ENVIRONMENTAL ENGINEERING SCIENCE
Volume 25, Number 6, 2008

DOI: 10.1089/ees.2007.0018

Changing Noise Climate of Ilorin Metropolis

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Abstract

Community noise levels in Ilorin metropolis were measured and analyzed. The noise climate variation was observed to be a function of time due to an increase in population density and other sources of environmental noise. There is increase in the day and night noise levels with growth in population. The noise levels have increased by 2 to 13 dB(A) in the past 20 years in Ilorin metropolis. Statistical analysis shows that the noise level exposure differs significantly from one location to another. High noise levels occur in the daytime at road junctions, followed by commercial centers and passengers loading parks. The noise map developed from this study based on the noise descriptors L_D, L_N, L_{DN}, TNI, and L_{NP} reveals high noise level exposure at the center of the city where commercial activities and clustered buildings with high population density exist. The noise map provides enough information for technical controls and interim legislation against environmental noise pollution in the metropolis.

Key words: noise; community noise; noise descriptors; noise exposure; noise pollution; noise levels

Introduction

THE URBAN ENVIRONMENT has always been an area of high population concentration in Nigeria, mainly because people tend to believe that the only hope of improving their standard of living is to live in an urban environment. The country (Nigeria) has, therefore, witnessed a progressive trend in its urbanization process over the years (Sati, 1998). The boom in Nigeria's economy due to the huge revenue earnings from the oil export during the 1970s stimulated the rapid growth of many urban centers in the country. As a result, the existing road networks could not cope with the increased number of vehicles plying the city and intercity roads (Saadu *et al.*, 1998). Among the implications of a high concentration of people and an increase in the number of vehicles in a limited urban space are excessive pressures on existing facilities and an increase in the environmental noise pollution in the cities (Paddison, 2001).

During the last 30 years, many environmental noise studies have been carried out in urban areas in different countries all over the world (Amando and Jose, 1998). All these investigations have shown that road traffic is the predominant and most generalized noise source in urban areas (Bisio, 1996; Nelson, 1997; Saadu *et al.*, 1998). Braj and Jain (1995) reported the measurements of noise levels in residential, industrial, and commercial areas in the capital city of India, Delhi, that commercial areas have the highest noise levels, followed by industrial and residential areas.

Existing evidence indicating that noise pollution may have negative impacts on human health has justified research to provide a better understanding of noise pollution problems and control (Georgiadou *et al.*, 2004). Noise pollution has been stated as a serious health hazard, with noise-related damage to humans ranging from annoyance to difficulty in falling asleep and high blood pressure (Saadu *et al.*, 1998; Schwela and Zali, 1999; Ahmad *et al.*, 2006).

In comparison with other pollutants, the control of environmental noise has been hampered by insufficient knowledge of its effects on humans and of dose–response relationships, as well as by a lack of sufficient data, especially in developing countries like Nigeria (Schwela and Zali, 1999). The effects of noise in developing countries are just as widespread as in developed countries, and the long-term consequences for health are the same. Practical actions to limit and control the exposure to environmental noise are therefore essential.

Noting the impact and effects of environmental noise pollution in urban areas, management and reduction of urban

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noise has been called for in urban development plans. The noise climate assessment and management of environmental noise requires the drawing of noise maps of communities with more than 100,000 inhabitants and of areas near the major transport infrastructures for the assessment of noise outdoors (Coelho and Alarco, 2006).

The noise pollution situation in Ilorin metropolis is similar to that in many urban areas. The city is relatively large, having a rapid increase in population growth rate. The population has increased from 423,340 in 1980 to 902,131 in 2006 (National Population Commission, 2006). The city has expanding continuously in all directions in the past 2 decades. Many significant changes have been experienced in terms of urbanization, industrialization, expansion of road network, and infrastructure. The city has been subjected to persistent in road traffic and commercial activities due to overall increase in prosperity, fast development, and expansion of economy. Very few studies have been carried out to investigate and assess noise pollution in Ilorin metropolis. Saadu (1988), carried out research on community and occupational noise survey and analysis in the city of Ilorin. Many recent survey changes in the demography and urban boundaries of the city have taken place, and consequently, further investigation of this phenomenon is needed.

The objectives of this paper are (1) to evaluate the environmental noise pollution of Ilorin metropolis, (2) to investigate the climatic noise variation of Ilorin metropolis with an increase in population density and commercial activities through comparison of past results with the recent data on noise measured in the metropolis, and (3) to develop a noise map for Ilorin metropolis.

Materials and Methods

Study area

This research is based on the results of outdoor sound level measurements carried out in July 2005 at 42 different locations (12 commercial centers, 12 road junctions, and busy roads, 6 passengers loading parks, 6 high-density areas, and 6 low-density areas) in Ilorin metropolis, the capital city of Kwara State. Table 1 shows the locations selected for the noise level measurements in Ilorin metropolis. Figure 1 is an overview of Ilorin metropolis showing the locations of noise measurements for this study.

Experimental Procedure

Instrumentation for the field measurements consisted of a precision-grade sound-level meter (according to IEC 651, ANSI S1.4 type), .05-in. condenser microphone and .33-octave filter with frequency range and measuring level range of 31.5 Hz–8 kHz and 35–130 dB, respectively. The instruments were calibrated by the internal sound-level calibrator before making measurements at each site. All the instruments comply with IEC standards. The measurements were made at street level (at road junctions, market centres, passengers loading parks, and residential areas). The instrument was held comfortably in hand with the microphone pointed at the suspected noise source at a distance not less than 1 m away from any reflecting object. L_{Ai} (A-weighted instantaneous sound pressure level) measurements were recorded at intervals of 30 s for a period of 30 min, giving 60-meter readings per sampling location. This procedure was carried out for morning (7:30–8:00 a.m), afternoon (1:00–1:30 p.m),

Table 1. Locations Selected for the Noise Level Measurements in Ilorin Metropolis

Designation no.	*Location*	*Designation no.*	*Location*
1	Ita-Alamu	22	Ita-Amodu
2	Offa Garage	23	Taiwo Road
3	Gaa-Akanbi	24	Agbooba Junction
4	GRA	25	Baboko Garage
5	Tanke	26	Agaka
6	Basin	27	Oja-Titun
7	Jebba Road	28	Kuntu
8	Maraba	29	Unilorin Junction
9	Yoruba Road	30	Adewole
10	Challenge Junction	31	Sawmill-Garage
11	Railway Station	32	Asa Dam Road
12	Unity Road	33	Geri Alimi
13	Niger	34	Airport
14	Ago Market	35	Adeta
15	Emir's Road	36	Pakata
16	Opo Malu	37	Oloje
17	Ipata Market	38	Okelele
18	Oja-Gboro	39	Shao Garage
19	Gambari	40	Sobi Road
20	Oja-Oba	41	General Hospital Round-about
21	Gegele	42	Balogun Fulani

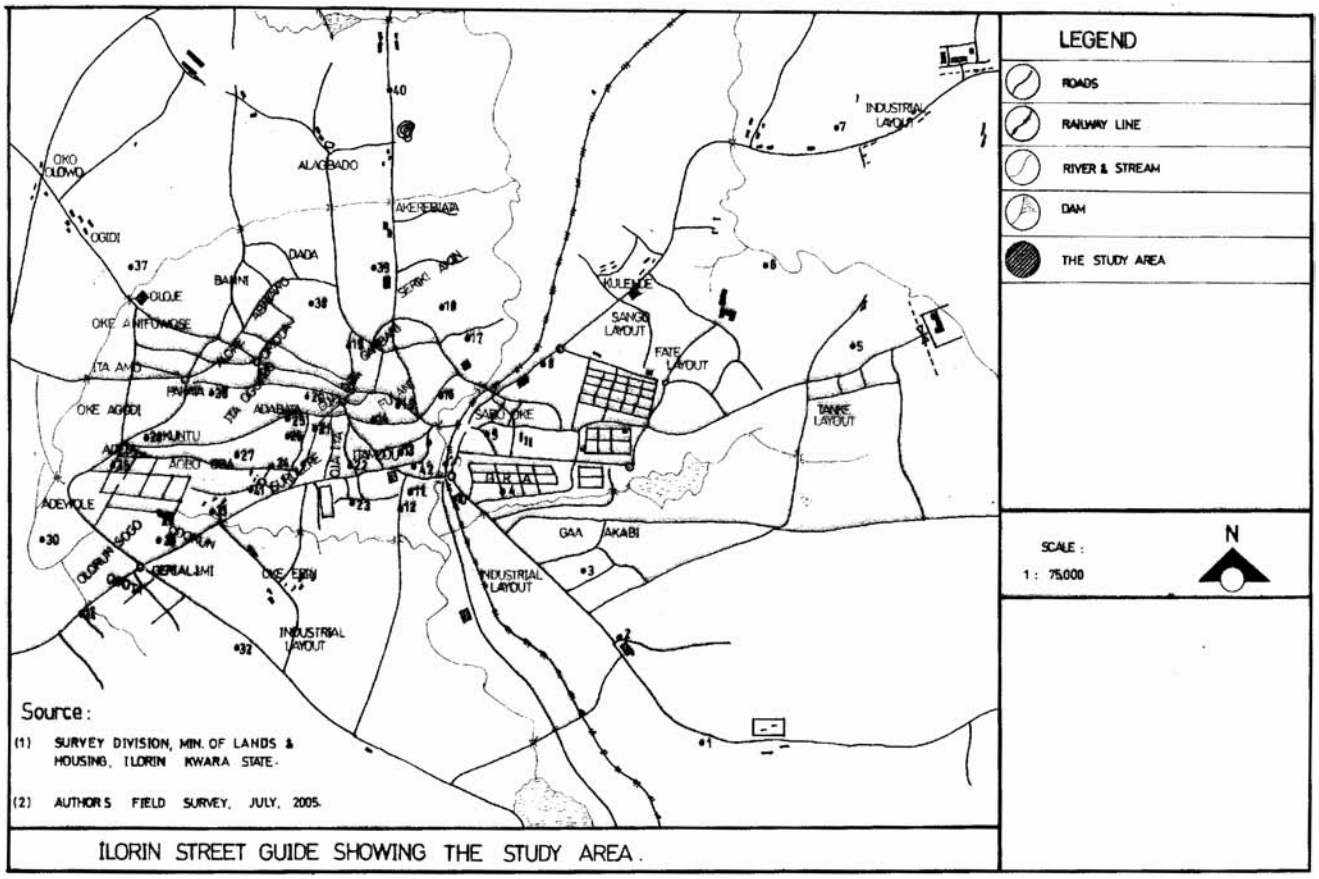

FIG. 1. Overview of Ilorin metropolis showing the locations of noise measurements throughout this study (source: Survey Division, Min. of Lands & Housing, Ilorin, Kwara State).

evening (4:00–4:30 p.m) and night (8:30–9:00 p.m) measurements. From these readings, commonly used community noise assessment quantities like the exceedence percentiles L_{10}, and L_{90}, the A-weighted equivalent sound pressure level, L_{Aeq}, the daytime average sound level, L_D, the day–night average sound level, L_{DN}, the noise pollution level, L_{NP}, and the traffic noise index, TNI were computed. These noise measures are defined as follows (Saadu *et al.*, 1998):

$$L_{Aeq} = 10 \log_{10}\left[\frac{1}{N}\sum_{i=1}^{N}\left(\text{anti log}\ \frac{L_{AI}}{10}\right)n_i\right] \quad (1)$$

$$L_D = 10 \log_{10}\left[\frac{1}{2}\left(\text{anti log}\ \frac{L_{AeqM}}{10} + \text{anti log}\ \frac{L_{AeqA}}{10}\right)\right] \quad (2)$$

$$L_{DN} = 10 \log_{10}\left[\frac{1}{24}\left(15 \times \text{anti log}\ \frac{L_D}{10} + 9 \times \text{anti log}\ \frac{L_N + 10}{10}\right)\right] \quad (3)$$

$$L_N = 10 \log_{10}\left[\frac{1}{2}\left(\text{anti log}\frac{L_{AeqE}}{10} + \text{anti log}\ \frac{L_{AeqN}}{10}\right)\right] \quad (4)$$

$$L_{NP} = L_{Aeq} + (L_{10} - L_{90}) \quad (5)$$

$$\text{TNI} = 4(L_{10} - L_{90}) + (L_{90} - 30) \quad (6)$$

where L_{Ai} is the ith A-weighted sound pressure level reading dB, N is the total number of readings, L_{Aeq} is the A-weighted equivalent sound pressure level, L_{AeqM} is the equivalent sound pressure for the morning measurement, $L_{AeqA}$is the equivalent sound pressure level for the afternoon measurement, L_{AeqE} is the equivalent sound pressure level for the evening measurement, L_{AeqN} is the equivalent sound pressure level for the night measurement, L_N is the nighttime noise level, L_D is the daytime noise level, L_{10} is the noise level exceeded 10% of the time, L_{90} is the noise level exceeded 90% of the time, L_{NP} is the noise pollution level, L_{DN} is the day–night noise level, TNI is the traffic noise index.

Results

Commercial centers noise levels

Due to an increase in urban migration in Nigeria, most Commercial centers (i.e., market areas and shopping centers) have increased in number and size. Every day, a large number of people troop in either on legs or with vehicles into these centers for commercial activities. As a result of this, the commercial centers in Nigeria cities are noted for as the busiest and noisiest places. In the process of carrying out commercial activities through human conversation with mouths or public address systems noise is generated. Other basic sources of noise in commercial centers include noise from generators, pepper grinding machines, radio player, beating of drums (for advertisement), blaring horns, loudspeakers (from religious worship centers located around the commercial centers), just to mention a

TABLE 2. COMMERCIAL CENTERS NOISE LEVELS

Site	Period of the day	Noise level descriptors (dB (A))							
		L_{Aeq}	L_{10}	L_{90}	TNI	L_{NP}	L_D	L_N	L_{DN}
Oja-Oba Market	Morning	82	87	71	105	98			
	Afternoon	84	88	74	100	98	83		
	Evening	85	89	78	92	96			
	Night	76	81	67	93	90		83	89
Oja-Ago Market	Morning	69	73	62	76	80			
	Afternoon	71	75	66	72	80	70		
	Evening	78	82	71	85	89			
	Night	66	66	53	75	79		75	81
Oloje Market	Morning	76	81	65	—	92			
	Afternoon	72	76	65	—	83	74		
	Evening	71	74	66	—	79			
	Night	59	62	53	—	68		68	76
Oja-Titun Market	Morning	68	71	59	77	80			
	Afternoon	76	79	63	97	92	74		
	Evening	74	77	62	92	89			
	Night	51	54	43	57	62		71	78
Ipata Market	Morning	73	78	64	90	87			
	Afternoon	74	79	64	94	89	74		
	Evening	66	72	57	87	81			
	Night	72	56	40	74	88		69	77
Oja-Gboro Market	Morning	78	71	59	77	80			
	Afternoon	75	79	63	97	92	72		
	Evening	76	77	62	92	89			
	Night	76	54	43	57	62		76	83
Gegele Market	Morning	77	80	63	101	94			
	Afternoon	80	84	66	108	98	79		
	Evening	84	87	75	93	96			
	Night	69	74	60	86	83		81	87
Gambari Market	Morning	79	81	68	90	92			
	Afternoon	86	90	77	99	99	84		
	Evening	83	86	73	95	96			
	Night	74	73	66	64	81		81	88
Agaka Shopping Center	Morning	78	80	70	80	88			
	Afternoon	83	86	76	86	93	81		
	Evening	82	84	75	81	91			
	Night	75	76	63	85	88		80	87
Yoruba Road Shopping Center	Morning	47	60	51	—	56			
	Afternoon	68	70	60	—	78	65		
	Evening	69	74	59	—	84			
	Night	47	50	43	—	54		66	72
Station Shopping Center	Morning	78	80	73	71	85			
	Afternoon	75	79	69	79	85	77		
	Evening	76	78	73	63	81			
	Night	72	74	66	68	80		75	81
Taiwo Road Shopping Center	Morning	66	69	59	69	76			
	Afternoon	75	79	69	79	75	73		
	Evening	74	74	65	71	86			
	Night	69	73	61	79	81		72	79
Mean Shopping Center	Morning	73	76	64		84			
	Afternoon	77	80	68		89	76	75	82
	Evening	77	80	68		88			
	Night	67	66	55		76			

few. All these contribute greatly to environmental noise pollution.

Table 2 shows the computed values of the noise levels descriptors for the commercial centers in the city surveyed. A glance through Table 1 shows that, the daytime noise level, L_D ranges from 65 dB(A) to 84 dB(A). The nighttime noise level, L_N, ranges from 66 dB(A) to 83 dB(A).

Among the factors responsible for differences in noise levels in the centers surveyed include location site and presence of sources of intrusive noise. The high day and night noise levels at the Gambari Shopping center is due to closeness to the main road. Therefore, apart from noise due to commercial activities there is traffic noise from vehicle horns, engines, and traffic volume. In addition to these, noise from loudspeakers

TABLE 3. TRAFFIC NOISE LEVELS AT MAJOR ROAD JUNCTIONS AND BUSY ROADS

		Noise level descriptors (dB (A))							
Site	*Period of the day*	L_{Aeq}	L_{10}	L_{90}	*TNI*	L_{NP}	L_D	L_N	L_{DN}
Challenge	Morning	89	94	75	121	108			
Junction	Afternoon	88	93	74	120	107	89		
	Evening	86	94	74	124	106			
	Night	81	87	65	123	103		84	92
Ita-Amodu	Morning	77	81	72	78	86			
Junction	Afternoon	81	86	71	101	96	79		
	Evening	81	84	72	90	93			
	Night	76	80	70	80	86		79	85
Unilorin mini-	Morning	70	75	63	81	82			
Campus	Afternoon	72	77	63	89	86	71		
roundabout	Evening	72	78	60	102	90			
	Night	69	71	60	74	80		71	77
General Hospital	Morning	74	79	69	79	84			
Junction	Afternoon	77	82	69	91	90	76		
	Evening	77	81	70	84	88			
	Night	76	80	62	102	94		77	83
Agbooba	Morning	78	81	71	81	88			
Surulere	Afternoon	77	80	73	71	84	78		
Junction	Evening	81	85	71	97	95			
	Night	77	81	71	87	86		79	85
Unity Road	Morning	78	81	72	78	87			
	Afternoon	78	83	73	83	88	78		
	Evening	78	82	73	79	87			
	Night	77	76	66	76	87		77	84
Emir's Road	Morning	80	82	71	85	91			
	Afternoon	85	89	71	113	103	83		
	Evening	87	92	70	128	109			
	Night	82	86	64	122	104		85	91
Asa Dam Road	Morning	72	77	64	86	85			
	Afternoon	75	76	65	89	86	74		
	Evening	74	77	66	80	85			
	Night	73	64	49	79	88		74	80
Sobi Road	Morning	81	84	71	93	94			
	Afternoon	81	83	71	89	93	81		
	Evening	85	88	74	100	99			
	Night	76	77	63	89	90		83	89
Pakata Road	Morning	74	77	68	74	83			
	Afternoon	75	79	63	97	91	75		
	Evening	75	80	66	92	89			
	Night	74	73	52	106	95		75	81
Jebba Road	Morning	72	76	54	112	94			
	Afternoon	75	78	53	123	100	73		
	Evening	69	74	58	116	93			
	Night	68	72	46	120	94		68	75
Adeta	Morning	73	75	68	66	80			
Junction	Afternoon	72	73	59	85	86	73		
	Evening	70	74	64	74	80			
	Night	74	79	55	121	98		72	79
Mean	Morning	77	80	68		89			
	Afternoon	78	82	67		93	78		
	Evening	78	82	69		93			
	Night	75	77	60		92		77	83

in a mosque located within the vicinity constitutes an intrusive noise at the time of prayer. At the Oja-Oba market, the same factors are responsible for high day and night noise levels. The Yoruba Road Shopping center is located in a secluded area (far from the main road) within a residential area. The major sources of noise are human conversation and noise from a radio player at the nucleus of the shopping center. Hence, the day and night noise levels recorded are very low in comparison with that of other commercial centers.

Traffic noise at major road junctions and busy roads

Many Nigerians living in urban centers are exposed to intracity road traffic noise every day, the most affected being the traders, commercial vehicle drivers, traffic wardens and police men, and school children having their schools close to the main road. This group may be exposed to day noise levels in excess of 75 dB(A). Similarly, the residents living close to the main road junctions or busy roads may be exposed to night noise levels in excess of 75 dB(A). The noise level descriptors for some selected major road junctions and busy roads in the city surveyed are shown in Table 3.

The intracity traffic can be slow moving (as in approach to a junction), congested (as in traffic holdups), or interrupted (by traffic lights or warden at a junction). Whichever the case, the noise emanating from intracity traffic is usually high depending, of course, on the traffic volume and magnitude of commercial activities in the area. For example, Challenge Junction, Emir's Road, and Sobi Road are examples of road junctions and busy roads with high traffic volume. In the morning and evening, the traffic is slow and congested. There is interruption by the traffic warden, and in such areas road traffic is the main source of the ambient noise while vehicle horns, human voices (in conversation), and radio player are the sources of intrusive noise. The L_D values for this type of district are in the range of 80 to 90 dB(A). On the other hand, Unity Road, Asa-Dam Roadm and Jebba Road are sites where freely flowing traffic noise dominate with little or no traffic interruption, and traffic volume is low. The noise levels are relatively lower here [70 to 80 dB(A)] because the major sources of noise here is the rolling noise produced by tires and noise generated aerodynamically. There is a slow and steady flow of vehicles in sites like the Unilorin mini-campus roundabout, General Hospital roundabout, Adeta Junction, and Pakata Road. The noise levels are relatively lower here because of no contribution from commercial activities or high traffic volume. The day noise levels are in the range of 70 to 75 dB(A) or more.

Passengers loading park noise levels

In Nigerian urban cities, passengers loading parks, otherwise known as "garages" create high noise levels through activities such as an operating noisy sound system used in calling passengers into commercial vehicles, blaring of ve-

TABLE 4. PASSENGERS LOADING PARKS (GARAGE) NOISE LEVELS

		Noise level descriptors (dB (A))							
Site	*Period of the day*	L_{Aeq}	L_{10}	L_{90}	*TNI*	L_{NP}	L_D	L_N	L_{DN}
Maraba garage	Morning	74	79	63	97	90			
	Afternoon	81	81	59	117	103	79		
	Evening	72	75	62	84	85			
	Night	69	67	54	76	82		71	80
Shao garage	Morning	76	71	60	74	87			
	Afternoon	71	74	64	74	81	74		
	Evening	72	76	66	76	82			
	Night	62	65	55	65	72		69	77
Offa garage	Morning	79	83	71	89	91			
	Afternoon	74	78	66	84	86	72		
	Evening	81	86	73	95	94			
	Night	73	77	66	80	84		79	85
Baboko garage	Morning	80	84	74	84	90			
	Afternoon	82	88	74	100	96	81		
	Evening	83	86	77	83	92			
	Night	81	86	71	101	96		82	88
Saw-mill garage	Morning	81	81	72	78	90			
	Afternoon	78	80	72	74	86	80		
	Evening	76	79	72	70	83			
	Night	71	75	62	84	84		74	82
Geri-Alimi garage	Morning	79	80	71	77	88			
	Afternoon	75	77	65	83	87	78		
	Evening	76	80	73	71	83			
	Night	73	77	62	92	88		74	82
Mean	Morning	78	80	69		89			
	Afternoon	77	80	67		90	77		
	Evening	77	80	71		87			
	Night	72	75	62		84		75	82

hicle horns, hawking around the park with the use of megaphone, stationed and mobile record player selling cassettes (audio or video), insecticides, or consumable goods. Such noise is not only annoying, it can be particularly irritating and disruptive to the passengers and the residents living close to the parks.

From Table 4, the range of the day noise levels, L_D of the surveyed loading parks is 70 to 80 dB(A) or more and the overall mean is 77 dB(A). Baboko loading park and Sawmill Garage have the highest day noise levels of 81 dB(A) and 80 dB(A), respectively. This is as a result of intrusive noise from a record player within these parks and noise from loudspeakers used in calling passengers into the commercial vehicles.

Residential areas noise levels

In Nigerian urban areas, residential areas can be grouped into two: the high-density areas (well developed areas with clustered buildings and high number of people living together) and low-density areas (developing areas with scattered buildings and few people living together). In a densely populated areas, high noise levels is generated compared with that of a sparsely (low density) populated areas. The major sources of noise in residential areas in Nigerian urban cities include noise from a generator plant, a pepper grinding machine, a record player, a street dance, an open party, human conversation, noise from religious worship centers located around the residential areas, etc. All these contribute greatly to environmental noise pollution.

Tables 5 and 6 show the residential noise levels for high-density and low-density areas, respectively. The range of daytime noise levels, L_D of high-density residential areas is 60–74 dB(A), while that of low-density residential areas is 43–59 dB(A). The range of night noise levels, L_N, of high-density residential areas is 59–76 dB(A), and that of low-density residential areas is 44–56 dB(A). There is a great disparity in the noise levels exposure by the residents in high-density residential areas and that of low-density residential areas.

Discussion

Influence of the characteristics of the locations and period of the day on measured sound levels

The environmental sound levels measured at a given location depend on a number of specific variables. In particular, many authors have found that the observed sound levels are mainly related to road traffic characteristics and especially traffic volume, vehicle horns, rolling stock and tires, unmuffled vehicles, etc. (Amando and Jose, 1998; Saadu *et al.*, 1998). Several studies have demonstrated that the urban conditions of a given area are also a very important factor influencing the environmental noise levels (Nelson, 1998).

The A-weighted sound levels measured from each site surveyed shows variation in the noise level with period of the day and nature of the site. In general, there are high noise

TABLE 5. RESIDENTIAL AREA NOISE LEVELS (HIGH DENSITY AREAS)

		Noise level descriptors [dB (A)]							
Site	*Period of the day*	L_{Aeq}	L_{10}	L_{90}	*TNI*	L_{NP}	L_D	L_N	L_{DN}
Opomalu	Morning	64	68	58	—	74			
	Afternoon	66	70	59	—	77	65		
	Evening	66	69	59	—	76			
	Night	65	68	58	—	75		66	72
Okelele	Morning	62	63	57	—	68			
	Afternoon	56	58	52	—	62	60		
	Evening	71	75	69	—	82			
	Night	66	70	61	—	75		69	75
Kuntu	Morning	63	73	57	—	79			
	Afternoon	60	63	52	—	71	62		
	Evening	68	67	56	—	79			
	Night	65	60	50	—	75		67	73
Niger	Morning	64	67	60	—	71			
	Afternoon	77	80	61	—	96	74		
	Evening	786	75	62	—	89			
	Night	76	80	68	—	88		76	82
Balogun fulani	Morning	60	63	57	—	66			
	Afternoon	62	66	56	—	72	61		
	Evening	61	63	52	—	72			
	Night	55	56	52	—	59		59	66
Gaa-Akanbi	Morning	66	69	62	—	73			
	Afternoon	56	60	51	—	65	63		
	Evening	65	69	60	—	74			
	Night	57	60	52	—	65		63	66
Mean	Morning	63	67	59		72			
	Afternoon	63	66	55		74	64		
	Evening	68	70	60		79			
	Night	64	66	57		73		67	83

Table 6. Residential Area Noise Levels (Low Density Areas)

Site	Period of the day	Noise level descriptors (dB (A))							
		L_{Aeq}	L_{10}	L_{90}	TNI	L_{NP}	L_D	L_N	L_{DN}
Tanke	Morning	59	55	46	—	68			
	Afternoon	51	47	40	—	64	57		
	Evening	57	53	43	—	67			
	Night	54	55	53	—	56		56	63
GRA	Morning	61	58	46	—	71			
	Afternoon	57	60	46	—	67	59		
	Evening	55	59	47	—	61			
	Night	56	59	54	—	52		56	53
Basin	Morning	45	48	41	—	52			
	Afternoon	41	43	38	—	46	43		
	Evening	46	49	43	—	52			
	Night	55	56	55	—	56		53	59
Adewole	Morning	57	54	43	—	68			
	Afternoon	47	51	38	—	60	54		
	Evening	51	52	43	—	60			
	Night	45	47	38	—	54		49	57
Ita-Alamu	Morning	49	52	43	—	58			
	Afternoon	49	54	45	—	58	49		
	Evening	48	52	43	—	57			
	Night	49	51	45	—	55		49	55
Airport	Morning	51	52	39	—	64			
	Afternoon	43	41	33	—	51	49		
	Evening	44	44	32	—	56			
	Night	44	40	33	—	51		44	52
Mean	Morning	54	53	43	—	64			
	Afternoon	48	49	40	—	58	52		
	Evening	50	52	42	—	60			
	Night	51	51	46	—	58		51	57

levels in the day time (7:30 a.m.–2.30 p.m.) compare with the nighttime (8:30–9:00 p.m.) except in the residential areas where the majority of the residents are not at home during the working days of the week; hence, the noise level is low in residential areas in afternoon time. Figure 2 shows an example of the results obtained for these measurements. For commercial centers and road junctions, the noise levels rise from morning and reach the peak in the afternoon and descend in the night to low level. The high noise levels at these locations can be justified as a result of morning rushing hours of office workers, business men, and market women to resume work at office and open shop for customers. At passenger loading parks, the majority of travelers going long distance, travel with commercial vehicles in the daytime (between 7:00 and 10:00 a.m.); hence, there is high A-weighted day noise levels at loading parks. The noise levels in the afternoon time (1.00–1.30 p.m.) at residential areas are generally low compare with that of evening and night times. This is because the majority of the residents are not available at home in the afternoon time. Some are in offices, markets, or shops, while children are in their schools by this time of the day.

The mean values of A-weighted equivalent sound level, L_{Aeq} for the sites surveyed with the period of the day are: Commercial centers [M: 73 dB(A), A: 77 dB(A), E: 77 dB(A), N: 67 dB(A)]; road junctions [M: 77 dB(A), A: 78 dB(A), E: 78 dB(A), N: 75 dB(A)]; passenger loading parks [M: 78 dB(A), A: 77 dB(A), E: 77 dB(A), N: 72 dB(A)]; high-density areas [M: 63 dB(A), A: 63 dB(A), E: 68 dB(A), N: 64 dB(A)]; and low-density areas [M :58 dB(A), A: 48 dB(A), E: 50 dB(A), N: 51 dB(A)].

High noise levels exposure in Nigerian urban areas occurs mostly in the day time at major road junctions. This is followed by commercial centers and passengers loading parks. In these locations, apart from traffic noise, other intrusive noise sources include noise from record players, loud speakers, hawking, and human conversation contribute majorly to environmental noise pollution.

To ascertain significant difference in the noise exposure level in all locations surveyed, analysis of variance (ANOVA) for a single factor experiment, using F-distribution was carried out on the A-weighted sound levels (LAeq) measured. At 90% confidence level, the mean square ratio (MSR) calculated is 50.81, while the tabulated value of MSR is 2.36 (Lipson and Seth, 1973). Since MSR calculated is greater than MSR tabulated, there is significant difference (P 0.05) in noise exposure levels throughout the period of the in Ilorin metropolis based on the data analyzed.

Climatic noise change of Ilorin metropolis

This research work presents the overall analysis of the data for noise survey in Ilorin metropolis. Like the experimental design, the current findings depart from the findings of previous researchers on community noise survey in the same city (Ilorin). Greater emphasis is placed on variations of noise

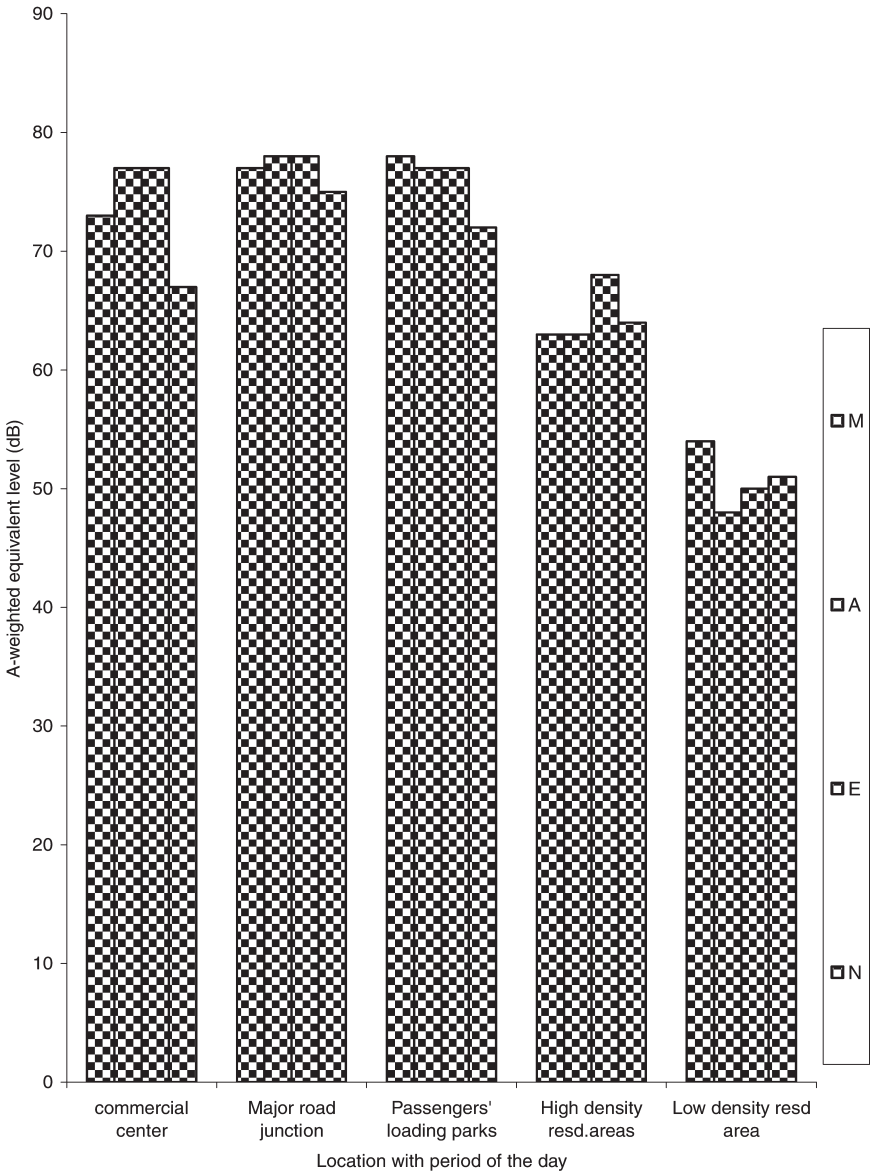

FIG. 2. Variation of the equivalent sound level L_{Aeq} with location and period of the day.

exposure levels with time of the day and locations in the urban area. Also, comparison of current noise exposure in Ilorin with past exposure levels measured about 20 years ago by Saadu (1988) is to be made. This is to affirm the fact that noise level changes with time as a result of an increase in population and commercial activities. The sites chosen for comparison are the locations where similar surveys were carried out some years ago in Ilorin.

Table 7 shows the computed L_{DN} levels of this present survey (designated as 2005) compared with that of Saadu (1988) carried out in 1985. The range of day–night noise levels (L_{DN}) in 1985 is 42–79 dB(A) with mean and standard deviation of 69.9 dB(A) and 11.36, respectively, while the range of L_{DN} levels in 2005 is 53–92 dB(A) with mean and standard deviation of 78.2 dB(A) and 10.82, respectively. This shows that the noise levels has increased by 2 to 13 dB(A) in the past 20 years in Ilorin metropolis. In general, there is an increase in noise exposure levels in Ilorin with length of time. This is due basically to an increase in population from 575,178 in 1985 to 833,386 in 2005 (National Population Commission, 2006). This gives the conclusion of the fact that levels of urbanization are closely correlated with noise pollution levels in urban areas.

Noise map for Ilorin metropolis

Noise maps describe spatial distributions of noise levels. They allow an efficient visualization of the noise distributions in areas where the land uses are sensitive to noise. Noise mapping is a very efficient noise assessment method in an urban area (Coelho and Alarcao, 2006).

In this work, noise mapping, and of course, noise abatement, plans drawn for noisy areas (commercial centers, major road junctions, passenger loading parks, high-density residential areas) and low noise areas (low-density residential areas) is presented. All the data collected at the 42 sites were used to develop a noise map for Ilorin metropolis. The noise map based on daytime noise levels (L_D), nighttime noise lev-

TABLE 7. CLIMATIC NOISE CHANGES OF ILORIN METROPOLIS

Location	*1985*	*2005*
Lagos Road	70	80
Jebba Road	73	75
Unity Road	79	84
GRA	42	53
Ago market	68	81
Okelenle	67	75
Taiwo Road	77	79
Abdul Azeez Attah Road	74	85
Muritala Road	79	92
Mean	69.9	78.2
Standard deviation	11.4	10.8

els (L_N), day–night noise levels (L_{DN}), traffic noise index (TNI), and noise pollution level (L_{NP}) have been developed. Figure 3 shows the noise map for Ilorin metropolis. The nucleus of the city is characterized with a high noise exposure level. The daytime noise level (L_D) is as high as 84 dB(A); the nighttime noise level (L_N) is 81 dB(A), the day–night time noise level (L_{DN}) is 91 dB(A), the traffic noise index (TNI) is in the range of 85–115 dB(A), and the noise pollution level L_{NP} is in the range of 90–105 dB(A). The outskirts area of the city is basically low-density residential areas and developing sites. The maximum day time noise level (L_D) is 74 dB(A), nighttime noise level (L_N) is 68 dB(A), day–night noise level (L_{DN}) is 76 dB(A), traffic noise pollution (TNI) is 80–95 dB(A), and noise pollution level is 90–100 dB(A). Generally, the suburbs of the city are characterized with low noise, but due to major roads that pass through some of these locations, traffic noise contributes as a major source of environmental noise pollution in some of the outskirt locations. In the center of the city, there is concentration of shops, markets, clustered buildings with high population and traffic volume. All these are responsible for high noise exposure level; therefore, the residents living or trading in these areas are exposed to noise levels of 80–90 dB(A) or more every day. This is very dangerous to the health of the people in these areas. According to the World Health Organization (WHO), generally 60 dB(A) sounds can result in temporary hearing impairment and 100 dB(A) sounds can cause permanent impairment (Kiely, 1998). The noise levels of Ilorin metropolis are similar to those reported for other cities around the world in Jordan, Spanish, Brazil, Greece, and India (Amando and Jose, 1997; Zannin *et al.*, 2002; Panadya, 2003; Geogiadou *et al.*, 2004; Ahmad *et al.*, 2006).

This work is an eye opener to see and understand the importance of the noise map for Nigerian urban areas—as it enables one to know areas that are noisy and the one with low noise. Also, the category of people in the urban areas expose to different noise sources and noise exposure dose base on their occupation is known with the help of the noise map. Furthermore, the noise map has the potential to enable

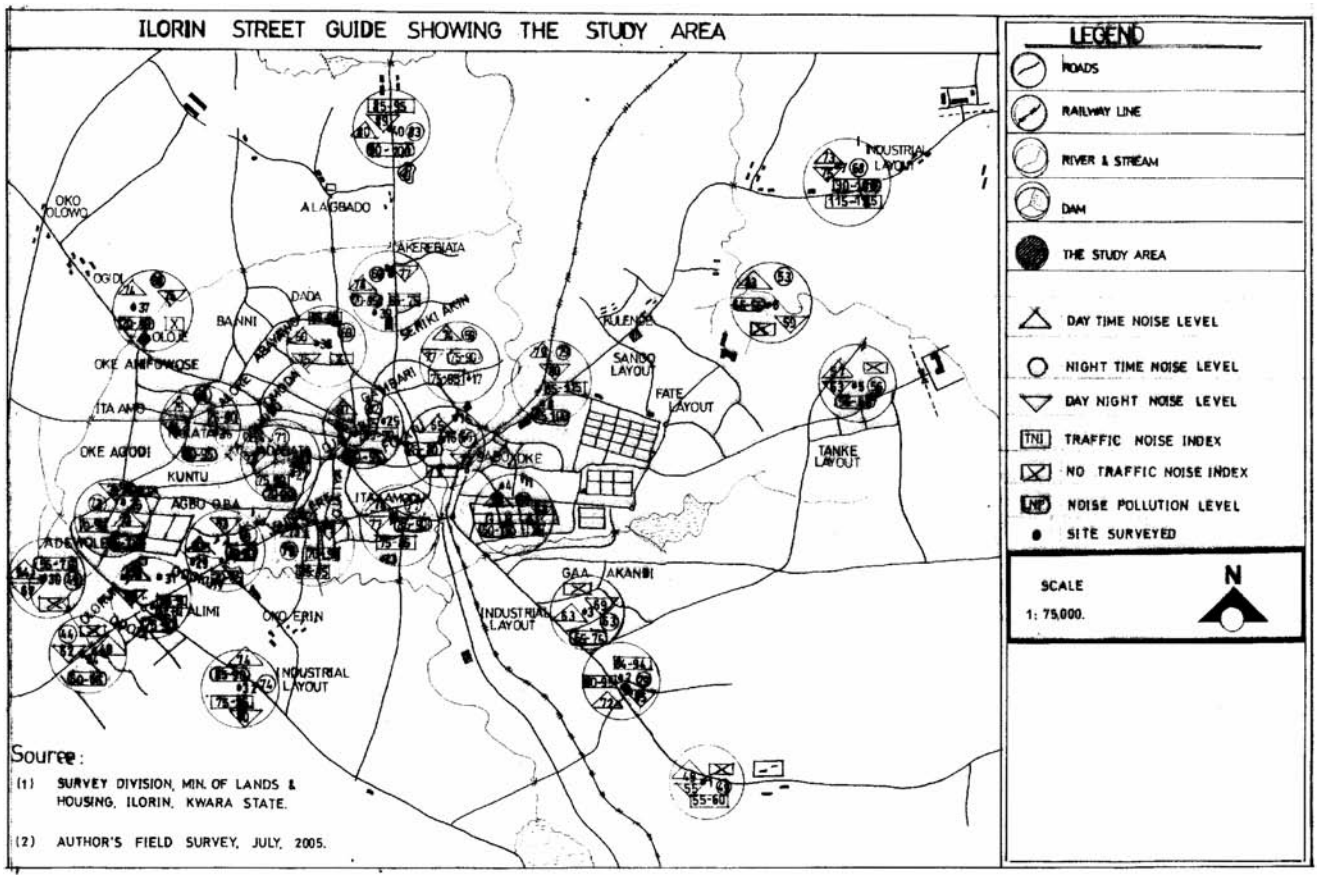

FIG. 3. Noise Map of Ilorin City.

data to be accessible to the general public in a way that is comprehensible. This could have the effect of raising people's awareness of noise as a pollutant, and thus create the climate necessary for the implementation of a noise reduction program.

Conclusion

Environmental noise pollution in Nigerian urban centers has been found to increase with an increase in population, commercial activities, and road traffic volume. There is a significant difference in the daytime noise levels and nighttime noise levels in urban areas. High noise levels occur in the daytime at road junctions. High noise levels are also recorded at commercial centers and passengers loading parks. The day time L_{Aeq} noise levels in these locations range from 73–78 dB(A), while the nighttime L_{Aeq} noise levels range from 67–75 dB(A). Apart from the ambient noise caused by exhaust, rolling stocks, and tyres, the intrusive noise sources include vehicle horns, vehicle-mounted loudspeakers, hawking, human conversation, record players, and loudspeakers used to call passengers into commercial vehicles at the passengers loading parks. The use of the equations given in this paper can provide a sufficient basis for predicting the noise level distributions (L_{10} and L_{90}) actually observed in most conditions usually found in urban areas. On the other hand, it has been shown that the values of the various noise descriptors are related to the commercial activities, population density, and traffic volume. The noise map itself with the values of noise descriptors provide baseline data for town planners, engineers, and other professionals and researchers for the planning and execution of their projects.

Recommendations

Noise maps are very powerful tools for communicating results of assessment of environmental noise to the general public, and also for the government (local and national) to devise noise correction measures. A number of action plans can be taken to abate the environmental pollution in Nigeria. These include technical, planning behavioral, and educational solutions. Because transport infrastructures can be recognized as major sources of noise, technical actions on the transport systems can produce interesting results. Possible technical controls include changes in road profiles, low noise pavements (porous or porous elastic) type, effective repairs to the silencers and vehicle suspensions so as to reduce exhaust and rolling stock noise, reductions, limitations or restrictions on traffic (types of vehicles, speed, hours of access, etc.), and building of acoustic barriers along the sides of heavily traveled highways running through residential areas. Transportation and land planning (private vs. public transportation, bus lanes, parking areas, shuttle buses, and pedestrian areas) are important components of the plan. Because noise also results from the citizen's behavior (driver, music player, hawker, etc.), information and education campaigns usually produce good results in the long term. Information on the different actions and on the results should be well disseminated, and should correspond to general aims and action plans. There is a need to establish environmental noise impact criteria levels for various land use purposes. These criteria levels would enable impacts to be determined. The authorities should pass laws to check excesses of the sources of high noise levels, other professionals such as town planners, architects, and environmental engineers as well, should have the problems of environmental noise pollution in mind when siting new roads, shopping centres, schools, hospitals, and both commercial and residential houses in general. The noise map developed in this work is based on the use of hand; other fast, efficient, and accurate method with electronic computer can be embarked upon for future work. Also, development of noise-mapping software for Nigerian urban centers is recommended for future work.

Author Disclosure Statement

The authors declare that no competing financial interests exist.

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