LEVELS AND SPECTRA OF AIRCRAFT NOISE AND PEOPLE'S REACTIONS IN SOME NIGERIAN CITIES

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Abstract

A study of sound levels and spectral distribution as well as people's reactions to aircraft noise in three Nigerian international airports have been conducted. The study comprised physical measurements and social survey. Results show that maximum octave band pressure levels (BPLs) for Margaret Ekpo, Port Harcourt and Murtala Mohammed International Airports were 88 dB(A), 94 dB(A) and 99 dB(A), respectively with corresponding the deafening levels recorded as 102.5dB(A), 122.5 dB (A) and 123.5 dB(A). Maximum sound level (L_{max}) was as high as 116 dB(A) in each case. The Day-night level (L_{dn}), weighted equivalent continuous perceived noise level (WECPNL), noise and number index (NNI), noise exposure forecast (NEF), A-weighted sound level (L_A), and noise pollution level (L_{NP}) were also obtained based on acoustical data generated at the airports under study, and were found to exceed the recommended doses of 55, 60, 20, 24, 45 and 60 dB (A), respectively. From these results it is clear that octave band pressure levels exceed the recommended 85 dB(A). Octave band pressure levels obtained tend to be Gaussian and the spectra were flat. Percentage responses correlated well with NNI with power law relationships between it and the latter in all the cases considered. Results clearly show that people resident near Nigerian airports are exposed to psychological and physiological damage as a result of excessive aircraft noise with serious activity interference.

Keywords: *Noise levels, spectra, aircraft noise, damage risk and activity interference.*

Introduction

Doolittle, *et al.* (1952) early observed the menace of aircraft and stated that aircraft noise had become a serious problem, which has constantly increased tremendously in scope. They admitted that aircraft noise has become an increasing nuisance to people living in communities near airport. Harris (1957) stated that intense aircraft noise injures health, influences property values, renders certain areas unsuitable for business activities and affects economic welfare of people living near airports.

Miller (1971), Magrab (1975) and Cunniff (1977), separately found out that exposure to noise (aircraft) of sufficient intensity for long periods produces changes in the inner ear and seriously decreases the hearing ability, and that these changes can range from only slight ear impairment to nearly total deafness. Molino (1979) stated, from the results of his studies on the effects of aircraft noise on people, that loud sounds tend to be annoying, and that annoyance increases with increasing sound level. Rylander and Dunt (1991) and Osada (1991) in their separate research findings asserted that excessive exposure to aircraft noise brings about sleep disturbance and also may cause psychological, physiological and socio-economic effects to the exposed population. Based on results of his extensive study on aircraft noise pollution Waitz (1995) submitted that aircraft noise impairs people's ability to work, to learn in school, and to sleep, and consequently results also in lowered property values in affected areas. Onuu, *et al.* (1996) from their work on spectral analysis of industrial noise in Calabar, Nigeria, asserted that high noise levels in industries may reduce productivity of workers, cause industrial accidents, annoy, interfere with speech and hearing, accelerate presbycusis, and cause permanent deafness and pathological damage. Morell *et al.* (1997) on the review of health effects on aircraft noise submitted that aircraft noise can influence the entire human body system, and that prolonged and repeated exposure to aircraft noise may adversely affect health and well being of individuals. Hansen (2002) in a separate research effort on the menace of aircraft noise generally, came out with similar findings. Obisung (2002) carried out a study on Measurements and Analysis of Aircraft Noise and Community Reaction in Parts of Southern Nigeria and found that people living or doing business in and near airports have a lot of psycho-social and physiological problems which include, annoyance, sleeplessness, communication interference, temporary hearing impairment, rest/relaxation disturbances, body irritation and general discomfort among other health effects, and finally asserted that aircraft noise in Nigerian airports is truly a public nuisance.

From the foregoing, it is clear that continuous exposure to high levels of noise seriously damage human hearing and causes a lot of discomfort to people both psychologically, socially and physiologically. Despite the various hazards caused by excessive aircraft noise, Nigerian Government or the airports authorities seem not to be bothered about the menace of excessive noise generally and aircraft noise particularly.

The study therefore, aims at investigating the conditions of aircraft noise, in Nigeria, generally, using three international airports named in this paper as representatives of all airports in Nigeria; obtaining spectral plots to help establish the frequency distribution of sound energy, and accumulating data that could be very useful to environmental scientists, aeronautical engineers/designers, acoustical engineers/scientists, town planners, public health officials, architects, psychologists, governments, airports authorities, physiologists, lawyers and other professionals/experts saddled with the responsibility of controlling or abating harmful noise or legislating and enforcing noise laws and ordinances in Nigeria. The study is also to help sensitize the general public and create the more needed awareness of the dangers of the aircraft noise in our communities. It is hoped that the findings of this study will contribute meaningfully towards solving the increasing aircraft noise problems in Nigeria.

Materials and Method

Acoustical and social surveys were conducted in this study. Acoustical measurements were made by the use of a precision sound level meter (Bruel and Kjaer, B&K) type 2203 calibrated with B&K piston-phone type 4220 with its associated octave band filter (B&K type 1613). The meter was set at A-weighting network generally used for aircraft noise measurement, and also set at slow meter response to have a more sluggish response for a more accurate reading to be obtained. The background noise level at each of the airports under study was taken using this sound level meter before the actual measurements were carried out. The distance between the noise source and point of measurement was 50 metres. The sound level meter was held very steadily, and aways from reflecting objects, and about 1.5 metres high (corresponding to the hearing position or ear level of an average person). Octave band pressure levels as

well as A-weighted band pressure levels were taken and recorded throughout the octave frequency band. Measurement of sound levels was done as aircraft engine was still steaming or tuning in the airports. Their corresponding spectra plots are shown in Figs. 1,2 and 3 , respectively.
A-weighted band pressure levels were obtained by adding the corresponding correction factor to appropriate octave pressure level, while deafening levels were obtained by subtracting 14.5 dB from the calculated A-weighted noise levels (Galt, 1930). The A-weighted sound level is used to assess hearing damage risk due to exposure to noise. The limiting duration of daily exposure LDD (in hours) at any noise level according to U.S. Air Force (1974) can be determined from eqn. (1):

$$L_{DD} = 16 + \exp[(L-80)+4]$$
$$= 2\exp[(96-L)+4] \qquad (1)$$

where L is A-weighted sound levels measured with slow time constant.

The U.S. Environmental Protection Agency, EPA (1974), has recommended an average equivalent noise level of 70 A-weighted dB(A) for continuous 24-hours exposure as the maximum exposure level required to protect hearing with an adequate margin of safety. The U.S. Air Force (1982) on its part, issued statutes and regulations on noise levels that are acceptable without hearing protection when the noise exposure occurs only once a day, for a given time of exposure as shown in Table 4.

The day-night level, L_{dn} is defined (Cunniff, 1977) as shown in eqn. (2):

$$L_{dn} = L_{Acq.24hr} = 10\log_{10}\frac{1}{24}\left[\sum_{i=1}^{N} f_i \times 10^{(L_i/10)}\right] \qquad (2)$$

where f_i is fraction of time (in seconds) the constant level is present. L_i is A-weighted band pressure level (in dBA).
L_{dn} of 55dBA is desirable outdoor noise level (Cunniff, 1977).

Weighted equivalent continuous perceived noise level WECPNL is an exposure index for aircraft noise defined (Yamamoto, *et al.*, 1999) as shown in eqn. (3).

$$WECPNL = L_{dn} + 10\log_{10}N - 27 \qquad (3)$$

where N = Total number of noise events in one day (day-and night-time) L_{dn} = day-night level expressed in eqn. (2).

WECPNL of 50-60 is recommended level. Noise and number index, NNI is a perceived noise level expressed (Harris, 1957) in eqn. 4:

$$NNI = 10\log_{10}\left[\frac{1}{24}\sum_{i=1}^{N} f_i \times 10^{L_i/10}\right] + 15\log N - 67$$
$$= L_{dn} + 15\log 10N - 67 \qquad (4)$$

where N is number of aircraft occurring in a specific period of time. NNI acceptable level is 20 or less (Anthrop, 1973).

Noise exposure forecast (NEF) is defined (Cunniff, 1977) as cumulative aircraft noise over a 24hr period measured around an airport, and is expressed as shown in eqn. (5):

$$NEF = L_{dn} - 35 \pm 3 \qquad (5)$$

NEF of < 24 is recommended as acceptable noise level (Cunniff, 1977).

A-weighted sound level, L_A is regarded to be the simplest and most widely used measure of environmental noise, generally (Kinsler *et al*, 1982). It can be expressed as shown in equation 6 (Magrab, 1975).

$$L_A = 10\log_{10}\left[\sum_{i=1}^{N} 10^{(L_P + c)/10}\right] \qquad (6)$$

where Lp = 1/3 - octave band pressure levels (dBA). C = correction factor (dBA)

L_A of < 45 dB(A) is acceptable level(Magrab, 1975).

Noise pollution level (L_{NP}) is expressed as shown in eqn.(7). Where is energy mean of A-weighted level over a specified period of time, and is expressed as

$$L_{NP} = L_{eq} + (L_{10} - L_{90}) \quad (7)$$

L_{10} is the decile A-weighted sound pressure level exceeded for 10% of the observation period.
L_{90} is the decile A-weighted sound pressure level exceeded for 90% of the observation period. Leg is energy mean of a weighted level over a specified period of time and is expressed as eqn. (8). L_{eq} of 60 is acceptable noise level (Magrab, 1975). L_{eq} is given as

$$L_{eq} = 10\log_{10}\left[\sum^{N} f_i \times 10^{\left(L_i/10\right)}\right] \quad (8)$$

Social (subjective) measurements were also taken through data generated from the questionnaire to assess the reactions of the respondents to aircraft noise. Five hundred and fifty copies of questionnaires were distributed to respondents around Margaret Ekpo International Airport (MEIA) but 389 copies were returned giving a response rate of 70.73%; three hundred were distributed to respondents around Port Harcourt International Airport (PHIA) but 203 were returned giving a response rate of 67.67% and four hundred were distributed to respondents around Murtala Mohammed International Airport (MMIA) but 294 copies were returned, giving a response rate of 73.50%. On the whole,1250 questionnaires were distributed but 886 copies were collected, giving a total response rate of 70.63%.

The questionnaire contained standard questions to elicit the required information. Some of the questions asked on the questionnaire were whether or not the respondents had temporary or permanent hearing impairment; whether they both were annoyed by aircraft noise had sleeplessness caused by aircraft noise, had their verbal conversation disrupted by aircraft noise, had ear irritation, body fatigue, mental or brain fatigue, headache, concentration interference during reading/study periods, rest/relaxation interference, whether they complained about aircraft noise to authorities concerned like Federal Government of Nigeria (FGN), Federal Airports Authority of Nigeria (FAAN), Airline Operators, National Assembly of Nigeria, etc, whether there were any response (positive or negative) from any or all of these bodies; how long they lived near airports (0-5 years, 6-10 years, 11-20 years,21 years and above), whether their lives were damaged by aircraft noise or not (and if yes, to what extent), and whether they needed aircraft noise be controlled or not, among other questions. The questionnaire was designed to have five (5) degrees of response namely Extremely Severe (ES), Very Severe (VS), Severe (S), Not Severe (NS) and Little Effect (LE) with scale ratings of 5,4,3,2, and 1, respectively.

In conducting this social survey, a number of measurement locations/sites were carefully chosen at each of the airports under study. All measurement locations/sites chosen for this study lie along the aircraft pathway to obtain a more reliable and true respondents' reactions to this noise.

Results and Discussion

Curves of band pressure levels and calculated A-weighted band pressure levels (or A-weighted sound levels) against octave band centre frequencies for Margaret Ekpo, Port Harcourt and Murtala Muhammed international airports, which indicate aircraft noise spectra are shown respectively, in Figs. 1, 2 and 3.
Tables 1, 2 and 3, show the noise levels and

indices obtained at Magaret Ekpo, Port Harcourt and Murtala Muhammed international airports, respectively.

A cursory look at Figs.1, 2 and 3, shows that the A- weighted band pressure levels ((A-weighted BPLs) tend to increase as the octave band center frequency increases. The A-weighted sound pressure level is one of the major indices used for

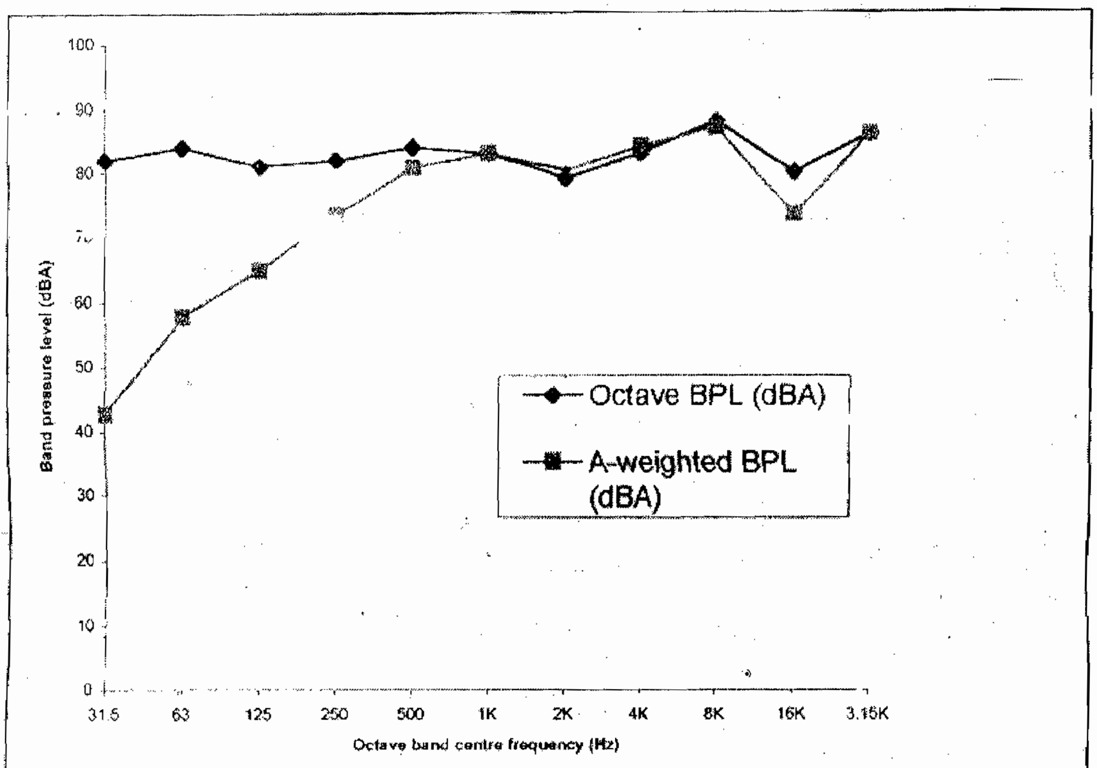


Fig. 1: Aircraft noise spectra for Margaret Ekpo International Airport, Calabar

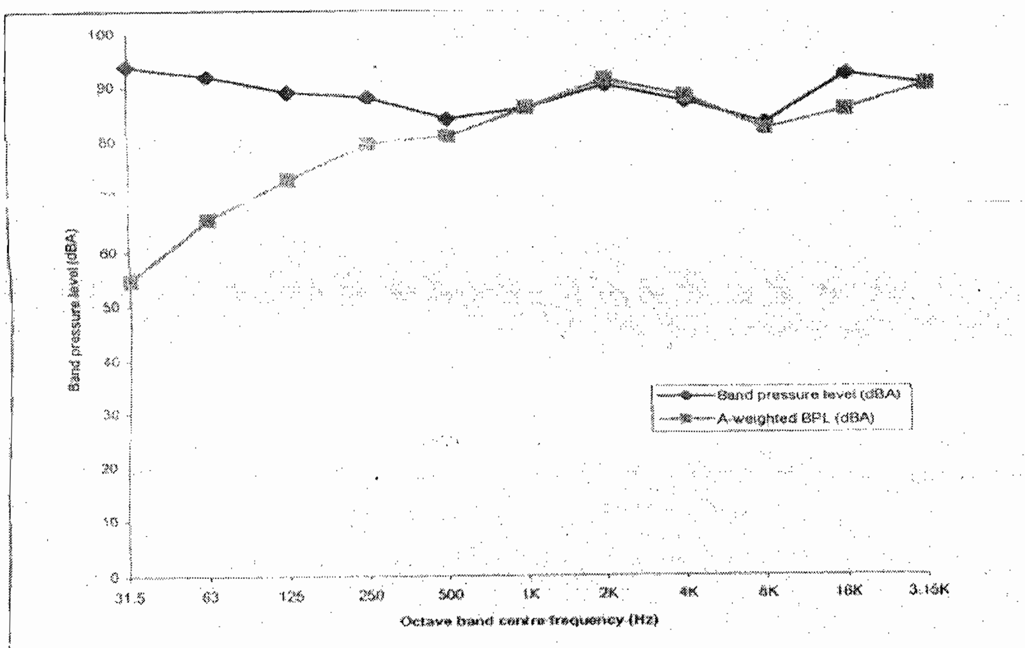


Fig. 2: Aircraft noise spectra for Port Harcourt International Aiport, Port-Harcourt

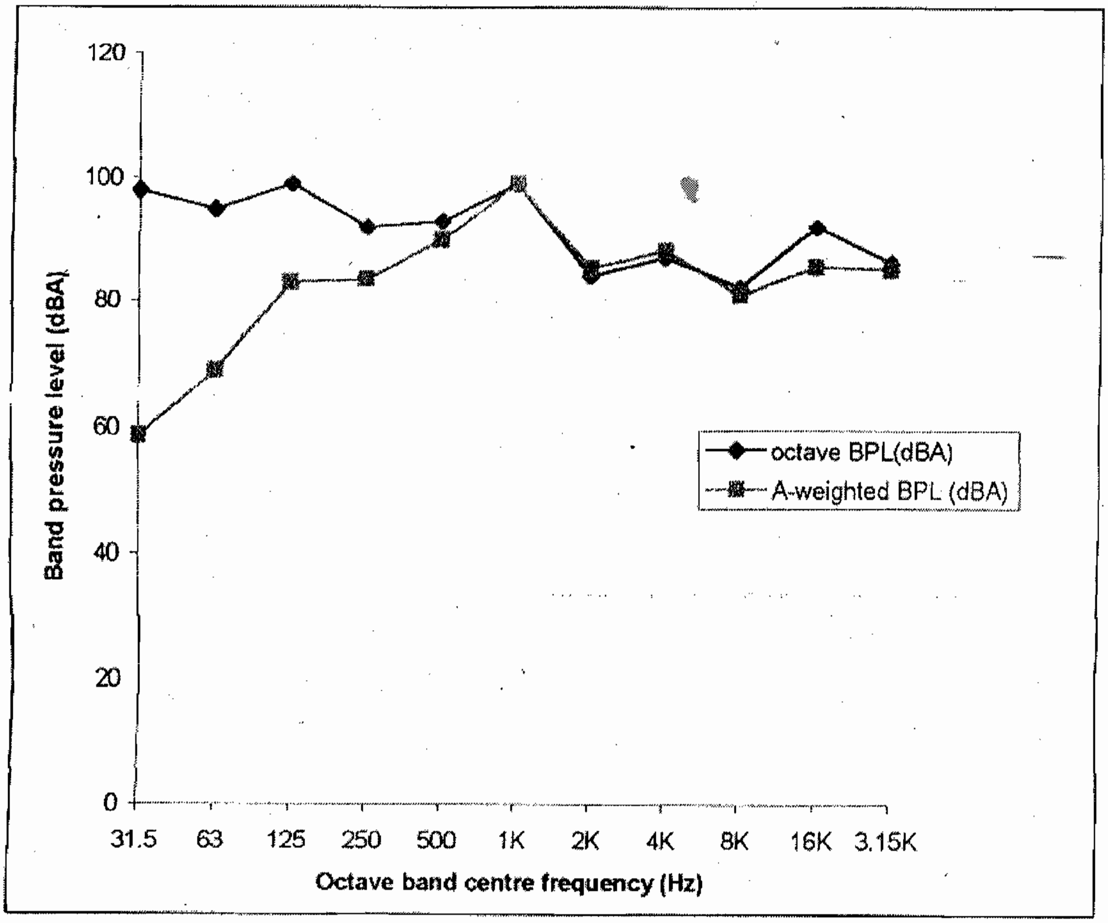


Fig. 3: Aircraft noise spectra for Murtala Muhammed International Airport, Lagos

evaluation of noise, including aircraft noise. From the spectra plots (Figs. 1-3) and data on Tables 2, 3 and 4 it could be observed that the recommended noise levels/indices are exceeded (EPA, 1974) in all the airports under study. Human ear is highly sensitive to sound with the frequency range of between 1kHz and 4kHz. We can see that within this frequency range A-weighted levels are high, indicating that people exposed to this aircraft noise suffer from serious possible hearing impairment as well as other health hazards and other pathological effects (Cunniff, 1977 and Onuu *et al.* 1996). The high A-weighted sound levels, octave band pressure levels and other noise levels/indices recorded in this study go to confirm that people living or doing business near Nigerian airports are exposed to serious health hazards. These findings tend to agree with the results of the work of other experts as Osada (1991); Onuu *et al.* (1996); Morell *et al.* (1997) and Molino (1997).

The spectra obtained are found to be Gaussian and reasonably flat. Table 4 clearly shows that for high A-weighted level, lower exposure time should be maintained. The higher the A-weighted level, the lower should be the time for better hearing acuity. Figures. 4-9 show plots of percentage of responses on annoyance reactions, telephone conversation interference reactions, radio/telephone interference reactions, verbal conversation interference, temporary hearing impairment and body

Table 1: Duration of total daily exposure time (T) as a function of A-weighted sound level (in dBA) (U.S. Airforce, 1982).

Sound level dB (A)	Exposure timeT (minutes)	Sound level dB(A)	Exposure time, T (minutes)
Above 115	-		
115	2.2	95	71
114	2.7	94	85
113	3.2	93	101
112	3.8	92	120
111	4.5	91	143
110	5	90	170
109	6	89	202
108	8	88	240
107	9	87	285
106	11	86	339
105	13	85	404
104	15	84	480
103	18	83	571
102	21	82	679
101	25	81	807
100	30	80	960
99	36	79	1142
98	42	78	1358
97	50	Below 78	No limit
96	60	-	

verbal conversation interference, temporary hearing impairment and body fatigue/irritation reactions versus Noise and Number Index (NNI) for Margaret Ekpo, Port Harcourt and Murtala Muhammed International Airports. Figure 4 is the plot of percentage of the responses on the annoyance reactions as a function of

Table 2: Noise levels/indices obtained by acoustical measurements/analysis at Margaret Ekpo international airport.

L_A(dBA)	L_{dn}(dBA)	L_{NP}(dBA)	NEF	NNI	WECPNL
64.0	77.0	91.0	44	29.0	63.0
64.0	78.0	91.0	45	31.0	64.0
64.0	78.0	95.0	45	38.0	69.0
64.0	77.0	90.0	44	33.0	65.0
64.0	77.50	91.80	44.50	32.80	65.30

Table 3: Noise levels/indices obtained by acoustic measurements/analysis at Port Harcourt international airport.

L_A(dBA)	L_{dn}(dBA)	L_{NP}(dBA)	NEF	NNI	WECPNL
64.0	77.0	86.0	45	41.0	71.0
64.0	78.0	88.0	46	44.0	73.0
64.0	77.0	88.5	45.5	40.0	70.0
64.0	78.0	88.3	46	43.0	72.0
64.0	77.5	87.9	45.6	42.0	71.5

Table 4: Noise levels/indices obtained by acoustic measurements/analysis at Murtala Muhammed International airport.

L_A(dBA)	L_{dn}(dBA)	L_{NP}(dBA)	NEF	NNI	WECPNL
64.5	79.0	106.5	47.0	49.0	77.0
64.5	79.0	93.0	47.0	52.0	78.0
64.5	78.0	91.5	48.0	50.0	77.0
64.5	79.0	93.7	47.0	53.0	80.0
64.5	78.8	96.1	47.2	51.0	78.0

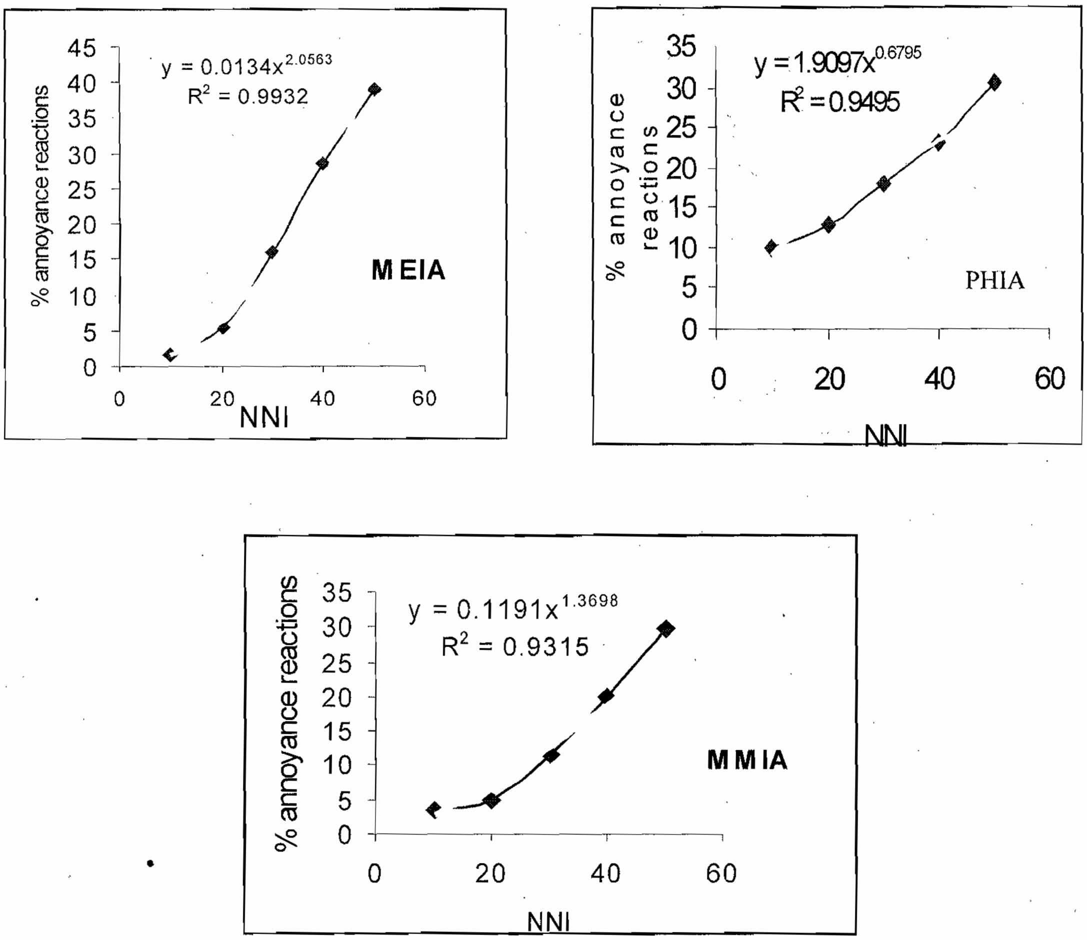
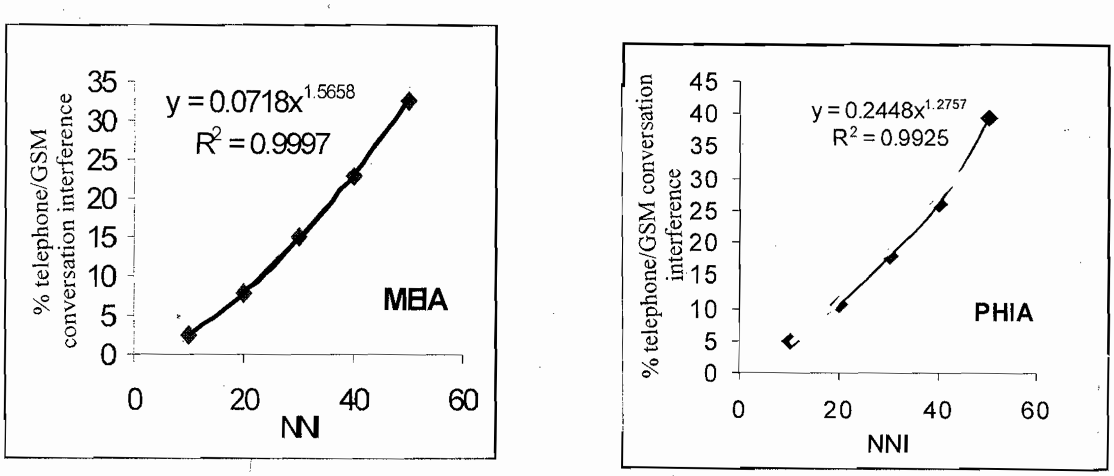


Fig. 4: Plots of percentage of response on annoyance reactions versus NNI for MEIA, PHIA and MMIA.



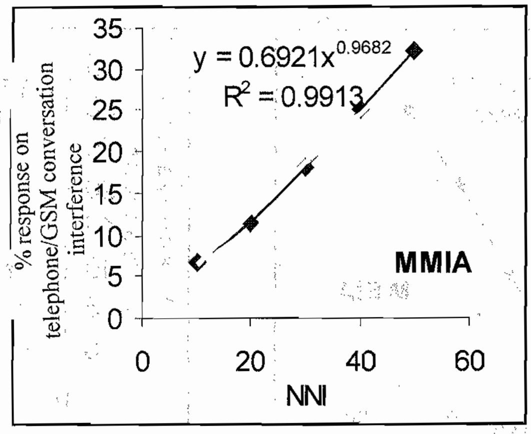
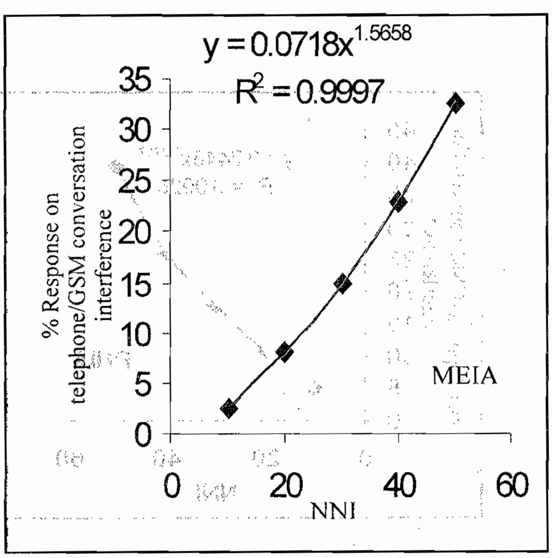
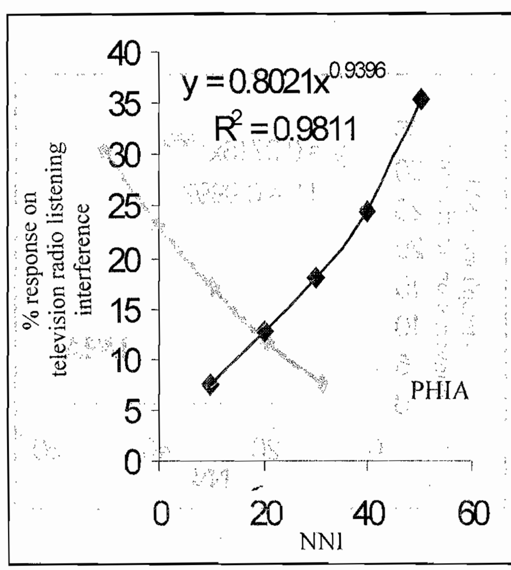


Fig. 5: Plots of Percentage of response on telephone/GSM conversation interference reactions versus NNI for MEIA, PHIA, MMIA .

of about 20 to about 50.An annoyance response (reactions) of about 39%, 31% and 30% rated aircraft noise Extremely Severe (Scale 5), while an annoyance response of about 2%, 6% and 6% rated it little (Scale 1) for Margaret Ekpo, Port Harcourt and Murtala Mohammed International Airports respectively. Figure. 5 shows plots of percentage of response on telephone conversation interference reaction as a function of NNI. The reactions increased as NNI increased. Response reactions of about 32%, 39% and 32% were Extremely Severe, while response reactions of about 3%, 5% and 7% rated it Little respectively. Fig. 6 demonstrates plots of percentage of response on television/radio listening interference reactions as a function of NNI. Response reaction of about 38%, 36% and 33% rated aircraft noise Extremely Severe, while about 2%, 7% and 9% rated it Little respectively. In Fig. 7, 48%, 40% and 34% rated temporary hearing impairment effect Extremely Severe, while about 0.5%, 9% and 10% rated it Little for MEIA, PHIA and MMIA respectively. From Fig 8, about 42%, 37% and 35% rated aircraft noise Extremely Severe on verbal conversation, while 4%, 3.5% and 9% rated it Little respectively. Finally, Fig. 9 shows that response





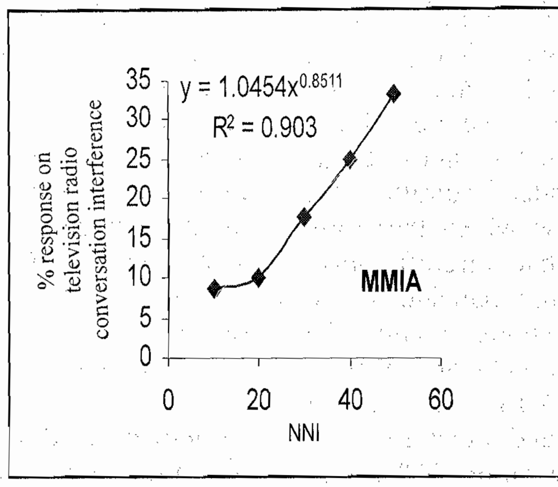


Fig. 6: Plot of percentages of response on television/radio listening interference reactions versus NNI for MEIA, PHIA and MMIA

MEIA

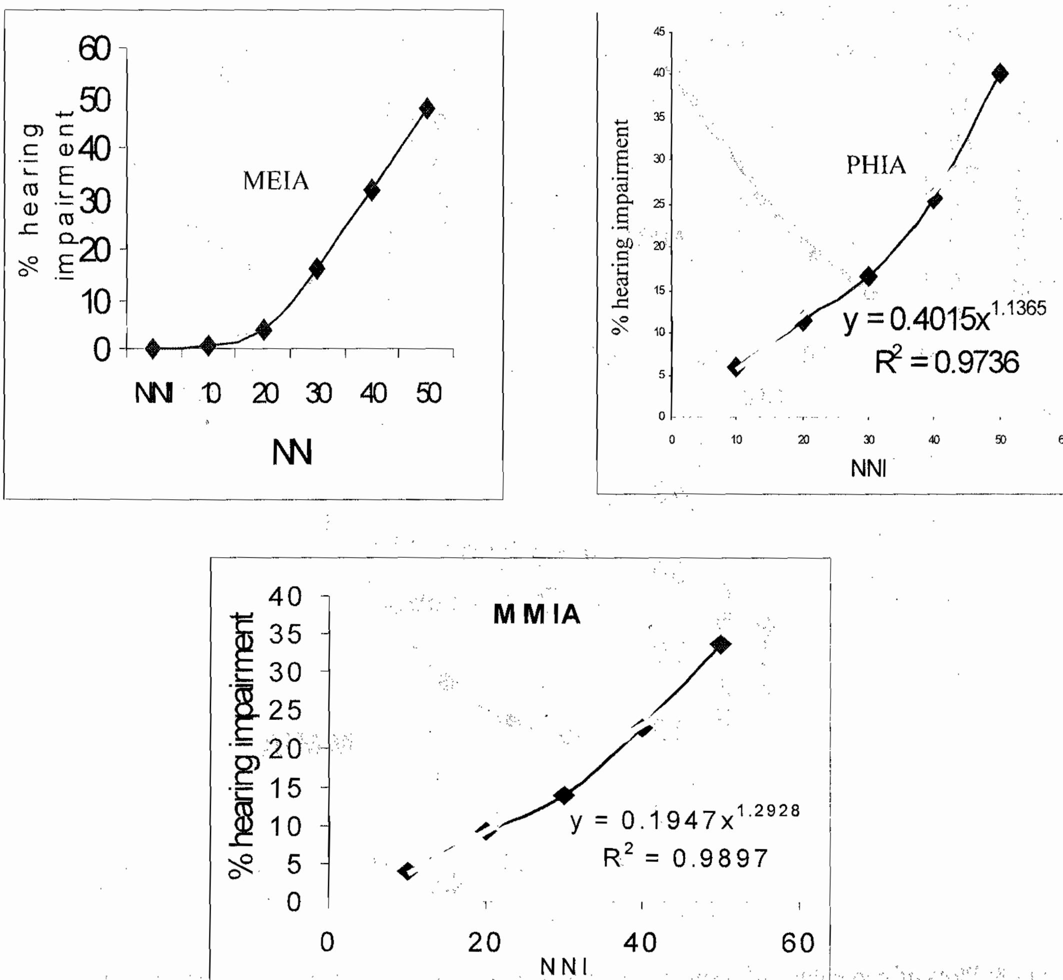


Fig. 7: Plots of percentage of response on hearing impairment reactions versus NNI for MEIA, PHIA and MMIA.

reaction on body fatigue/irritation of about 30%, 44% and 36% rated aircraft Extremely Severe, while about 5%, 3% and 5% rated it Little respectively. From the results obtained in this study it was clear that no respondent admitted No Effect of aircraft noise which therefore, further confirmed that aircraft noise pollution causes intense damage to the population. On the whole, it could be summarized that 97%, 94% and 92% of respondents around MEIA, PHIA and MMIA respectively, rated it disturbing on telephone/GSM conversation; 98%, 93% and 91% respectively rated it disturbing on radio/television listening; 96%, 95% and 90% respectively, rated it bothering on verbal conversation. Also 95%, 97% and 95% rated it body fatigued/irritating, respectively, while 99%, 91% and 90% respectively admitted aircraft noise caused serious temporary hearing impairments. From this investigation it was found that the percentage of people responding that some takes are effected by aircraft noise and noise and number index (NNI) are related by a power law with reasonably high correlation coefficients.

Conclusion and Recommendation

From the findings of this study it is clear that people resident near or doing business in Nigerian airports are exposed to serious health danger. Recommended noise doses

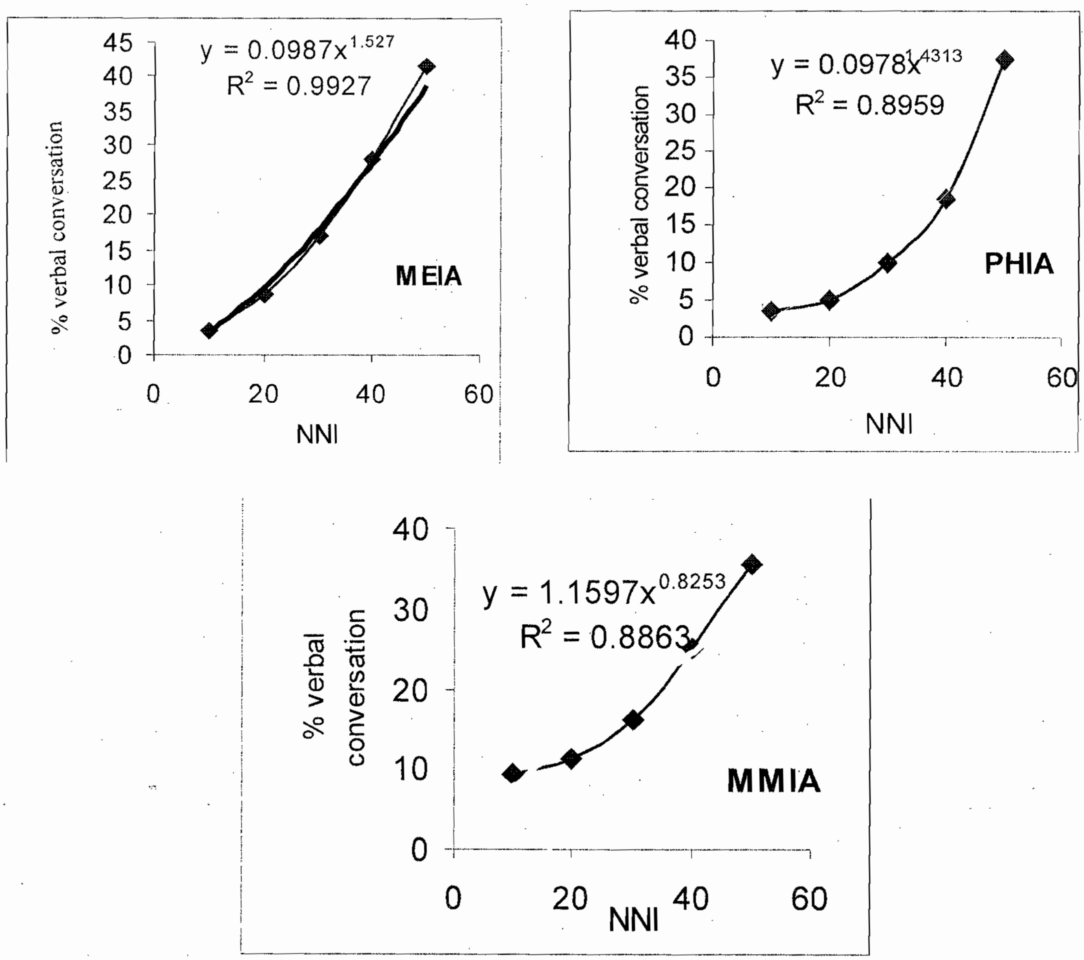


Fig.8: Plots of percentage of response on verbal conversation reactions versus NNI for MEIA, PHIA and MMIA.

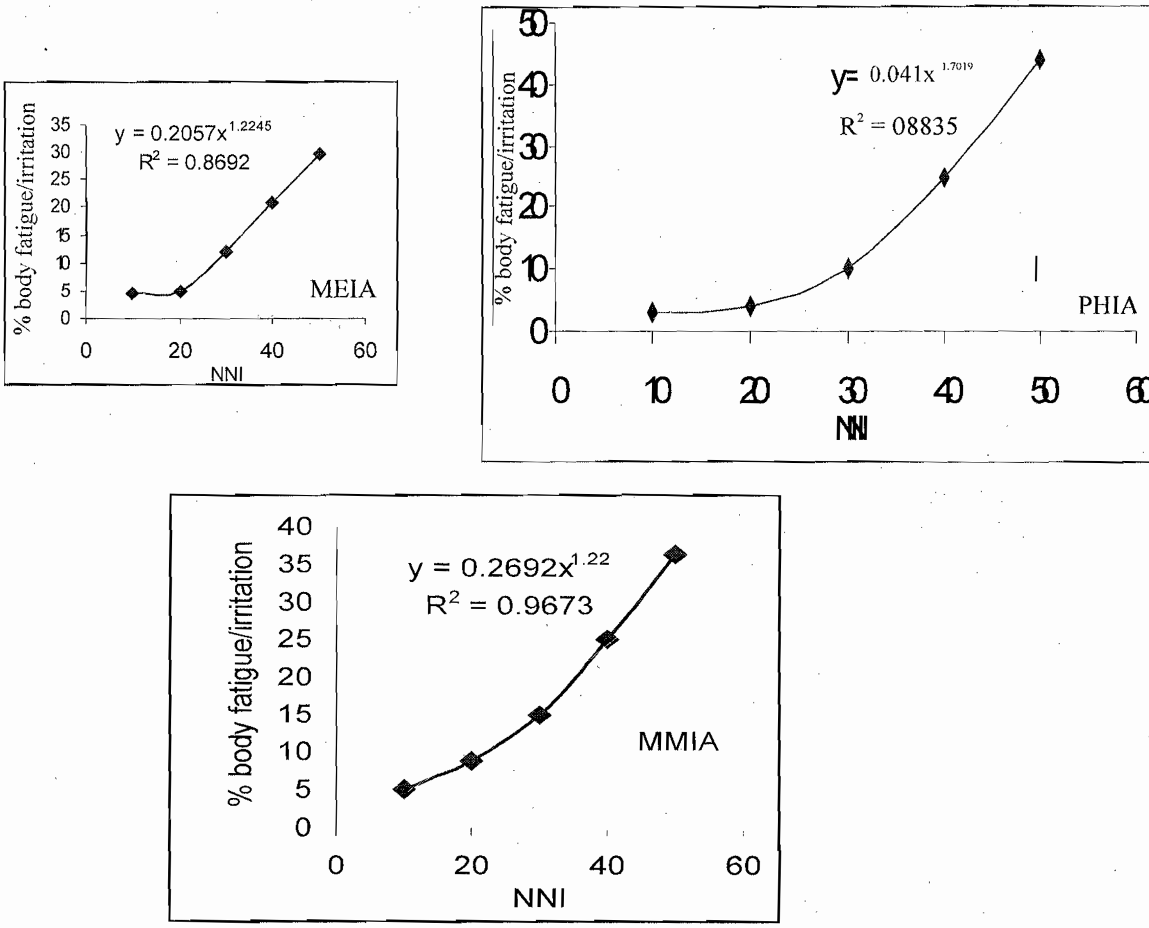


Fig. 9: Plots of percentage of response on body fatigue/irritation reactions versus NNI for MEIA, PHIA and MMIA.

are exceeded. Governments and airport authorities should immediately enforce faithfully the existing anti-noise laws, regulations and ordinances to control or abate "unwanted" sound in Nigerian communities, as the people exposed to excessive noise generally, and aircraft noise particularly are "dying" without themselves even knowing about it.

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