Uniport Journal of Engineering and Scientific Research (UJESR)

Vol. 2, Issue 1, December/2018
ISSN: 2616-1192

(www.ujesr.org)

Effects of airport noise on workers and residents within Port Harcourt International Airport, Rivers State, Nigeria

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Abstract
This study was carried out to determine the level of aircraft noise within and outside Port Harcourt airport and model the effects on workers and residents within the airport. Instruments used for the investigation include a structured questionnaire and sound level meter. Noise levels were monitored for one month from 7am to 5pm and field data were collected, analyzed and modelled. The equations for several cases were solved and verified using field data. The results showed that noise at administrative, arrival, departure, staff quarters and neighbouring Ipo community were within Federal Ministry of Environment (FMEnv) permissible limit of 90dB(A). At control tower and ramp area, the noise level exceeded FMEnv limit, therefore indicated high noise level. The coefficient of correlation between measured aircraft noise and predicted aircraft noise is R^2 *of 0.955 and* $p < 0.05$*. This indicated that the relationship between measured and predicted aircraft noise equal to or exceeded 70dB(A) is highly significant at 95% confident level. Models were developed to predict aircraft noise at low, medium and high background noise levels and the computed Noise Gap Index (NGI) values in the different levels of background environmental noise showed that people within air field of the airport were most affected by aircraft noise. The study concluded that majority of airport workers were disturbed and thus not comfortable with aircraft noise. Therefore, the study recommended the use of suitable personal protective gears (ear muff) and shorter exposure time to reduce side effects.*

Key words: *Airport, Noise, Model, Noise gap index, Port Harcourt*

1. Introduction

Noise is an unwanted sound observed at the wrong place at the wrong time. It is a hazard, and if extreme, may cause damage to the hearing organ (Basner et al., 2015). Noise pollution is a serious global problem (Piccolo and Plutino, 2005). It is an everyday occurrence, especially in the urban areas. Though noise disturbance cuts across all fields, the most common source of noise is transportation noise including road traffic, railways and aviation (airport).

Airport noise is a noise generated by aircraft or its mechanisms throughout different phases of a flight including noise while on ground which is caused by auxiliary power unit (APU), during take-off and landing. This noise originates from aircraft engine, mechanical system and vehicular transport operating around the airport air field and environs. When evaluating airport projects, airport noise is one of the most important environmental aspects to consider. The most obvious noise in the airport and environs is generated from aircrafts and traffic and can be annoying when occurrence is regular. Aircraft noise is of great concern and major challenge for people living close to the airport (Airports Commission, 2013).

Airports are basically essential nationwide as it serves to transport people and goods in local, state and global businesses. In the developing world, the presence of bad road and insufficient means of transportation, particularly for long distance travels have increased the use of aircrafts for transport. Aircraft noise has been associated with different health issues. For example, the risk of increased blood pressure and hypertension are associated with prolonged (5 – 30 years) exposure to aircraft noise averaging 65dB to 75dB. Sleep disorder caused by aircraft noise can result in risk of hypertension, fatigue, risk of heart and respiratory problems. It can also lead to lack of concentration, increased risk of accidents and depression (Geert, 2013).

Another possible effect of airport noise is hearing loss, an impairment of the ear caused by long-term exposure to high noise levels (Omubo-Pepple et al., 2010). It could be temporal or permanent. According to Defra (2007), the major impact of noise pollution at the airport depends on exposure, location, time of the day, frequency of noise, duration, number of aircraft events at certain level and constant elevated sound level.

Aircraft noises are regulated through standards set internationally and are applied when an aircraft is acquiring its air worthiness certification. Therefore, regulating and adopting specific guidelines for the effective management of the flight operations in airports are necessary coupled with proper evaluation of the effects of interventions before their implementation. The International Civil Aviation Organization (ICAO) recommended balanced approach noise management. This includes noise abatement operational procedures, land-use planning and management, operational restrictions and reduction of noise at source (ICAO, 2007).

Due to researches into noise generated during aircraft operation, a great success has been achieved in developing moderately silent aircraft. Every new aircraft must meet the terms with noise standards developed by ICAO. Although aircraft noise has reduced, airport noise has become worse due to increase in the number of aircraft events (ICAO, 2007). Thus, airport noise monitoring is essential when locating and designing airports for expansion so as to optimize flight paths in order to reduce noise exposure to people especially the neighboring communities. This study therefore assessed and evaluated the effects of airport noise on workers and residents within Port Harcourt International Airport, Nigeria.

2. Materials and methods

2.1. Study Area

The Port Harcourt International Airport and the Ipo community are the areas of study (Fig. 1). Both locations are situated in River state, under the Ikwerre local government area with coordinates between latitude 5° 14' 30'' N and 4° 58' 10'' N; and longitude 6° 54' 30'' E and 7° 0' 0'' E.

The Port Harcourt airport is the only international airport in the South-South region of Nigeria, making it key in air travel to and from the region. It is sited on the outskirts of the city with a few communities surrounding it, like the Ipo community. The Ipo community have an estimated population of about 10,000. Their major occupation is farming.

2.2. Noise Level Measurement

Noise level was measured at the airport by the use of WENSN1361 digital sound level meter with computer USB interface and SD card compatible. The WENSN1361 sound level meter is a type 2 sound level meter calibrated at the factory. Its sound level range is between 30dBA and 130dBA. The sound level meter was hand held because of the frequency of movement from one sampling point to another and to avoid disruption of workflow that a tripod might cause since the airport is a busy environment. Baseline data acquisition was gathered with the use of this modern noise instrument.

2.3. Model Development

To ensure quality assurance and control of data analysis, the data obtained were divided into background and aircraft noise, measured background noise was further divided into low, medium and high noise groups and aircraft noise was predicted based on these noise groups which were modelled using relevant equations.

The long-term average background noise level for low, medium and high was computed using Equation (1):

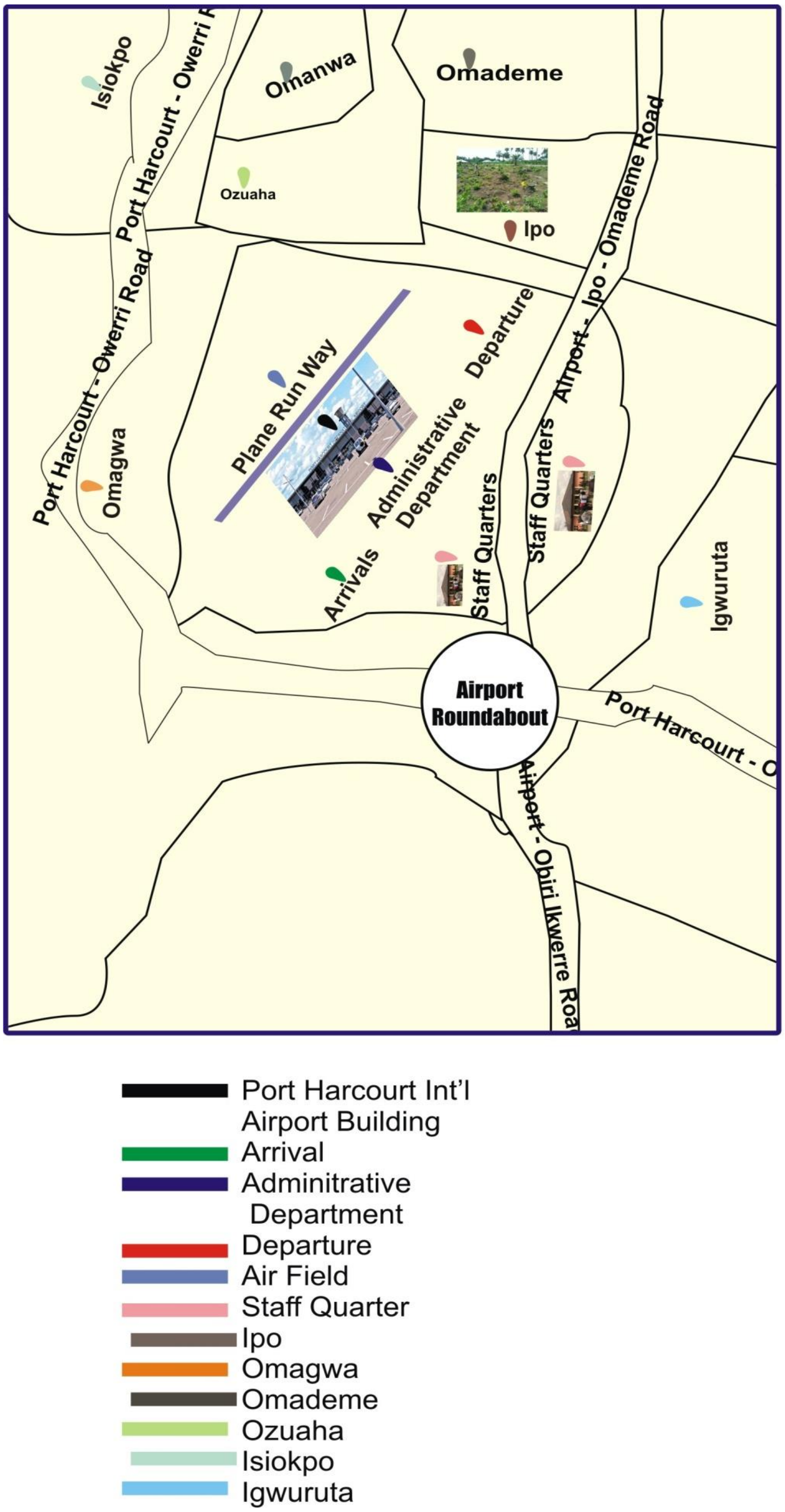
$$L_{AeqBgr(8hr)} = 10Log\frac{1}{N}\sum_{i=1}^{N}\left(10^{\frac{L_i}{10}}\right) \quad (1)$$

Sound exposure level for any single aircraft event was calculated using Equation (2):

$$L_{SELi} = 10Log\left(\frac{1}{T}\int_{t_1}^{t_2}10^{L(t)/10}dt\right) \quad (2)$$

where L_{SELi} is the perceived noise level of an individual aircraft event, t_1 and t_2 represent the start and end of an aircraft event and T is the time interval.

The cumulative exposure was modeled using Equation (3):



IKWERRE L.G.A. FACTS BEARING	
North	= 5° 14' 30" N
South	= 4° 58' 10" N
West	= 6° 54' 30" E
East	= 7° 0' 0" E
Minimal elevation	= 12 m
Maximal elevation	= 95 m
Land/Water	= Upland

Map of Rivers State showing the Airport location in Ikwerre L.G.A.

Figure 1: Study location and environs

$$L_{SEL(8hr)} = 10\text{Log}\begin{bmatrix}\text{Total Sound Energy} \\ \text{during Aircraft event}\end{bmatrix}$$

$$L_{SEL(8hr)} = 10Log\frac{1}{N}\sum_{i=1}^{N}10^{L_{SELi}/10} \quad (3)$$

where L_{SELi} is a single aircraft noise event and N is the number of aircraft noise events that are equal to or exceed 70dB (A).

Equation (3) was used to model the average aircraft noise as follows:

$$L_{AeqAN} = L_{SEL} + 10Log(N70) + \text{constant} \quad (4)$$

where L_{AeqAN} is the average A-weighted sound pressure levels of aircraft noise, L_{SEL} is the sound exposure level of the N70 noise events, N70 is the total number of aircraft noise events that is equal to or exceed 70 dB (A) between 8am and 4pm local time (averaged over the 10-day period), and constant = - 10 log (measurement period, T).

Substituting constant into Equation (4) for a single aircraft noise event gives:

$$L_{AeqANi} = L_{SELi} - 10Log(Ti) \quad (5)$$

Where L_{AeqANi} is the average aircraft noise level measured at each point, L_{SELi} is the aircraft noise exposure level that equals or exceeds 70dB (A) during i background noise time interval, and T_i is the i^{th} background noise time interval.

The long-term average aircraft noise was computed from Equation (1) as:

$$\hat{L}_{AeqAN(8hr)} = 10Log\left(\sum_{i=1}^{K}10^{\frac{L_{AeqANi}}{10}}\right) \quad (6)$$

where K is the number of reference background noise time intervals.

Statistical regression analysis was performed by MS Excel and SPSS software using Equations (7) and (8).

$$y = 19.293\log(N70) + 36.521 \quad (7)$$

$$\hat{L}_{AeqAN}(8hr) = 19.293Log(N70) + 36.521 \quad (8)$$

Equation (8) was used to predict aircraft noise levels that exceed 70 dB (A).

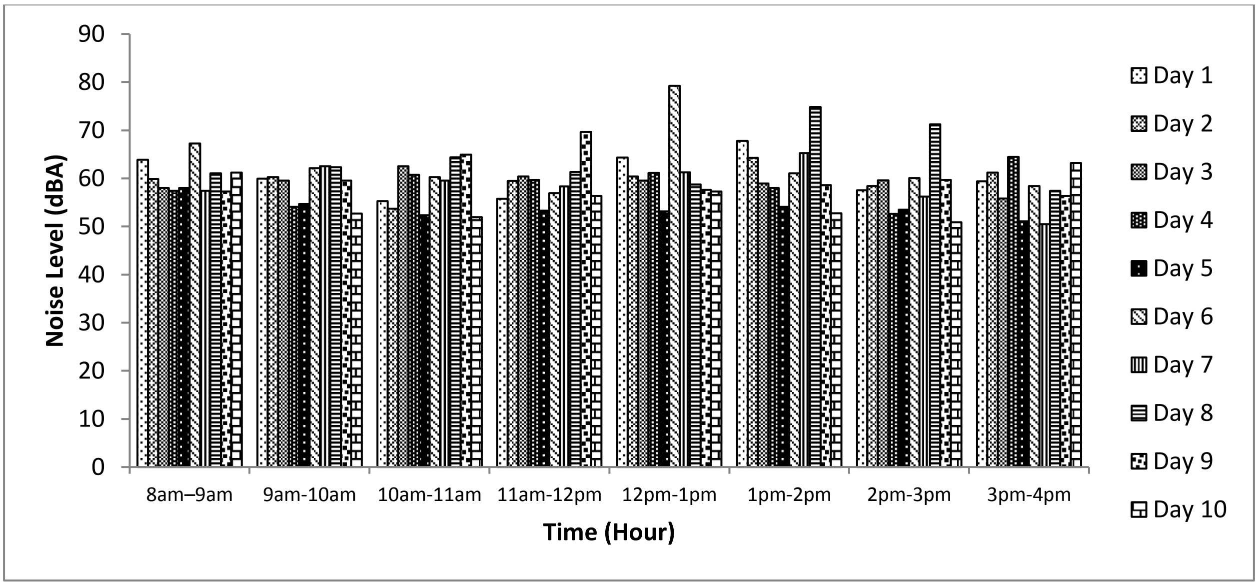


Figure 2: Noise levels at administrative area

3. Results

Results of noise levels measured at each location within the airport and its environs during monitoring exercise were presented in Figures 2 to 8. Computed average background noise levels in the low, medium, and high noise groups were shown in Figure 9. Variation of aircraft noise levels with time is presented in Figure 10. The maximum noise level and computed sound exposure level is shown in Figure 11. Contribution of aircraft noise to background noise in the low, Medium, high is presented in Figure 12, while the computed noise gap index for the different noise groups is shown in Figure 13.

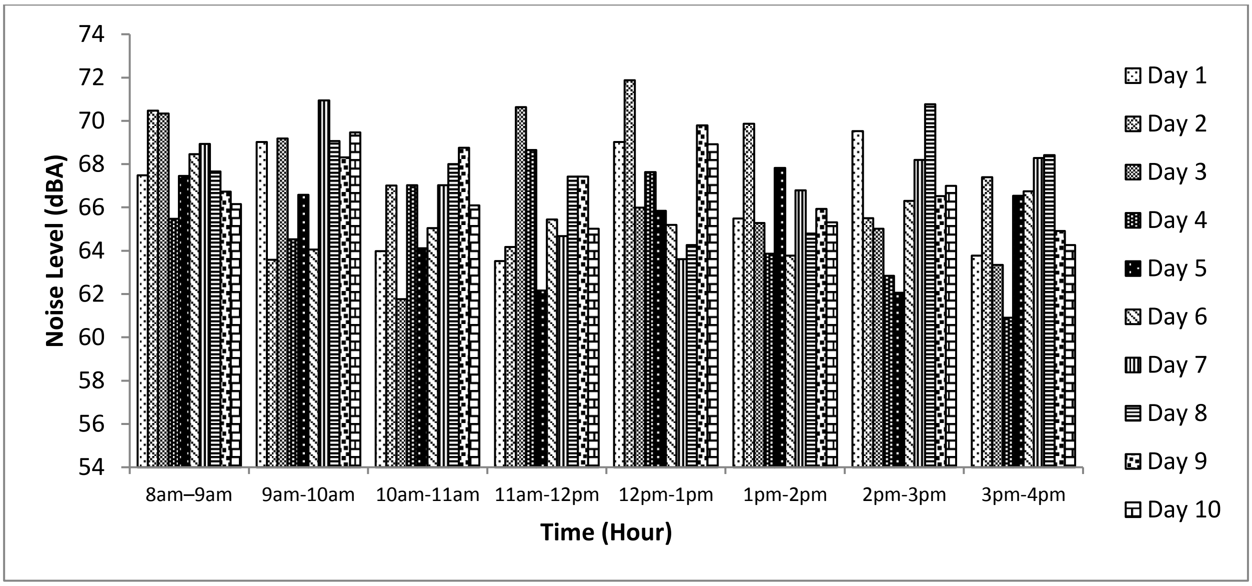


Figure 3: Noise levels at arrival area

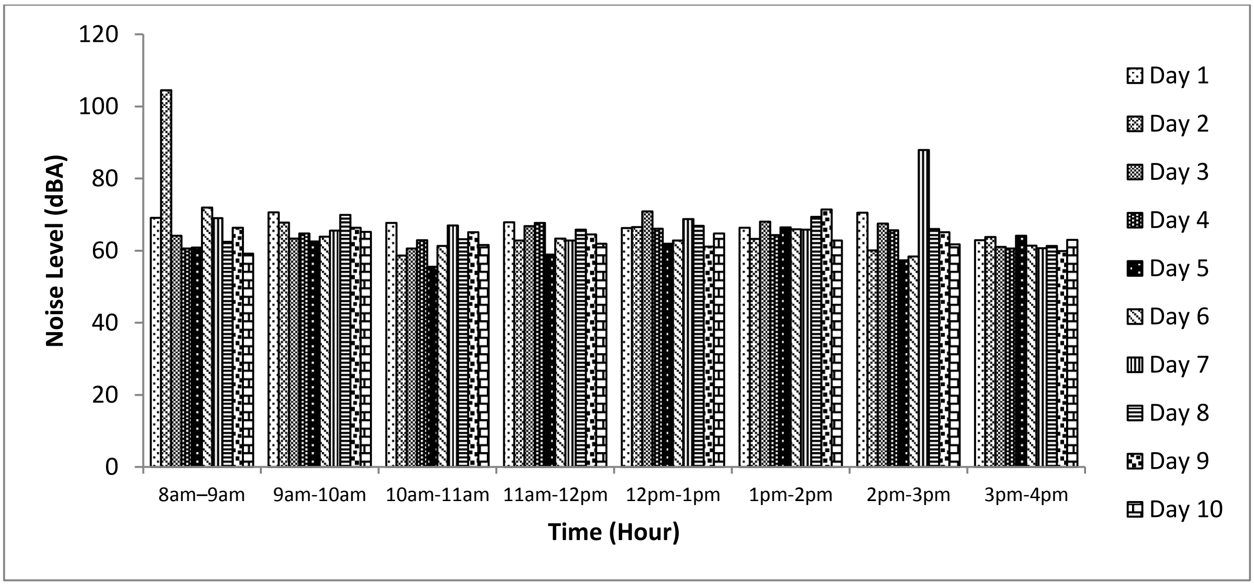


Figure 4: Noise levels at control tower

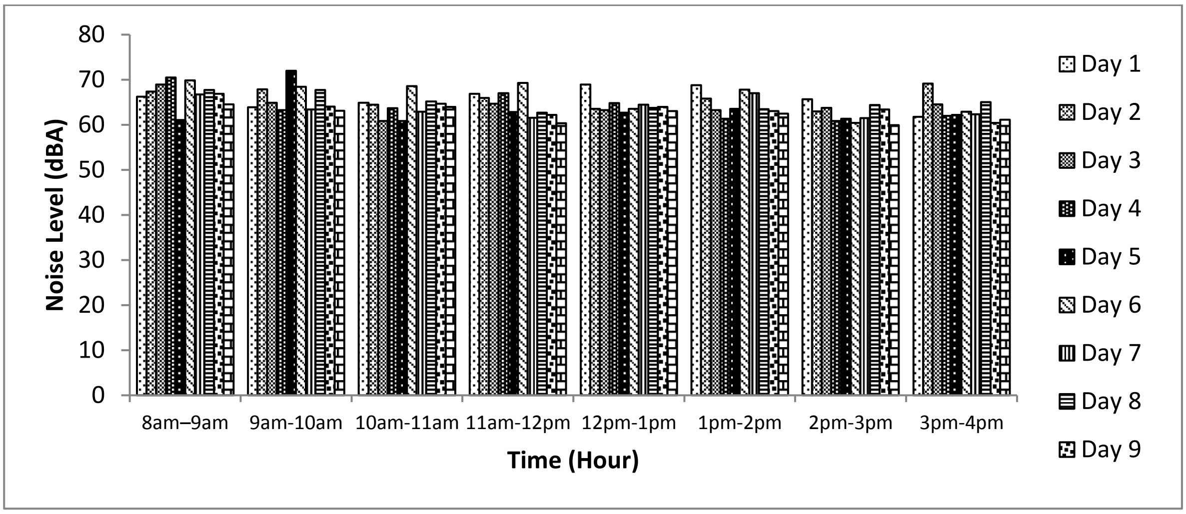


Figure 5: Noise levels at departure area

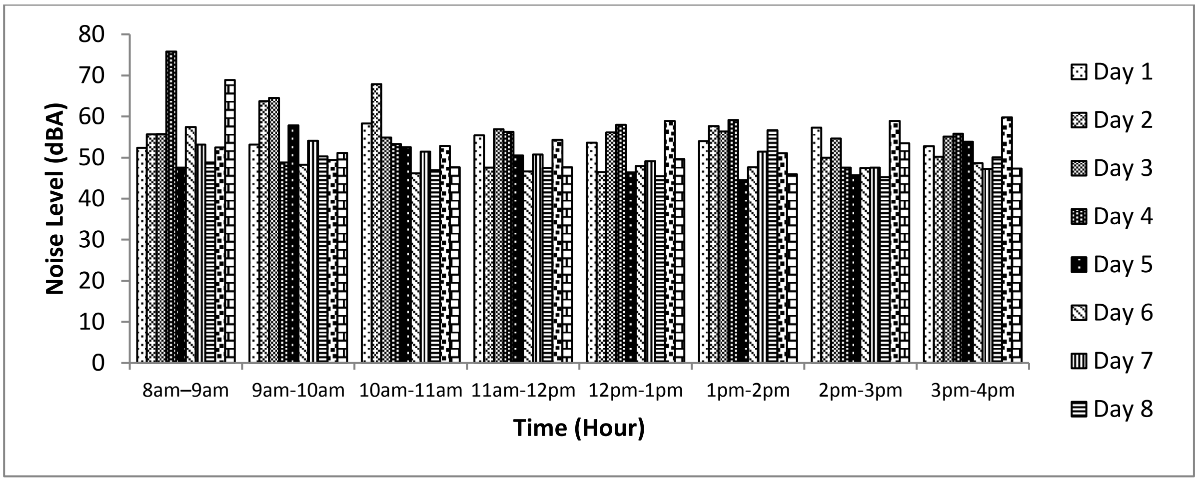


Figure 6: Noise levels at residential quarter

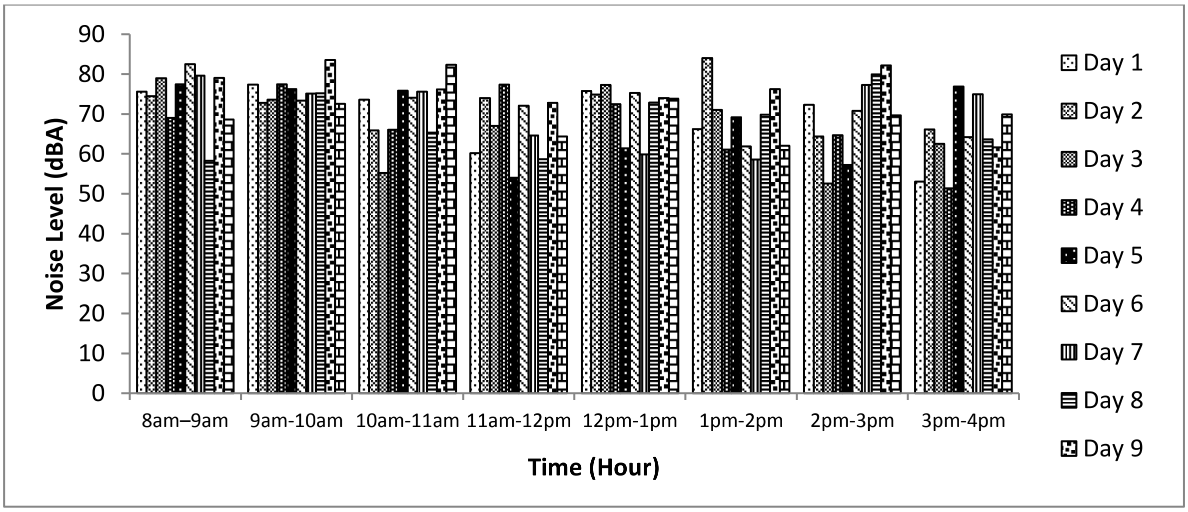


Figure 7: Noise levels at ramp area

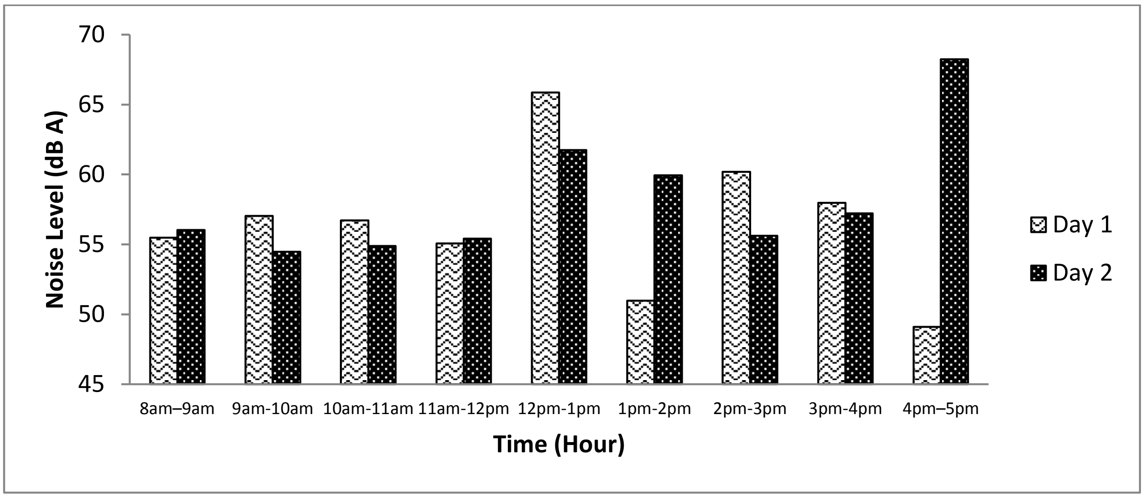


Figure 8: Noise levels at Ipo community

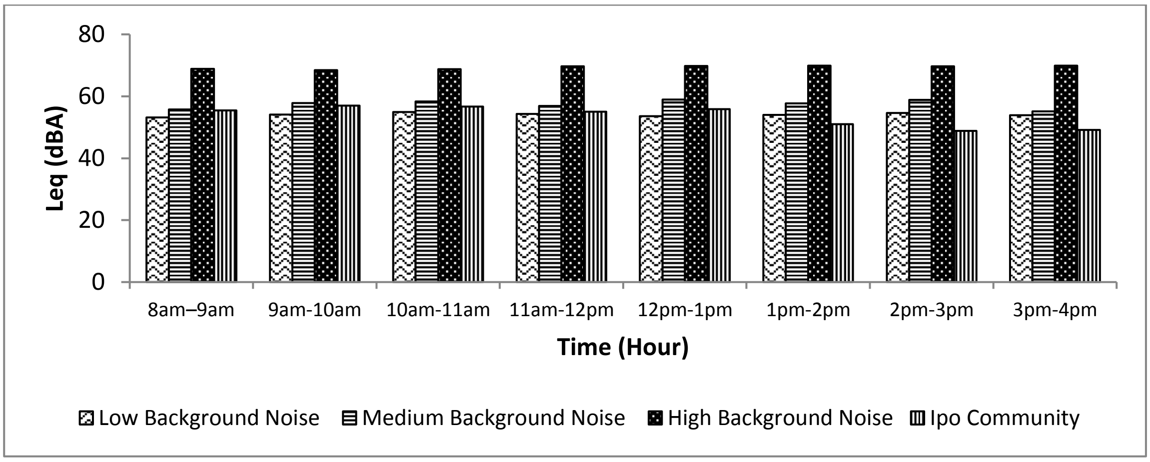


Figure 9: Background noise levels for the different noise groups

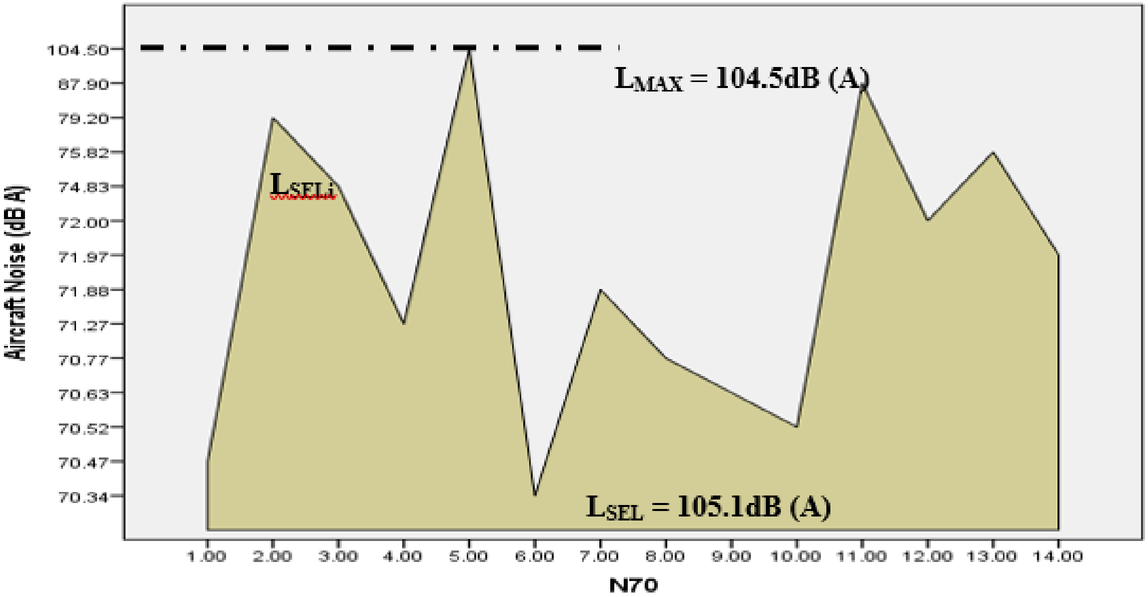


Figure 10: L_{max} and L_{SEL} of Aircraft noise

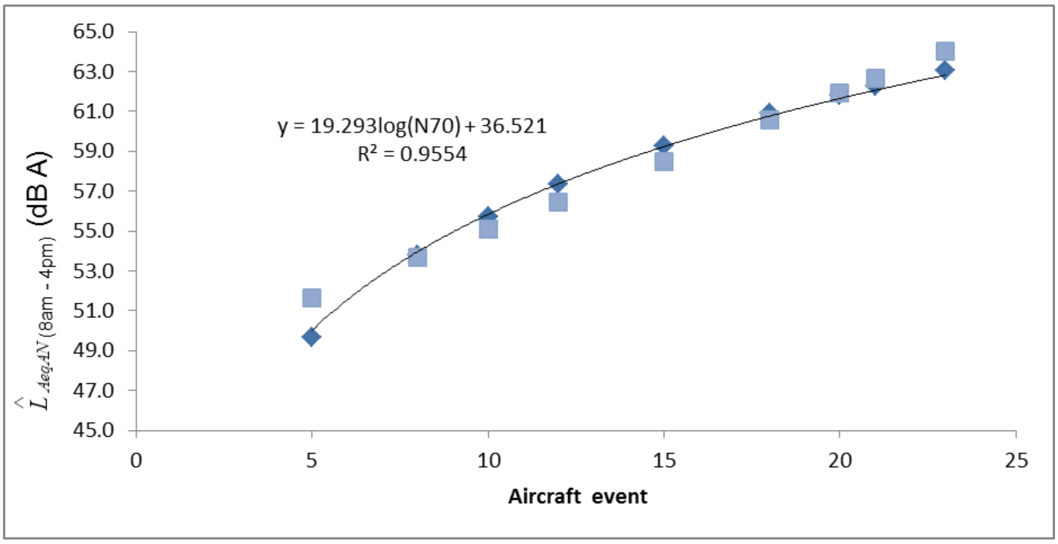


Figure 11: Relationship between aircraft noise events and *N70*

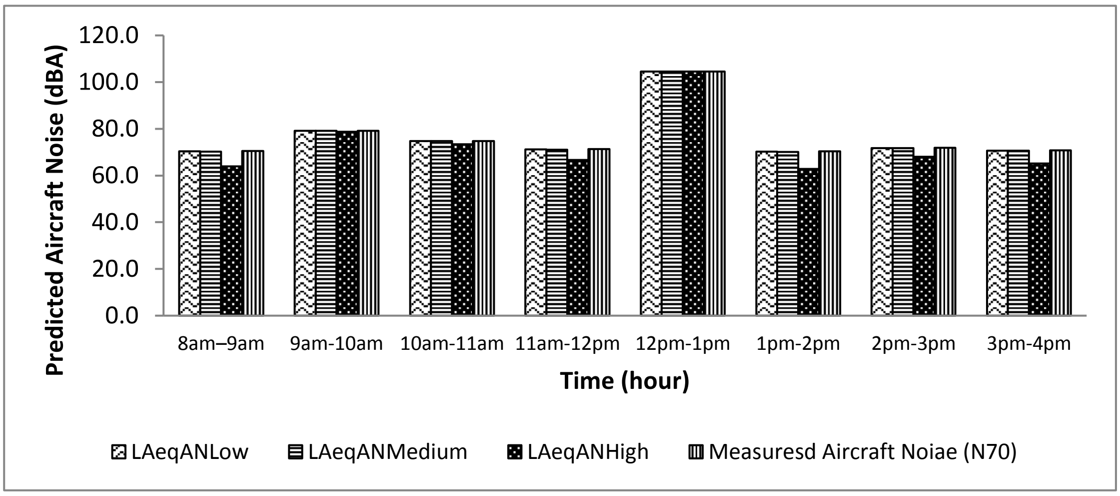


Figure 12: Predicted aircraft noise levels in the background noise groups

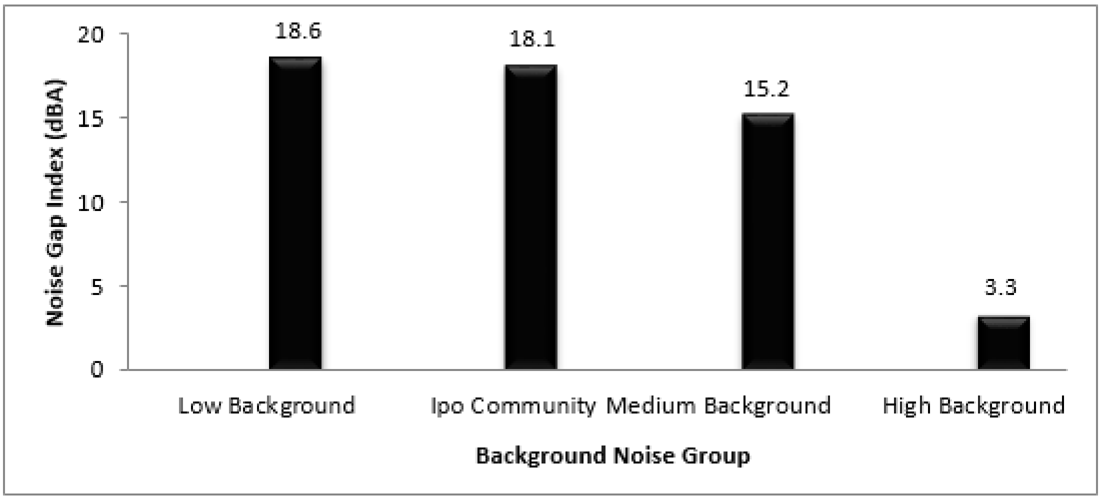


Figure 13: Computed NGI for different background environmental noise groups

4. Discussion

The noise levels measured at the administrative area of the airport ranged from 50.49dB(A) to 74.83dB(A) with a mean deviation of 65.3±4.8dB(A) (see Figure 2). The noise levels at the arrival area ranged from 60.91dB(A) to 71.88dB(A) with a mean deviation of 68.13±1.0dB(A) (see Figure 3). The noise levels at the airport control tower ranged from 55.50dB(A) to 104.50dB(A) with a mean deviation of 86.60±10.2dB(A) (see Figure 4). The noise levels at the departure terminal ranged from 59.90dB(A) to 72.00dB(A) with a mean deviation of 66.60±1.4dB(A) (see Figure 5). The noise levels at the residential quarter ranged from 44.20dB(A) to 75.82dB(A) with a mean deviation of 60.70±5.4dB(A) (see Figure 6). The noise levels at the ramp area ranged from 51.34dB(A) to 84.04dB(A) with a mean deviation of 76.1±1.9dB(A) (see Figure 7). The noise levels at the neighbouring Ipo community ranged from 49.9dB(A) to 68.25dB(A) with a mean deviation of 54.20±1.3dB(A) (see Figure 8).

Excluding noise at the control tower, the noise levels at the other areas of the airport were below the Federal Ministry of Environment (FMEnv) permissible limit of 90dB(A) (FMEnv., 1991). These noise levels may not pose immediate threat to human health, however, prolong exposure could lead to hearing impairment. The maximum noise level of 104.5dB(A) at the control tower exceeded FMEnv permissible limit by 16.11% and can impact on human health.

Models were calibrated to predict the aircraft noise that exceeded 70dB(A) and to predict aircraft noise in different backgrounds which were further divided into low background (40-55dBA), medium background (56-60dBA) and high background (61-69.9dBA). The average background noise for low, medium and high were 54.1dB(A), 57.5dB(A) and 69.4dB(A), respectively while that for Ipo community was 54.6dB(A) (see Figure 9). This showed that Ipo community falls within low background noise level group of 40-55dB(A).

In order to properly analyze aircraft noise in this study, a noise level of 70dB(A) was selected as aircraft noise threshold because it is assumed that the aircraft noise level equal to or higher than 70dB(A) will interfere with or disturb human activities (Issarayangyun et al., 2004). Therefore, Figure 10 showed the aircraft noise levels that were equal to or exceeded 70dB(A) plotted against time of measurement. The maximum aircraft noise (L_{MAX}) recorded was 104.5dB (A), while the minimum aircraft noise (L_{MIN}) was 70.34dB (A). The maximum aircraft noise of 104.5dB(A) occurred as a single aircraft event during measurement. Sound exposure level (L_{SEL}) is shown in the shaded area of Figure 10. L_{SEL} was computed to be 105.1dB(A). Therefore, the total cumulative aircraft noise that enters the receiver's ears during the study is 105.1dB(A). This level of L_{SEL} is capable of inducing annoyance in people resulting in spontaneous reaction to issues.

Statistical regression analysis was performed with MS Excel and SPSS software using Equations (7) and (8) and the trend line or curved line indicating events was derived (see Figure 11). Equation (8) was used to predict aircraft noise levels that exceeded 70 dB(A) and plotted against number of aircraft noise events that exceeded 70dB(A) as shown in Figure 11. The result gave a coefficient of determination (R^2) of 0.955 and $p < 0.05$, indicating that the relationship between measured aircraft noise that exceeded 70dB(A) and predicted number of aircraft noise that exceeded 70dB(A) is highly significant at 95% confident level. This R^2 value is higher than 0.82 reported by Issarayangyun *et al*. (2004) and 0.79 reported by Issarayangyun *et al*. (2005).

The predicted aircraft noise levels in the low, medium and high background noise were modeled using the difference between aircraft noise equal to or exceeding 70dB and background noise in the low, medium and high background noise groups. These were expressed using Equations (9) and (10).

$$L_{AeqANpred} = \hat{L}_{AeqAN(8hr)} - L_{AeqBgr(8hr)} \quad (9)$$

$$L_{AeqANpred} = 10Log\left[\begin{array}{l} Log^{-1}\left(\frac{\hat{L}_{AeqAN(8hr)}}{10}\right) - \\ Log^{-1}\left(\frac{L_{AeqBgr(8hr)}}{10}\right) \end{array}\right] \quad (10)$$

Predicted aircraft noise in different background environmental noise groups are shown in Figure 12. It is seen from the figure that Equation (10) accurately predicted aircraft noise with R^2 of 0.9984, 0.9986 and 0.9885 for low, medium and high background environment noise, respectively. This result showed that Equation (9) can be generally used to predict aircraft noise levels in the background environment. Equations (7) to (10) are valid for aircraft noise level that equalled or exceeded 70dB(A). From Figure 12, the relationship between predicted and measured aircraft noise in the low, medium and high background noise group are expressed as shown below. The model to predict aircraft noise in the low background group is expressed as:

$$L_{AeqANLow} = 198.9753 Log(N70) - 298.05 \quad (11)$$

for N70≥70dB (A)

The model to predict aircraft noise in the medium background group is expressed as:

$$L_{AeqANMedium} = 199.7596 Log(N70) - 299.62 \quad (12)$$

for N70≥70dB (A)

The model to predict aircraft noise in the medium background group is expressed as:

$$L_{AeqANHigh} = 234.347 Log(N70) - 368.37 \quad (13)$$

for N70≥70dB (A)

Noise gap index (NGI) defined the difference between aircraft noise and background noise (Issarayangyun *et al.*, 2004). Combining Equations (8) to (10) and applying computed average background noise levels of 54.1dB(A), 57.5dB(A), 69.4dB(A) and 54.6 dB(A), gave:

$$NGI = 19.293 Log(N70) - f \quad (14)$$

where, *f* is noise gap adjustment factor (17.579 for low background noise, 20.979 for medium background noise, 32.879 for high background noise, and 18.079 for Ipo community)

The average NGI values computed for low, medium, high, and Ipo community background noise groups were 18.6, 15.2, 3.3 and 18.1 dB(A) respectively as shown in Figure 13. These NGI values indicated that people in the background environmental noise were affected by aircraft noise; however, people in the high background noise areas may be more affected by aircraft noise than people in the low and medium background noise areas including Ipo community. These groups of most affected people were airport workers and those who conduct daily business in the airport. NGI values will serve as a useful tool to determine level of aircraft annoyance in people.

4. Conclusions

The following conclusions were drawn based on results of field measurements and data analysis.

i. There is a moderate noise pollution around the administrative, arrival, departure and residential quarters of the airport as well as in Ipo community that poses no immediate threat to human health but may interfere with speech communication during aircraft events especially in Ipo community. However, the high noise pollution at the control tower and ramp areas of the airport can significantly affect human health.
ii. The developed aircraft noise prediction model with a coefficient of determination (R^2) of 0.955 and $p < 0.05$ accurately predicted aircraft noise in the airport.
iii. The relationship between measured and predicted aircraft noise that was equal to or exceeded 70dB(A) was highly significant at 95% confident level.
iv. The computed noise gap index values in the different levels of background environmental noise showed that people in the airport were affected by aircraft noise.
v. The study concluded that majority of airport workers were disturbed and thus not comfortable with aircraft noise.
vi. Therefore, it is recommended that airports should be constructed with partitions that are noise dampers to reduce noise.

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