THE SPATIO-TEMPORAL DISTRIBUTION OF URBAN NOISE ISLANDS IN CALABAR METROPOLIS, NIGERIA

J. N. Obiefuna[1]; G. N. Njar[2]

[1]*Department of Geography and Environmental Science, Faculty of Social Sciences, University of Calabar, Nigeria. Email: JoeObiefuna@GMail.com* [2]*Department of Geography and Environmental Science, Faculty of Social Sciences, University of Calabar, Nigeria. Email: Harjogold01@yahoo.com*

* Corresponding author's contact: Dr. J. N. Obiefuna: JoeObiefuna@GMail.com

ABSTRACT

This study examined the spatial and temporal distribution of urban noise islands in Calabar Metropolis. Noise levels were acquired from the secondary source, after Obiefuna, Bisong and Ettah, 2013. Analysis of variance (ANOVA) test was used to test the hypothesis. The null hypothesis was rejected after having examined the main effect of space and time which happened to be significant at $P<0.001$ indicating a variation. It was therefore, recommended that in order to maintain the tranquile status of the residential areas, activities that generated high noise in the commercial and industrial landuses should be discouraged from springing up in the residential zones. Finally, the source, path and receiver (source-path-receiver) techniques of noise attenuation were recommended as a general way of reducing noise in Calabar Metropolis.

Keywords: Urban Noise Level, Noise Islands, Spatial Distribution, Temporal Distribution, GIS, Noise Attenuation

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INTRODUCTION

Noise, being an unwanted sound is perceived as an environmental stressor and nuisance. One of the primary characteristics of the unwanted nature of noise is its loudness or perceived intensity. Loudness comprises of the intensity of sound, its total distribution or variation and its duration or temporal dimension. The evidence is mixed on the importance of both the duration and the frequency components of sound and also, the number of events involved in determining annoyance (Field, 1984).

Having a good knowledge of the spatial distribution of noise level in any urban centre is a pointer that planning of facilities would take a good course. For instance, an educational facility should not be located in close proximity to a recreational landuse element such as sports stadium. Again, an airport should not be located in close proximity to a residential landuse element. This is why there is need for master plan update of most urban centres in Nigeria. This would re-evaluate the current landuse elements and correct any crisis or conflict that has been created due to economic growth and unplanned urban development.

In Calabar, quest for urban growth and development has led to the establishment of several growth poles such as the Calabar airport, the industrialized zone, e.t.c. These ``poles`` cannot be functional without noise being generated at varying magnitude and temporal periods. The good news is that these noise levels generated at different temporal periods and magnitudes could be measured and tested scientifically or quantitatively.

The essence of this research is to assess the spatio-temporal distribution of noise islands in Calabar Metropolis, due to perceived updates in the configuration of the urban dynamics. Noise Islands as being used in this research are simply noise spurs or distinct noise levels at different spatial locations, caused by varying social, cultural, religious and economic activities.

Statement of the research problem

Obiefuna, Bisong and Ettah, (2013) have been able to generate a Geographic Information Systems (GIS) based Noise Islands map of Calabar Metropolis. These maps depicted various noise

levels at different spatial locations and at varying temporal periods. Unfortunately, the study failed to test its statistical significance. It is widely known that mathematisation or quantification leads to accuracy and precision in scientific enquiry. According to Enger and Smith (2008), one of the important components of the scientific method includes constructing and testing of hypothesis.

A ground truthing or confirmatory survey for this research made using a sound level meter revealed that there is still wide distribution of high noise level (75dB to 105dB) at various spots in Calabar metropolis as identified by Obiefuna, Bisong and Ettah, (2013). These noise levels exceeded the World Health Organization (WHO) and the United Nations Environmental Programme (UNEP) noise exposure limit recommendation of 75dB (WHO and UNEP, 1980). Even the 90dB industrial and environmental noise threshold stipulated by the Federal Environmental Protection Agency (FEPA, 1991)) was also exceeded in most places in Calabar. Examples of such locations where noise level spans from 80 to 105dB are the Stone Craft Industry, M-Saleh Industry, Calabar Road area, Watt Market, Marian Road area, Etta-Agbor Road, and Ekpoabasi Roundabout. Noise level in these areas is beyond the ceiling, and is capable of causing hearing loss if one is exposed to it for a long period of time.

Noise pollution apart from being a nuisance is a slow and subtle killer, yet little efforts have been made to study it in a more comprehensive and digitally friendly way in Calabar Metropolis. Kiernan (1997) stated that even relatively low level of noise affects human health adversely. Noise causes hypertension, disrupts sleep, disturbs academic activities and hinders cognitive development in children. The effect of excessive noise could be so severe that either there is a permanent loss of memory or a psychiatric disorder (Bond, 1996).

In Calabar, there is deficient planning as noise levels were not and are still not being considered during location of strategic services in the city. Some examples of such services are the police station, court of justice, hospitals and schools and even the University of Calabar. Since noise is able to mask speech and interfere with tasks and communication (Dijk, Souman and deVries, 1987; Smith and Broadbent, 1992), these services cannot be said to be efficient because high noise level interferes with, and causes poor communication. This is the ill of poor spatial planning of facilities. If noise levels are known at various locations, abatement and attenuation measures would be easily determined.

Research Objectives

The main aim of this study is to examine the spatial and temporal distribution of noise islands in Calabar Metropolis. The objectives are as follows:

1) To examine the spatial and temporal variation in noise level in Calabar Metropolis
2) To make recommendations on the best attenuation mechanism for noise generating landuses.

Research hypothesis

$H_{O:}$ There is no significant spatio-temporal variation in noise level in Calabar Metropolis.

2. Method of Study

2.1 Data sources

This research depended solely on secondary dataset from Obiefuna, Bisong, and Ettah (2013). A two-way analysis of variance (ANOVA) was used to test this hypothesis.

Table 1.
Sampled points with their coordinates.

SN	Landuse type/ location	Activity Type	GPS value Long.	Latt.	Noise sources
1	Industrial-EPZ	Stone Craft Industry (manufacturing)	5.02563	8.32704	Point source: Cutting and smoothening equipments for Marb production
2	Industrial-EPZ	M-Saleh Industry (manufacturing)	5.02485	8.32704	Point source : Metal cutting, smoothening, welding.
3	Transportation (Eleven-Eleven area)	Round About	4.96384	8.32488	Line Source: Car horn blasting, vehicle engines
4	Transportation (Effio-Ette area)	Road Junction	4.99343	8.3451	Same as 3 above
5	Transportation (MCC)	Road Junction	4.98754	8.33346	Same as above
6.	Transportation(IBB Way)	Round About by Rabana	4.96304	8.33608	Same as above
7	Transportation (Calabar Road)	Road Node by Total filling station	4.95736	8.31927	Same as above
8.	Transportation (Ekpoabasi Rd)	Road Node by CRUTECH	4.93151	8.3284	Same as above
9.	Transportation (Etta-Agbor Road)	Round About (Unical Main Gate)	4.95254	8.33921	Same as above
10.	Transportation (Etta-Agbor Road)	Round About (by IBB Rd)	4.95933	8.32164	Same as above
11.	Transportation (Calabar Road by Atakpa)	Road Node	4.95773	8.32013	Same as above
12.	Residential (Satellite Town)	Church (Demonstration Chapel)	4.96033	8.3569	Point Source: worship activities, generator
13.	Residential (Satellite Town)	worship (Church of God Mission)	4.96189	8.3514	Same as 12 above
14.	Residential (Ekong Bassey Street)	worship centre	4.97071	8.35195	Same as above
15.	Residential (Edem Street)	Worship	4.96269	8.31679	Point source: worship activities, vehicles, electric generator
16.	Residential (Satellite Town)	Worship	4.96085	8.35385	Same as 12 above
17.	Residential (Victor Akan Street)	Worship	4.9533	8.3218	vehicles, worship activities
18	Residential (Palm Street))	worship	4.95075	8.32363	Worship activities, vehicles
19...	Commercial (Marian Market)	Grinding Section	4.97559	8.33927	Point source: Grinding
20.	Commercial(Marian Market)	Music Store	4.9753	8.33922	Point source: loud music.
21..	Commercial (Watt Market Area)	Music Store	4.95653	8.32221	As in 20 above
22..	Commercial (238 Etim Edem Street)	music Store	4.96039	8.3243	As above
23.	Commercial (179 Etim Edem Street)	Music Store	4.95931	8.32309	As above

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24.	Commercial (Watt Market area)	Music Store	4.95736	8.31927	As above
25.	Commercial (Watt Market area	Grinding Section	4.9583	8.32143	Point source: Grinding machines,

Source: Obiefuna, Bisong and Ettah, 2013

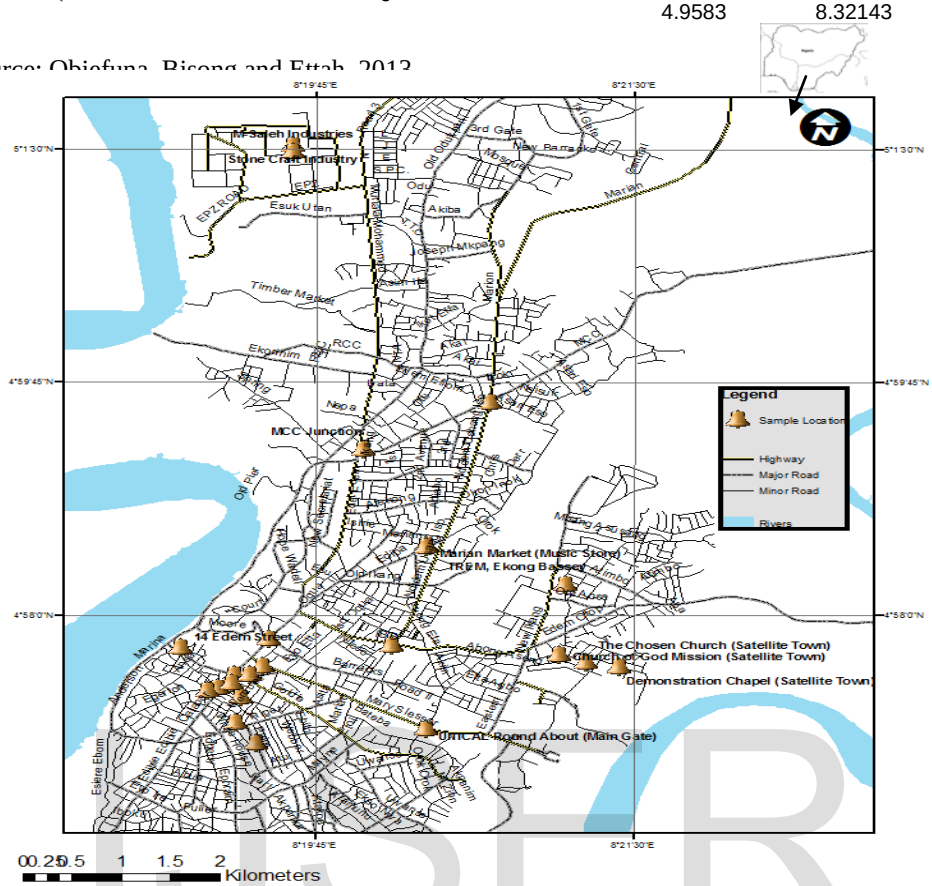

FIG. 1. Sampled points in Calabar Metropolis
Source: Obiefuna, Bisong and Ettah, 2013.

Data Presentation and Analysis

Variation in noise level across sampled locations and landuses

Table 2 shows the mean noise level for all the sampled locations for the three time periods: morning, afternoon and evening. From the tables, numbers 1 and 2 represent the industrial landuse; the numbers ranging from 3 to 11 represent the transportation landuse; numbers 12 to 18 represent the residential zone while numbers 19 to 25 represent the commercial landuse. From the tables, it could be revealed that the commercial landuse has the heavier mean decibel values within the range of 68.0dB and 95.8dB. The residential landuse happens to have a lower mean decibel value ranging from 44.9dB to 71.4dB.

Table 3 shows the mean noise level for all the identified landuses. From the table, the industrial landuse has the highest noise values in the morning, which spans from 88.5dB at 8am, 89.1dB at 8.30am and 89.5dB at 9am. The least is the residential landuse, with value ranging from 55dB to 57dB at the same time period. In the afternoon, the commercial zone emerged the first in terms of noise level with the following figures: 84.8dB at 12 noon, 85.6dB at 12.30pm, and 86.5dB at 1pm. In the evening, the commercial zone also emerged the first with the following figures: 86.5dB at 4.pm, 86.6dB at 4.30pm, and 86.9dB at 5pm.

Table 2: Mean noise level (in dB).

Location/ Landuse	1 Ind	2 Ind	3 Tran	4 Tran	5 Tran	6 Tran	7 Tran	8 Tran	9 Tran	10 Tran	11 Tran	12 Res	13 Res	14 Res	15 Res	16 Res	17 Res	18 Res	19 Com	20 Com	21 Com	22 Com	23 Com	24 Com	25 Com
Morning (8-9am)	90.4	85.7	71.9	**72.2**	**75.6**	**61.8**	**66.4**	**75.8**	**69.3**	64.0	71.5	56.5	53.0	50.2	66.1	54.9	67.5	50.3	90.4	75.4	74.8	92.5	81.8	70.7	88.5
Afternoon (12-1pm)	80.3	79.0	**77.4**	**76.0**	**77.6**	**73.5**	**72.7**	81.0	76.5	71.6	76.7	53.1	53.5	49.5	70.3	49.9	68.7	46.6	93.4	81.5	78.1	93.1	85.8	76.1	91.4
Evening (4-5pm)	84.8	79.8	83.3	84.7	85.2	72.7	70.9	72.0	77.2	74.6	79.7	52.8	53.8	47.2	67.4	47.8	63.2	45.7	94.3	83.2	83.2	95.5	87.9	77.2	86.3

Ind = Industrial, Tran = Transportation, Res = Residential, Com = Commercial

Source: Obiefuna, Bisong and Ettah, 2013.

TABLE 3

Table 3: Mean noise level for the identified landuses expressed in dB.

		Industrial	Transportation	Residential	Commercial
Morning	8.00am	88.5	65.6	55.4	79.0
	8.30am	89.1	70.9	57.7	83.2
	9.00am	89.5	73.0	57.6	83.8
Afternoon	12.00pm	77.8	75.0	56.9	84.8
	12.30pm	71.4	76.0	55.7	85.6
	1.00pm	90.1	76.7	55.2	86.5
Evening	4.00pm	83.7	79.3	54.7	86.8
	4.30pm	81.0	78.5	54.7	86.6
	5.00pm	82.4	75.7	52.4	86.9

Source: Obiefuna, Bisong and Ettah, 2013

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Table 4 shows the two-way ANOVA output.

TABLE 4

Result of two-way analysis of variance.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	39967.796	74	540.105	33.429	.000
Intercept	1192536.801	1	1192536.801	7.381E4	.000
Space	37653.853	24	1568.911	97.104	.000
Time	348.084	2	174.042	10.772	.000
Space * Time	1965.858	48	40.955	2.535	.000
Error	2423.553	150	16.157		
Total	1234928.150	225			
Corrected Total	42391.349	**224**			

R Squared = .943(Adjusted R Squared = .915)

Source: Analysis by the authors, 2017.

TABLE 5

Estimated marginal means of space.

Space	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Location 1	85.178	1.340	82.530	87.825
Location 2	81.511	1.340	78.864	84.159
Location 3	77.544	1.340	74.897	80.192
Location 4	77.644	1.340	74.997	80.292
Location 5	79.456	1.340	76.808	82.103
Location 6	66.367	1.340	66.719	72.014
Location 7	70.000	1.340	67.353	72.647
Location 8	76.267	1.340	73.619	78.914
Location 9	74.344	1.340	71.697	76.992
Location 10	70.078	1.340	67.430	72.725
Location 11	75.933	1.340	73.286	78.581
Location 12	54.144	1.340	51.497	56.792
Location 13	53.244	1.340	50.597	55.892
Location 14	48.956	1.340	46.308	51.603
Location 15	67.922	1.340	65.275	70.570
Location 16	50.867	1.340	48.219	53.514
Location 17	66.456	1.340	63.808	69.103
Location 18	47.500	1.340	44.853	50.147
Location 19	92.678	1.340	90.030	95.325
Location 20	80.033	1.340	77.386	82.681
Location 21	78.667	1.340	76.019	81.314
Location 22	93.711	1.340	91.064	96.259
Location 23	85.144	1.340	82.497	87.792
Location 24	74.678	1.340	72.030	77.325
Location 25	88.733	1.340	86.086	91.381

Source: Analysis by the authors, 2017.

TABLE 6

Estimated marginal means of time

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Morning	71.085	.464	70.168	72.002
Afternoon	73.329	.464	72.412	74.246
Evening	73.992	.464	73.075	74.909

Source: Analysis by the authors, 2017.

Interpretation: main effect

From table 4, the main effect of space is significant F (24, 150) = 97.10, P<0.001. From the estimated marginal means in table 5, the difference in the noise level at each of the locations is significantly different from one another.
For time, the main effect is significant F (2, 150) = 10.77, p<0.001. From the estimated marginal means in table 6, it could be seen that noise level increases for morning (71.09dB) through afternoon (73.33dB) to evening (79.99dB)

Interaction Effect

The space * time interaction is also significant as F (48, 150) = 2.54 and P<0.001. The graph of space * time interaction is shown (FIG 2).

Decision

In view of the above findings, (P<0.05), the null hypothesis was rejected in favour of the alternative. In other words, the variation of noise level within the locations studied, and time periods considered is statistically significant.

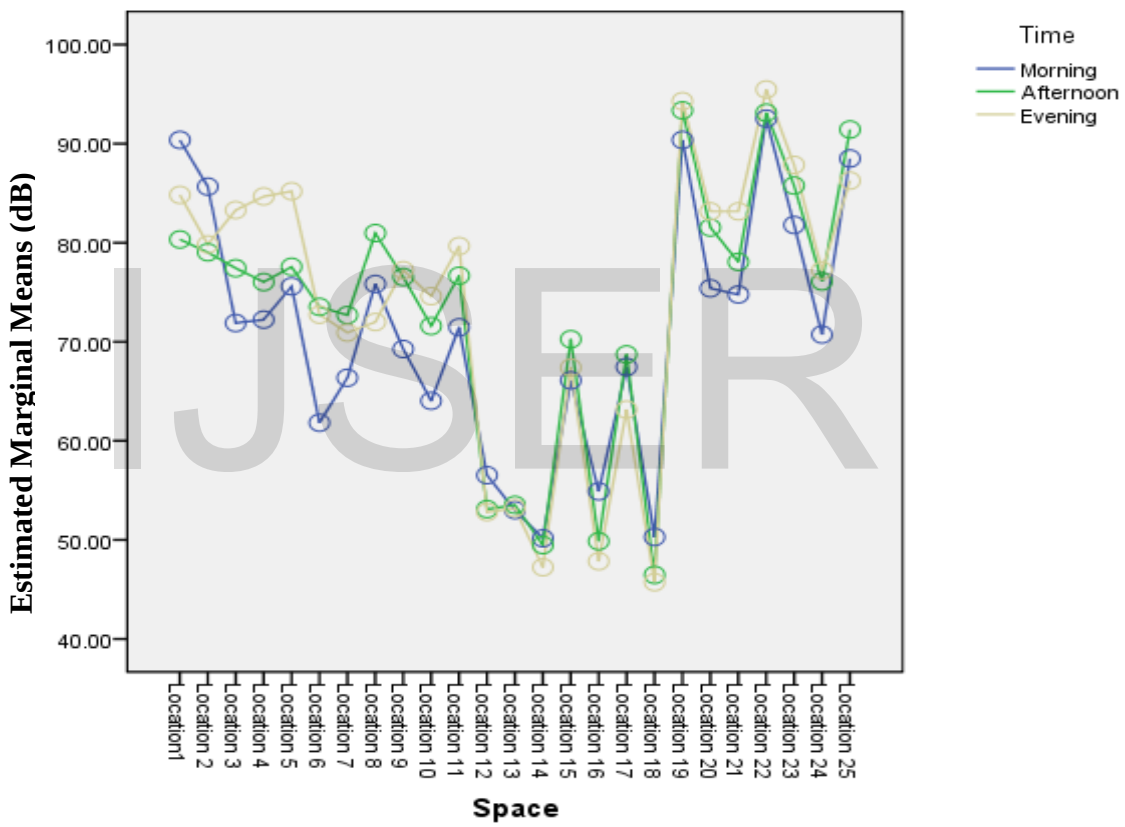

FIG 2. Estimated marginal means over time and space
Source: Analysis by the authors, 2017.

4.2.5 Post-hoc comparison

The post-hoc test that was conducted for time reveals that the level of noise in the morning is significantly different from those of afternoon and evening (Table 7). Hence, the cause of the variation lies within morning hours.

TABLE 7

Result of post-hoc test for variation of noise with time

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig. [a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Morning	Afternoon	-2.244*	.656	.001	-3.541	-.947
Evening		-2.907*	.656	.000	-4.204	-1.610
Afternoon	Evening	2.244*	.656	.001	.947	3.541
Morning		-.663	.656	.314	-1.960	.634
Evening	Morning	2.907	.656	.000	1.610	4.204
Afternoon		.663	.656	.314	-.634	1.960

Based on estimated marginal means

*. The mean difference is significant at the .05 level
a. Adjustment for multiple comparisons: Least significant difference (equivalent to no adjustments)
Source: Analysis by the authors, 2017.

Discussion of Findings

The spatio-temporal distribution of noise islands in Calabar Metropolis has been investigated. Though mean noise level from different sampled locations was used, noise level was significantly high in most locations. The highest recorded noise level was from the commercial zone, where the mean noise level for morning was 82dB, 85.6dB for afternoon and 86.8dB for the evening.

The industrial area was ranked second in terms of noise generation. The statistics for the industrial area is 89.0dB (morning), 79.8dBm (afternoon) and 82.4dB for the evening. The drop in noise level in the afternoon in the industrial zone was as result of leisure hours usually being enjoyed by the staff of the industries between the hours of 12noon and 2pm.

The transportation landuse generated average noise level within the threshold of 75dB. From findings, the average noise level for the landuse is 69.8dB (morning), 75.9dB (afternoon) and 77.8dB (evening). Data collected from transportation landuse show that noise from the zone was very erratic. The unpredictability of noise level in the transportation landuse was caused by the mobile status of noise generators, traffic light and to an extent, the round about. In the transportation landuse, higher and constant noise level was recorded on road nodes that lacked traffic light and roundabout, because, horn blasting caused by traffic congestion, impatience and struggle to gain access to way is prevalent at such location.

The residential landuse generated the lowest noise level. Noise level in the residential area varies from 56.9dB for morning to 55.9dB for afternoon as well as 53.9dB for evening. From the data, the residential area generated more noise in the morning and evening hours of Sunday, Wednesday, and Saturday. However, though noise level from the residential zones is not above the noise threshold, religious activities have been identified as the factor responsible for elevated noise level for these days.

In some locations such as points in the commercial zone at the city centre, noise level increases gradually from morning through afternoon and starts waning in the evening. This is because, the city centre often called the central business district (CBD) is most busy at day time. People would always retire to their homes towards evening, leaving the CBD bare. In few other locations, particularly along the transportation landuse, noise level dropped in the afternoon and then increased in the evening as movement of people increased.

In support of the theory of sound propagation, noise in Calabar has been found to emanate from both point and line sources, which is as a result of various economic activities. In addition,

noise level in the metropolis slowly changes with the daily cycle of human activities. This means that as activities changed in type and volume, noise level also changed. For example, the industrial landuse generated high noise level in the morning and evening hours. Areas identified to have high noise intensity are areas with intensified social, economic and other activities.

Bye and large, noise from the industrial, commercial, transportation and residential areas is primarily generated by stone cutters, filling machines, grinding machines, loud speakers, car horns, vehicle engines, tyre screeching and other vibrating bodies. FIGs 3 to 6 depict various sources of noise at the industrial, commercial and transportation landuses.

FIG 3: Stone cutters: Point sources of noise in an industrial landuse.
Source: Obiefuna, 2012

FIG 4: Automobiles: Line sources so noise (transportation landuse).
Source: Obiefuna, 2012.

FIG 5: Grinding machine: Point source of noise at the commercial zone.
Source: Obiefuna, 2012.

FIG 6: Loudspeaker: Point source of noise at the commercial zone.
Source: Obiefuna, 2012.

Conclusion

This study has been able to establish the presence of high noise level across various spatial locations. There cannot be a proper urban planning without putting noise sources and noise

level to consideration. When this is done, a path to a planable and livable urban environment would have been created.

Two hypotheses were formulated and tested. The first hypothesis was centred on the spatial and temporal variation in noise level in Calabar Metropolis. The result of the test shows that the main effect of space is significant at $F(24, 150) = 97.10$, $P<0.001$. From the estimated marginal means table, there exists a significant difference in the noise level at each of the locations. For time, the main effect is significant at $F(2, 150) = 10.77$, $p<0.001$. It could, therefore, be said that noise level increases in the morning (71.09dB) through afternoon (73.33dB) and the evening (79.99dB). The study also discovered that there is a significant spatio-temporal variation in noise level in Calabar Metropolis. Furthermore, a post-hoc test carried out for time revealed that the level of noise in the morning is significantly different from those of afternoon and evening.

The study was also able to establish the existence of significant variation in the level of noise. However, because the direction of the variation was not identified, a post-hoc test had to be carried out. The test indicated that the difference in noise level was caused by the residential and transportation landuses. The most vulnerable landuse in terms of noise risk is the commercial landuse, closely followed by the industrial and transportation landuses. The residential landuse generated the lowest noise.

Recommendations

The following noise attenuation and tranquility-sustaining mechanisms have been offered in this research as antidotes to noise problems in Calabar Metropolis. These mechanisms concertedly, make up the source-path-receiver technique of noise attenuation. Preventive checks have also been offered.

(a) Activities that generate high noise as identified in the commercial and industrial landuses should be discouraged from springing up in the residential neighbourhood. Besides, the source method of noise attenuation, where noise is reduced at the source should be adopted in homes. For example, loud music should be discouraged. Also, worship centres located in the residential areas should be advised to adopt the path concept by erecting a barrier or fence in order to further protect the residential and the vulnerable areas. Relocation of non-conforming worship centres by the government is advised.

(b) Industrial safety standard should be upheld by considering the receiver method of noise attenuation as an obligation and not a choice in the industrial zones. By this, the employees should be obligated to adhere to the use of ear mufflers or head phones.

(c) As development progresses, the path technology of noise attenuation, which is the use of barrier walls of sufficient height and material along the transportation networks, is advised. This innovation can substantially reduce the intensity of noise from the line sources that encroach into the nearby residences and offices on the same linear position. Again, unnecessary blasting of horns by motorists should be fined or discouraged.

(d) Regular and periodic investigation of noise levels by relevant and concerned environmental outfits would provide town planners and policy makers' tools for managing the dynamic physical and socio-economic problems associated with high noise levels.

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