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ROAD TRAFFIC NOISE IN NIGERIA: MEASUREMENTS, ANALYSIS AND EVALUATION OF NUISANCE

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The investigation comprised field measurements of road traffic noise at over 60 sites in 8 cities in South-Eastern Nigeria and psychological survey, by questionnaires, of respondents living and working close to the sites. Instantaneous and 24 h noise measurements were made at the noisiest points, near the facades, of the houses of more than 150 respondents in the neighbourhood of each site. Several noise descriptors were either measured or calculated. Measured values of L_{max} were as high as 105 dB (A) while residents were exposed to instantaneous levels of road traffic noise as high as 110 dB (A). Values of L_{eq} and L_{dn} were 84·6 and 68·0 dB (A), respectively, and sometimes higher in some of the sites. The calculated L_{10} correlated positively with field data with a correlation coefficient of 0·8551. It was found that the measured L_{10} was always higher than the calculated L_{10} by about 4·5–8·8 dB (A) probably because of the reckless use of horn by motorists and reflection from the hills and trees. The type of house lived in, the disturbance of various activities by road traffic noise and neighbourhood noises which were most annoying to residents, were found to strongly affect the percentage of responses obtained with respective correlation coefficients of 0·9925, 0·9714 and 0·7237. The usual poor correlation, ranging from 0·3 to 0·4, between dissatisfaction response and noise exposure were obtained in this investigation. There appeared to be an income bias with respect to community response to road traffic noise, with low-income neighbourhoods reporting less annoyance and disruption of various activities by road traffic noise, and some evidence of adaptation to road traffic noise by residents of busy cities in South-Eastern Nigeria.

1. INTRODUCTION

The impact of road traffic noise, which has far-reaching and wide-ranging effects, has increased because of industrialization and urbanization resulting in an increase in noise levels. Thus, road traffic noise has become an issue of immediate concern to many authorities. Anti-noise laws, ordinances, major highway control regulations and other governmental laws that concern environmental noise cannot be decreed without *a priori* empirical considerations. Therefore, it is necessary first to carry out extensive measurements, in order to analyze road traffic noise levels and community response. It should then be possible to predict subjective response to road traffic noise along motorways and in residential areas. Equivalent continuous sound level (L_{eq}) and other indices have been used to describe the noise generated by road traffic [1, 2]. In his survey dealing with effects of road traffic noise in Greater London under free-flow conditions, Langdon [3] found that over the range of noise levels from 60 to 80 dB (A) L_{10} (the level exceeded or equalled for 10% of the measurement time), nuisance was found to be highly correlated with noise level measured as L_{10} over 24, 18 or 12 h and as L_{eq} over 24 h. Social surveys and field

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measurements [4] indicate a correlation between L_{10}, averaged over 18 h and human dissatisfaction.

Studies [5, 6] have reported equations relating subjective response to measured sound levels which could be used to predict subjective response to road traffic noise along motorways and in residential areas. Hall and Taylor [7] found several noise measures, (L_{eq}, L_{10} and the day–night average sound level, L_{dn}) to be equally good predictors of subjective response and concluded that the reliability of the predictions can be validly estimated by using the standard errors of regression estimate, thus strengthening the basis for such predictions. Although it has been reported that road traffic noise in developing countries has not yet been recognized as a major problem [8], work carried out in Jeddah city [9, 10] indicates that noise from road traffic is very intensive, and relatively high sound pressure levels (90 dB (A) and higher) were recorded in many cases. Recent work [11] has shown that in the Nigerian environment the kind of noise that bothers people most is road traffic noise. More recently, predictive equations with respect to community response (attitude measures) to road traffic noise in Nigeria have been developed [12]. The equations were derived by using regression models with significance tests and correlation analysis to test their reliability.

A comfortable environment is one in which there is little or no annoyance and distraction so that working or leisure tasks can be carried out unhindered either physically or mentally. Unfortunately, environmental noise (mainly due to road traffic) has become a serious problem in many countries, and it is difficult to regulate by physical means alone. It is well known that environmental noise may affect sleep, conversation, and cause annoyance as well as affect task performance. Road traffic noise is the worst offender in this category because it is more or less a continuous sound which fluctuates from hour to hour in a more or less irregular fashion with the passage of individual vehicles.

Although many social surveys on the effects of noise on people have been conducted throughout the world, they have been performed in Northern areas with moderate climates such as Europe and Northern America [13]. Research and analysis of the difference caused by climate [14] has been conducted in Nigeria [11, 12] and in Kumamoto, Japan [15]. These are some of the few surveys that have been carried out in areas with warmer climates. Research into subjective response to road traffic noise [16–19] has resulted in one important conclusion that the effects of road traffic noise are constant over time, there being no evidence of adaptation over 17–22 years and evidence of only limited adaptation over 7–9 years [20, 21]. Raw and Griffiths [22] have stated that studies of adaptation over much longer period would be difficult to achieve because too few original residents would be present. Relster [23] investigated two areas exposed to high and low levels of road traffic noise in Copenhagen. She found a greater use of tranquilizers (25% versus 17%) and higher frequency of medical consultations for psychiatric problems (19% versus 12%) in the high–low noise areas.

The present study was undertaken because a survey in this part of the world is necessary to implement a better more practical procedure for noise assessment for urban and town planning. The objectives of the present study were therefore to accumulate noise and social survey data for Nigeria and to investigate the relationship between various factors and annoyance.

2. ABOUT SOUTH-EASTERN NIGERIA—THE STUDY AREA

South Eastern Nigeria is made up of 8 states in the Federal Republic of Nigeria—the most populous country in Africa. Some parts of this region are on the coast, bordering the

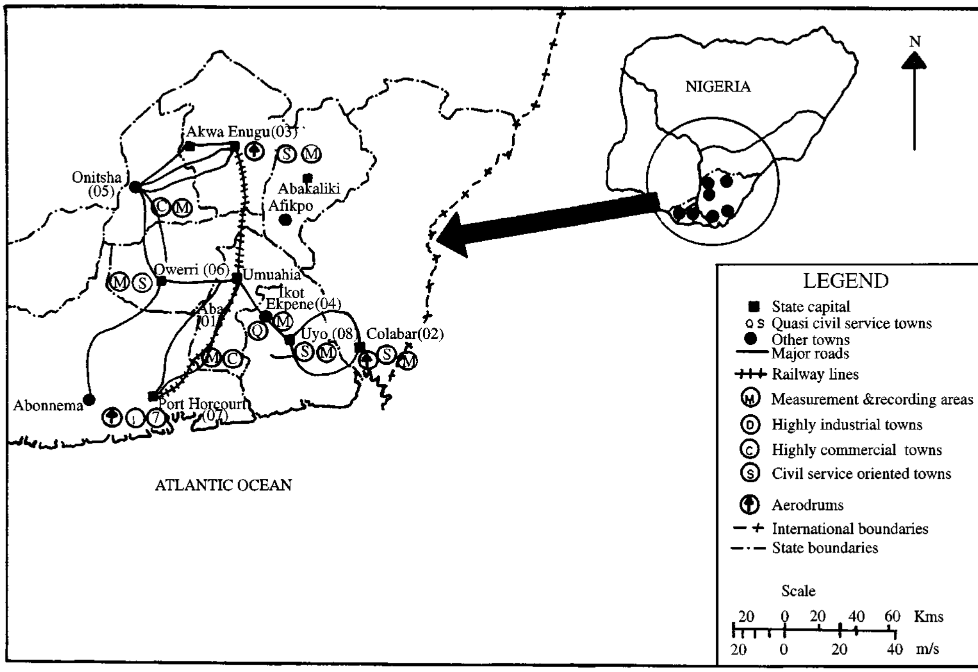

Figure 1. Map of South-Eastern Nigeria showing measurement and recording towns.

Atlantic Ocean, while rivers and streams run across and within the states and cities that form the conglomerate (Figure 1). Apart from the lakes that are found in this part of the country, South-Eastern Nigeria is hilly, thereby constituting uneven terrains which accounts for the predominant use of low gear by motorist. There are also mangrove and fresh water swamp forests as well as rain forests in South-Eastern Nigeria. The relative humidity within South-Eastern Nigeria is 75–95% (dry–wet season) with mean temperatures of 25·0 and 27.5°C for wet and dry seasons respectively.

South-Eastern Nigeria has cities with a wide range of urban conditions. Most of the cities are congested or densely built-up as there is little or no urban planning, resulting in frequent use of horns by motorists and sirens by government officials, fire fighters at (and from) local fire stations and vehicles that convey money to and from various branches of Central Bank of Nigeria. Generally, the cities are highly industrial and commercial as they are the home base of the country's technocrats. South-Eastern Nigeria ranks highest in road transportation business in the country. The rapid industrialization, commercialization and urbanization witnessed by South-Eastern Nigeria in recent years has given rise to the steady increase in the environmental noise climate in this part of the country. Added to this is the indiscriminate importation and use of (used) old vehicles, called *tokumbo* or *belgium* in Nigeria, for both private and commercial purposes. Thus, road traffic noise is a major environmental problem in South-Eastern Nigeria and noise levels are higher than those measured in cities in well planned and developed countries [24]. The press has been helping to educate the public on the impact of road traffic noise [25, 26]. Generally, annoyance reactions and complaint actions about road traffic noise in South-Eastern Nigeria are high. Referring to those residents who claim to have a definite and conscious response to road traffic noise, analysis [12] show that a maximum of 14% have to be highly annoyed for any single complaint action to be taken whilst 82·5% of the residents want road traffic noise controlled or reduced.

Recently, various local and state governments have adopted zoning as a means of abating the dominant influence of road traffic noise in South-Eastern Nigeria. The Nigerian Building and Road Research Institute has entered a joint study programme with the University of Calabar, Nigeria, with the objective of measuring sound levels, carrying out social surveys of community responses to road traffic noise in residential areas and producing a road traffic noise (map) contour of South-Eastern Nigeria and other parts of the country from time to time. The President, as one of the highlights of a major national policy has charged the Federal Environmental Protection Agency with making laws to regulate and control the levels and impact of noise in Nigeria.

3. EXPERIMENTATION

The experiment consisted of physical measurements, interviews and analysis.

3.1. SITE SELECTION

A good representation of sites covering a wide range of noise levels was made. The survey covered 60 sites in 8 major cities in Nigeria. The choice of these cities arose from the fact that they have high volumes of road traffic with a wide range of urban conditions. The cities involved in the investigation were coded for easy reference. They included Aba (01), Calabar (02), Enugu (03), Ikot Ekpene (04), Onitsha (05), Owerri (06), Port-Harcourt (07) and Uyo (08). The city Aba consisted of 8 sites. Ten were selected in Calabar, 8 in Enugu, 7 in Ikot Ekpene, Onitsha, Owerri, Port-Harcourt and 6 in Uyo. Eighteen of these sites were alongside major expressways; 20 along arterial roads located well away from traffic lights; 22 on secondary roads, away from arterial roads along which schools and hospital were situated. These sites were selected based on a number of criteria. None was near any other. Non-roadway noise such as industry, construction, rail lines or airport was close to the experimental locations. Each site consisted of a single row of housing, parallel to the road which was the source of the road traffic noise. There was free and non-free flow of traffic at these sites. The sites which were far from uneven terrain where environmental influences were present were also selected based on traffic volume, composition and maximum impact. Some were selected with reference to the unpublished data of Federal Road Safety Commission, Calabar.

3.2. NOISE MONITORING AND ANALYSIS

The purpose of the noise monitoring was to obtain sound-level information which was representative for each site, neighbourhood and each city. This was obtained for the 8 cities. The data were obtained at the noisiest point near the facades of a particular house facing the road. The equipment was held on a tripod closest to the noise source, and with the microphone position from roads varying from 6 to 50 m.

This was similar to other noise monitoring programmes in Ontario [27] and U.S.A. [28] and was in conformity with the IEC, BSI and ISO standards after calibration of the microphone.

Measurements were made at over 200 reference points. Simultaneous measurements were made at the edge of the road and in front of the houses where there were no intervening structures. At some of the sites, measurements were made each day for 24 h: during the daytime (0700–2200) and nighttime (2200–0700) periods, Monday to Friday. The precision sound level meter (B & K Type 2203) with a $\frac{1}{3}$ octave band filter and sound-level recorder (B & K Type 7005) which has frequency modulation for clarity were used in measuring (monitoring) and recording noise levels. The microphone was placed 1·0 m from the facades of the houses and from any reflecting surface and 1·2 m above the ground corresponding to the ear level of an average human height. The ground cover at every measurement site was sand.

At each site, measurements of volume (per hour) and composition of road traffic were made. Counting was done for 20 min by the three men involved in the fieldwork; the hourly volume of vehicles was estimated for each site. Any vehicle passing the site was entered in the appropriate column on the tally sheet provided. The approximate number of vehicles which included the heavy vehicles, buses, cars and motor cycles were then counted. Relative humidity and temperature of sites varied from 75 to 80% and 25 to 28°C at the times of measurement.

The tapes were subsequently played back, sampled at 2 s and analyzed using a level recorder (B & K 4426) with an A-weighted filter in the Applied Acoustics Laboratory of the Department. The noise-level analyzer which formed the output to the tape recorder was used for a direct readout of the level values L_{10}, L_{50} (noise level exceeded for 50% of the measurement time) and L_{90} (noise level exceeded for 90% of the measurement time). Physical descriptors of the noise such as L_{eq} and L_{dn} were calculated. These are hourly values for the noise levels for each site throughout the day. The levels were plotted against time for the 24 h survey period and this provided an indication of the daily cycle of noise exposure at each site. L_{10} (24 h) values were obtained by averaging the data throughout the period from 07·00 to 06·59 h the following day [29]. L_{50} and L_{90} values were treated in the same manner.

3.3. NOISE-LEVEL REDUCTION

The noise ratings were translated to day–night average A-weighted sound level L_{dn}, being a measure of noise exposure, using the equation in reference [30]

$$L_{dn} = 10\log\frac{1}{24}(15\times 10^{L_d/10} + 9\times 10^{(L_n 10)/10}) \tag{1}$$

where L_d and L_n are the energy-average noise levels during the day-time (0700–2200) and

night-time (2200–0700) periods respectively. The equivalent (mean) energy level index (L_{eq}), which is widely used, has been recommended by a subcommittee of the Noise Advisory Council [31] as an index worthy of careful consideration. Hourly values of L_{eq} were calculated from the cumulative noise data obtained with the statistical analyzer using the formula

$$L_{eq} = 10\log\left(1/100\sum_{i=1}^{n} f_i\, 10^{l_d/10}\right). \tag{2}$$

In equation (2), f_i is the dB (A) sound level corresponding to the mid-point of class. The 24 h average values for L_{eq} were obtained by averaging the hourly values logarithmically over the relevant time periods. Mean values of L_{10} dB (A) over a period of 1 h were calculated for each class interval for road traffic noise using the relation

$$L_{10}(1h) = 10\log(q) + 33\log(V + 40 + 500/V)$$

$$10\log(1 + 5p/V) - 27{\cdot}6\ \text{dB (A)} \tag{3}$$

[32] where q is the number of vehicles per hour during the recording time, p is the ratio of the number of heavy vehicles to the total number of vehicles and V is the speed in km/h.

4. SOCIAL SURVEY

4.1. HOUSEHOLD INTERVIEWS AND ANALYSIS

A total of 2892 responses were obtained out of 4000 questionnaires distributed. This gave a response rate of 72·3%, which is considered good for this kind of survey in Nigeria. The questionnaire was pre-tested to determine various aspects of response of residents to noise and to collect data on personal characteristics. Household interviews were conducted as a general survey of attitude towards the neighbourhood noise, thus screening the road traffic noise focus from the respondent. To reduce the gaps which usually exist in the information presented in publications and which have been especially serious problems for combined social and acoustical surveys of residents' responses to environmental noise, some basic noise reaction questions were reproduced. This will help resolve readers' questions about wording responses, among others [33].

Each respondent was simply asked whether or not they were annoyed by noise. The next question was "what type of noise is most annoying to you?" Options given were (i) Aircraft, (ii) Road traffic, (iii) Children, (iv) Animals, (v) People, (vi) Factory, (vii) Radio/TV. The annoyance results came from the direct question: How do you feel about road traffic noise? The three named unipolar response categories were as follows: (i) Very annoyed, (ii) Moderately annoyed and (iii) Little annoyed. Every housing unit in one site was exposed to an identical external noise environment. This implied only the inclusion of a number of small units in each site. In each neighourhood, it was therefore assumed that the inhabitants were exposed to the same amount of noise as recorded by the equipment set-up to measure the noise level at the facades in that area. It was observed, however, that there was a wide range of subjective responses in a particular neighbourhood. To those respondents who reported that they were disturbed (annoyed) by road traffic noise were asked additional questions pertaining to complaint actions, among others. The interviewer wanted to know the following: (1) If the respondent had complained, (2) To whom he complained and, (3) If he (the complainant) took any action. Yes and no were the steps on the two-step complaint scale for items 1 and 3 above while (i) Friends, (ii) Local government official(s), (iii) Driver(s), (iv) Cyclist(s), (v) Police, Public Health Officer, or any law enforcement agency were the options for item 2. Further, the interviewer sought to know why the complainant did not take any action, if he did not. The six named response categories were the following: (i) I did not want to worry myself, (ii) I was afraid money might be involved, (iii) I did not know I have the right to take any action, (iv) I was afraid nothing serious may be done by the authority, (v) Difficulty in identifying any particular offender and (vi) Inability to conceive of any appropriate authority.

Only the respondents who reported that they were annoyed or highly annoyed were the only ones counted as having so felt. There was no group classification in respect of residents who responded to the annoyance question. This type of classification adopted in the analysis eliminated the problem encountered by other investigators [30, 31] who classified the annoyance categories into "group" reporting categories thus ensuring the "absence" of error in the computation of the percentage of the population who lie in any reporting category. This procedure eliminated the likelihood of no under- or over-estimation of the population responding to that particular item. The responses were expressed as the percentage of the persons at each site giving the particular response. The variables involved in the analysis were ordinal and so the Pearson product-moment correlation coefficient was calculated and used as a measure to determine the degree of the relationship.

5. RESULTS AND DISCUSSION

5.1. MEASUREMENTS, CALCULATION AND NUISANCE

Figures 2 and 3 show the relationship between measured and calculated L_{10} (1 h) dB (A) and the number of vehicles per hour. The variables in Figure 2 are for a site in a congested (or non-free flow) condition with 12·8% of Heavy vehicles. This particular measurement was at 15 m from the source line. It is clear from these Figures that measured L_{10} was always higher than calculated L_{10} by about 4·5–8·8 dB (A). This may be attributed to the use of horns, reflections of noise from the hills and vehicles racing along with their sirens wailing. Because of the congested nature of the cities in South-Eastern Nigeria, there is widespread use of horns. Sirens from local police stations, fire engines, ambulances and escorts were usually left to operate continuously for upwards of about 2 min or more within a city. The consequence was that noise levels were raised to a very high level and this airborne noise contributed considerably to the high environmental noise climate in these cities. Sirens and horns were also, most of the time, sounded recklessly by drivers most of whom were youths. Similar results were obtained in Amman, Jordan [32], where it was observed that values of measured L_{10} (1 h) were always higher than calculated values by 4 dB. This was also attributed to widespread use of horns and reflection from the hills. McNulty [34] studied the impact of transportation noise in New Industrial Countries and stated that there is a widespread fashion of enhancing the noise output from noise-emitting

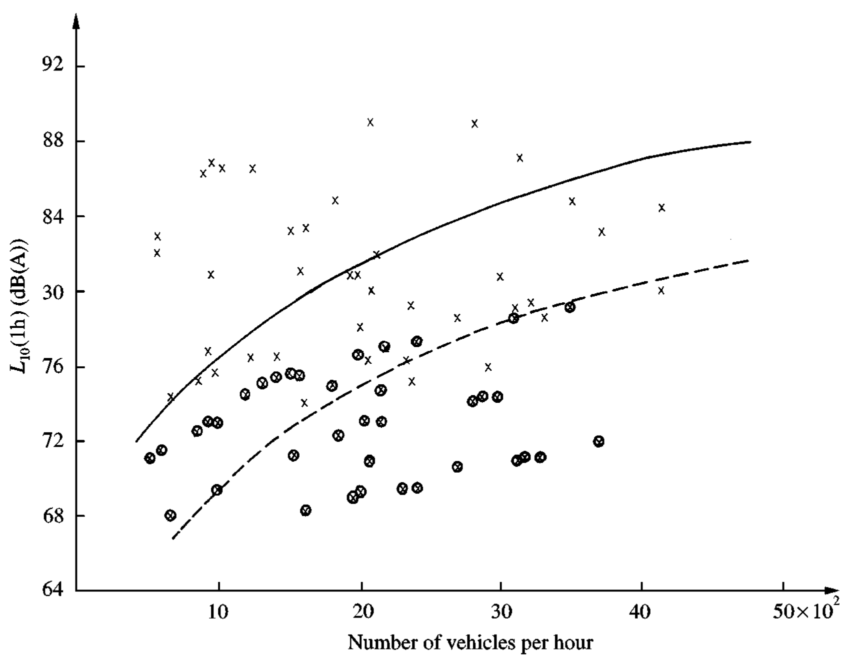

Figure 2. L_{10} and its relation to the number of vehicles per hour (VPH): – – – ⊗, calculated level using equation (3); × × × × ×, measured values; ———, mean values of measured results.

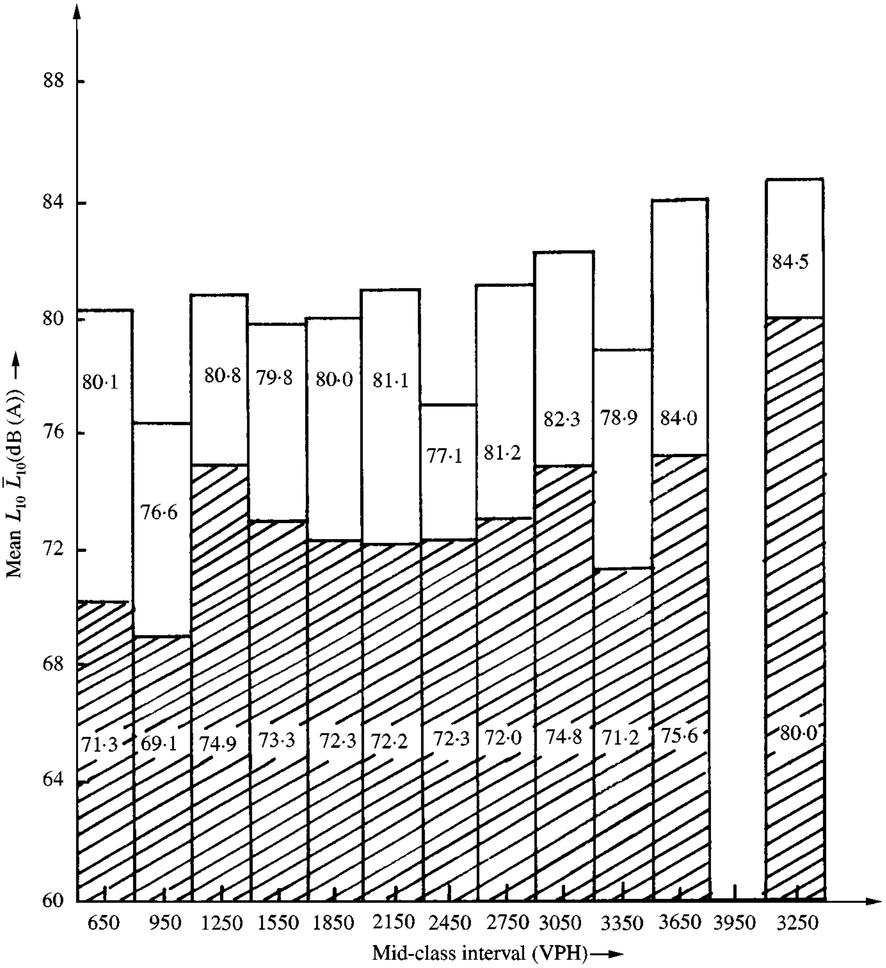

Figure 3. Mean noise level and vehicles per hour (VPH): □, measured; ▨, theoretical (calculated).

machines by suitably adjusting their silencer. According to him, teenage riders have a propensity for this fashion. Menkiti [25] had earlier observed this fashion among the teenagers in Nigeria when he described the silencers of the motorcycles as *unsilenced.*

A plot of measured and calculated values of L_{10} (1 h) is shown in Figure 4. The Figure also shows the 95% confidence limits when the correlation coefficient, r, is calculated to be 0·8551. This value of r (=0·8551) implies that 73% of the variance of the dependent variable (measured L_{10} (1 h)) is explained by the variable, calculated L_{10} (1 h). Thus the line fits into the data well which means that the claim that the variables are linearly dependent on each other is appropriate.

In most parts of South-Eastern Nigeria measured L_{10}, L_{50}, L_{90} and L_{max} values were very high (Table 1). In some cases the values rose to 89·3, 82·0, 76·4 and 105 dB (A) respectively. Respective values of L_{dn} and L_{eq} were calculated as 68·0 and 84·6 dB (A) and sometimes higher. In Jeddah city, road traffic noise has also been found to be very intense and sound pressure levels of 90 dB (A) and higher were recorded in many cases [9]. The results of this investigation are in agreement with those of Galt [35] who earlier measured maximum outdoor noise in the streets of New York and found them to be of the order 90–100 dB

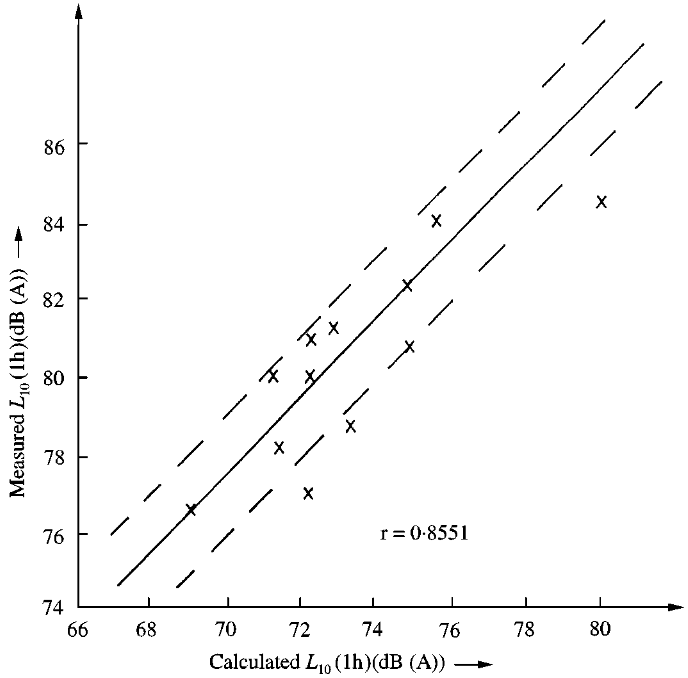

Figure 4. Relationship between calculated and measured L_{10}.

which were labelled *unsafe*. Instantaneous noise levels in some parts of the surveyed sites in Nigeria were as high as 115 dB (A).

Measured L_{10} values at the facade (and inside) in most schools and hospitals in South-Eastern Nigeria were as high as 81·0 (72·4) and 83·8 (72·2) dB (A) respectively. Values of 75·5–78·4 dB (A) (66·4–69·5 dB(A)) for L_{50} and 65·8–67·0 dB (A) (55·5–58·2 dB(A)) for L_{90} were also measured at the facade (and inside) in the majority of the school-hospital sites. From noise measurements in schools in Korea and Malaysia it was found that noise levels inside classrooms were in the range between 55 and 70 dB (A) even though noise levels in classroom should be 45 dB (A) for reasonable communication [34]. According to the U.S. Environmental Protection Agency [36], only 45% sentence intelligibility is possible for noise level of 70 dB (A). Therefore, in most schools in South-Eastern Nigeria less than 45% sentence intelligibility is possible. Relster [23] investigated areas exposed to high and low levels of road traffic noise in Copenhagen. She found that hospitals were also vulnerable and a greater use of tranquilizers (25% versus 17%) and higher frequency of medical consultations for psychiatric problems (19% and 12%) in high-low noise area. Thus, the incidence of high levels of road traffic noise in South-Eastern Nigeria bodes ill for psychiatric and other patients with similar health problems in this part of the world.

5.2. COMMUNITY RESPONSE

Regarding community response to road traffic noise 65% of the respondents reported that they were worried by road traffic noise while 37·3% claimed that the most annoying noise was that of road traffic. Analysis has shown that 33·7% of the people interviewed said they were most annoyed at home by road traffic noise, 44·3% in schools, places of study and work. 71·9% of the residents said they would like to live in a quieter area. Of the total

TABLE 1

Showing sound levels (recorded and calculated) and the percentage of vehicles per hour

City	Measured noise levels (dB (A))				Calculated noise levels (dB (A))			Vol. of vehicle per hour (%)				Total no. of vehicle per hour
	L_{10}	L_{50}	L_{90}	L_{max}	L_{10}	L_{eq}	L_{dn}	Heavies	Buses	Cars	Motor cycles	
Aba (01)	85·0	78.4	75·7	104	79·2	80·0	63·0	14·5	12·8	51·8	20·8	3520
Calabar (02)	80·8	75·0	68·0	98	69·9	77·7	62·4	6·3	0·00	25·4	68·3	2376
Enugu (03)	87·8	76·0	63·0	101	72·7	86·3	70·0	14·3	15·0	69·2	1·5	1896
Ikot Ekpene (04)	85·5	77·0	64·2	99	71·2	90·8	69·4	13·5	3·1	60·0	23·1	2493
Onitsha (05)	89·3	82·0	76·4	105	74·1	84·6	68·0	12·8	21·3	58·3	7·6	2820
Owerri (06)	87·5	83·8	80·5	102	72·1	81·2	64·2	4·6	9·6	79·5	10·3	1812
Port-Harcourt (07)	84·5	78·5	73·8	103	80·0	80·4	62·6	8·5	12·9	77·6	3·0	4176
Uyo (08)	80·8	76·1	69·6	100	71·4	78·2	62·8	9·6	10·9	41·0	38·4	3090

number of respondents who reacted adversely against road traffic noise concerning complaint actions, 29·9% did not take any action because they did not want to worry themselves; 26·9% did not take any action because they were afraid nothing serious might be done by the authority. Other reasons why respondents did not take any action about road traffic noise (even after they had complained) are: they did not know they have the right to take any action (14·2%); they were afraid they might need to spend some money (12·2%); difficulty in identifying any particular offender (10·4%) and inability to conceive of any appropriate authority (7·0%). These results are in good agreement with those obtained by Hammad *et al.* [32], who reported that the percentage of people who were disturbed by road traffic noise varied between 20 and 80% and who further claimed that people prefer to move to quieter streets.

There appeared to be an income bias in respect of community response to road traffic noise. Low-income neighbourhoods reported less annoyance and disruption of various activities by road traffic noise than their high-income counterparts when exposed to the same noise levels. This implies that consideration of socio-economic composition of residential areas is important when making decisions about noise laws, ordinances and other governmental acoustical matters that relate to noise. There is evidence of subjective adaptation to road traffic noise by residents of the boisterous cities in South-Eastern Nigeria. 57·7% of the community interviewed had the desire to complain about road traffic noise. Concerning actions taken, West German respondents had much greater experience in complaining directly to neighbours. This, interpreted by Namba *et al.* [37], may be a result of education in West Germany. In the other countries, U.S.A., Japan, China and Turkey, some respondents answered that they hesitated to complain so as not to harm relations with neighbours by complaining directly [37]. This study has revealed evidence of subjective

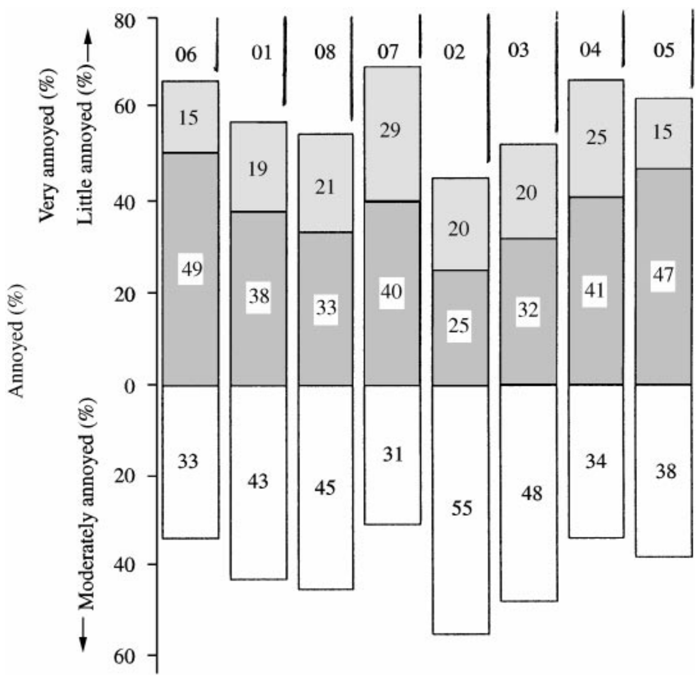

Figure 5. Feeling about road traffic noise: ▒ %, very annoyed; ░ %, little annoyed; □ %, moderately annoyed. 06 - OWERRI, 01 - ABA, 08 - UYO, 07 - PORT HARTCOURT, 03 - ENUGU, 04 - IKOT - EKPENE, 05 - ONITSHA, 02 - CALABAR.

TABLE 2

Summary of prediction of community response to road traffic noise [12]

S/No.	Regression/prediction equation	Correlation coefficient	Significant test	
			5% level	1% level
1.	% complaining = 0·5x (% feeling like complaining) + 6	0·7682 (3·1)	Not significant	Not significant
2.	% annoyed = 0·8x (% complaining) + 37·4	0·4363 (3·2)	Significant	Significant
3.	% highly annoyed = 0·7x (% complaining) + 13·8	0·7031 (2.7)	Significant	Not significant

Figures in parentheses are standard errors of estimates.

TABLE 3

Correlation between mean sound levels, index and some dissatisfaction response [12]

Dissatisfaction response correlated with mean sound levels and index	Pearson product–moment correlation coefficient r with					
	Mean sound levels					Mean index
	10%	50%	90%	L_{eq}	L_{NP}	TNI
% Complaining	0·2910 (12·2)	0·5631 (13·4)	0·2820 (9·1)	0·4208 (11·9)	0·0918 (10·2)	0·2051 (9·6)
% Highly annoyed	0·2315 (11·0)	0·4242 (11·8)	0·0331 (10·1)	0·4264 (11·8)	0·2248 (11·0)	0·1858 (8·9)
% Taking action	0·2675 (10·9)	0·295 (10·7)	0·3674 (7·7)	0·2625 (10·9)	0·1706 (10·5)	0·3308 (11·2)
% Wanting to live in a quieter area	0·1459 (10·3)	0·2591 (9·6)	0·6804 (14·4)	0·07 (10·8)	0·0534 (11·4)	0·0760 (20·7)

Figures in parentheses are standard errors of parameter estimates.

adaptation to road traffic noise by respondents living and working in Aba(01) and Onitsha(05) which are the busiest commercial cities in South-Eastern Nigeria and which rank very high in industrial activity in this part of the country. Figure 5 shows the feeling of respondents about road traffic noise. Research into subjective response to road traffic noise has led to one important conclusion that there is evidence of adaptation by people who have lived in a particular city for sometime [16–19, 21, 22, 37]. On whether they would want road traffic noise to be controlled (or reduced), 82·5% responded in the affirmative. 85·2% of the population said they would want government or any appropriate authority to carry out the control. Earlier studies of community response to road traffic noise in South-Eastern Nigeria [12] (Tables 2 and 3) and elsewhere [13] have led to the development of prediction equations with typical poor correlation, ranging from 0·3 to 0·4, found between community dissatisfaction response and noise measures. In this study, possible relationships between the percentage of respondents and some noise parameters such as type of house lived-in, most annoying noise and activity interference with road

TABLE 4

Correlation between percentage of respondents and some noise parameters

Noise parameters	Pearson product–moment correlation coefficient r with percentage of respondents
Type of house	0·9925 (15·4)
Most annoying noise	0·7237 (19·6)
Activity interence with road traffic noise	0·9714 (10·2)

Figures in parentheses are standard errors of parameter estimates.

traffic noise were sought. It was found that the variables were positively correlated with high-correlation coefficients (Table 4). The correlation coefficients are comparatively high. This validates the high levels of road traffic noise obtained in this investigation for these cities.

6. CONCLUSION

Analysis of data from a series of measurements and surveys leads to the following conclusions.

1. Measured L_{10} was always higher than calculated L_{10} by about 4·5 to 8·8 dB (A) in South-Eastern Nigeria
2. Road traffic noise is a major environmental problem in South-Eastern Nigeria and noise levels are higher than those measured in cities in well-planned and developed countries.
3. Residents of South-Eastern Nigeria suffer a level of annoyance and disturbance and therefore prefer to move away and live in quieter area.
4. There is poor correlation between community dissatisfaction response and reaction, and noise exposure in South-Eastern Nigeria.
5. There is a strong evidence of subjective adaptation to road traffic noise by some of the residents in the boisterous cities in South-Eastern Nigeria.

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REFERENCES

1. F. J. MEISTER 1956 *Journal of Acoustical Society of America* **28**, 783. Traffic noise in West Germany. Evaluation of noise levels, and experience in noise control.
2. D. W. ROBINSON 1969 *Ministry of Technology*, *National Physical Laboratory Aero*, *Report AC* **38**. The concept of noise pollution level.

3. F. J. LANGDON, 1976 *Journal of Sound and Vibration* **47**, 243–282. Noise nuisance caused by road traffic in residential areas: Parts I and II.
4. W. E. SCHOLES and J. W. SARGENT 1971 *Applied Acoustics* **4**, 203–234. Designing against noise from road traffic.
5. I. D. GRIFFITHS and F. J. LANGDON 1968 *Journal of Sound and Vibration* **8**, 16–32. Subjective response to road traffic noise.
6. A. ALEXANDRE, J. P. BARDE, C. LAMURE and F. J. LANGDON 1975 *Road Traffic Noise*. New York: Halsted Press.
7. F. L. HALL and S. M. TAYLOR 1977 *Journal of Sound and Vibration* **52**, 387–399. Predicting community response to road traffic noise.
8. G. I. FUCHS 1975 *Journal of Sound and Vibration* **43**, 387–394. Subjective evaluation of transport noise in Latin America.
9. A. I. EL-SHARKAWY and A. A. ABOUKHASHABA 1983 *Applied Acoustics* **16**, 41–49. Traffic noise measurement and analysis in Jeddah.
10. K. A. ALSHORBAGY 1984 *Applied Acoustics* **17**, 261–274. Environmental acoustic and quality in Jeddah urban sites.
11. A. I. MENKITI 1998 *Journal of West African Science Association*. Analysis of noise bother by survey method. To be published.
12. M. U. ONUU and A. I. MENKITI 1996 *Journal of Science, Engineering and Technology* **3**, 536–547. Analysis of Nigerian community response to road traffic noise.
13. T. J. SCHULTZ 1978 *Journal of Acoustical Society of America* **64**, 377–405. Synthesis of social surveys on noise annoyance.
14. K. D. KRYTER 1985 *The effects of noise on man*. New York: Academic Press, second edition.
15. T. YONO, T. YAMASHITA and K. IZUMI 1991 *Journal of Sound and Vibration* **151**, 487–495. Community response to road traffic noise in Kumamoto.
16. F. J. LANGDON and I. D. GRIFFITHS 1982 *Journal of Sound and Vibration* **83**, 171–182. Subjective effects of traffic noise exposure II, comparison of noise indices, response scales, and the effect of changes in noise exposure.
17. A. L. BROWN, A. HALL and J. KYLE-LITTLE 1985 *Journal of Sound and Vibration* **98**, 235–246. Response to a reduction in traffic noise exposure.
18. G. J. RAW and I. D. GRIFFITHS 1985 *Journal of Sound and Vibration* **101**, 273–275. The effect of changes in aircraft noise exposure (letter to the editor).
19. I. D. GRIFFITHS and G. J. RAW 1986 *Journal of Sound and Vibration* **111**, 209–217. Community and individual response to changes in traffic noise exposure.
20. N. D. WEINSTEIN 1982 *Journal of Environmental Psychology* **2**, 87–98. Community noise problems: evidence against adaptation.
21. I. D. GRIFFITHS and G. J. RAW 1987 *Applied Acoustics* **21**, 89–95. Response to changes in noise exposure: testing a model.
22. G. J. RAW and I. D. GRIFFITHS 1990 *Journal of Sound and Vibration* **141**, 43–54. Subjective response to changes in road traffic noise; a model.
23. E. RELSTER 1975 *Polyteknik Lyngby*. Traffic noise annoyance: the pscyhological effects of traffic noise in housing areas.
24. M. U. ONUU and A. I. MENKITI 1993 *Nigerian Journal of Physics* **5**, 1–9, Spectral analysis of road traffic noise in parts of South-Eastern Nigeria.
25. A. I. MENKITI 1976 *Daily Times* **28**, 28–29. Combating the menance of noise.
26. M. U. ONUU and A. I. MENKITI 1990 *Champion Newspaper* **27**, 5. Effective noise control.
27. J. J. HAJEK 1975 *Research Report* 197, *Downsview*. Ontario Ministry of Transportation and Communications. Ontario Highway noise prediction method.
28. *National Cooperative Highway Research Programme*, *Washington*: *Transportation Research Board*. Highway noise-a design guide for Engineers.
29. E. JONSSON, S. SORENSEN, O. ARVIDSON and K. BERGLUND 1976 *Archives of Environmental Health* **30**, 104–106. Reliability of forecasts of annoyance reactions
30. *U.S. Environmental Protection Agency*, *Washington*, *D.C.* 20460 1973 *Report* 550/9-74-004. Information on levels of environmental noise requisite to public health and welfare with an adequate margin of safety.
31. R. RACKL, L. C. SUTHERLAND and J. SWING 1975 *Report by Wyle Laboratories for the Motor Vehicle Manufacturers Association*, *Springfield*, *Va*: *National Technical Information Service*. Community noise counter-measures cost effectiveness analysis.

32. R. N. S. Hammad and M. K. Abdelazeez 1987 *Applied Acoustics* **21**, 309–320. Measurements and analysis of the road traffic noise in Amman, Jordan and its effects.
33. J. M. Fields 1995 *Proceedings of the 15th International Congress on Acoustics, Trondheim, Norway* 26–30 June, 89–92. Proposed guidelines for reporting core information from community noise reaction surveys.
34. G. J. McNulty 1987 *Applied Acoustics* **21**, 81–87. Impact of transportation noise in some New Industrial Countries.
35. R. H. Galt 1930 *Journal of Acoustical Society of America* **2**, 30–58. Results of noise surveys, Part I: noise out-of-doors.
36. *ENVIRONMENTAL PROTECTION AGENCY* 1978 *EPA Document*, *November*, 550/9-79-100, *U.S.A.* Protective noise levels.
37. S. Namba, S. Kuwano, A. Schick, A. Aclar, M. Florentine and Z. D. Rui 1991 *Journal of Sound and Vibration* **151**, 471–477. A cros-cultural study on noise problems: comparison of the results obtained in Japan, The U.S.A, China and Turkey.