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Evaluation and analysis of noise levels in Ilorin metropolis, Nigeria

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Abstract Evaluation and analysis of noise pollution levels have been carried out to determine the level of noise and its sources in Ilorin metropolis. Noise measurements have been done in the morning, at noon, in the evening, and at night to determine noise pollution all over the city. The selected areas of study are commercial centers, road junctions/busy roads, passenger loading parks, and high-density and low-density residential areas. The road junctions had the highest noise pollution levels, followed by commercial centers. The results of this study show that the noise levels in Ilorin metropolis exceeded allowed values at 30 of 42 measurements points. There is a significant difference ($P < 0.05$) in the noise pollution levels and traffic noise index in all the locations. From the measured noise values, a map of noise pollution was developed for Ilorin. Many solutions proposed for noise abatement in the city are set out.

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Introduction

Noise pollution, a by-product of urbanization and industrialization, is now worldwide recognized as a major problem for the quality of life in urban areas. The increase in the population and in the number of circulating vehicles has led to an increase in noise pollution, but noise pollution has been considered less than other contaminants in the environment (Mansouri et al. 2006). In contrast to many other environmental problems, noise pollution continues to grow and is accompanied by an increasing number of complaints from people exposed to the noise. The growth in noise pollution is unsustainable because it involves direct, as well as cumulative, adverse health effects. It also adversely affects future generations and has sociocultural, aesthetic, and economic effects (Yilmaz and Ozer 2005). The most important factors raising noise pollution in urban areas include interalia appliances, vehicular traffic, neighborhood electrical appliances, TV and music systems, public address systems, railway and air traffic, and generating sets. Even we fall prey to the noise generated by the household equipments used by us (Singh and Daver 2004).

The need for studies regarding urban noise pollution and its consequences on the environment has motivated various researchers on the problem in several countries (Ugwuanyi et al. 2004; Zeid et al. 2000; Zheng 1996; Zannin et al. 2003). Many researchers have reported that road traffic is the predominant and most generalized noise source in urban areas (Saadu et al. 1998; Bisio 1996; Nelson 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. It has been generally accepted that noise pollution, particularly road traffic noise, is severe in rapidly expanding cities, such as those of southeastern Nigeria (Onuu 1992), where insufficient control is exercised and cities are poorly planned. Ilorin is not an exception to this ugly scenario.

Existing evidence indicating that noise pollution may have negative impacts on human health has justified research in order to provide 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 (Ugwuanyi et al. 2004; Saadu et al. 1998; Ahmad et al. 2006; Schwela and Zali 1999).

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. The effects of noise in developing countries are just as widespread as those 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.

The noise pollution situation in Ilorin metropolis is similar to that in many urban areas. The city is relatively large, having rapid increase in population growth rate. The population has increased from 423,340 in 1980 to 902,131 in 2006 (NPC 2006). The city has expanded continuously in all directions in the past two 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 road traffic and commercial activities due to overall increase in prosperity, fast development, and expansion of the 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 demography and urban boundaries in the city have taken place, and consequently, further investigation of this phenomenon is needed. Oyedepo and Saadu (2008) studied the changing noise climate of Ilorin metropolis. In the study, noise levels in Ilorin metropolis were investigated and a noise map for Ilorin was developed.

The prime objectives of this investigation are (1) to evaluate the noise levels in strategic locations (i.e., commercial centers, busy roads/road junctions, passenger loading parks, and residential areas) in the city, (2) to investigate if there is significant difference in noise pollution levels (L_{NP}) in the locations surveyed throughout the day (i.e., day time and night time), and (3) to compare the traffic noise index (TNI) of the locations surveyed.

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, six passenger loading parks, six high-density areas, and six 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. Figures 1 and 2 show an overview of Ilorin metropolis showing the locations of noise measurements for this study and the population growth of the city, respectively.

Experimental procedure

Instrumentation for the field measurements consisted of precision-grade sound level meter (according to IEC 651, ANSI S1.4 type), 1/2-in.

Table 1 Locations selected for the noise level measurements in Ilorin metropolis

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

GRA government-reserved areas

condenser microphone, and 1/3-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 centers, passenger 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-m readings per sampling location. This procedure was carried out for morning (7:30–8:00 a.m.), afternoon (1:00–1:30 p.m.), 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 TNI were computed. These noise measures are defined as follows (Saadu et al. 1998):

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

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

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

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

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

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

Where L_{Ai} is the ith A-weighted sound pressure level reading decibels, N is the total

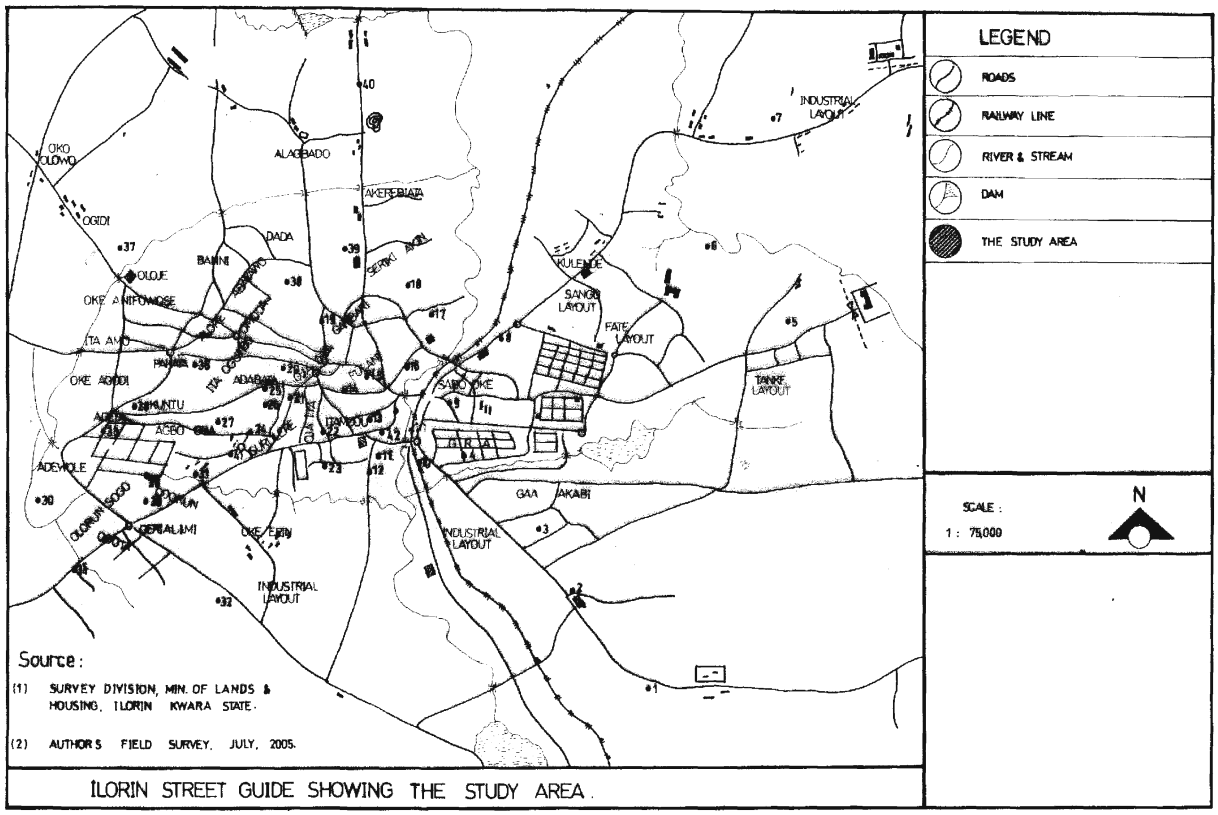

Fig. 1 Overview of Ilorin metropolis showing the locations of noise measurements. Throughout this study (Source: Survey Division, Min. of Lands & Housing, Ilorin, Kwara State)

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 nighttime noise level, L_{D} is 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 noise pollution level, L_{DN} is day–night noise level, and TNI is the traffic noise index.

Results

Commercial center noise levels

Table 2 shows the computed values of the noise level descriptors for the commercial centers in the city surveyed. A glance through Table 2 shows that the noise pollution level, L_{NP} ranges from 56 dB (A) to 98 dB (A). The TNI ranges from 41 dB (A) to 108 dB (A).

The factors responsible for differences in noise level in the centers surveyed include location site and presence of sources of intrusive noise. The high noise pollution levels and TNI at Oja-Oba Market and Gegele Market is due to their 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 a loudspeaker in a mosque located within the vicinity constitutes an intrusive noise at the time of prayer. 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 L_{NP} and TNI are very

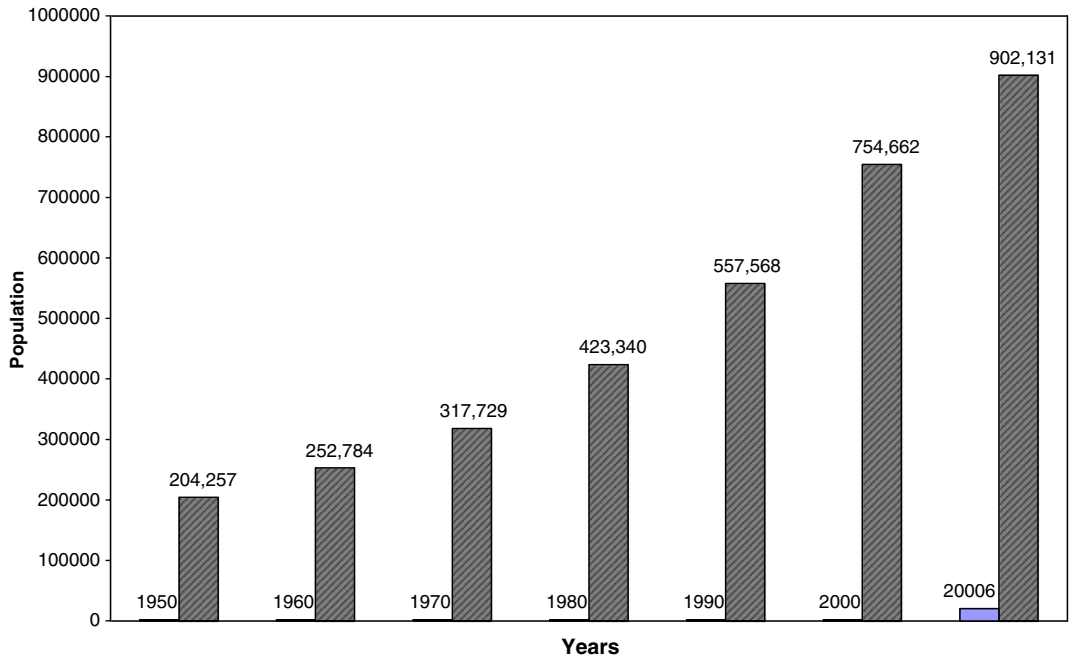

Fig. 2 The increase in population of Ilorin

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 hold-ups), or interrupted (by traffic lights or warden at a junction). Which ever is 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 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 players are the sources of intrusive noise. The L_{NP} values for this type of district are in the range of 90 to 108 dB (A). On the other hand, Unity road, Asa-Dam road, and Jebba road are sites where freely flowing traffic noise dominate with little or no traffic interruption, and traffic volume is low. The noise pollution levels (L_{NP}) are relatively lower here [85 to 100 dB (A)] because the major sources of noise here are the rolling noise produced by tires and noise generated aerodynamically. There is a slow and steady flow of vehicles in sites like Unilorin mini campus round-about, General Hospital round-about, Adeta junction, and Pakata road. The noise pollution levels are relatively lower here because of no contribution from commercial activities or high traffic volume. The L_{NP} are in the range of 80 to 98 dB (A). The values of TNI range from 66–124 dB (A) for the road junctions/busy roads surveyed.

Table 2 Commercial center 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	Morning	73	76	64		84			
	Afternoon	77	80	68		89	76		
	Evening	77	80	68		88			
	Night	67	66	55		76		75	82

Table 3 Traffic noise levels at major road junctions and busy roads

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}
Challenge Junction	Morning	89	94	75	121	108			
	Afternoon	88	93	74	120	107	89		
	Evening	86	94	74	124	106			
	Night	81	87	65	123	103		84	92
Ita-Amodu Junction	Morning	77	81	72	78	86			
	Afternoon	81	86	71	101	96	79		
	Evening	81	84	72	90	93			
	Night	76	80	70	80	86		79	85
Unilorin Mini Campus	Morning	70	75	63	81	82			
Round-about	Afternoon	72	77	63	89	86	71		
	Evening	72	78	60	102	90			
	Night	69	71	60	74	80		71	77
General Hospital Junction	Morning	74	79	69	79	84			
	Afternoon	77	82	69	91	90	76		
	Evening	77	81	70	84	88			
	Night	76	80	62	102	94		77	83
Agbooba-Surulere Junction	Morning	78	81	71	81	88			
	Afternoon	77	80	73	71	84	78		
	Evening	81	85	71	97	95			
	Night	77	81	72	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 Junction	Morning	73	75	68	66	80			
	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

Passenger loading park noise levels

From Table 4, the range of the noise pollution levels (L_{NP}) of the surveyed loading parks is 72 to 103 dB (A). Maraba Garage has the highest noise pollution levels and TNI of 103 dB (A) and 117 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 on passengers into the commercial vehicles.

Residential area 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 area, high noise levels are generated compared with those of a sparsely (low density) populated area. The major sources of noise in residential areas in Nigerian urban cities include noise from generator plants, pepper grinding machines, record players, street dances, open parties, 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 noise pollution levels, L_{NP}, at high-density residential areas is 59–96 dB (A), while that of low-density residential areas is 46–71 dB (A). The range of TNI at high-density residential areas is 46–107 dB (A), and that of low-density residential areas is 31–72 dB (A). There is a great disparity in the noise level exposure by the

Table 4 Passengers loading parks (garage) 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}
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

Table 5 Residential area noise levels (high-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}
Opomalu	Morning	64	68	58	68	74			
	Afternoon	66	70	59	73	77	65		
	Evening	66	69	59	69	76			
	Night	65	68	58	68	75		66	72
Okelele	Morning	62	63	57	51	68			
	Afternoon	56	58	52	46	62	60		
	Evening	71	75	69	63	82			
	Night	66	70	61	67	75		69	75
Kuntu	Morning	63	73	57	91	79			
	Afternoon	60	63	52	66	71	62		
	Evening	68	67	56	70	79			
	Night	65	60	50	60	75		67	73
Niger	Morning	64	67	60	58	71			
	Afternoon	77	80	61	107	96	74		
	Evening	76	75	62	84	89			
	Night	76	80	68	86	88		76	82
Balogun fulani	Morning	60	63	57	51	66			
	Afternoon	62	66	56	66	72	61		
	Evening	61	63	52	66	72			
	Night	55	56	52	33	59		59	66
Gaa-Akanbi	Morning	66	69	62	60	73			
	Afternoon	56	60	51	57	65	63		
	Evening	65	69	60	66	74			
	Night	57	60	52	54	65		63	66
Mean	Morning	63	67	59	63	72			
	Afternoon	63	66	55	69	74	64		
	Evening	68	70	60	70	79			
	Night	64	66	57	62	73		67	83

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 noise pollution levels (L_{NP}) and TNI

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. (Saadu et al. 1998; Amando and Jose 1998; Mansouri et al. 2006). 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).

There is variation in the noise levels with the period of the day and the nature of the location. In general, there are high noise pollution levels (L_{NP}) in the daytime (7:30 am–2:30 pm) compared with the nighttime (8:30 pm–9:00 pm), except in the residential areas where the majority of the residents are not always at home during the working days of the week; hence, the noise levels are low at residential areas (especially in low-density residential areas) in afternoon time. Figures 3 and 4 show the variations of noise pollution levels and TNI with location and period of the day. At commercial centers, road junctions, passenger loading parks, and high-density areas, both the L_{NP} and TNI rise from morning and reach peak values in the afternoon and evening but descend in the

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	52	68			
	Afternoon	51	47	40	38	64	57		
	Evening	57	53	43	53	67			
	Night	54	55	53	31	56		56	63
GRA	Morning	61	58	46	64	71			
	Afternoon	57	60	46	72	67	59		
	Evening	55	59	47	65	61			
	Night	56	59	54	44	52		56	53
Basin	Morning	45	48	41	39	52			
	Afternoon	41	43	38	28	46	43		
	Evening	46	49	43	37	52			
	Night	55	56	55	29	56		53	59
Adewole	Morning	57	54	43	57	68			
	Afternoon	47	51	38	60	60	54		
	Evening	51	52	43	49	60			
	Night	45	47	38	44	54		49	57
Ita-Alamu	Morning	49	52	43	49	58			
	Afternoon	49	54	45	51	58	49		
	Evening	48	52	43	49	57			
	Night	49	51	45	39	55		49	55
Airport	Morning	51	52	39	61	64			
	Afternoon	43	41	33	35	51	49		
	Evening	44	44	32	50	56			
	Night	44	40	33	31	51		44	52
Mean	Morning	54	53	43	54	64			
	Afternoon	48	49	40	47	58	52		
	Evening	50	52	42	51	60			
	Night	51	51	46	36	58		51	57

GRA government-reserved areas

night to low levels. The high noise pollution levels in the morning and evening at these locations can be justified as a result of morning rushing hours of office workers and business men and women, to resume work at offices and open shop for customers. The noise pollution levels in the afternoon time (1:00 pm–2:30 pm) at low-density residential areas are generally low. This is because the majority of the residents are not always available at home in the afternoon. Some are in their offices, markets, or shops while children are in their schools by this time of the day. Moreover, most of the low-density residential areas are developing areas, while some are government-reserved areas. The numbers of vehicles that ply the roads in these areas are very minima, and of course, there is a speed limit (40 km/h) for every vehicle that passes through these areas. Blaring of horns and movement of unmuffled vehicles are prohibited in some of these areas.

At the time of this measurement, the highest and lowest noise pollution levels and TNI were 109 dB (A), 128 dB (A) at Emir's road and 46 dB (A), 28 dB (A) at Basin (low-density residential area), respectively.

Emir's road and Challenge junction were found to be the noisiest sites with peak noise levels (L_{10}) of 92 dB (A) and 94 dB (A), respectively, compared to the peak noise value of 91.5 dB (A) in Markurdi (Ugwuanyi et al. 2004) and between 86 and 106 dB (A) in Aba and Uyo (Onuu 1992). The high noise pollution values of these sites may be a result of the noise produced by music players and the proximity of these sites to the high traffic density of roads and presence of nearby rail stations.

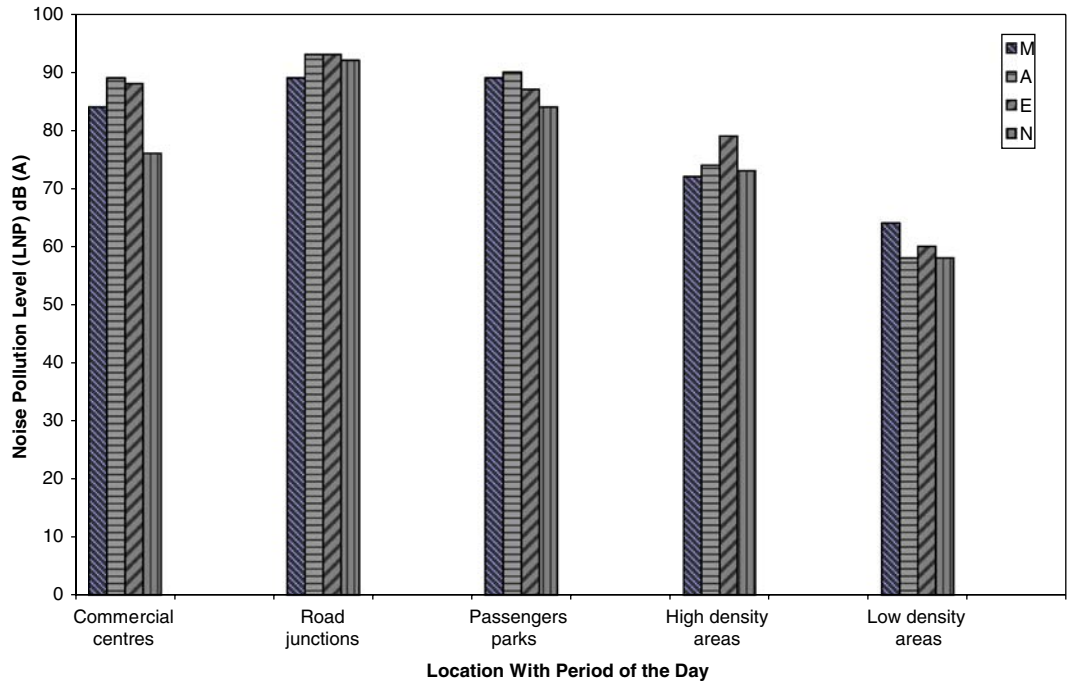

Fig. 3 Variation of noise pollution levels with location and period of the day

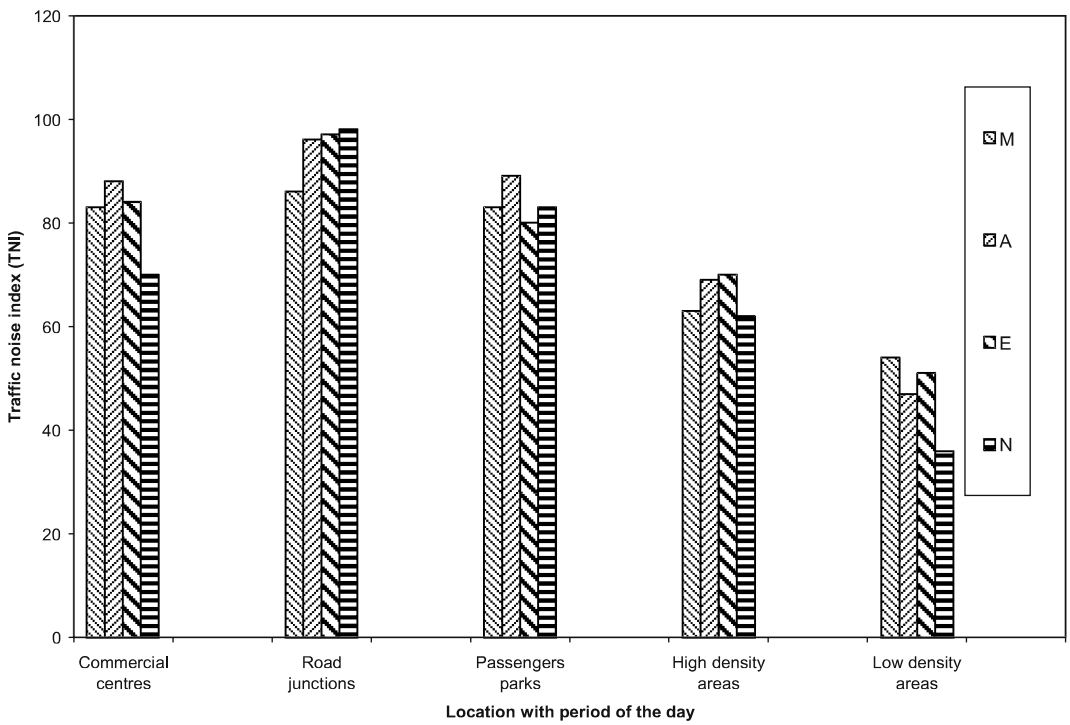

Fig. 4 Variation of the TNI with location and period of the day

Table 7 Analysis of variance for noise pollution level (L_{NP})

Source of variation	SS	DF	MS (MS = SS/DF)	MSR ($MSR_c = MS_c/MS_r$)	$MSR_{tabulated}$ ($F_{0.1,4,15}$)
Column	2,567.3	$C - 1 = 4$	641.825		
Residual	189.5	$(N - 1) - (C - 1) = 15$	12.633	50.81	2.36
Total	2,756.8	$N - 1 = 19$			

SS sum of squares, *DF* degree of freedom, *MS* mean square

The noise levels in all the locations surveyed, except at low-density residential areas, are higher than the recommended level of 60 dB (A) for commercial areas and residential areas (ISO:R 1996/I-1982 2004). The noise level is about 1 to 27 dB (A) above the recommended limit of 82 dB (A) (Ramalingeswara and Rao 1992) in all the locations surveyed except for the residential areas.

To ascertain the significant difference in the noise level exposure in all the sites surveyed throughout the day (from morning to night time), statistical analysis of variance for single factor experiment, using F-distribution, was carried out on L_{NP} and TNI. Tables 7 and 8 are analysis of variance tables for noise pollution levels (L_{NP}) and TNI, respectively. At 90% confidence level, the mean square ratio (MSR) calculated for L_{NP} is 50.81, while the tabulated value is 2.36 (Lipson and Seth 1973). Similarly, at the same confidence level, the MSR calculated for TNI is 36.50 and the tabulated value remains as 2.36. Since, in the two cases, the calculated MSR is greater than the tabulated value, there is a significant difference ($P < 0.05$) in the noise pollution level and TNI in the locations surveyed based on the data analyzed at 90% confidence level.

The noise levels for both daytime and nighttime are higher than those reported by Saadu (1988) for all the locations surveyed. This is basically due to an increase in population density, commercial activities, and traffic volume in the city.

Tables 2–6 show that the average TNI ranges from 70 to 84 dB (A) at commercial centers, 86–98 dB (A) at road junctions/busy roads, 80–89 dB (A) at passengers loading parks, 62–70 dB(A) at high-density residential areas, and 36–54 dB(A) at low-density residential areas. Road junctions/busy roads and low-density residential areas have the highest and lowest annoyance responses due to traffic noise, respectively. It should be noted that a TNI of 74 dB (A) has been reported to be associated with less than 3% annoyance in social survey (Ahmad et al. 2006). Also, the noise levels are very much higher than the levels reported for living rooms. The bedroom noise of levels of 25–30 dB (A) reported by Davis and Masten (2004) has been exceeded in all locations of Ilorin metropolis during the nighttime, resulting in more possible sleep disturbance due to traffic noise. It should be noted that the World Health Organization recommends a noise level of less than 35 dB (A) based on the continuous equal energy concept for the restorative process of sleep (Mufuruki 1997).

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 urban areas (Coelho and Alarcao 2006).

Table 8 Analysis of variance for TNI

Source of variation	SS	DF	MS (MS = SS/DF)	MSR ($MSR_c = MS_c/MS_r$)	$MSR_{tabulated}$ ($F_{0.1,4,15}$)
Column	5,398.7	$C - 1 = 4$	1,349.68		
Residual	554.25	$(N - 1) - (C - 1) = 15$	36.95	36.50	2.36
Total	5,952.95	$N - 1 = 19$			

SS sum of squares, *DF* degree of freedom, *MS* mean square

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) are presented. All the data collected at the 42 sites were used to develop a noise map for Ilorin metropolis. A noise map based on daytime noise level, nighttime noise level, day–night noise level, TNI, and noise pollution levels has been developed.

Figure 5 shows the noise map of Ilorin metropolis. The nucleus of the city is characterized by a high noise exposure level. The daytime noise level is 84 dB (A), the nighttime noise level is 81 dB (A), the day–night time noise level is 91 dB (A), the TNI is in the range of 85–115 dB (A), and the noise pollution level is in the range of 90–105 dB (A). The outskirt area of the city is basically low-density residential areas and developing sites. The highest daytime noise level is 74 dB (A), the nighttime noise level is 68 dB (A), the day–night noise level is 76 dB (A), traffic noise pollution is 80–95 dB (A), and noise pollution level is 90–100 dB (A). Generally, the suburbs of the city are characterized by 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 are concentrations of shops, markets, and clustered buildings with high population and traffic volume. All these are responsible for high noise exposure levels; 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, 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

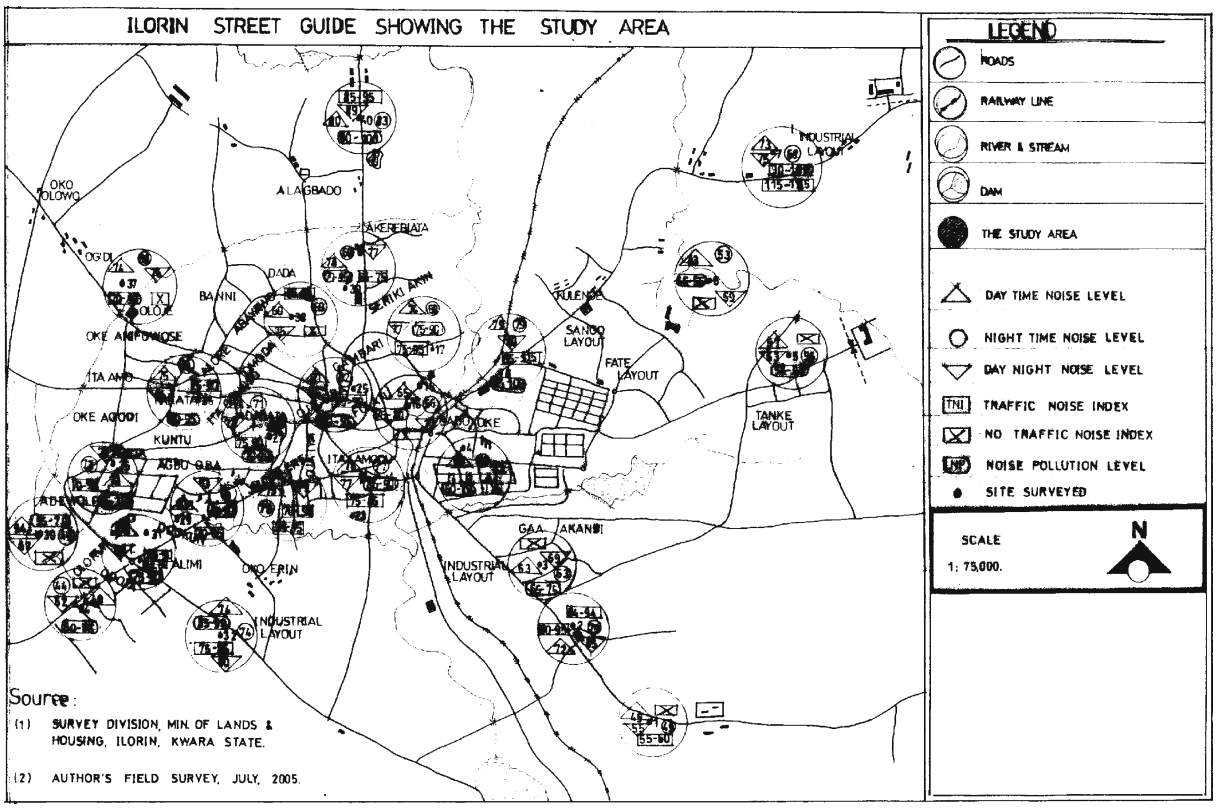

Fig. 5 Noise map for Ilorin metropolis

those reported for other cities around the world in Jordan, Spain, Brazil, Greece, and India (Ahmad et al. 2006; Amando and Jose 1998; Zannin et al. 2002; Georgiadou et al. 2004; Panadya 2003).

This work is an eye-opener to see and understand the importance of noise map for Nigerian urban areas—as it enables one to know areas that are noisy and ones with low noise. Also, the category of people in the urban areas exposed to different noise sources and noise exposure dose based on their occupation is known with the help of the noise map. Furthermore, the noise map has the potential to enable 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, creating the climate necessary for the implementation of a noise-reduction program.

Conclusions

This study was carried out to evaluate the noise pollution levels in Ilorin metropolis. The focus was on six selected areas: commercial centers, road junctions/busy roads, passengers loading parks, high-density residential areas, and low-density residential areas.

This investigation reveals that noise levels at 30 of 42 measurement points exceeded the recommended limit of 82 dB (A) by values of 1–27 dB (A). Hence, the present status of noise pollution in Ilorin metropolis poses a severe health risk to the residents. Furthermore, discomfort and irritation being caused by the pollution can drastically reduce productivity, both in public service and private sectors. In addition, some areas may soon reach the threshold of pains and lead to permanent loss of hearing and death.

Due to these possible adverse effects of noise pollution on the populace, a number of action plans can be taken to abate the environmental noise pollution in Nigeria. These include technical, planning, behavioral, and educational solutions. Since 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 pavement (porous or porous elastic) types; 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. Since 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, should have the problems of environmental noise pollution in mind when setting new roads, shopping centers, schools, hospitals, and both commercial and residential houses in general. The most valuable step to decrease noise pollution in a big city like Ilorin is the preparation of noise maps. Noise maps are very powerful tools for communicating results of assessment of environmental noise to the general public and for the government (local and national) to devise noise correction measures. The noise map itself, with the values of noise descriptors, provides baseline data for town planners, engineers, and other professionals and researchers for the planning and execution of their projects. Most of the cities in Nigeria have not presented noise pollution maps. It is suggested that noise maps should be developed for every big city in Nigeria to serve as a noise control measure.

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