ARCHIVES OF ACOUSTICS
32, 2, 367–375 (2007)

COMMUNITY ANNOYANCE FROM AIRCRAFT INDUCED NOISE IN DELHI

SANYOGITA, Krishan KUMAR, V. K. JAIN

Jawaharlal Nehru University
School of Environmental Sciences
New Delhi-110067, India
e-mail: sanyo1610@gmail.com

(*received March 14, 2007; accepted April 24, 2007*)

Air traffic noise is a major cause of community annoyance in the residential areas near airports. The present study has been prompted by the need to examine the noise levels induced by the increased air traffic in Delhi in recent years. Noise levels have been measured in the indoor environment of two prominent residential areas of Delhi, namely, University Campus (UC) and Vasant Vihar (VV) which lie underneath the landing flight path of aircraft in Delhi. Spectral distributions show higher noise levels at lower frequencies and exhibit a declining trend with increase in frequency. With the help of spectral information, an index of aircraft noise, PNdB (perceived noise levels in decibels) is determined to assess relative annoyance or noisiness felt by the community of residential areas. PNdB values in the case of UC vary from a minimum of 66.7 to a maximum of 85.2. Further down the landing path, PNdB levels at VV are found to be appreciably higher in the range of 76.18–91.37.

Results of social survey conducted to assess the community response to aircraft noise reveal that a majority (73%) of the respondents experience moderate to extreme annoyance. This is in conformity with the rather high PNdB values obtained for both the residential areas.

Keywords: aircraft noise, annoyance, PNdB, SEL, spectral distribution.

1. Introduction

Aircraft noise is known to have numerous physiological as well as psychological adverse effects on human health (KRYTER, [9]; SUTER, [19]). Hearing loss (Temporary and Permanent) is the most common physiological effect (KRYTER, [10]; PROSSER *et al.*, [13]; AKHTAR, [1]). Other adverse physiological effects of noise exposure include rise in blood pressure level (SAWAD, [16]; REGECOVA, [14]; ELISE, [2]; the Okinawa study [22]), incidence of peptic ulcers (NETTERSTROM and JUEL, [12]) and complications in pregnancy (GOULET and THERIAULT, [6]; HARTIKAINEN *et al.*, [8]). Noise induced annoyance is the most important psychological effect which may occur as a result of (i) sleep disturbance, (ii) speech interference, (iii) reduction in work performance

(SCHULTZ, [17]; KRYTER, [10]; UPADHAYA and JAIN, [21]; FIDELL *et al.*, [5]; EVANS *et al.*, [4]; TESTSURO *et al.*, [20]). Community annoyance caused by aircraft noise exposure in the residential areas near the airports may often be found to be more than that due to street traffic noise exposure because of its intermittent and unpredictable nature (HALL *et al.*, [7]; SUTER, 1994; EEA, [3]).

An index of aircraft noise, the perceived noise level in decibel (PNdB) is considered as a quantitative measure of community annoyance because of its good correlation with the latter. Computation of PNdB however requires knowledge of the spectral characteristics of aircraft noise. The present study has been conducted with a view to study the spectral characteristics of aircraft noise and then determine the perceived noise levels at some of the prominent localities which lie underneath the landing flight path of aircraft in Delhi. In the only study conducted earlier for the city of Delhi, UPADHAYA and JAIN, [21] found strong association between peak aircraft induced noise levels and community annoyance in Delhi. However, this study didn't take into account the spectral nature of aircraft induced noise. The present study assumes special significance in view of rapid growth of air traffic in Delhi ever since the entry of private airlines in the aviation sector has been allowed by the Indian Govt. Figure 1 depicts the sharp increase in the volume of traffic at Delhi airport after liberalization of aviation sector in 1991.

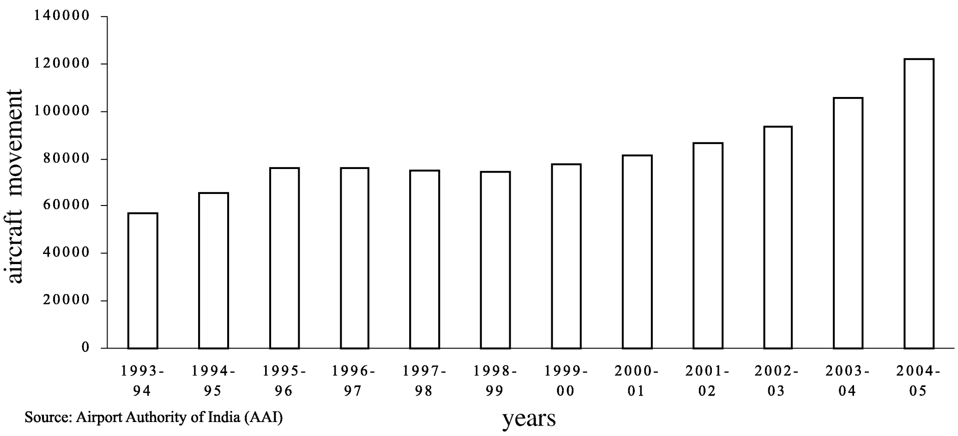

Fig. 1. Average total number of aircrafts per year in Delhi.

2. Experimental procedure

In the present study, monitoring of noise levels has been done at two different sites, namely, Jawaharlal Nehru University campus (UC) and Vasant Vihar (VV) which are situated underneath the landing flight path of aircrafts (Fig. 2). The approximate distances of these locations from the Indira Gandhi International (IGI) airport, New Delhi are 5.1 kms and 4.3 kms respectively. The height of the overhead aircraft above ground level (AGL) at these locations is approximately 1653 ft and 1510 ft, respectively (UPADHAYAY and JAIN, [21]).

Fig. 2. Location of sampling sites on the map of Delhi.

For the purpose of making the noise measurements, a type-I Sound Level Meter (SVAN 945) with the facility of integration, spectrum analysis and data logging in real time was used. The instrument was mounted on a tripod stand at a height of 2.5 ft above the floor in the indoor environment of a residential apartment at each site. Noise measurements were made continuously for a period of approximately 10,000 sec at a sampling rate of one measurement per second starting from 10 p.m. onwards on a typical day. During each observation, the instrument recorded the A-weighted noise levels and also noise levels at different 1-octave frequencies (linear mode) in real time.

From the time series data of A-weighted noise levels, L_{eq} levels (integrated noise levels) and the statistical percentile indices, namely, L_1 (peak noise level), L_{10} (noise levels during periods of intense noise) and L_{90} (background noise levels) were computed for each site. These noise indices provide a method of characterizing a noise episode and have been reported in a number of studies (e.g. KUMAR and JAIN, [11]; FIDELL *et al.*, 1995; SANYOGITA *et al.*, [15]).

Additionally, the sound exposure level (SEL) associated with each noise event (overhead flight) and perceived noise level in PNdB were also computed. Noise events corresponding to each flight were identified from the time series plots of noise levels at each 1-octave frequency. Spectral information corresponding to the peak of each noise event was then used to compute the total perceived noise (N_t) (KRYTER, 1959) using the equation.

$$N_t = N_m + F\left(\sum N - N_m\right) \quad \text{noys}, \tag{1}$$

where, N_t is the total noisiness (in noys); N_m is the maximum value of noys in a given frequency band, and $F = 0.3$ for 1-octave band of noise.

N_t and PNdB are related through the equation:

$$\text{PNdB} = 40 + 100/3\ \log_{10} N_t\,. \tag{2}$$

In order to assess the community response in terms of annoyance due to aircraft noise exposure, a questionnaire based social survey was also conducted in the residential areas of UC and VV. The questionnaire also sought responses on interference in different activities like speech interference, study, sleep, etc. Responses of 200 residents were obtained on a 5-point scale indicating the degree of activity interference due to aircraft noise exposure.

3. Results and discussion

Statistical indices computed from the time series data of noise levels at various sites are presented in Table 1. It is found that the values of L_1, L_{10} and L_{eq} indices are higher at VV. It may be noted that the value of noise climate is appreciably higher at VV. This is expected as VV is closer to the airport compared to UC. However, the L_{90} values are found to be relatively higher at UC. This can be attributed to the night time activities of students residing in hostels of UC.

Table 1. Various statistical indices at different sites.

Sites	Noise Indices (dBA)				
	L_1	L_{10}	L_{90}	L_{eq}	Noise climate $(L_{10} - L_{90})$
UC	71.1	57.2	49.0	51.0	8.2
VV	74.3	58.5	42.4	52.0	16.1

To have a better understanding of the noise exposure from single noise event due to aircraft overpasses, SEL was computed corresponding to all the noise events at these sites. The histogram plot of SEL at UC (Fig. 3) reveals that 11 out of total 29 aircrafts have the SEL in the range 68–70 dBA. At VV, modal value of the SEL lies in the range 70–72 dBA (Fig. 4). The increase in the modal SEL values indicates enhanced community noise exposure at VV. It shows that at VV aircraft noise during nocturnal hours contributes significantly contributes towards the noise environment.

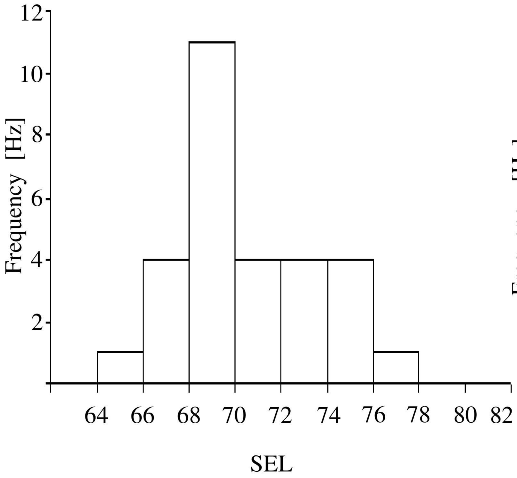

Fig. 3. Histogram of SEL(dBA) at UC.

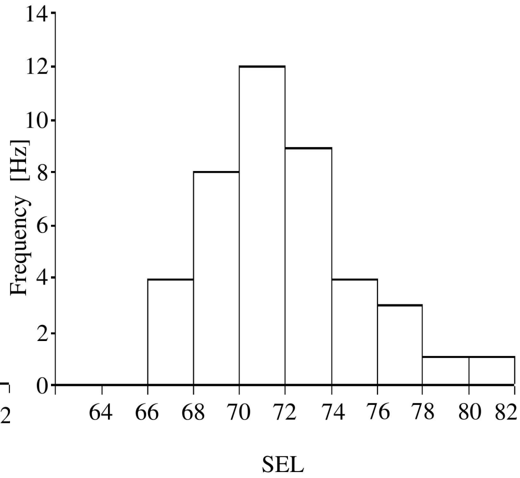

Fig. 4. Histogram of SEL(dBa) at VV.

3.1. Spectral distribution

The average spectral distributions at different 1-octave centre frequencies obtained for the peak noise level of each event (i.e. when an aircraft passes overhead) and for the entire measurement duration are given in Figs. 5 and 6. It may be observed from Fig. 5 that spectral character of noise levels at these sites is similar at mid frequencies (500–2000 Hz). In general, noise levels are found to be high at lower frequencies and exhibit a declining trend with the increase in frequency. The average power levels at lower frequencies (31.5–250 Hz) are higher at VV as compared to those at UC. At higher frequencies (4000–16000 Hz), however, the power levels are lower at VV compared to UC. The average power spectra for the entire duration at both sites (Fig. 6) are

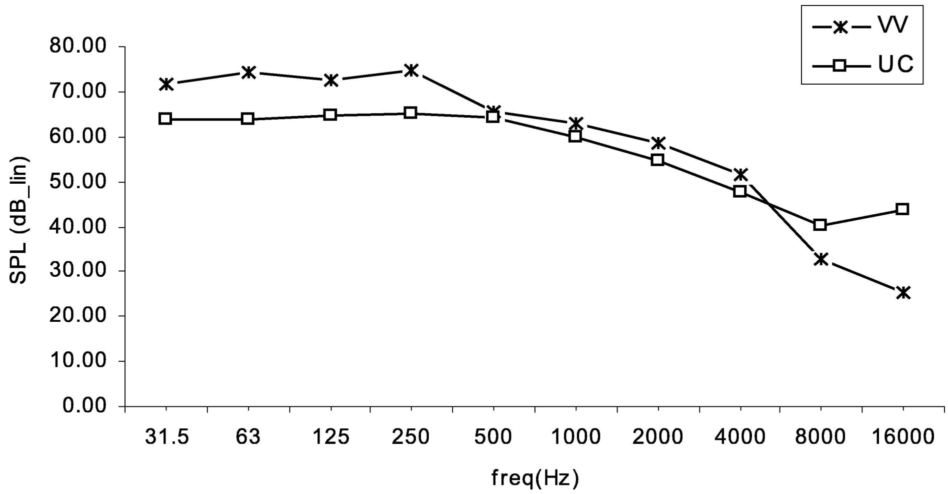

Fig. 5. Spectral distribution of aircraft noise at both the sites.

almost similar in the frequency range of 31.5 to 1000 Hz. The nature of the spectral characteristics is significantly different in the high frequency range 4–16 KHz.

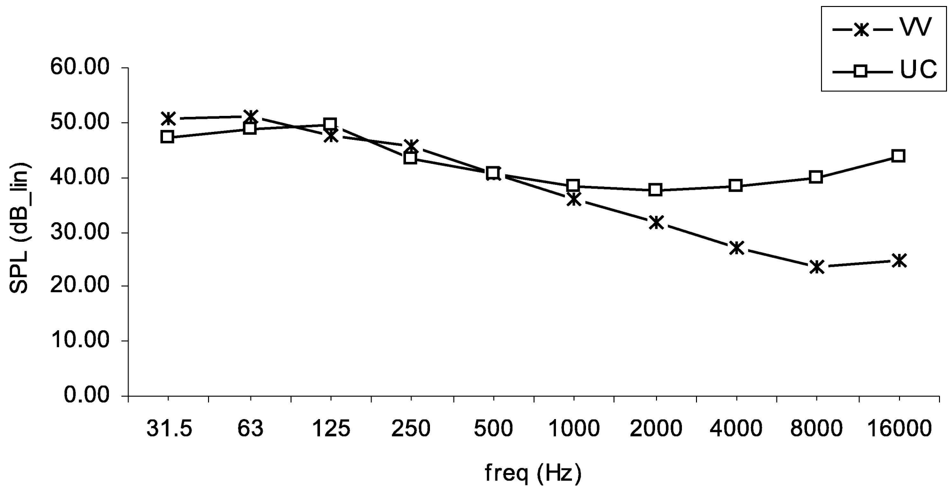

Fig. 6. Spectral distribution of noise of total measurement duration at both the sites.

3.2. Perceived noise level

Although the noise indices L_1, L_{10}, L_{90}, L_{eq}, and SEL provide meaningful information about the statistical character of a noise episode, they are not found useful in the context of the assessment of community annoyance due to aircraft noise exposure. Perceived noise level (PNdB), which is determined from the spectral characteristics of a noise event is found to be a more useful index in this regard. PNdB provides an objective scale for subjective response of people to noise and can be used to assess relative

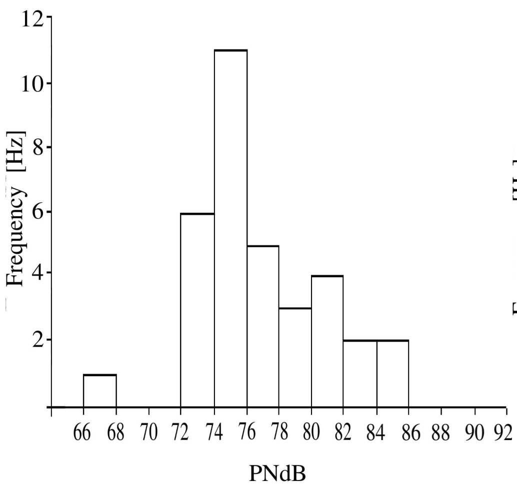

Fig. 7. Histogram of PNdB at UC.

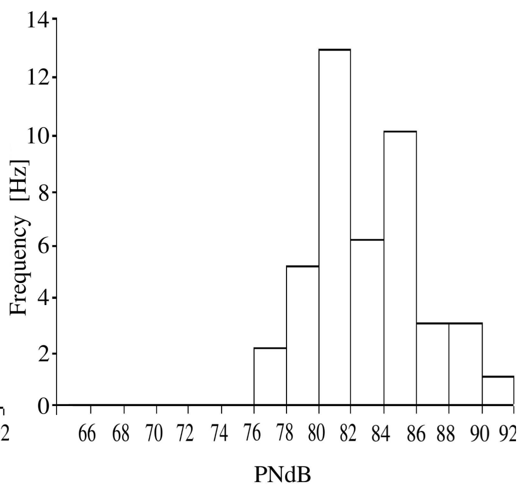

Fig. 8. Histogram of PNdB at VV.

annoyance or noisiness. Figures 7 and 8 depict the histograms of PNdB values obtained for different noise events at UC and VV.

The perusal of these histograms clearly reveals higher modal values of PNdB at VV in comparison to UC indicating significantly more noisiness and therefore annoyance at VV in comparison to UC.

3.3. Social survey

The results of the survey on community response to aircraft noise in the indoor environment are summarized in Table 2.

Table 2. a) Percentage distribution of community responses.

	Responses (%)					
Scaling	1	2	3	4	5	3 + 4 + 5
Effect	No	Slight	Moderate	High	Extreme	
Disruption in Simple work	38.0	33.5	21.2	5.6	1.7	28.5
Disruption in Sensitive work	9.5	25.7	35.2	20.7	8.9	64.8
Interference with Rest and relaxation	14.5	25.7	24.6	22.9	12.3	59.8
Interference in Speech/Conversation	0.6	10.6	15.1	38.5	35.2	88.8
Disturbance in sleep	21.2	27.9	22.3	15.1	13.4	50.8
Rattling of Window Panes	24.6	67.6	3.9	2.2	1.7	7.8
Annoyance during night	12.0	14.9	12.6	33.7	26.9	73.2

Table 2. b) Percentage community responses of health effects.

Health Effects	Responses (%)	
	No	Yes
Gastric problem	66.5	33.5
Hearing problem	71.5	28.5
Rise in blood pressure	82.7	17.3

It is found that a high proportion ($\sim 73.2\%$) of the residents felt moderate to extreme annoyance. It may also be inferred that significantly large percentages viz., 64.8%, 59.8%, 88.8% and 50.8% of the population experience moderate to extreme disturbances in sensitive work, rest and relaxation, speech/ conversation and sleep respectively. On the other hand, only 28.5% of the respondents felt moderately to extremely disturbed in doing simple work.

In terms of other health effects (Table 2b) $\sim 17\%$ people reported a rise in their blood pressure level, $\sim 29\%$ people reported hearing problem and $\sim 34\%$ reported gastric problem. This indicates that aircraft noise may also be affecting the physiological well being of the residents along the flight path.

A comparison of the results of social survey of the present study with the findings of a survey carried out in an earlier study by UPADHYAY and JAIN [21] reveals that the percentage of people feeling high to extreme annoyance has gone up drastically from 36% to 60.6% in a span of 7 years. This increase in the affected population can clearly be attributed to phenomenal growth of air traffic over Delhi.

Table 3. A comparison of community response (in terms of annoyance) of the present study (2006) with the previous study (1999).

Annoyance	People affected (%)	
	2006	1999
High + Extreme(8–10)	60.6	36
Moderate (4–7)	12.6	30
No + Slight (0–3)	26.9	34

4. Conclusion

It is found that the significant fluctuations in the noise levels over the background noise, as evident from the observed values of the noise climate $(L_{10} - L_{90})$, occur at both the localities (UC and VV). The perceived noise levels derived from the spectral characteristics of the noise are found to be rather high at both the sites, which corroborates the community response in terms of annoyance in the social survey carried out in the two localities. It is found that the percentage of people affected with "high-extreme" annoyance has gone up drastically upto nearly 61% compared to 36% observed in an earlier study in 1999. This appreciable increase in the percentage of affected people can be attributed to the quantum growth in air traffic in recent years over Delhi.

References

[1] AKHTAR N. H., *Noise-induced hearing loss in traffic police constables*, Journal of the College of Physicians and Surgeons Pakistan, **6**, 5, 265–268 (1996).

[2] ELISE E. M. M., KEMPEN V., KRUIZE H., HENDRICK C., BOSHUIZEN, CAROLINE B., *The association between noise exposure and blood pressure and ischemic heart disease*, Environmental Health Prospects, **110**, 307–317 (2002).

[3] European Environment Agency (EEA) Report, 2001.

[4] EVANS G. W., LERCHER P., MEIS M., ISING H., KOFLER W. W., *Community noise exposure and stress in children*, Journal of the Acoustical Society of America, **109**, 3, 1023–1027 (2001).

[5] FIDELL S., PEARSONS K., TABACHNCK B., HOWE R., SILVATI L., *Effects of sleep disturbance of changes in aircraft noise near three airports*, J. Acoust. Soc. Am., **107**, 5, Pt 1: 2535–2547 (2000).

[6] GOULET L., THERIAULT G., *Association between Spontaneous Abortion and Ergonomic factors. A Literature Review of the Epidemiological Evidence*, Scandinavian Journal of Work and Environmental Health, **13**, 399–403 (1987).

[7] HALL F. L., BIRNIE S. E., TAYLOR S. M., PALMER J. E., *Direct comparison of community response to road traffic noise and to aircraft noise*, J. Acoust. Soc. Am., **70**, 1690–1699 (1981).

[8] HARTIKAINEN A. L., SORRI M., ANTTONEN H., TUIMALA R., LAARA E., *Effect of occupational noise on the course and outcome of pregnancy*, Scandinavian Journal of Work and Environmental Health, **20**, 444–450 (1994).

[9] KRYTER K., *The Effects of noise on man*, Academic press Inc., New York 1985.

[10] KRYTER K. D., *Community annoyance from aircraft and ground vehicle noise*, Journal of the Acoustical Society of America, **72**, 1222–1242 (1982).

[11] KUMAR K., JAIN V. K., *A study of noise in various modes of transport in Delhi*, Applied Acoustic, **43**, 57–65 (1994).

[12] NETTERSTROM B., JUEL K., *Peptic ulcers among urban bus drivers in Denmark*, Scandinavian Journal of Social Medicine, **18**, 2, 92–102 (1990).

[13] PROSSER S., TARTARI M. C., ARSLAN E., *Hearing loss in sports hunters exposed to occupational noise*, British Journal of Audiology, **22**, 85–91 (1988).

[14] REGECOVA V., *Effects of urban noise pollution on blood pressure and heart rate in preschool children*, Journal of Hypertension, **13**, 4, 405–412 (1995).

[15] SANYOGITA, PRAKASH AMIT, JAIN V.K., *A study of noise in CNG driven modes of transport in Delhi*, Applied Acoustics, **65**, 195–201 (2004).

[16] SAWAD Y., *Reproducible increase in blood pressure during intermittent noise exposure*, European Journal of Applied Physiology, **67**, 4, 367–374 (1993).

[17] SCHULTZ T., *Syntheses of social surveys on noise annoyance*, Journal of the Acoustical Society America, **64**, 2, 377–405 (1978).

[18] SINGH B. B., JAIN V. K., *A comparative study of noise levels in some residential, industrial and commercial areas of Delhi*, Environmental Monitoring and Assessment, **35**, 1–11 (1995).

[19] SUTER, *Noise and its effects*, Administrative Conference of the United states, 3–4, 1991.

[20] TETSURO, SAEKI, TAKEO, FUJII, SHIZUMA, YAMAGUCHI, SYUJI, HARIMA, *Effects of acoustical noise on annoyance, performance and fatigue during mental memory task*, Applied Acoustics, **65**, 9, 913–921 (2004).

[21] UPADHYAY J. K., JAIN V. K., *Aircraft-induced noise levels in some residential areas of Delhi*, Environmental Monitoring and Assessment, **56**, 195–207 (1999).

[22] *The Okinawa study: effects of chronic aircraft noise on blood pressure and some other physiological indices*, 5-th Japanese-Swedish Noise Symposium on Medical Effects, 2004.