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Spatial Association between Environmental Noise Levels and Occurrence of Children Hearing Impairments in Ibadan Metropolis, Nigeria

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Abstract

Reports in the past few decades indicate that Nigerian cities have high noise levels that is claimed to impact the health of residents negatively. The present article therefore examine the relationship between levels of environmental noise in selected residential areas in Ibadan metropolis with varying reported cases of hearing impairments (HI). Data on cases of HI were collected from one hospital; noise monitoring was conducted with the aid of a noise level meter while copies of questionnaire were administered to residents to elicit information on public perception. The distribution of reported cases of HI among residential areas in Ibadan city showed varying magnitude ($p<0.001$). About 75% of children diagnosed with HI cases were within ages of 4-12 and female children suffered more (53.9%). Sensorineural and conductive impairments accounted for 88.2% of all reported HI cases. Monitored noise levels vary significantly among the selected residential area at each of morning, after-noon and evening ($p<0.05$). Noise levels at morning and evening showed significant correlation with cases of HI reported at each of the 10 selected residential areas ($r = 0.81; 0.82$). Regression analysis showed that noise level explained 70.1% of the spatial pattern of HI cases. Residents indicated that their neighbourhoods were noisy, that noise levels were on the increase and that ceremonies and generator use were major sources of noise. An integrated strategy for noise control is urgently required to stem the tide of noise pollution so as to safeguard human health in Nigerian cities.

Keywords: Environmental noise; children health; hearing impairment; pollution; Nigeria

Introduction

Noise is a ubiquitous environmental pollutant both in the developed and less developed societies. Unfortunately, appropriate attention in terms of designing effective structural measures and formulation of comprehensive policy frameworks for noise control are absent or at best very weak in most developing countries. Noise in the human environment has become a major threat to the quality of human life; especially children, that have been identified to be at risk of negative impacts of noise pollution due to their high susceptibility level. Although the definition of noise is highly subjective, it is unanimously recognised as the most pervasive of all environmental pollutants. Noise control has been hampered in LDCs as a result of low public awareness of the associated hazards and the lag between exposure period and impact manifestation. Considered from all perspectives, noise is a pollutant which impacts population health and specifically, hearing capability [1, 2].

According to U.S EPA estimates, noise causes about 40 million U.S citizens to suffer hearing damage and other related health problems [3]; a quarter of this noise was traced to human activities. In urban Nigeria, a similar percentage was estimated to emanate from human activities [4]. Noise generated by music players and food grinding machine around homes topped the sources of noise in Nigeria [5]. In spite of the fact that urban centres in Nigeria and other developing countries have been tagged "noise risk" zones, most acoustic research efforts focus on industrial work place and occupational exposure [6-8].

Generally, sound louder than 80 dB(A) in residential areas is considered potentially hazardous [9, 10]. The impact of noise is determined not only by the sound level but also the duration and frequency of exposure. Prolonged and often irregular noise to which human populations are exposed causes non-auditory effects linked to abnormal social behaviour and also hearing impairments. Subjects exposed to high noise levels suffered impacts such as headache, dizziness, nervousness, irritability, loss of sleep, anger, dissatisfaction, depression, anxiety, distraction, agitation, cardiovascular and gastric disturbances, increased blood cholesterol level and hearing loss [11-13].

It was estimated that 3.9 million children in Africa had mild hearing loss and 1.2 million had moderate to severe hearing loss [14]. In order to prevent human discomforts (annoyance) and hearing impairment in residential environment, noise level should not exceed 55 and 70 dB(A) in 16 hours of exposure during daytime [10]. Similarly, the Japan Ministry of Environment, set daytime noise limit at 70 dBA [15]. Exposure to noise levels above 80 dBA for 24 hours increases the risk of noise-induced hearing impairment [10]. Supporting this view, Adelowo [16] stated that most clinically diagnosed cases of tinnitus in Nigeria resulted from the habit of loud noise.

Although all population groups are affected adversely by noise pollution, neonates, infants, children, the elderly, and infirmed persons are particularly more vulnerable. The vulnerability of children to noise induced hearing loss is of upmost concern due to their fragile body system, inability to protect themselves [17] and more years of lifetime. Hearing loss, in varying degrees, affects two in every 100 children under the age of 18 [18], and noise is a major environmental risk factors of acquired hearing loss [19].

The American Academy of Paediatrics [20] indicated that exposure to excessive noise during pregnancy may result in high frequency of hearing loss in new-borns while exposed neonates likewise could experience cochlear damage. Children exposed to chronic environmental noise have been found to have poorer auditory discrimination and speech perception [21], experienced raised blood pressure, stress and defects in reading abilities and often reported feeling of helplessness [22, 23].

The peculiar status of children exposed to environmental noise is the motivation for this study, while its outcome has capability to provide information for policy formulation and design of intervention programme for noise control. The current research therefore seeks to examine the profile of clinically diagnosed hearing impairments among children, the distribution within residential areas in Ibadan city, and the correlation with and prediction by prevailing noise levels.

1) The Study Area

Ibadan, capital of Oyo State is located in southwestern Nigeria about 120 km east of the border with the Republic of Benin. It is about 145 km away from Lagos, the commercial nerve centre of the country. Located on Latitude 7°23′16″ N and Longitude 3°56′47″ E, it has an estimated land area of about 400 km^2 [24]. The population of Ibadan according to the 2006 population census was 3,565,810 people. The city ranges in elevation from 150 metres in the valley area, to 275 metres on the major north-south ridge which crosses the central part of the city. Ibadan, one of the three biggest cities in Africa, has witnessed rapid growth both in population size and spatial expansion over the years.

Ibadan is a typical Third World city with a dual structure (traditional and modern sectors) [25] that have implications for its internal structure and land-use pattern. While the dual nature of the city portrays marked difference in the socio-economic characteristics of inhabitants of the sections, it equally reflects in the planning of land-use. Land-use such as residential, commercial and transportation are not well planned (zoned) in the old traditional sector compared with the new and the outer emerging periphery. This could also have implications for the auditory health due to exposure to noise apart from other health issues already pointed out by Iyun [26].

Materials and Methods

Data used in this study were generated from three sources. These include clinic data on hearing impairments among children, a questionnaire survey among residents and measurement of noise levels in selected areas.

1) Clinic data on Hearing Impairments

Firstly, clinic data on hearing impairments (HI) diagnosed among children aged 0-15 years (2006-2009) were collected from ENT Department of the University College Hospital (tertiary health centre), Ibadan (Nigeria). A short proposal of the study was submitted for the consideration and approval of Ethical Committee of the hospital. Upon approval, the specific data collected on children diagnosed for different HI include age, gender, HI type and residential area within the city. The selection of age cohort 0-15 is in line with the medical literature that considers 0-18 years for childhood auditory assessment [18, 27]. Although the hospital record does not capture all morbidity cases, it gives a fair representation of diseases types and spatial patterns. According to the WHO [10], cli-nic data remain a reliable source of information for health related studies.

2) Questionnaire survey

Secondly, a well-structured questionnaire was administered to residents sampled from ten areas; five residential areas of high cases of HI and another five of low HI cases. The intent is to collect information on residents' evaluation of noise, the sources and effects of noise in their neighbourhoods. Ten residents sampled from each residential area were asked questions to elicit information on their assessment of noise in the neighbourhood, impact of noise and measures for noise level abatement. The residents selected for this survey were those who gave verbal consent to participate after being informed of the purpose of the study. In all, 90 copies of the questionnaire were used for the analysis. Out of the 100 returned copies of questionnaire answered by respondents, ten copies were voided for inadequate information.

3) Environmental Noise Measurement

Finally, environmental noise levels were assessed in the 10 residential areas selected for questionnaire administration in the morning (7-9 am), afternoon (12-2 pm) and evening (6-8 pm) in replicates in 2009. A calibrated portable sound level meter (model JTS-1357) was employed to measure noise levels (A-weighted scale–dB(A) of three different locations randomly selected within each residential area. In all, 30 sample sites were selected for noise measurement. The instrument with its microphone fixed appropriately was held at breast height (approximately 1.2 m) from the ground to take ambient sound levels.

Data analysis

The three categories of data collected for this study were analysed with the aid of Statistical Package for the Social sciences (SPSS®IBM® version 20). Analytical tools used include frequency run, Analysis of variance (ANOVA), correlation and regression. Data were entered into Excel spreadsheet and exported into SPSS data editor before selecting the specific statistic. To portray the pattern of HI occurrence in Ibadan city, the number of reported cases in each area was exported into ArcGis environment for mapping and graphical representation. In addition, Daily Noise Dose was computed for each residential area using occupational noise exposure formula [28]. Although, the daily dose underestimates residential noise exposure going by WHO [10] noise guideline, it gives an indication of pollution status of the residential areas. The Daily Noise Dose formula is of the form:

$$D = [\frac{C_1}{T_1} + \frac{C_2}{T_2} + \frac{C_3}{T_3} + \ldots \ldots + \frac{C_n}{T_n}] \text{x } 100$$

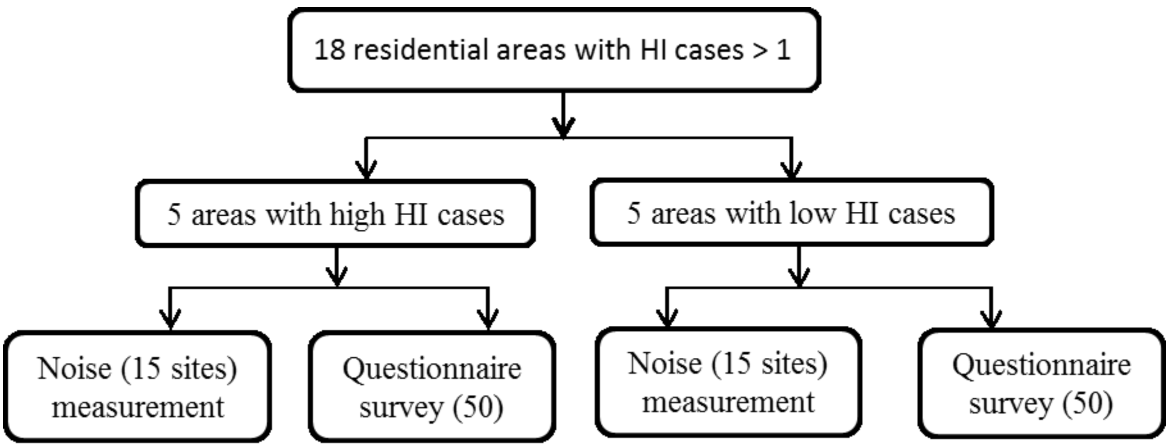
C_n = total time of exposure at a specified noise level, and
T_n = exposure duration for which noise at this level becomes hazardous

The correlation coefficients (r) and coefficients of determination (R^2) in the regression analysis were employed to indicate association between noise levels and cases of HI, and the contribution of measured noise levels to areal pattern of HI cases. The simple regression equation is of the form:

$$Y = a + bX + e$$

where Y represents number of HI cases per location, X stands for measured noise level, a, b and e are constants. Alphabet a is the intercept of the regression line when X is zero, b is the slope of the line and **e**, the error value in case of prediction/estimation.

Sketch of data collection in the study area



Results and Discussion

The distribution of reported cases of HI among residential areas in Ibadan city showed varying magnitude (Figure 1) although a presentation of an incidence rate would portray more accurate statistics. Agbeni area recorded the highest number of cases followed by Agodi, Odogbo cantonment, Gbagi and airport area. Many of the remaining residential areas reported less than three cases within the study period. T-test showed a significant difference ($p<0.001$) in the number of HI cases among residential areas. Most of the areas that recorded high cases have markets, large business centres or motor parks situated within the neighbourhood. At Odogbo cantonment military training and activities that generates high noise levels may explain the observed relatively high cases among children living in the area.

Generally, homes situated in noisy neighbourhoods predispose residents, especially children to risk of hearing problems due to possible damage of their hear drum [12]. The fact that most noisy neighbourhoods are also areas of low socio-economic status increases the risk of occurrence of hearing problems that are caused by infections and delay in seeking medical attention for childhood diseases.

From clinic records, about 75 percent of cases of HI were diagnosed among children within ages of 4 -12 years while children in lower and higher age brackets had fewer cases (Table 1). Gender categorisation showed that female children reported more cases of HI (53.9%) than males. Moreover, sensorineural impairment and conductive impairment cases accounted for 88.2 percent of all HI cases. Other types of hearing-related ailments were fewer (11.8%) in the study area.

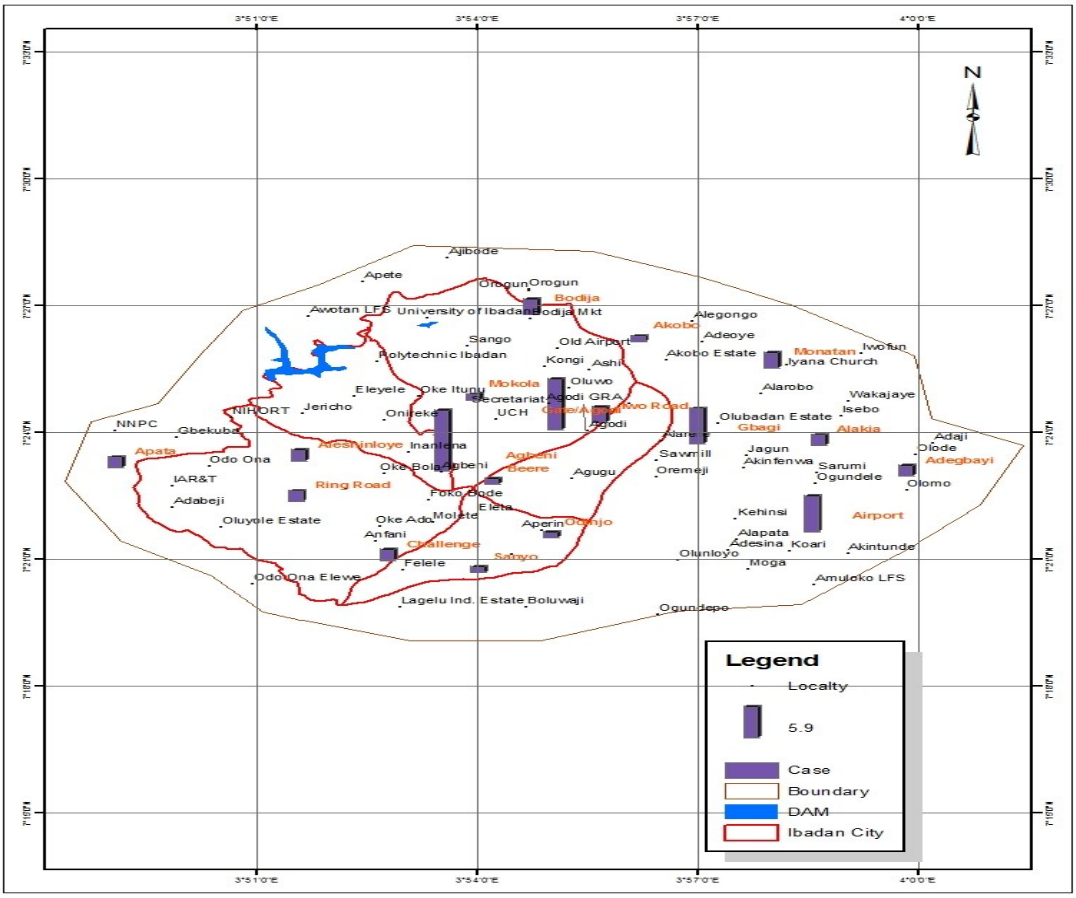


Figure 1 Distribution of Hearing ailments in residential areas of Ibadan Metropolis

High occurrence of HI cases among children aged 4-12 resembles the findings of Olusanya et al. and NECP [30, 31]. Poor detection of sensorineural impairment at earlier ages, linked possibly to the mildness of cases [19], low public awareness of hearing problems [31] and delayed medical reporting among Nigerian population [32, 33] may explain the observed low cases among ages below 4. There is also the possibility of higher exposure to noise from diverse sources, head injury from fall, and also infections at ages above 4 years since children are more mobile to interact with the ambient environment.

The observed gender bias of HI cases for female children is similar to higher male-female ratio observed in Port-Harcourt city [34] and in Ghana [35] but different from 4:5 indicated for Ilorin city [36]. Social allocation of household chores to women and girls in most African societies makes mothers to retain female children around homes while males are allowed outside. If household activities emit noise, the female children will be more exposed and put at higher risk of noise-induced hearing problems.

Moreover, the prevalence of sensorineural and conductive impairment cases in the study area is similar to the profile found in Port Harcourt and part of Lagos city in Nigeria [34, 31]. In Ghana, cases of sensoneural impairments were higher than other types hearing loss while conductive hearing loss accounted for 50% at Karachi [35, 37] in Pakistan.

More than 60 percent of the residents indicated their neighbourhoods were noisy and that noise has been increasing over the years (Table 2). While 59% of the respondents were aware of noise effects on their health, only a few felt the prevailing noise level could be reduced. Diminished hearing (16%) and tinnitus were the noise induced hearing problems suffered and identified by residents. Non-auditory problems included headache (59%), disturbed sleep (47%) and annoyance (38%). Environmental noise sources identified were ceremonies/festivities (33%), electricity generator use (20%), music record playing and use of food grinding machine.

Some of the noise sources identified by the respondents were equally identified by previous studies [2, 5, 38]. Additional sources points to the emergency of new sources of noise in urban environment. The health problems suffered by the residents impacted by noise were similar to those identified by other acoustic researchers [12, 13, 16, 39].

Temporal changes in noise levels among areas and within same area as indicated by this study can be attributed to changes in activities within the areas. The disparity in noise levels among selected areas are attributed to diverse activities such as markets and motor parks located in residential areas. According to reports by Egunjobi [5] and Ijaiya [40], locating food grinding machine, use of music players and electricity generators within residential units were responsible for high noise level experienced in Nigerian cities.

Table 1 Patients' characteristics and profile of HI cases among children

Characteristics	No. of HI cases	Percent
Age (years)		
<1 – 3	5	4.9
4 – 6	25	24.5
7 – 9	26	25.5
10 – 12	25	24.5
13 – 15	13	12.7
> 15	8	7.8
Total	102	100.0
Gender		
Male	47	46.1
Female	55	53.9
Total	102	100.0
Profile of HI		
Sensorineural impairment	45	44.1
Conductive impairment	45	44.1
Auditory hallucination	9	8.8
Partial deafness	3	2.9
Total	102	100.0

Table 3 shows that during morning hours, the mean noise level was highest at Odogbo canton ment (104.5 dBA) followed by Gate (94.5 dB(A) and Agbeni (94.4 dB(A). Noise levels at the other locations were less than 70 dB(A), the permissible limit for 16 hours exposure by WHO (1995). The afternoon noise level at Odogbo cantonment declined (65.7 dB(A) compared to other locations that recorded similar higher noise levels in the morning. Although noise levels increased at other sites, Agbeni, Gate, Gbagi, Iwo road and Bashorun recorded noise levels higher than the permissible level for daytime exposure.

From field observations, the presence of markets, music playing shops, vehicular traffic, and other small-scale informal activities are major contributors to high noise emission in the areas mentioned above. Although some of these sources have been identified by other researchers [4, 5], the rapid growth of informal businesses, which lacked proper coordination in urban centres, is identified as an emerging source of noise generation in the areas.

Noise levels increased in the evening in all locations with the exclusion of New Ife road, Akobo and Idi-Ape. Generally, areas with noise levels higher than the permissible limit, sustained the high level from afternoon till evening except at Akobo area. ANOVA results show that noise level varied significantly ($p< 0.05$) among the selected residential area. Overall, daily noise dose (DD) was the highest at Odogbo with 5400%, closely followed by Agbeni (5200%) and Gate/Agodi (1152%) against 100% maximum for occupational exposure.

While the high noise dose indicates presence of environmental noise at levels far beyond the tolerable limits for human beings, it did not mean exposure to several hundred in numerical values as the case is in drug dose. It is noteworthy, that human auditory and non-auditory health will be negatively impacted in the areas found with high noise levels [1, 7, 11, 13].

Table 2 Residents opinion about noise level, sources and associated health problems

Residents' noise assessment	No. of respondents	Percent
This area noisy	63	70.0
Noise has been on the increase	63	70.0
Noise affects my health	59	65.0
Noise in this area can be reduced	30	33.3
Problems associated with Noise		
Headache	50	58.9
Diminished hearing capability	15	15.5
Sleeping difficulty	51	46.6
Speech interference	18	20.0
Annoyance	34	37.8
Other problems (tinnitus, stress, fatigue)	13	14.3
Sources of noise in the area		
Ceremonies and Festivities	26	33.3
Generator engine	18	19.8
Music/record stores	18	19.8
Food grinding machine	14	15.4
Public address system	14	15.4
Motorcycle engine/horn	11	12.1
Others (worship centre, vehicles, dog)	39	40.8

Table 3 Mean±sd Noise levels (dBA) measured at the selected residential areas

Residential area	Morning	Afternoon	Evening	Daily Dose (%)
Agbeni	99.44±1.42	99.30±1.14	99.59±1.05	5200
Gate	94.55±3.10	95.32±3.47	96.75±1.33	1151
Odogbo	104.5±3.10	69.75±8.56	93.93±1.87	5400
Gbagi	83.17±1.73	86.07±1.68	87.43±2.15	142
Iwo road/Monatan	83.70±1.73	85.32±1.75	86.71±1.94	140
New Ife road	60.95±1.92	66.90±0.76	62.99±0.72	ND
Akobo	78.25±1.28	82.78±0.77	77.68±1.35	33
Idi-Ape	72.72±2.62	78.76±8.43	73.76±3.66	ND
Bashorun	83.89±1.53	85.75±1.78	86.69±2.00	140
Adegbayi	56.49±0.76	60.91±1.82	60.12±1.49	ND
ANOVA result (F, α)	272.6 (0.001)	29.7 (0.001)	212.9 (0.001)	

- *Noise limit by WHO 55 and 70 dBA for non-auditory and auditory impairments (16 hrs of exposure in ambient environment)*
- *ND – Not Determined (values below hazardous level)*

From the correlation analysis of noise levels and occurrence of HI cases, a significant positive correlation was observed between cases of HI and noise level in the morning and evening (r = 0.81; 0.82) in the selected residential areas (p< 0.01). Hence, there was spatial association between noise level and occurrence of HI cases. Furthermore, regression analysis showed that noise levels explained 70.1 percent of the variation in the distribution of HI cases among the residential areas. The positive association between noise and occurrence of hearing loss has been observed by some researchers [18, 19, 27]. In addition to the spatial correlation between noise level and cases of HI, medium to low socio-economic residential areas are more likely to house low income earners who are more likely to be susceptible to poverty and infections [31]. Worse still, these population groups are not likely to patronise competent medical services in case of illnesses. Unsurprisingly, practitioners associate hearing loss largely to infections [36, 41, 42].

Predictive equations of HI cases by noise level during the morning, afternoon and evening are presented as follows:

y = 0.2253x-13.418-[r=0.81] model 1 morning
y = 0.2044x-11.571-[r=0.57] model 2 afternoon
y = 0.2618x-16.612-[r=0.82] model 3 evening

From the estimation of the linear models above, a noise level at 80 dB(A) is capable of inducing five HI cases while 10 cases will be induced if children are regularly exposed to noise at 100 dB(A) over time in the residential areas. Although the interaction between noise and HI may not be linear as portrayed in the models and one needs to account for an error margin, more cases of HI will be induced by the trend of the monitored noise levels in the studied residential areas in Ibadan city.

Conclusion

Monitored daytime noise levels varied among the sampled areas and were different in pattern in morning, afternoon and evening. Significant spatial associations exist between noise levels at morning and evening, and cases of hearing impairment (r = 0.81; 0.82 at p< 0.05) among residential areas in the city. Residents were aware of and concerned about the increasing noise level in their communities (65–70%). Effects of high noise level on the health of residents include headache (58%), deteriorating hearing (16%) and sleep discomfort (47%) among others. Although noise levels explained 70.1% of the areal distribution of HI cases, there is an indication of a possible synergy between exposure to noise and infections in the spatial distribution of childhood hearing ailments. This synergy may be seen in other communities in the sub-Sahara African region as well as in other regions where disadvantaged population groups are exposed to multiple hazards (pathogenic and physical) in the environment.

An integrated strategy that incorporates noise awareness, effective noise control, and proper city planning that zones noisy activities away from human residence is required for noise induced HI. Early children screening for medical intervention among low-income or disadvantaged residential areas should be pursued more vigorously than the pace at which current national health policy is handling childhood hearing loss.

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