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Effective Noise Control Measures and Sustainable Development in Nigeria

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Abstract 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. Due to the ignorance of Nigerians on the fact that there exist a close nexus between noise pollution and sustainable city, little or no attention is paid to the control of noise pollution in Nigeria. This study examines the environmental noise levels of Ilorin metropolis, one of the capital cities in Nigeria. Forty- two (42) different locations throughout Ilorin were selected to establish background noise level, peak noise level and dominant noise sources at these locations. The result of this study shows that the major source of noise in Ilorin metropolis can be attributed to traffic noise. Based on the recommendations of Committee on Environmental and Occupational Health (CEOH), World Health Organization (WHO) and Housing and Urban Development (HUD), only 6 locations out of 42 are under normally acceptable situation while the noise levels of other areas are not acceptable. Hence, the present status of noise pollution in Ilorin metropolis poses a severe health risk to the residents. This paper addresses the problems of environmental noise pollution in Ilorin metropolis in particular and Nigerian urban areas in general with the implications of implementing its control measures on the sustainability of the urban areas. Among the effective noise control measures discussed in this paper include: noise mapping, technical, planning, behavioural, and educational solutions. The result of this study is useful as reference and guideline for future regulations on noise limit to be implemented for urban areas in Nigeria.

Keywords: *noise pollution, environment, traffic noise, noise descriptors, sustainable development, urban areas, noise control measures*

1. Introduction

An important factor for the life quality in urban centres is related to the noise levels to which the population is submitted. Several factors interfere with the amount of noise pollution throughout the city. A major challenge is the quantification of the noise effects on the population. Growth in terms of economic, social development and population increases the tendency towards increasing noise generation. Considering the connectivity of vicinity, transport routes could result to an increase in noise volume generated. Noise is considered a growing health threat, and if, left unchecked could result to hazardous conditions [1].

Noise pollution is recognized as a major problem for the quality of life in urban areas all over the world. Because of the increase in the number of cars and industrialization, noise pollution has also increased. Noise in cities, especially along main arteries, has reached up disturbing levels. Residences far from noise sources and near silent secondary roads are currently very popular. People prefer to live in places far from noisy urban areas [2].

Many surveys addressing the problem of noise pollution in many cities throughout the world have been conducted [3-11], and have shown the scale of discomfort that noise causes in people's lives [12,13]. 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 [14].

Depending on its duration and volume, the effects of noise on human health and comfort are divided into four categories; physical effects, such as hearing defects; physiological effects, such as increased blood pressure, irregularity of heart rhythms and ulcers; psychological effects, such as disorders, sleeplessness and going to sleep late, irritability and stress; and finally effects on work performance, such as reduction of productivity and misunderstanding what is heard [13,15].

City noise levels can be investigated in three different ways as traffic and transportation; industrial activities; Sport, marketing and entertainment facilities [16]. In comparison to other pollutants, the control of environmental noise has been hampered by insufficient knowledge of its effects on human and lack of defined criteria. Noise pollution is a significant environmental problem in many rapidly urbanizing areas. This problem is properly not recognized despite the fact that it is steadily growing in developing countries. It is well established now that noise is a potential hazard to health, communication and enjoyment of social life. It is becoming an unjustifiable interference imposition upon human comfort, health and quality of life.

In Nigeria, the problem of noise pollution is wide spread. Several studies report that noise level in metropolitan cities exceeds specified standard limits. A study by Ugwuanyi et al. [17] conducted in Makurdi, Nigeria found that the noise pollution level in the city was about 3 dB(A) to 10 dB(A) above the recommended upper limit of 82 dB(A). Anomohanran et al, [18] also found that the peak noise level at road junction in Abraka, Nigeria to be 100 dB(A). This noise level is higher than the recommended level of 60 dB (A) for commercial and residential areas. Ighoroje et al. [19] investigated the level of noise pollution in selected industrial locations in Benin City, Nigeria. The average ambient noise level in Sawmills, Electro-acoustic market and food processing industrial areas was determined to be above 90 dB (A). This noise level is well above the healthy noise level of 60 dB (A).

In Nigeria, there is no legal frame work upon which noise pollution can be abated. Federal Environmental Protection Agency (FEPA) in Nigeria only provided daily noise exposure limits for workers in industry (i.e 90 dB(A) for 8h exposure).In short, the Nigerian Government and her citizenry appear not to be conscious of the present and future impacts of noise induced health hazards in their environment. Unless and until measures are taken to control the level of noise, the ongoing urbanization and industrialization may complicate the problem so much that it becomes incurable.

Generation of noise in a metropolitan setting can be viewed in the light of city planning disorderliness and the increasing number of vehicular traffic in the face of urban growth and development. The planning, development, and establishing a noise control capacity is an important consideration in the aspect of noise control [21,22]. There is need for abatement plans for noise generation areas like areas around major transport facilities especially at bus stops along traffic routes having economic activities and major market areas. Consideration is given in this study to the problem of noise generation at road junctions, along traffic route, passengers loading parks, residential areas and commercial areas (market) and its spread on its surrounding neighbours.

Noise has always been a major environmental stressor in urban areas. The ability to measure ambient noise levels and represent them on a map should provide a powerful tool for spatially identifying noise sources, its spread and its impact and make decisions relating to its control and management [23,24].

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 [25]. 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.

Hence, the prime objectives of this investigation are (1) to carryout comprehensive assessment of the noise levels in the city, and (2) to suggest possible effective noise control measures for the city and Nigerian urban areas.

2. Materials and Methods

2.1. 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 & 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 shows an overview of Ilorin metropolis showing the locations of noise measurements for this study.

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 R/about
21	Gegele	42	Balogun Fulani

2.2. Experimental Procedure

Instrumentation for the field measurements consisted of precision grade sound level meter (according to IEC 651, ANSI S1.4 type), ½- in. condenser microphone and ⅓-octave filter with frequency range and measuring level range of 31.5Hz – 8 KHz and 35-130dB respectively. The instruments were calibrated by the internal sound level calibrator before making measurements at each site. All the instruments comply with IEC standards.

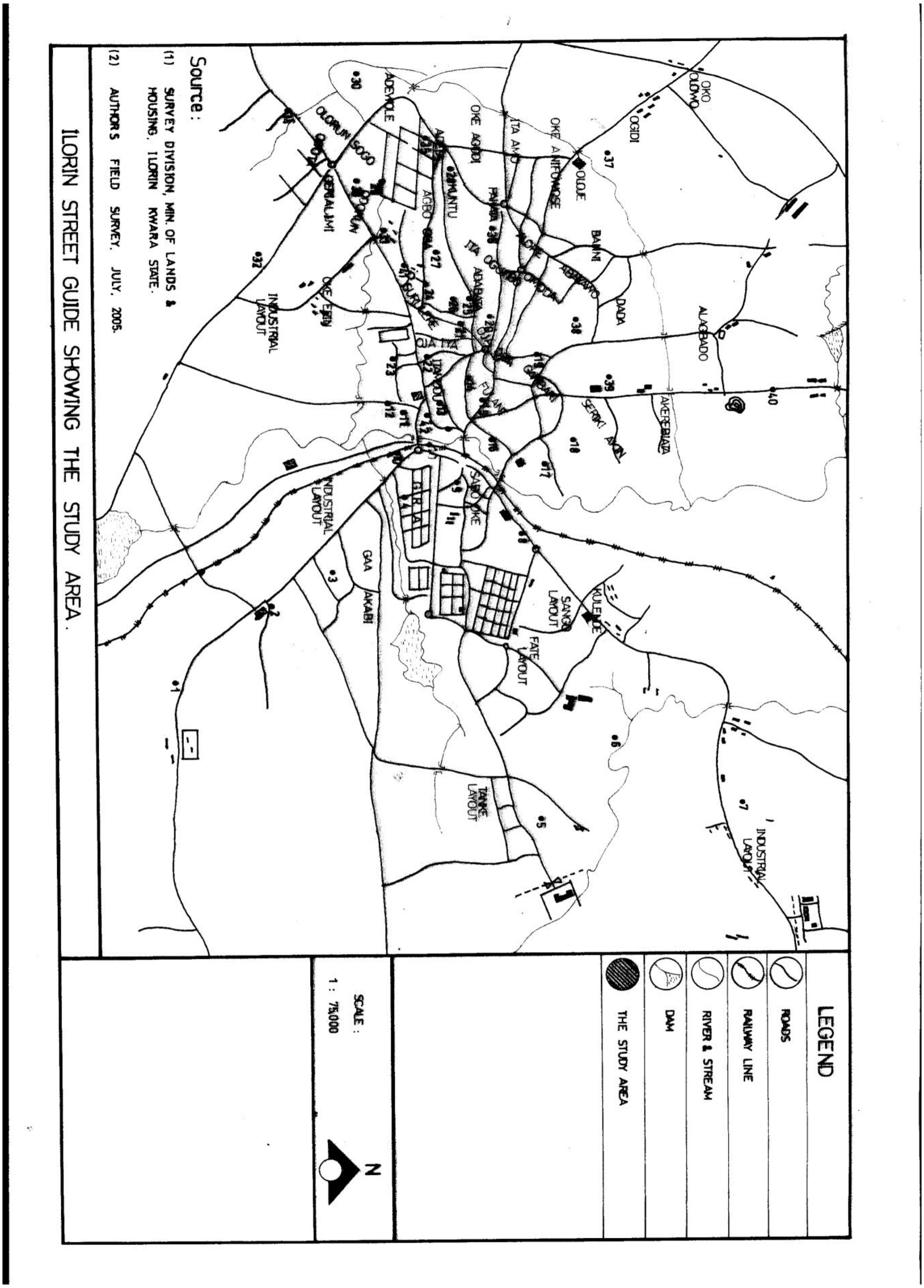


Figure 1. Overview of Ilorin metropolis showing the locations of noise measurements throughout this study (Source: Survey Division, Min. of Lands & Housing, Ilorin, Kwara State)

The measurements were made at street level (at road junctions, market centers, 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 seconds for a period of 30 minutes, 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), 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 [27]:

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

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

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

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

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

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

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 night time noise level, L_D is day time 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, TNI is the traffic noise index.

3. Results and Discussion

3.1. Assessment of Noise Descriptors

Noise measurements were done when the effects on the noise sources of variable factors (e.g. wind speed, rainfall etc) were at minimum. All the data were obtained on weekdays and under suitable meteorological conditions, i.e., no rain. Measurements were recorded at interval of 30 seconds for a period of 30 minutes, giving 60 meter readings per location. The data were used to evaluate noise descriptors in the form of L_{Aeq}, L_{10}, L_{90}, TNI, L_{NP}, L_D, L_N and L_{DN}.

The average noise descriptors were determined per location. Table 2 shows the daily average values of noise descriptors for all the sites surveyed. The sites are designated with numbers 1 to 42.

Table 2. Average Noise Descriptors at Study Locations

Site	L_{Aeq} dBA	L_{10} dBA	L_{90} dBA	TNI dBA	L_{NP} dBA	L_D dBA	L_N dBA	L_{DN} dBA
1	49	52	44	47	57	49	49	55
2	77	81	69	87	89	72	79	85
3	61	65	56	59	69	63	63	66
4	57	59	48	61	63	59	56	53
5	55	53	46	44	64	57	56	63
6	47	49	44	33	52	43	53	59
7	71	75	53	118	95	73	68	75
8	74	76	60	94	90	79	71	80
9	58	64	53	46	68	65	66	72
10	86	92	72	122	106	89	84	92
11	75	78	70	70	83	77	75	81
12	78	81	71	79	87	78	77	84
13	73	76	63	83	86	74	76	82
14	71	74	63	77	82	70	75	81
15	84	87	69	112	102	83	85	91
16	65	69	59	70	76	65	66	72
17	71	71	56	86	86	74	69	77
18	76	70	57	81	81	72	76	83
19	81	83	71	87	92	84	81	88
20	82	86	73	98	96	83	83	89
21	78	81	66	97	93	79	81	87
22	79	83	71	87	90	79	79	85
23	71	74	64	75	80	73	72	79
24	78	82	72	84	88	78	79	85
25	82	86	74	92	94	81	82	88
26	80	82	71	83	90	81	80	87
27	67	70	57	81	81	74	71	78
28	64	66	54	72	76	62	67	73
29	71	75	62	87	85	71	71	77
30	50	51	41	53	61	54	49	57
31	77	79	70	77	86	80	74	82
32	74	74	61	84	86	74	74	80
33	76	79	68	81	87	78	74	82
34	46	44	34	44	56	49	44	52
35	72	75	62	87	86	73	72	79
36	75	77	62	92	90	75	75	81
37	70	73	62	80	81	74	68	76
38	64	67	60	57	72	60	69	75
39	74	76	60	94	90	79	71	80
40	91	83	70	93	94	81	83	89
41	76	81	68	89	89	76	77	83
42	60	62	54	54	67	61	59	66

From Table 2, location 10 has the highest values of L_{Aeq} (86 dBA), L_{10} (92 dBA), L_D (89 dBA), TNI (122 dBA), L_{NP}(106 dBA), L_{DN} (92 dBA) and second highest value of L_{90} (72 dBA) and L_N (84 dBA). Location 15 has the second highest values of L_{Aeq} (84 dBA), L_{10}(87 dBA), TNI (112dBA) , L_{NP} (102 dBA), L_{DN} (91dBA) and highest value of L_N (85 dBA). These two locations are road junction/busy roads in the city surveyed. In order of high noise descriptors, next to these two locations are sites 20 and 25. The average values of noise descriptors of these locations are: L_{Aeq} (82 dBA), L_{10} (86 dBA), L_{90} (73 dBA), TNI (98dBA), L_{NP} (96dBA), L_D(83 dBA), L_N (83dBA) ,L_{DN}(89dBA) and L_{Aeq} (82 dBA), L_{10} (86 dBA), L_{90} (74 dBA), TNI (92dBA), L_{NP} (94dBA), L_D(81 dBA), L_N (82dBA) , and L_{DN}(88dBA) respectively.

Locations 20 and 25 are commercial centre and passengers loading park respectively. The background noise levels (L_{90}) at these locations are higher than locations 10 and 15. This is due to intrusive noise sources from human conversation due to commercial activities, radio player, electric generator noise etc. The lowest noise descriptor values were recorded at location 34 and 6 with values LAeq (46 dBA), L10 (44 dBA), L90 (34 dBA), TNI (44dBA), LNP (56dBA), LD(49 dBA), LN (44dBA) ,LDN(52dBA) and LAeq (47 dBA), L10 (49 dBA), L90 (44 dBA), TNI (33dBA), LNP (52 dBA), LD(43 dBA), LN (53 dBA) ,LDN(59 dBA) respectively. These locations are low density residential areas. Among the factors responsible for differences in noise levels in the centers surveyed include location site, presence of intrusive noise, traffic volume, commercial activities etc.

At the time of this measurement, the highest and lowest average noise pollution levels (L_{NP}) , traffic noise index (TNI) and equivalent pressure noise level (L_{Aeq}) were 106 dB (A), 122 dB (A), 86 dB(A) at location 10 (road junction) and 52 dB (A), 33 dB (A), 46dB(A) at locations 6 and 34(low-density residential area), respectively.

Locations 10 and15 were found to be the noisiest sites with peak noise levels (L_{10}) of 92 dB (A) and 94 dB (A), respectively. The high noise pollution values of these sites may be as 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. The high noise levels at road junctions confirm once more the previous findings of many authors pointing to the existence of a very close association between the sound levels measured at a given urban location and the road traffic volume flowing by that location [27,28].

High noise levels exposure in the city occurs in the day time at road junctions/ major roads. This is followed by passengers loading parks and commercial centers. 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.

Most of the countries, keeping in view the alarming increase in environmental noise pollution, have come up with permissible noise standards. The US Federal Highway Administration (FHWA) in April 1972 published interim noise standards for various land use as shown in Table 3. The World Health Organization (WHO) has suggested a standard guideline value for average outdoor noise levels of 55 dB(A), applied during normal daytime (16 hours) in order to prevent significant interference with the normal activities of local communities, and is considered as serious annoyance, while a value of 50 dB as moderate annoyance. Table 4 shows the *WHO* Guidelines values for community noise listing also critical health effects ranging from annoyance to hearing impairment.

Table 3. FHWA noise standards [30]

S/No	Land use	Noise Level L_{10}	Description of Land use Category
1	A	60 dBA (Exterior limit)	For parts and open spaces
2	B	70 dBA (Exterior limit)	Residential area, Hotels, Schools, Libraries, Hospitals etc
3	C	75 dBA	Developed areas
4	D	55 dBA (Interior limit)	Residential areas, Hotels,Libraries

The result of this study shows that noise levels (L_{10}) in all the passenger loading parks surveyed (ranges from 72–86 dB(A)) are higher than the recommended values by FHWA (i.e., 60 dB(A)). In other locations, such as developed areas and residential areas the measured noise values (L_{10}) can be classified as normally acceptable. Out of 12 developed areas (commercial centers) surveyed only 5 locations having noise level higher than 75 dB(A), out of 6 high density residential areas, only 2 locations recorded noise levels higher than 70 dB(A) and out of 6 low density residential areas, only 1 location had noise levels higher than 55 dB(A).

The U.S. Department of Housing and Urban Development (HUD) [32], recommends the following noise levels for residential areas, measured outdoors:

$L_{Aeq} \leq 49$ dB(A) —clearly acceptable

$49 < L_{Aeq} \leq 62$ dB(A) (or $L_{DN} \leq 65$ dB(A)) —normally acceptable

$62 < L_{Aeq} \leq 76$ dB(A) (or $65 < L_{DN} \leq 75$ dB(A)) —normally unacceptable

$L_{Aeq} > 76$ dB(A) (or 75 dB(A)< L_{DN}) —clearly unacceptable

Considering the criteria from HUD, only 9 locations representing 21.4% out of the 42 locations surveyed, can be classified as normally acceptable, while 14 locations representing 33.3% can be classified as clearly unacceptable. A widely accepted scientific fact is that living in black acoustic zones, where the equivalent sound level is higher than 65 dB(A) [8] put an urban population in a high risk status for numerous subjective effects of noise, including psychological, sleep and behavioural disorder.

Based on the National Guidelines for Environmental Noise Control by Federal-Provincial Advisory Committee on Environmental and Occupational Health (CEOH), a generally acceptable road traffic noise level L_D for residential areas should be less than 55 dB(A) and for night, L_N should not be greater than 50 dB(A). An area with environmental noise level less than 55 dB (A) is usually considered as a comfortable environment with little or no annoyance so that no negative physical and mental influence will be caused to essential activities such as working leisure and sleeping [33,34]. Among all the locations surveyed, only the low density residential areas like locations 1 and 34 are acceptable in terms of the noise levels per recommendations of CEOH and WHO. If the standard of HUD is considered, the dwelling areas like locations 1, 4, 5, 6, 30 and 34 are under normally acceptable situation and the noise levels of the other areas are still not acceptable. It may therefore be stated that the locations that fall under commercial centers, road junctions/ major roads, passenger loading parks and high density residential areas do not satisfy the recommended noise limit requirements according to these standards.

Table 4. WHO guideline for community noise [16]

Environment	Critical Health Effect	Sound Level dB(A)	Time (hours)
Outdoor living areas	Annoyance	50 -55	16
Indoor dwellings	Speech intelligibility	35	16
Bedrooms	Sleep disturbance	30	8
School classrooms	Disturbance of communication	35	During class
Industrial, commercial and traffic areas	Hearing impairment	70	24
Music through earphones	Hearing impairment	85	1
Ceremonies and entertainment	Hearing impairment	100	4

3.2. Effective Noise Control Measures and Sustainable Development in Nigeria

Due to the ignorance of Nigerians on the fact that there exist a close nexus between noise pollution and sustainable city, little or no attention is paid to the control of noise pollution in Nigeria. The execution and implementation of the law as regards environmental pollution is never implemented to the letter. It is observed that the persistence of this problem could endanger the future stability of human health and could aggravate the human health catastrophe in the fast growing cities in Nigeria.

The Nigerian experience as far as the sustainable development of its cities is concerned is quite appalling. The challenges to sustainable built-up environment in Nigeria cities and urban areas are embodied in urbanization. Among the common negative consequences resulting from urbanization is environmental noise pollution. The urban environmental noise pollution simply entails all what make the urban centre not to be conducive for living and also makes the environment to be unhealthy for living. This is a source of worry going by the problems and challenges presently faced in ensuring that urban areas of Nigeria become functional, liveable, and aesthetically pleasing. Urbanization has been the primary reason commonly advanced by scholars for the present deplorable state of many cities in the country [36].

A sustainable city could be defined as a city in which the population enjoys a high quality of life and which takes care not to transfer socioeconomic and environmental or health problems to other placed or future generations [35]. Sustainable development 'seeks to deliver basic environmental, social and economic services to all residents of the community without threatening the viability of the natural, built and social systems upon which the delivery of these services depends'. The main characteristics of sustainable development, as stated in the European Union's Fifth Environmental Action Programme [37] are:

1. To maintain the overall quality of life;
2. To maintain continuing access to natural and built resources; and
3. To avoid lasting environmental damage.

In spite of the extensive generation of noise in urban areas of Nigeria, surprisingly little research and documentation exist on the nature and extent of noise generation activities, their accompanying impacts and the implication for urban communities and their residents. In order to achieve sustainable urban development in Nigeria there is need to combat the main sources of noise pollution in Nigerian urban areas both at Local Government level and Federal Government level. This study reveals high noise level in Ilorin metropolis. A number of action plans can be taken to abate the environmental (traffic) noise pollution in this city. The possible technical and of course most effective control measures to abate noise pollution in Ilorin metropolis and in Nigerian urban cities in general are discussed below.

3.2.1. Noise Mapping

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 [38]. A noise map is considered as a tool to improve or to preserve the quality of the environment regarding noise pollution, allowing a comprehensive look at the problem of multiple sources and receivers. Noise map is also an excellent tool for urban planning. According to Santos [39], the use of noise maps techniques as a planning tool allows:

- Quantification of noise in the studied area;
- Evaluation of the population exposition;
- Creation of a database, for urban planning with localisation of noisy activities and mixed and sensible zones;
- Modelling of different scenarios of future evolution;
- Prediction of impact noise of projected infrastructure and industrial activities.

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 (L_D), night-time noise level (L_N), day–night noise level (L_{DN}), traffic noise index (TNI), average weighted equivalent noise level (L_{Aeq})and noise pollution levels (L_{NP}) has been developed.

Figure 2 shows the noise map of Ilorin metropolis. The noise map reveals that the nucleus of the city is characterized by a high noise exposure level. The daytime noise level is 84 dB (A), the night-time 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 night-time 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. The noise levels of Ilorin metropolis are similar to those reported for other cities around the world in Jordan, Spain, Brazil, Greece, and India [14,40,41,42].

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.

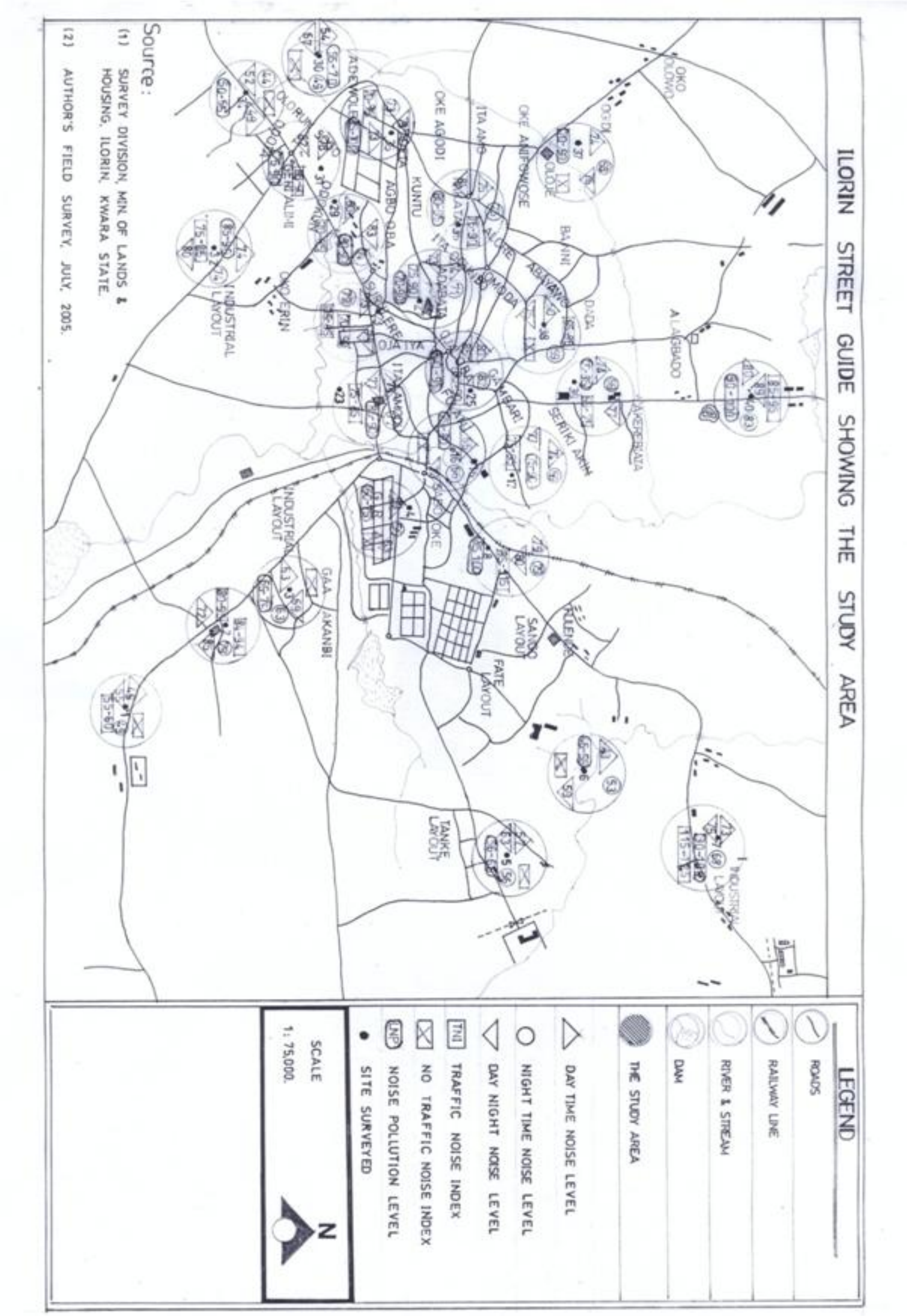


Figure 2. Noise map for Ilorin metropolis [28]

3.2.2. Noise control at the source

Vehicle noise comes from the engine, transmission, exhaust, and suspension, and is greatest during acceleration, on upgrades, during engine braking, on rough roads, and in stop-and go traffic conditions. Poor vehicle maintenance is a contributing factor to this noise source. Frictional noise from the contact between tires and pavement also contributes significantly to overall traffic noise. The level depends on the type and condition of tires and pavement. Frictional noise is generally greatest at high speed and during quick braking.

The first approach and effective measure of abating traffic noise pollution has been to reduce noise at source. As shabby cars (mostly ‘second hand’ cars) are still used in Ilorin metropolis and Nigerian urban areas in general, the quantity of the noise production made by automobile components such as engine, tires, exhaust and motive power is in a very high level. Motor vehicle noise can be reduced at source, for example through vehicle construction, selection of tires and exhaust systems, as well as vehicle maintenance. Control of vehicle noise emissions can be attempted using vehicle design rules and in-use noise regulations and enforcement.

3.2.3. Prescription of Noise Limits for Vehicular Traffic

The noise production of a particular traffic stream is determined by a number of factors: the type of vehicles in the stream and their level of maintenance; the number of vehicles passing per unit time; the constancy of flow - vehicles tend to be noisier in stop-and-go traffic; and the speed of traffic flow -noisiest at high speeds.

Different vehicle types produce different levels of noise. In general, heavy vehicles such as transport trucks make more noise than do light cars; they tend to have more wheels in contact with the road, and often use engine brakes while decelerating. Poorly maintained vehicles, such as those with incomplete exhaust systems or badly worn brakes, are noisier than well-maintained ones. Also, certain types of tires, such as off-road or snow tires are especially noisy. Apart from this, drivers of public vehicles contribute to road noise by using their vehicles’ horns, by playing loud music, by shouting at each other, and by causing their tires to squeal as a result of sudden braking or acceleration.

Noise pollution can be reduced by prescribing noise limits for vehicular traffic, ban on honking of horns in certain areas and planning main traffic arteries, industrial establishments, amusement areas, residential colonies, creation of silent zones near schools and hospitals and redesigning of buildings to make them noise proof. Other measures can involve reduction of traffic density in residential areas giving preferences to mass public transport system. In a steady and continuous traffic stream (traffic management), the speed and also the noise level of road is reduced. According to Tsunokawa and Hoban [43], reducing speeds to half, decreases road noise level up to 6 decibels.

3.2.4. Use of Combination of Barriers and Berms Along Road Side

Noise barriers are among the most common mitigative measures used. They are most effective if they break the line of sight between the noise source and the receptors being protected, and if they are thick enough to absorb or reflect the noise received. Various materials and barrier facade patterns have been extensively tested to provide maximum reflection, absorption, or dispersion of noise without being aesthetically ugly. According to Mehravaran, et al [44], if the line of sight between receiver and highways is blocked with barriers, the 5 dB(A) attenuation can be expected. Then, adding 1 meter to the barrier height provides the additional 1.5 dB(A) attenuation. Length of barriers should be long enough, to diffract only small portion of noise through the edge of the barriers. Barriers should be so long that the distance between receiver and barrier end in at least four times of the perpendicular distance between receiver and barrier.

The types of noise barriers most commonly employed consist of earth mounds or walls of wood, metal, or concrete which form a solid obstacle between the road and roadside communities. Noise mounds require considerable areas of roadside land; for narrow alignments, bridges, and roads on embankments, wall-type barriers may be the only viable option. Two or more barrier types are often combined to maximize effectiveness. Plantations of trees and shrubs, for instance, contribute little to actual noise reduction, but they do confer a psychological benefit in reducing the perceived nuisance of traffic noise, and they are often used to ‘soften’ the visual appearance of mounds and walls. Vegetation with appropriate height, width and enough density can decrease the traffic noise. According to the Federal Highway Administration (FHWA) reports, vegetation is not adequate to provide instance reduction. It is necessary to use the combination of barrier and berms with vegetation to obtain a good aspect [45].

3.2.5. Smooth and Good Road Maintenance

On high speed roads the predominant noise is that produced by vehicle tires as they roll over the road surface. There are three effective factors on noise production when the vehicles tires contact with road surface: shape of curves or treads on surface of tire, kind of tires of vehicles and age of asphalts. The physical characteristics of the road surface and its surroundings play a large role in determining noise output. Well-maintained, smooth-surfaced roads are less noisy than those with cracked, damaged, and patched surfaces. Expansion joints in bridge decks are especially noisy. Roadside surfaces such as vegetated soil tend to absorb and moderate noise, while reflective surfaces like concrete or asphalt do not have any beneficial function. In Ilorin metropolis and Nigerian urban areas in general, roads are poorly maintained. Hence, traffic noise pollution is high due to traffic congestion as a result of bad roads. Most residential buildings are very close to main roads in Nigerian urban areas. Hence, there is high impact of traffic noise on residents close to the main roads [27]. Increasing distance between residential buildings (receivers) with road decreases the noise pollution effectively. Doubling the distance between the road and the receptor results in a decrease of 3 dB (A) in the noise level [43].

Perhaps the greatest determinant of noise impacts is the spatial relationship of the road to number of vehicles potential noise receptors. The closer the road to receptors, the greater the impact. The higher the population density in roadside areas, the greater the number of people likely to be receptors and, consequently, the greater the impact. Consequently, using of noise buffer zones between buildings and highways is one of the main attenuation methods for the noise pollution before implementation development plan. If the government could increase the distance of roads from buildings in Ilorin metropolis, the impact of traffic noise on the populace will reduced.

Vehicles in steep roads and sharp corners produce more noise pollution. Hence this factor should be considered when a road is designed. Building insulation, such as double windows glazing and noise absorption material in walls, can prevent the traffic noise effects on buildings as a receptor. When the buildings are designed adjacent the highways, bedrooms, sitting rooms and balconies should not face the highway in order to reduce the noise effects [44].

3.2.6. Changing the Pavement Composition and Porosity

Conventional asphalt pavement usually consists of a mixture of bitumen and a range of graded aggregate materials, yielding *densely graded asphalt pavement.* In contrast, *drainage asphalt pavement* uses an open graded asphalt mixture, which eliminates the aggregates of intermediate grading to obtain a higher porosity mixture.

The noise emission levels from vehicles travelling on the drainage asphalt pavement (DA) are lower than on the densely graded asphalt pavement (DGA). In comparison to the DGA pavement, the peak noise levels at various cruising speeds are reduced on the DA pavement as shown in the line graphs (Figure 3). For example, the peak noise reduction would be in the range of 0.1 and 0.4 decibel with the DA porosity of 10 to 15 percent. With the porosity of 20 to 25 percent, the peak noise levels would decrease by the range of 0.1 to 1.0 decibel. The two bar charts (Figure 4 and Figure 5) compare the measured noises between the DGA pavement, with a porosity of 5 percent (upper chart), and the DA pavement, with a porosity of 20 percent. The noise reduction by the DA pavement falls in the range of 5 to 6 decibels in the former case, and from 1 to 3 decibels in the latter case. Compared with the DGA pavement, the noise levels of vehicular traffic drop by some 10 decibels on the porous elastic pavement that uses urethanebonded rubber particles [46]. Most existing roads in Nigerian urban areas are of densely graded asphalt pavement (DGA), hence, there is a high traffic noise level in Nigerian urban areas.

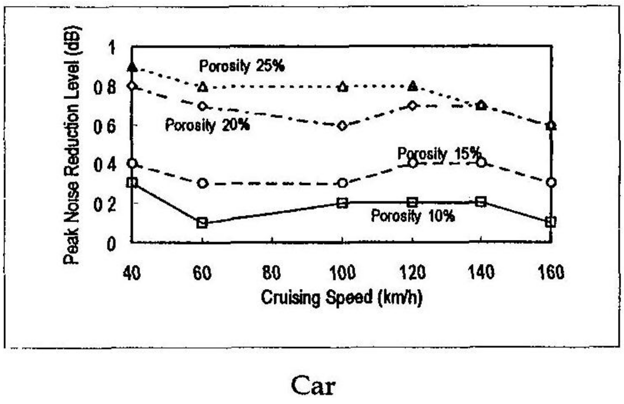


Figure 3. Peak noise reduction level against cruising speed

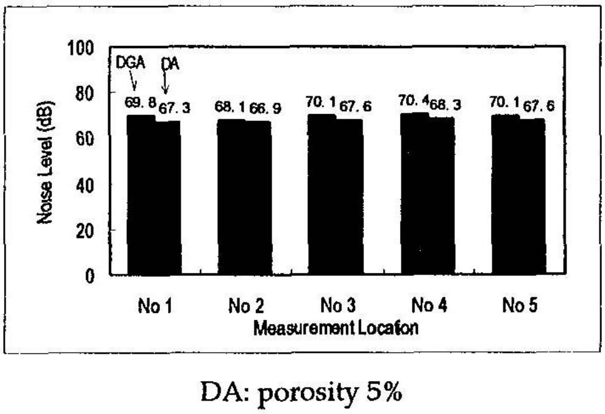
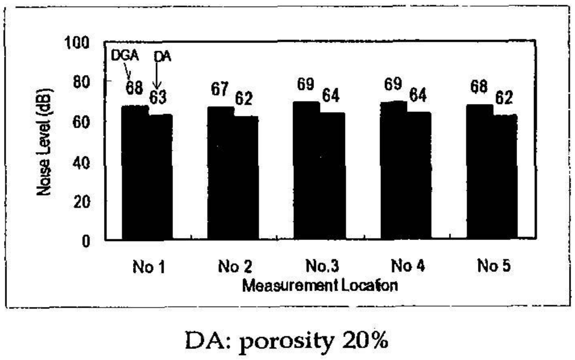


Figure 4. Comparative of noise level on DGA and DA (with porosity 5%)



Source: Ref.[46]

Figure 5. Comparative of noise level on DGA and DA (with porosity 20%)

3.2.7. Public Awakening and Education

Due to the ignorance of Nigerians on the fact that there exist a close nexus between noise pollution and sustainable city, little or no attention is paid to the control of noise pollution in Nigeria. It is important that public awakening is very essential for the control and prevention of environmental noise pollution. In Nigeria, most of the persons lack an idea about the ways in which noise pollution could be controlled. Very few scientists are aware of the problem and its control. Masses are still ignorant of the grave effects of the noise pollution. In this regard television, radio, internet, and newspapers should give a campaign for wide publicity.

Since noise also results from the citizen's behaviour (driver, music player, hawker etc), information and education campaigns usually produce good results in the long term. People can be educated through radio, TV and newspapers about noise pollution. Public vehicles drivers should be educated not to horn unnecessarily on the roads, avoid quarrelling amongst each other and so on. There should be complete ban of loudspeakers from 8 p.m. to 7 a.m.

Information on different actions and on the results should be well disseminated and should correspond to general aims and action plans. There is 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 citing new roads, shopping centers, schools, hospitals and both commercial and residential houses in general.

4. Conclusion

In this study, comprehensive assessment of environmental noise levels of Ilorin metropolis has been carried out. Forty two (42) selected sites were surveyed for noise pollution levels. The result of this study shows that at locations near the busy roads/ road junctions, commercial centers and passengers loading parks the equivalent noise level, background noise level and peak noise level are higher compared to monitoring station near low density residential areas.

This investigation reveals that noise levels at 30 of 42 measurement points exceeded the recommended limit of 60dB (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.

The sources of noise pollution identified in this paper also exposed the common channels of environmental pollution through noise and its effects on the public in Ilorin metropolis which is most significantly similar throughout the Nigerian cities and the world in general. The challenges posed by noise pollution on human health and the environment have not yet received full attention which it deserves. Though, generally statutory and policy provisions regulating noise on pollution in Nigeria as well as the world over have lofty aims and are quite salutary, however, there is need for proper implementation.

In this work, transport infra-structures have been recognized as major sources of noise in Ilorin metropolis. Hence, technical actions on the transport systems can produce interesting results. Possible technical controls include (i) changes in road profiles, (ii) low noise pavements (porous or porous elastic) type, (iv) effective repairs to the silencers and vehicle suspensions so as to reduce exhaust and rolling stock noise, (v) reduction limitations or restrictions on traffic (types of vehicles, speed, hours of access etc) and (vi) building of acoustic barriers along the sides of heavily travelled highways running through residential areas. Transportation and land planning (private versus public transportation, bus lanes, parking areas, shuttle buses and pedestrian areas) are important components of 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 different actions and on the results should be well disseminated and should correspond to general aims and action plans. The most valuable step to decrease noise pollution in a big city like Ilorin is the preparation of noise maps. 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.

Based on the importance of noise map as a tool to abate noise pollution in urban areas and for sustainable urban cities in Nigeria, it is therefore recommended that noise map should be made available for Nigerian urban cities. 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 centres is recommended for future work.

Conclusively, aggressive implementation of the existing laws, policies and guidelines on environmental pollution will go a long way in addressing the problem of noise pollution and brings about sustainable urban development in Nigeria.

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