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Air pollution emission inventory along a major traffic route within Ibadan Metropolis, southwestern Nigeria

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Increasing road congestion and high traffic volume is often times an indicator of atmospheric air pollution. Ibadan, being the largest metropolitan city in southwestern Nigeria, experiences steady influx of vehicular movement on daily bases. The situation is made worse as a greater number of these vehicles are old and poorly maintained. This study therefore investigated the likely impact of high traffic volume along a major roadway (the Ojoo-Mokola road) within the Ibadan metropolis on atmospheric air quality. Eight sampling points along a stretch of the roadway were identified for traffic density and air quality monitoring. Data was collected monthly over a period of four months in the morning peak, off peak and evening peak hours. Air quality parameters, carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), hydrogen sulphide (H_2S) and ammonia (NH_3) were measured using handheld Crowcon Triple Plus+ and Crowcon Tetra-Portable Multi-Gas Detectors. The average concentration of CO range between 3.25 and 50.8 ppm with highest concentration observed during the morning and evening peak hours. There was a strong correlation ($p=0.05$) between ambient CO levels and traffic density. Relatively low levels of H_2S, and NH_3 were detected while NO_2 levels were relatively constant (<0.1 ppm). Sulphur dioxide was generally not detected within the study locations. Though this study did not cover the whole city of Ibadan, findings from the eight sampling points suggest that this major stretch of road may altogether not be safe from traffic related problems. There is need for constant monitoring of vehicular emissions to forestall possible air pollution.

Key words: Air quality, vehicular emissions, traffic density, carbon dioxide.

INTRODUCTION

The rising number of cars on major roads is an emerging problem in most developing and developed cities (Baldasano et al., 2003; Schrank and Lomax, 2007; Shiva et al., 2007; Kai and Stuart, 2013; Chao et al., 2014). In most developing cities, rapid urbanization has resulted in uncontrolled growth characterized by poor physical planning, deteriorating environment and increasing vehicular traffic. In such urban environments, traffic emissions are the dominant source of gaseous pollutants, such as NO_X, CO and volatile organic

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compounds (Hellen et al., 2006; Kumar et al., 2011; Pirjola et al., 2012). This has created high levels of traffic-related air pollutants, which have been shown to constitute up to 80-90% of CO emissions. Atmospheric air pollution problems are here and are still rising on many fronts despite consented efforts by government regulatory agencies. The number of motor vehicles globally - excluding motorbikes and three wheelers has significantly increased by a factor of 10 since the 1950's and is now above 600 million (WHO/UNEP, 1992). In addition to this, there is now an estimated 80 million motorcycles (OECD, 1995). Traffic congestion increases vehicular emissions and degrades ambient air quality, and recent studies have shown excess morbidity and mortality for drivers, commuters and individual's a-like living or working near major roadways (Kai and Stuart, 2013). Furthermore, epidemiological studies have demonstrated adverse health effects of short-term and long-term exposure to traffic-related air polution (Kettunen et al., 2007; Su et al., 2008; Jacobs et al., 2010).

Information on air pollution in developing countries and some countries with economies in transition is limited and longer time-series are very rare. In some cases, general trend in air quality can only be estimated on the basis of emission inventories. Data presented in the open literature are seldom up to date and normally concern with specific cities, which may or may not be fully representative. In recent years, many governmental and private institutions from the industrialized countries have acted as consultants to developing countries on air quality investigations, but not all the efforts are reported in open literatures (Fenger et al., 2002). Unconfirmed statistics from the Ibadan city transport authority has shown that there is an average of 150 vehicles and 180 motor cycles to every kilometer of road within the metropolis.

Increasing road congestion and high traffic volume is a fundamental issue in some major roads within Ibadan metropolis. Being the largest metropolitan city in southwestern Nigeria, Ibadan experiences steady influx of vehicular movement on daily bases. The situation is made worse as a great number of these vehicles are old and poorly maintained, and worse still in an environment with ineffective or no transport regulating laws. One such important major road with high flux of traffic is the Mokola-Ojoo route which transverses about 10 km and currently undergoing major road reconstruction works. This research work was therefore, aimed to assess the levels and magnitude of ambient air pollutants on this stretch of major road (hot spot) which was undergoing major reconstruction work in relation to traffic density. Monitoring of traffic density distribution and concentrations of ambient carbon dioxide, nitrogen dioxide, sulphur dioxide, hydrogen sulphide and ammonia was carried out along designated traffic areas on the route. Concentrations of CO_2, SO_2, NO_2, H_2S and NH_4 along the route were also compared with ambient air quality standards. It is hope that this study will help unfold if any, the relationship between traffic density, road reconstruction and ambient air quality. The outcome will therefore be useful for addressing interventions to reduce exposure rates to air pollutants by city dwellers.

MATERIALS AND METHODS

The study area and design

The designated study area is the Ojoo and Mokola road, along Oyo road on the north eastern side of Ibadan city metropolis in Oyo State, southwestern Nigeria (Figure 1). Eight monitoring locations identified along the roadway were selected because they are representative of typical urban commuting routes traversing residential and commercial districts in Ibadan. These locations includes: Ojoo (L-1); Olororo (L-2); Orogun (L-3); University of Ibadan (L-4); Samonda (L-5); Sango (L-6); Premier Hotel road (L-7) and Mokola (L-8). Locations L-1, L-4, L-6 and L-8 were majorly characterized by high human and vehicular traffic, and commercial activities. Major reconstruction work was ongoing on the study route with the construction of a flyover bridge on location L-8 as at the time of this study. Traffic volume monitoring [comprising of articulated vehicles, cars and motorcycles] and data collection on air quality parameters [carbon monoxide (CO), nitrogen dioxides (NO_2), sulphur dioxides (SO_2), hydrogen sulphide (H_2S) and ammonia (NH_3)] were carried out at these active locations. To assess the magnitude of air pollution within the stretch of the road, air quality data was also monitored at night when traffic volume approached zero. Control results showed zero levels of CO, NO_2, SO_2, H_2S and NH_3 at all sample locations. Data collection was carried out on monthly bases between March and June 2013. Each of the months' data was collected twice in the morning (7:00-10:00am), afternoon (12:00-3:00 pm), evening (4:00-7:00pm) and night (12pm-1am).

Data collection

From the eight locations identified, traffic volume of trucks (articulated vehicles), cars (including minibuses) and motorcycles (tricycles and motorbike) were estimated by personal observation (traffic flow per hour). Air quality parameters: carbon monoxide, nitrogen dioxides, sulphur dioxides, hydrogen sulphide and ammonia within these designated locations were instantly measured at 2.4 m above ground level and 2.0 m from the road. Monitoring of these ambient air pollutants were done using a handheld Crowcon Triple Plus+ (Model M07701) and Crowcon Tetra-Portable (Model M07237) multi-gas microprocessors controlled portable gas detectors. The M07701 model was used to measure NO_2 (0-10ppm) and H_2S (0-100ppm) at -10 to 50°C while M07237 was for CO (0-500 ppm), SO_2 (0-10 ppm) and NH_3 (0-100 ppm) at -20 to +55°C. The instruments were synchronized and zero calibrated (by covering the sensor) before the start of each measurements.

Data were subjected to descriptive and explanatory (inferential) statistical analysis. The descriptive statistics included measures variations (dispersion). The inferential statistical tool used to test the hypotheses was the Analysis of Variance (ANOVA) and Pearson's correlation coefficient. Furthermore, a graphical plot was used to express data set relationships.

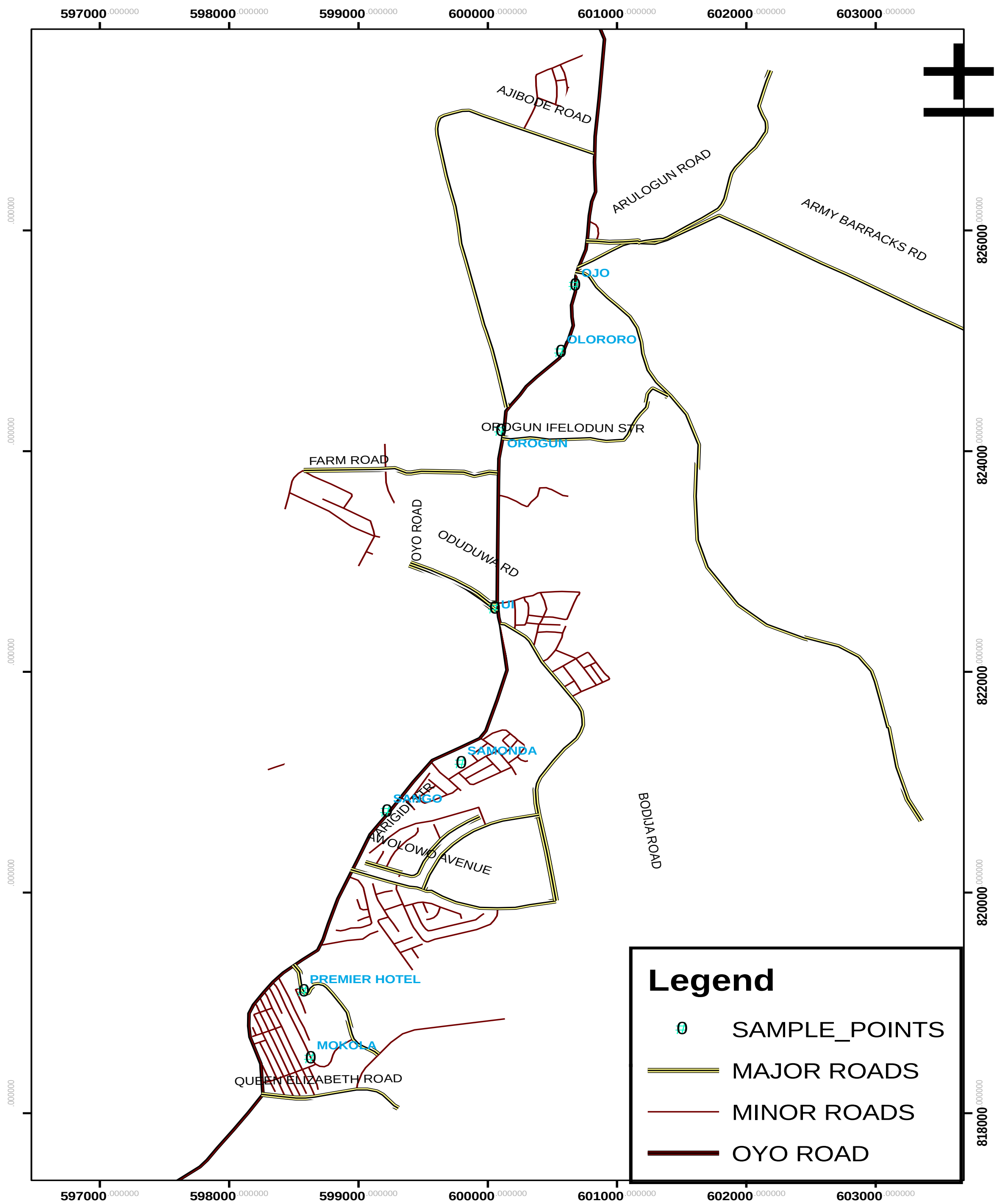

Figure 1. Map showing the study locations.

RESULTS AND DISCUSSION

Carbon monoxide levels

The average traffic volume distribution (Table 1) shows that cars rather than bikes and trucks were more prevalent across the duration of study (cars>bikes>trucks) along the Mokola-Ojo roadway. The total volume of vehicular traffic from all locations which included cars, trucks and bikes was much higher during

Table 1. Average number of vehicles/hour on Ojo-Mokola road.

Sample Code	Morning peak hours				Off peak hours				Evening peak hours			
	Trucks	Cars	Bikes	Total	Trucks	Cars	Bikes	Total	Trucks	Cars	Bikes	Total
L-1	240	2880	1095	4215	95	925	145	1165	180	3150	1185	4515
L-2	135	1725	870	2730	60	530	115	705	165	1965	570	2700
L-3	105	2130	1125	3360	25	636	125	786	135	1475	785	2395
L-4	105	2640	1005	3750	40	1020	135	1195	180	2490	1185	3855
L-5	33	1175	885	2093	22	460	105	587	42	1265	955	2262
L-6	60	3375	945	4380	35	1160	125	1320	75	2790	1200	4065
L-7	15	1785	525	2325	9	675	75	759	30	1075	515	1620
L-8	0	2580	780	3360	0	985	120	1105	0	2595	1455	4050

morning and evening period, hence classified as peak hours. Trucks and bikes were more prevalent during the evening peak hours comparatively to cars in the morning hours. Traffic density was generally high along the Ojoo (L-1), University of Ibadan (L-4), Sango (L-6) and Mokola (L-8) axis of the roadway during the morning, off peak and evening peak hours (Table 1). These current traffic volume are higher than previously reported for in the late 90's (Onianwa, 2001), which could be attributed to the rapid urbanization of the city metropolis over the years. A significant difference (p=0.05) was observed in traffic distribution between the morning, afternoon and evening periods, indicating the cosmopolitan nature of the city.

The average concentration of CO for the selected sampling sites ranged between 3.25 and 50.8 ppm with highest concentration observed during the morning and evening peak hours. As shown in Table 2, the highest average CO concentration was measured at locations, L-1 (27.5-36.3 ppm), L-4 (15.8-50.8 ppm), L-6 (33.8-38.3 ppm) and L-8 (10.5-19.5 ppm). These locations were mostly characterized by high traffic congestion as well as commercial activities with ongoing road reconstruction work. The magnitude of CO emission compared to the control values of zero recorded at night will most likely be attributed to high traffic volume/congestion and ongoing reconstruction work along the stretch of the road. Changes in driving pattern (that is traffic flow and speed) due to traffic congestion result in increased number of speedups, slowdowns, stops and starts, which explains the increase concentration of CO at these locations. Evidence of up to 4-, 3- and 2-fold increases in CO emissions have equally been attributed to high traffic congestion with average speed of 20.9 km/h as compared to uncongested conditions with average speed of 61.2-70.8 km/h (Sjodin et al., 1998; Ntziachristos and Samaras, 2001). The statistical significance of peak and off peak hour measurements were assessed using Levene's *t*-test of homogeneity of variance, and no statistical difference in CO concentration was detected (p>0.238). Similarly, analysis of variance (p>0.05) showed no statistically difference between the morning and evening peak hours and off-peak hour CO concentrations.

The relationship between traffic volume and ambient CO concentration in Figure 2 further indicates a positive trend between CO levels and car density during morning, afternoon and evening hours. Pearson's correlation (Table 3) confirms this with a positive correlation in levels of CO with car density for morning (0.664), afternoon (0.810) and evening (0.905) hours. Prevailing meteorological conditions such as exhaust emissions increase with decreasing ambient temperature and high traffic, quality of vehicles; age, maintenance and fuel type (Faiz et al., 1996; WHO, 2005) could possibly explain the high CO levels during the morning and evening period as observed by the correlation coefficient. There was no significant correlation of CO concentrations with trucks and bikes density during the period of study. Concentrations of CO in locations L-1, L-4, L-6 and L-8 which range between 10.5 and 50.8 ppm mostly exceeded the FMENV allowed daily average limit of 10 ppm (FEPA, 1991). Whereas, only one sixth of the measurement periods (16.7%) had CO levels exceeding the USEPA national ambient air quality standards of 35 ppm for an hourly exposure limit (USEPA, 2011). These observed levels of CO are a result of heavy traffic volume around these locations, since vehicular emissions are major sources of CO levels in the atmosphere. The average daily concentration of CO obtained from high traffic congestion areas (L-1 30.4 ppm; L-4 30.9 ppm; L-6 36.2 ppm and L-8 15.3 ppm) where slightly higher than 11.9 ppm recorded around similar areas in Enugu metropolis (Nwadiogbu et al., 2013) as well as with results obtained for heavy traffic intersections of major roads in Ogbomosho (Ojo and Awokola, 2012).

Nitrogen dioxide and other pollutants

Result shows that SO_2 was not generally detected,

Table 2. Average levels (ppm) of air pollutants.

Sample code	CO			NH_3			H_2S			NO_2		
	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening
L-1	36.3±32.2	27.5±15.5	27.5±15.5	0.2±0.3	0.23±0.5	0	0.50±0.6	0.75±0.5	<1.0	<0.1	<0.1	<0.1
L-2	8.0±4.8	7.25±9.2	4.50±5.3	0.05±0.1	0.08±0.2	0.05±0.1	0.50±0.6	0.75±0.5	<1.0	<0.1	<0.1	<0.1
L-3	4.0±2.3	7.50±6.6	12.8±8.3	0	0.38±0.8	0	0.75±0.5	0.75±0.5	<1.0	<0.1	<0.1	<0.1
L-4	26.0±11.7	15.8±5.8	50.8±5.1	0.26±0.6	0.43±0.5	0.08±0.2	1.00	1.25±0.9	<1.0	<0.1	<0.1	<0.1
L-5	3.75±2.6	3.25±2.5	4.50±4.0	0.23±0.5	0	0	0.75±0.5	1.00	<1.0	<0.1	<0.1	<0.1
L-6	38.3±18.4	36.5±17.1	33.8±14.3	0.23±0.5	0.20±0.3	0.20±0.4	1.00	1.00	<1.0	<0.1	<0.1	<0.1
L-7	12.5±8.1	8.25±5.3	8.75±6.4	0	0.10±0.2	0	0.75±0.5	0.75±0.5	<1.0	<0.1	<0.1	<0.1
L-8	19.5±12.8	10.5±9.7	15.8±7.1	0.05±0.1	0.18±0.4	0.25±0.5	0.75±0.5	1.00	<1.0	<0.1	<0.1	<0.1

SO_2 was not detected.

Table 3. Pearson's correlation coefficient (p=0.05) for CO and traffic volume distributions.

	Morning peak hour	Afternoon off peak hour	Evening peak hour
Trucks	0.428	0.458	0.357
Cars	0.664	0.810	0.905
Bikes	0.583	0.528	0.245

whereas relatively low concentrations of NO_2, H_2S and NH_3 were detected. Ammonia and H_2S range from 0 to 0.38 and 0.50 to 1.0 ppm, respectively. Concentration of NO_2 remained constant throughout the period of study. The result also indicates no significant variation in NH_3 and H_2S concentration during the course of this study for all locations. Concentrations were about the same levels for the morning, afternoon and evening periods. Traffic volume did not reflect so much in the levels of NH_3 and H_2S recorded on the different locations. Since SO_2 was generally not detected on the study area, this confirms that Directive 2003/17/EC on introduce modifications to maximum sulphur content in fuels has proved not only effective but also successful (WHO, 2005). The value of NO_2 less than 0.1 ppm at all locations is within the USEPA national ambient air quality standard of 0.1 ppm for hourly exposure rate (USEPA, 2011). These levels were far less than values of 66.5 to 70.5 ppm NO_2 reported around busy streets in the city center of Helsinki, Finland (Pirjola et al., 2012). The health challenges associated with high concentration of air pollutants are enormous. These results further underscore the immediate need to precisely characterize emissions of primary particles from the fugitive sources such as road and windblown dust. This information is essential in future efforts to reduce the levels of atmospheric pollutants.

Conclusion

This study helps strengthen the fact that road intersections usually account for high traffic density and invariably lead to much higher concentration of air pollutants. At such intersections particularly during peaks hours, cars remain the dominant source of air pollution. The Ojoo, University of Ibadan, Sango and Mokola intersections were mostly associated with high traffic volume and congestions. Concentration of CO was therefore associated with this high vehicular volume during morning and evening peak hours. The increasing severity and duration of traffic congestion have the potential to greatly

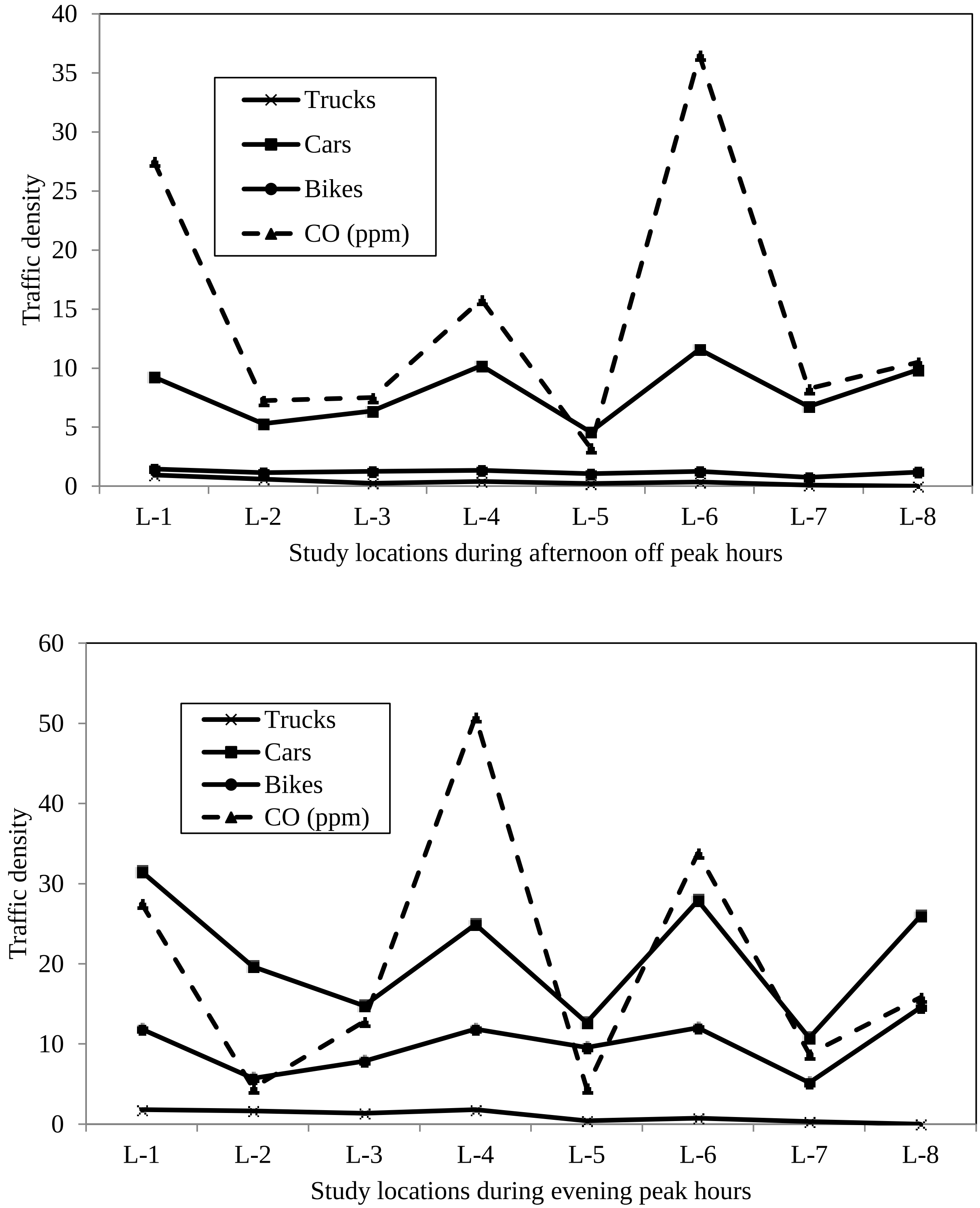

Figure 2. Relationships between traffic volumes ($x10^2$) and atmospheric CO (ppm) levels.

increase pollutant emissions and to degrade air quality, particularly near large roadways. This research, although confined to nodal traffic points on one important roadway suggest that major roads within Ibadan metropolis may not altogether be safe from traffic related pollution threats. Thus, there is the need for concerted efforts to reduce the threat in order to stem possible air pollution episodes in Ibadan. This can be achieved through legislative and economic measures.

Conflict of Interests

The author has not declared any conflict of interests.

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