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# Dose-effect relationship on annoyance and sleep disturbance due to industrial and aircraft noise in Calabar, Cross River State, South-South Nigeria.

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**Abstract**

Dose-effect relationship on annoyance and sleep disturbances due to industrial and aircraft noise in Calabar, Cross River State, South-South Nigeria has been investigated. The objectives of the work was to find a quantitative dose-response relationship on annoyance and sleep disturbance for persons exposed to industrial and aircraft noise in the study area Calabar, Cross river State, South-South Nigeria, these effects of the noise from these two sources on people have also been compared. Noise levels from industrial machines ranged between 101-131 dB(A) while that of aircraft was 95 -127 dB(A) as it affected the workers and residents around the neighborhood. It has also been established from the findings that with increase in day-night sound levels from these noise sources, the level of annoyance of the people also increased. On comparison, aircraft noise increased annoyance on the people than industrial noise. This trend was not different when comparing the effects of noise from these two noise sources on sleep of the people. It is believed that the high level of aircraft noise from aircraft when landing and taking off and the sudden and intermittent nature of the noise as compared to the steady noise levels of industrial machines are contributory factors. Speech intelligibility of the pupils in Federal Airport Authority of Nigeria (FAAN) nursery primary/secondary school and that of the students of the Federal Government Girls College, Calabar is likely to be greatly affected by this high level of noise as rated by the respondents. Workers in the industries and airport are also bound to surfer other effect such as hearing loss, conversation disturbance, headache and fatigue. Respondents in the noise exposed group were more sharply annoyed by aircraft and industrial noise than the non exposed group. Sleep disturbance is deemed undesirable and may be considered an impact caused by noise exposure. Subjective reactions to noise vary greatly from person to person and from time to time and sleep disturbance and annoyance is no exception.

Keywords: Dose-Effect, Annoyance, Sleep disturbance, Industrial noise, Aircraft noise, Day-night sound levels.

## 1. Introduction

There has been serious concern over the years in many countries when one considers the noise level in and around airports and industries. Attempts have been made to produce measures to predict and assess the effects or impacts caused by this environmental hazard in the communities which include annoyance and sleep disturbance (Eric and Sabine 2011). It has been established that environmental noise has serious effects on the health of people as considered by the World Health Organization which include annoyance, sleep disturbance, and cardiovascular disease. Exposure response relations for these end points indicate that the prevalence of noise-related health effects gradually increases with increasing noise exposure. (WHO 2011, Miedema and Vos 1998, Miedema and Ousdshoorn 2001, Asuquo et al 2005, Morell et al 1997)

Aircraft and industrial noise is the dominant and most common sources of noise exposure in residential neighborhoods and annoyance in its most consequential effects (Akpan et al 2003, Akpan et al 2006, Akpan et al

 

2007, Hiramatsu et al 1997)

A simple quadratic fitting function provides an undated but purely empirical basis for estimated the prevalence of annoyance in communities.

$$\% \text{ Highly annoyed} = 0.036L_{dn}^{2} - 3.27L_{dn} + 79.14 \qquad (1)$$

For relatively low level of noise exposure associated with relatively high proportion of the reported annoyance.

$$\% \text{ of Highly annoyed} = \frac{100}{[1+\exp(11.13-0.141)L_{dn}]} \qquad (2)$$

These are direct methods of estimating the prevalence of annoyance due to noise exposure if the conduct of a well-designed social survey is impracticable (Schultz 1978)

For noise duration greater than 0.5 seconds annoyance will increase with increasing duration (Kryter 1982, Akpan et al 2007). An impulsive noise such as an explosion, a sonic boom from planes, punch press noise with rise time of 0.001 second or less may startle (shock or frighten) the listener. It is judged to be more annoying than steady noise having the same energy content. Even when the impulse are regular and expected, their sharpness and startle effects contribute to annoyance (Molino 1979, Onuu and Akpan 2007). Noise exposure for the exposure-response relations is represented by an A-weighted sound level averaged over the day, evening and night period (Eric and Sabine 2011 Issarayangyun et al 2003, Issarayangyun et al 2004). The day-night average sound level Ldn is an Leq A-weighted sound level during a 24 hour period with a 10 dB penalty for night time sound levels and is calculated as:

$$L_{dn} = 10\log_{10}\left[0.625 \times 10^{\left(\frac{L_d}{10}\right)} + 0.375 \times 10^{\frac{[L_n+10]}{10}}\right] \qquad (3)$$

Where Ld is the daytime sound levels and Ln is the night time sound levels. Daytime is the time between 6am – 10pm while nighttime is the time between 10pm and 6am.

The A-weighted sound level is related to health effects of environmental noise, but is only a limited representation of direct perception of noise. A quantity that is more closely related to the direct perception of noise is the loudness level (Berglund et al 1976). While annoyance caused by environmental noise is related to the loudness of the noise, it also depends on other acoustic and personal factors (Eric and Sabine 2011). Similarly, sleep disturbance by environmental noise may be related to the loudness of the noise but also depends on other factors. A complicating factor is that annoyance depends also on other acoustic characteristics than loudness. For example, tonal noise is found to be more annoying than broadband noise at the same sound level ( Griefahn 1978, Hellman 1984, Bray 2010, Fingold 1993, Akpan and Onuu 2004)

Investigators have also shown that noise disturbs sleep. The 1999 UK field study of aircraft noise and sleep disturbances at major airports in the United Kingdom reported an average outdoor aircraft noise event sound level of

 

80dBA max threshold. This study found a low incident of objectively measurable sleep disturbance (both minor arousals and brief awakening from persistent sleep) attributed to aircraft events (Flender et al 2004)

Study design, sleep disturbance measurements, and noise exposure assessment have been employed in Sleep disturbance studies, differences in these techniques can have influences on the results of the studies, and a basic understanding of the differences is important for interpreting the results (Griefahn and Muzet 1978). The effect of aviation noise on sleep is a long-recognized concern to those interested in addressing the impacts of noise of people (Lukas 1975, Pearson et al 1989, Pearson et al 1999). Historical studies of sleep disturbance were conducted mainly in laboratories, using various indicators of response (electroencephalographic recordings, verbal response, button push, etc). Field studies also were conducted, in which subjects were exposed to noise in their own homes, using real or simulated transportation noise (Ollerhead et al 1992, Fidell 1995). Single event measures that have been used in sleep disturbance studies include the Maximum A-weighted Level (Lmax), Perceived Noise Level (PNL), Sound Exposure Level (SEL), Effective Perceived Noise Level (EPNL), and C-Level (CL). Cumulative measures are used to characterize the noise events over an entire night or day and have included the Equivalent Noise Level (Leq), Composite Noise Level (CNL), Day-Night Average Sound Level (DNL), Community Noise Equivalent Level (CNEL), and Cumulative Distribution Levels or Percentile Levels, (Lx) (Finegold 1993, Griefahn and Muzet 1978, Pearsons et al 1989, Pearson et al 1995, Menkiti and Ajah 1993, Meister and Donatelle 2000)

## 2. Materials and Methodology

Cross River State (CRS), South-South Nigeria was selected for this work. The choice was influenced by the fact that this State has an international airport and industries with high rate of noise events where investigations could be made. Cross River State shares a common western boundary with Akwa Ibom State which in turn has a common boundary with Rivers State all in South-South Nigeria. Towards the south they all empty into the Atlantic Ocean. Eastward, Cross River State shares a boundary with the Republic of Cameroon.

Both objectives are subjective assessment of the selected industries and airport was carried out. From the objective assessment, extensive and wide range measurement of industrial and aircraft noise was carried out in selected industries and Margaret Ekpo International Airport and environment using precision sound level meter Bruel and Kjaer (B & K) type 2203 calibrated with B & K piston phone type 4220 with associated octave band filter B & K type 1613. Industries to be investigated were carefully chosen after a preliminary survey.

Aircraft noise measurements were made three times a week for five (5) months when planes were landing or taking off and the average intensities were calculated. Same was done for industrial noise when the machines were fully in operations at different hours of the day.

For the social survey, questionnaires made up of items based on the level or degree of annoyance and sleep disturbance caused by the noise and the duration of exposure of respondents were distributed to industry and airport workers as well as people living in the neighborhoods, exposure implies the average sound intensity over specific period. Respondents were grouped depending on the intensity of the noise where they are residing or working. Those living along the airplanes fly-paths and those working in or living near industries were duly considered in the distribution of questionnaires. Since the respondents felt the effect of both industrial and aircraft noise either at their places of work or where they are residing, they were all served with the same questionnaire.

Questionnaires were also distributed to people living and working in areas where neither industrial nor aircraft noise was heard for a control. Respondents were also asked to rate the noise from aircraft and industrial machines by using opinion scale 0 to 4 where zero means very low, one means low, two means moderate, three high and four means very high. No experimental test on respondents was carried out.

This work was aimed at finding a quantitative dosage-response relationship on annoyance and sleep disturbance for persons exposed to industrial and aircraft noise in the study area in Cross River State, they constitute the respondents in this work.

 

Table 1. Permissible occupational noise exposure time per day allowed under the limit 90 dB(A).(Shaikh, 1999)

| Noise Level dB(A) | Occupational noise exposure time per day | | |
|---|---|---|---|
| | Hrs | Min. | Sec. |
| 90 | 8 | 00 | 00 |
| 91 | 6 | 00 | 00 |
| 92 | 5 | 00 | 00 |
| 93 | 4 | 00 | 00 |
| 94 | 3 | 00 | 00 |
| 95 | 2 | 00 | 00 |
| 96 | 2 | 00 | 00 |
| 97 | 1 | 30 | 00 |
| 98 | 1 | 15 | 00 |
| 99 | 1 | 00 | 00 |
| 100 | 0 | 45 | 00 |
| 101 | 0 | 37 | 30 |
| 102 | 0 | 30 | 00 |
| 103 | 0 | 22 | 30 |
| 104 | 0 | 18 | 45 |
| 105 | 0 | 15 | 00 |
| 106 | 0 | 11 | 15 |
| 107 | 0 | 09 | 23 |
| 108 | 0 | 07 | 30 |
| 109 | 0 | 05 | 38 |
| 110 | 0 | 04 | 42 |
| 111 | 0 | 03 | 45 |
| 112 | 0 | 02 | 49 |
| 113 | 0 | 02 | 21 |
| 114 | 0 | 01 | 53 |
| 115 | 0 | 01 | 25 |

## 3. Results

Different locations were selected at the airport as well as fly-path of planes in residential areas around the airport. Table 2 shows the selected industries, major machineries in use and the average noise levels generated by the machines while Table 3 shows the measurement locations at Margaret Ekpo International Airport and surroundings and the average noise levels at these locations.

Table 2. Industry/location, major machineries and Noise Levels.

| S/No | Industry/Location | Major Machinery | Noise levels (dB(A) |
|---|---|---|---|
| 1 | Strabag Company, Old Netim, Akamkpa, Cross River State. | Stone cracking and crushing machine. | 115-122 |
| 2 | Crush Rock Company, Old Netim, Akamkpa, Cross River State. | Stone cracking and crushing machine. | 116-119 |
| 3 | Hitech Company, Old Netim, Akamkpa, Cross River State. | Stone cracking and crushing machine. | 119-124 |
| 4 | Pamol (Nig) Limited, Calabar, Cross River State. | Crepper Hammer Mill | 120- 125 |
| 5 | Pamol Plastic Division, Calabar, Cross River State. | Frazer Machine | 105-109 |
| 6 | System Metal Company, Calabar, Cross River State. | Pressing Machine | 112- 115 |
| 7 | Mechanical Workshop, Physics Department, University of Calabar, Calabar, Cross River State. | Lathe, milling, boring, cutting and shaping machine. | 102-108 |
| 8 | Bao Yoa Huan Jain Iron/Steel Company CFTZ, Calabar, Cross River State. | Welding, shaping and cutting machine. | 111-115 |
| 9 | Kevin Wood Industry CFTZ, Calabar, Cross River State. | Sawing, planning and spraying machine. | 101-109 |
| 10 | Ayos Wood International Company CFTZ, Calabar, Cross River State. | Sawing, planning and spraying machine. | 109-112 |
| 11 | Larna Gold Industry CFTZ, Calabar, Cross River State. | Weaving machines. | 105-109 |
| 12 | Niger Mills Company Plc, Calabar, Cross River State. | Roller mills (Buhler). | 129-131 |

 

Table 3. Noise levels at measurement locations of the airport

| Locations | Noise Levels (dB(A) |
|---|---|
| FAAN Nursery/Primary/Secondary Schools. | 104 – 116 |
| FAAN Staff Quarters, Calabar. | 102 – 114 |
| Federal Government Girls College, Calabar. | 108 – 118 |
| Towards MCC Road. | 95 - 108 |
| IBB Way/Marian Road Direction. | 100 – 112 |
| Airport Premises, Calabar. | 115 -127 |

995 questionnaires were distributed out of which 818 valid responses were received representing 82.2 percent of the total number distributed.

Table 3.0 shows the daily duration of exposure of respondents to industrial and aircraft noise. Figure 1.0 compares the respondents' dose-effect relationship on sleep disturbance while Figure 2.0 compares their dose-effect relationship on annoyance due to industrial and aircraft noise in Cross River State.

Table 3.0: Daily exposure time of respondents to industrial and aircraft noise.

| Exposure Time (hrs) | Industrial Noise | Aircraft Noise |
|---|---|---|
| 3 – 5 | 25 | 4 |
| 6 – 8 | 260 | 196 |
| 9 – 12 | 176 | 143 |
| Above 12 | 9 | 5 |

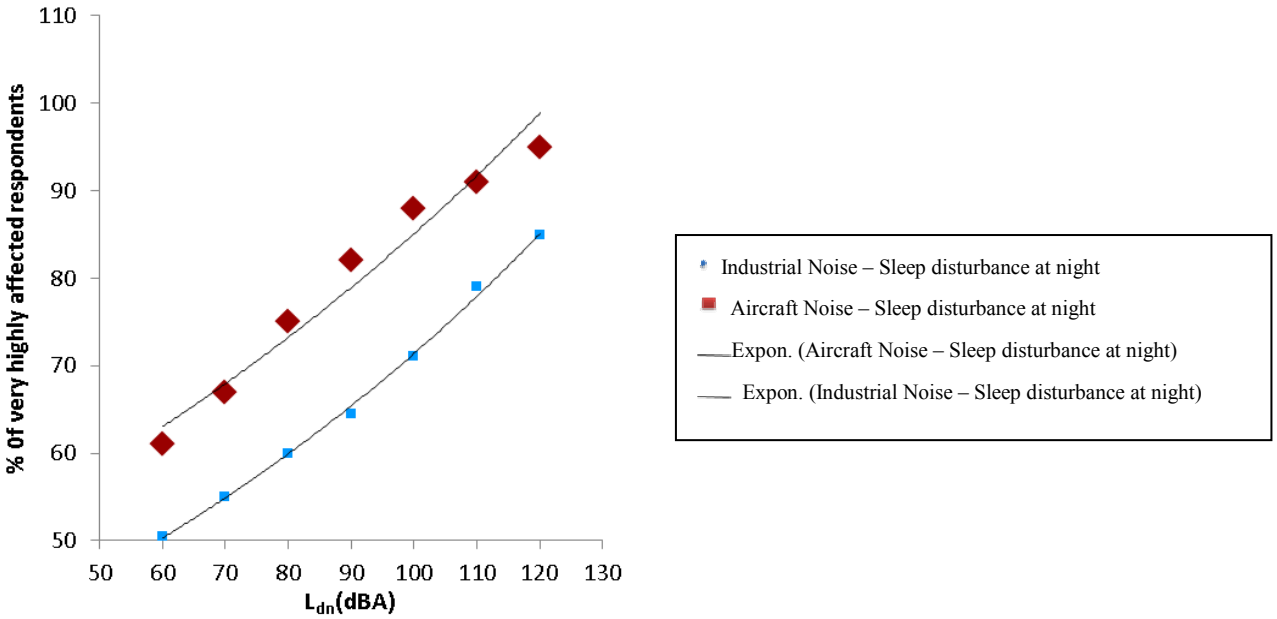


Fig1.Comparing respondents' dose- effect relationship on sleep disturbance due to industrial and aircraft noise in Calabar, Cross River State.

 

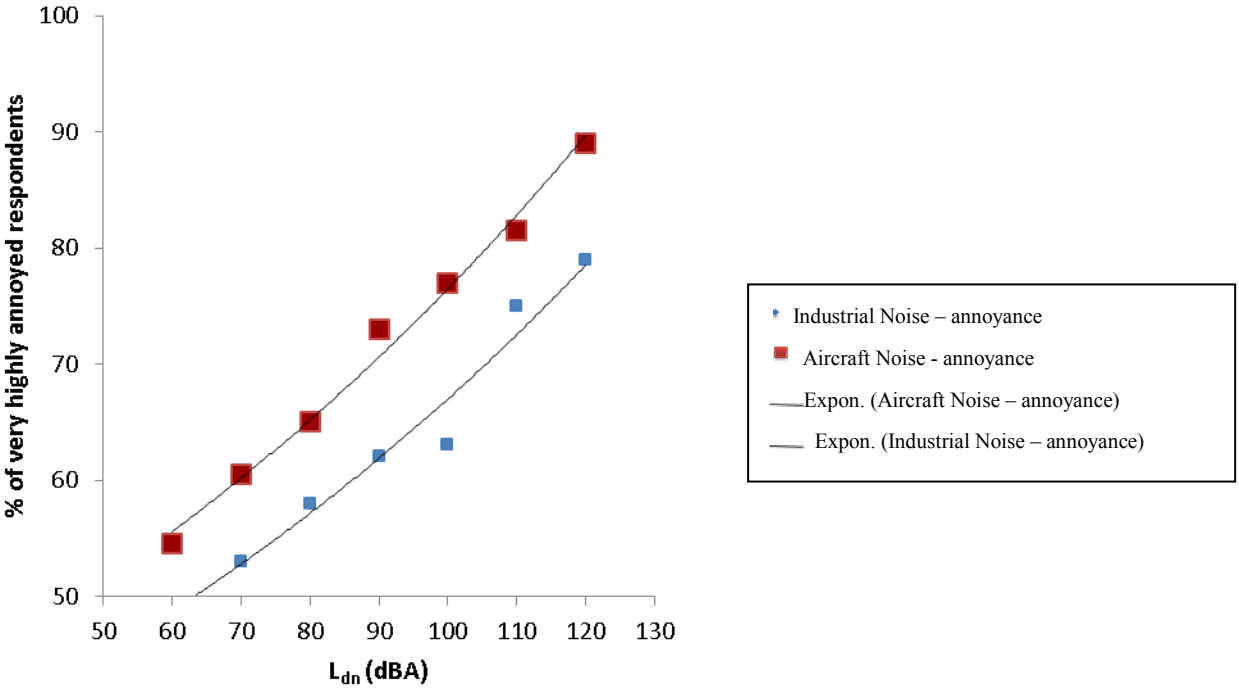


Fig2. Comparing effect on the annoyance of respondents due to industrial and aircraft noise in Calabar, Cross River State.

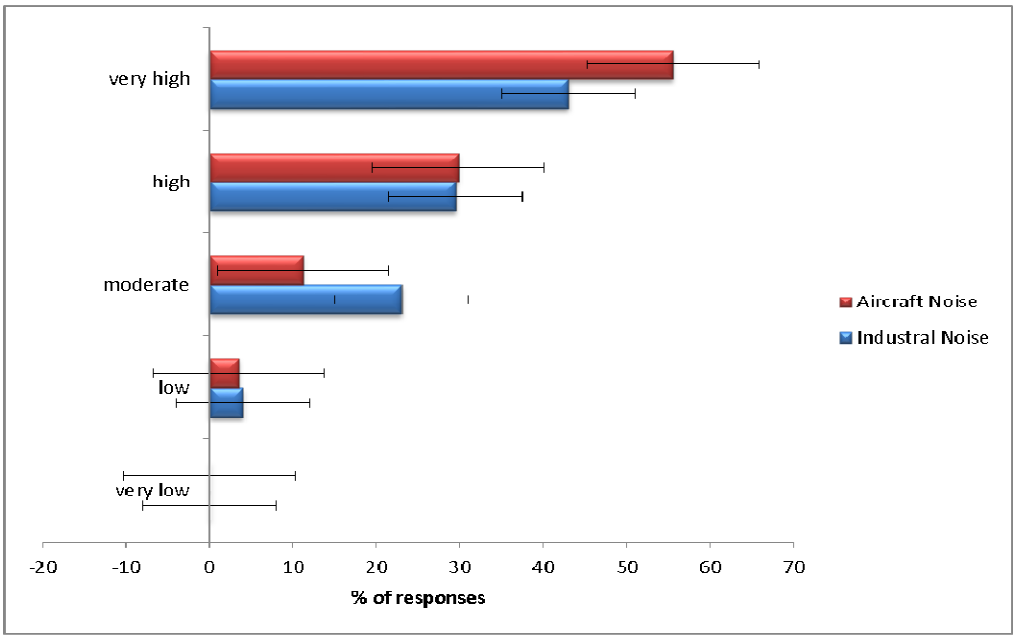


Fig 3. Comparing respondents' industrial and aircraft noise rating in Cross River State.

 

## 4. Discussion of results

It can be established from Figure 1.0 that as the A-weighted sound pressure level from aircraft and industrial noise increased, the sleep of respondents become very highly disturbed at night. It also shows that aircraft noise had more sleep disturbance effect on the respondents than industrial noise. This trend is not different when comparing the effect of these two types of noise on the annoyance of respondents as shown on Figure 2.0. It is believed that the high level of aircraft noise when landing and taking off and the sudden and intermittent nature of the noise are contributory factors when compared to the steady noise levels of industrial machines. Aircraft ground noise during the start of the take off roll on the runway is of low frequency (LF) hence the high level and loudness of the noise

(Hodgdon et al 2011, Buikema et al 2010, Welkers 2010) Respondents in the noise exposed group were more sharply annoyed by aircraft and industrial noise than the non exposed group. Table 2 shows that the Niger Mills Company with Roller Mills (Bubbler) machines produced the highest noise level of 129-131 dB(A) followed by Pamol (Nig) Limited with noise level of 120 – 125 dB(A) from Crepper Hammer Mill machines as compared to noise levels from machines in other surveyed industries. All the surveyed industries generated noise levels above 90 dB(A) which is the permissible occupational noise exposure level per day for 8hr exposure time (Table 1) (Shaikh 1999). Apart from annoyance, and sleep disturbance , it is certain that workers in these industries will suffer other effects such as hearing loss, speech interference, headache and fatigue. The noise exposure rating, which is the measure of the severity of industrial noise exposure of these workers exceeded unity and need to be controlled.

Noise levels at measured locations of the airport and environments also exceeded 90 dB(A) with that of the airport premises being the highest (115 – 127 dB(A)). Sentence intelligibility of the pupils in Federal Airport Authority of Nigeria (FAAN) nursery primary/secondary school and that of the students of the Federal Government Girls College, Calabar is likely to be greatly affected by this high level of noise (EPA 1978, Onnu and Taiwo, 2006). Majority of the respondents rated the noise levels from industries and aircraft to be very high (Fig. 3) which of course is in line with the result of the objective assessment.

## 5. Conclusion

Having established the relationship between the dose and the effect of aircraft and industrial noise on the workers and residents of these surroundings, effort should be geared towards reducing the amount of exposure of these workers and community residents to the noise and also reducing the noise levels to recommended standard.

No specific adverse health effects have been clearly associated with sleep disturbance, characterized either by awakening or by sleep-state changes. Nevertheless, sleep disturbance is deemed undesirable, and may be considered an impact caused by noise exposure (Pearson, et al 1999). All subjective reactions to noise vary greatly from person to person and from time to time, sleep disturbance and annoyance is no exception.

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