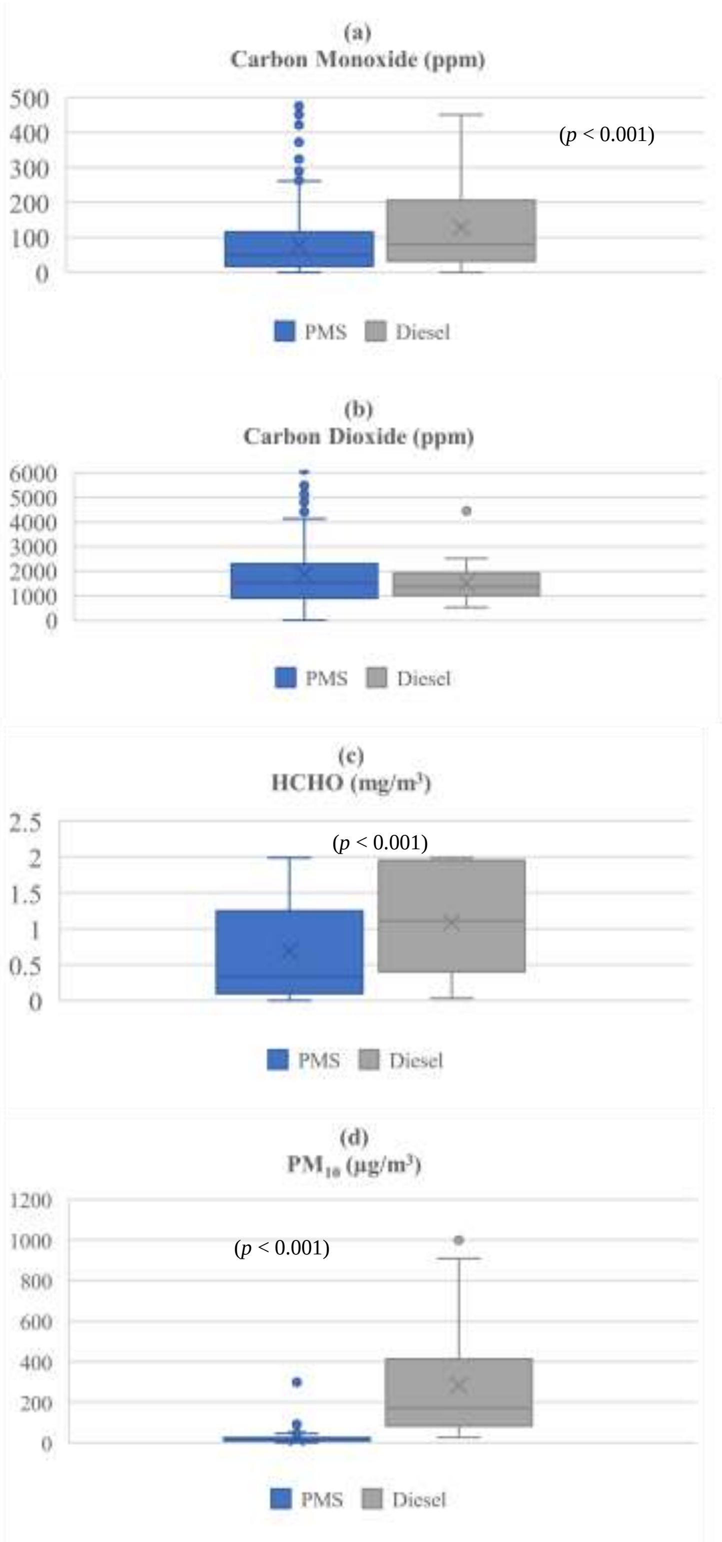
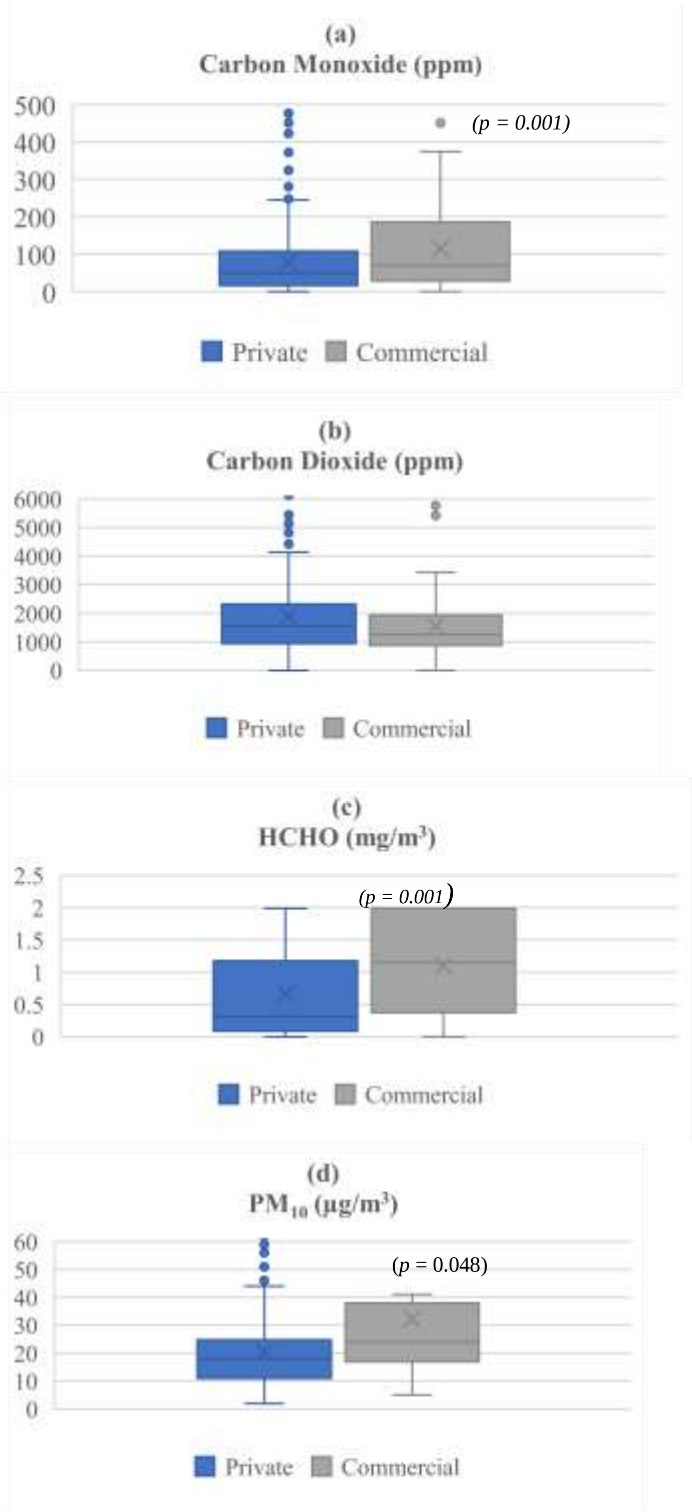


Figure 6. Values of pollutants by Use Category



Discussion

While reiterating the deleterious effects of air pollution on public health, our study tried to quantify and characterize vehicular emissions, and highlight their contribution to air pollution in Abuja municipality, Nigeria. Previous studies have established the significant contribution of vehicular emission to air pollution in Nigeria. However, unlike this study, those studies[18–20,34,42–44] mostly assessed the ambient concentration of pollutants in areas exposed to vehicular traffic and compared this with extant Ambient Air Quality Standards, without direct link to the vehicular factor. However, the determination of the direct emissions from vehicles is more desirable and gaining popularity.[45]

Several factors complicated the evaluation of direct exhaust emissions in this study. For example, the unit of measurement of our handheld devices was ppm which constrained comparability with the Euro standard in g/km.[46] This challenge was highlighted also by Ibeto and Ugwu,[41] who measured direct exhaust emissions with portable combustion analyzers from differently fueled combustion engines in Nsukka, (estimated population, 444,100) and evaluated the values against the Euro 2 standard.

In general, our results align with previous studies in Nigeria and other parts of the world, which identified vehicular emissions as a major source of air pollution in city centers,[18,43,47] with adverse health effects.[18–20] Seventy percent of the vehicles in this study were older than ten years and produced more emissions than newer vehicles, a trend similarly observed in other studies.[46,48–51] Previously, in Lagos, dominance of older vehicles was identified as the greatest obstacle to effective emission reduction.[52]

Further, most of the vehicles studied are acquired as pre-owned with diminished efficiency attributed to accumulated mileage, and deterioration or tampering of the originally fitted emission control devices.[50] pre-owned vehicles, locally known as 'Tokunbo' are commonplace in Nigeria due to the low-income economic environment. In 2012, pre-owned vehicles constituted 75% of all vehicles imported into Nigeria.[53] This is comparable to our study findings that showed that 85.5% of the vehicles were pre-owned, with only 14.5% purchased as new (Table 1a).

As expected, the vehicles purchased as new emitted lower levels of CO_2. Apart from more efficient emission control mechanisms in newer vehicles, owners with higher income who can afford new vehicles also have a better maintenance culture,[48] and mostly use their vehicles for private purposes. Surprisingly, vehicles purchased as new, which, in general, are not as old as the pre-owned vehicles, emitted higher PM_{10} levels. In a similar trend, a previous study showed progressive increase in PM emissions of vehicles between Euro 5 (2009-2011) and Euro 6 (2014) eras before a decline set in.[49] The improvement is attributed to the introduction of catalytic conversion technology in subsequent vehicles.[49,54,55] There is a need for further exploration of this phenomenon given the gravity of adverse health effect of PM.

This study highlighted the influence of fuel type on pollutant emissions. The levels of CO, HCHO and PM_{10} were higher in vehicles using diesel which is corroborated by other studies in which diesel fueled vehicles emitted six to ten times more PM than vehicles using PMS.[56] Similarly, vehicles used for commercial purposes also had higher emission levels for these pollutants (CO, HCHO PM_{10}). Given that the vehicles using diesel are also relatively older and mostly used for commercial purposes, these factors may have contributed to their higher emission ranking.

The proportion of diesel-fueled vehicles, mostly used for commercial purposes in our study, was small (Table 1b). This may be due to the timing of our testing, (10:00 am to 3:00 pm, Mondays, Wednesdays, and Fridays), which was during typical business hours when commercial vehicles are in use. It is likely that owners/operators of these commercial vehicles bring their vehicles for the annual road worthiness test on Saturdays or outside of main business times. This may also explain why most of the vehicles tested (87.3%) were privately owned, whilst 12.7% were for commercial/business functions. The disparity in the proportions of the various vehicle categories in our sample (Figure 1, Table 1) is a limitation in our study. Previous researchers found that most of the pollutants are emitted by a small proportion of vehicles referred to as 'gross or high emitters.[46,50,57,58]

The emissions varied widely as also noted in other emission studies.[46] The mean values of the pollutants are shown in Table 2. These values are not denominated in g/Km of the Euro standard[59] and therefore precluded direct comparison with that benchmark. Of all the pollutants measured, the Euro standard stipulates values for only CO and PM.[41] The estimated value of CO of 0.74g/Km is above the ECOWAS recommended Euro 4 standard of 0.5g/Km for diesel vehicles, and 1g/Km for PMS vehicles.

Epidemiological studies in Nigeria have demonstrated adverse health effects resulting from air pollution exposures. Nwachukwu et al found that pertussis, pulmonary tuberculosis, cerebrospinal meningitis, pneumonia, measles, chronic bronchitis, and upper respiratory tract infection are more prevalent in areas with higher ambient air pollution in Rivers State.[20] In Ibadan, South-West of Nigeria, Ana et al found that proximity to high traffic roadways and other AP sources are associated with asthma and respiratory symptoms.[19] Also in Abuja, Okobia et al found a higher incidence of cancer, respiratory and cardiovascular diseases due to AP.[60]

The social and economic burden of these diseases can be reduced in the medium and long-term if deliberate actions are taken soon to control traffic emissions and AP. The NESREA national vehicular emission control programme and the mandatory annual road worthiness test by the Vehicle Inspection Office are both promising steps in the right direction. However, the continued delay of one program and the non-comprehensiveness of the other undermine their utility.

Conclusion

Strong regulatory policy to drive gradual phase-out, retirement/scrapping of over-aged combustion engine vehicles is needed to protect the public's health and the environment in Abuja and other parts of Nigeria. Policies and guidelines relevant for regulating vehicular emission in Nigeria are dated and poorly enforced with little or no synergy among responsible government agencies. Improved collaboration and coordinated implementation of an updated effective I/M programme by relevant government agencies at national and subnational levels are urgently needed. The adoption of the ECOWAS guidelines on cleaner fuels should be concluded and brought to effect as soon as possible.

Major efforts to improve public transport will be needed in concert with efforts to reduce air pollution from vehicular traffic. This should be a gradual process whereby introduction of vehicles powered by electric and solar energy or compressed natural gas, riding of bicycles, and designation of one-way traffic and pedestrian zones, work in concert to reducing vehicular air pollution.

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