Original Article

Analysis of on-ground and in-flight sound levels produced by Chetak and Pratap helicopters

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ABSTRACT

Aviation environment exposes both aircrew and ground crew to intense noise levels. This study was conducted to measure and analyze sound levels to which the crews are exposed, during the ground run and in-flight of Chetak and Pratap helicopters. Data was recorded using a portable computerized Integrating Sound Level Meter (SLM) having automatic data acquisition capability. A-weighted Leq and peak values on-ground and in-flight, as well as the percentile distribution of sound levels over the duration of sortie were determined for the two helicopters. The maximum A-weighted Leq values for the Chetak helicopter on-ground at a distance of 10 m from the axis of the main rotor varied between 93.1 to 113.9 dB(A). The corresponding values for Pratap helicopter varied between 103.7 to 108.3 dB (A). The maximum value of A-weighted rms sound level (Lmax) in-flight was 108.6 dB(A) for both the helicopters while the maximum peak values recorded for Chetak and Pratap were 129.4 and 124.7 dB(A) respectively. The percentile distribution of in-flight A-weighted Lmax values for Chetak and Pratap helicopters show that the sound levels exceeded 102.9 and 97.6 dB(A) for less than 2% and 101.3 and 96.2 dB(A) for less than 10% of the sortie duration. However, the sound levels were in excess of 94.8 and 91.7 dB (A) for more than 90% of the time. As the time of exposure increases, the sound levels to which both ground and flight crew are exposed may exceed the maximum permissible exposure limit for safe occupational environments. The study, therefore, recommends mandatory use of efficient and properly fitting ear protective devices for conservation of hearing.

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KEY WORDS: In-flight sound measurement, A-weighted sound level, Equivalent sound pressure level, Permissible noise level, Chetak helicopter, Pratap helicopter

Noise is one of the inescapable physical stressors in any kind of transportation in general and military aviation in particular. [1] In any motor vehicle, the principal source of noise is the propulsion system of the vehicle itself. In helicopters, the engine and transmission system that conveys engine power to the main and tail rotors are the primary sources of noise. However, the physical characteristics of noise vary markedly from one type to another. It also depends upon the power setting, angle of attack of the rotor blades and the location of the listener. High levels of noise inside the aircraft is wearisome to the flier

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and can have serious physical, physiological and psychological effects starting from mild interference' with essential communication to irreversible damage to the hearing organ [2].

The noise produced by aircraft during ground run can be hazardous to the ground crew as well as to other personnel working in that area. Pilots operating rotary wing aircraft are also exposed to noise at high amplitude that is usually distributed over the entire audible frequency range. At many operational stations, pilots undertake several sorties on the same day, the cumulative effects of which can be a serious hazard. This study was, therefore, taken up to record, analyze and to estimate the levels of exposure of sound levels produced by Chetak and Pratap helicopters on-ground as well as in-flight.

Materials & Methods

Sound Level Meter. A precision handheld and battery operated SLM cum Octave Band Analyzer was used for real-time sound data acquisition, analysis and storage (System 814, Larson-Davis Laboratories, USA) [3]. A random incidence and pressure response condenser microphone of 1/2 inch diameter (Larson Davis Model 2559) having a flat frequency response between 4 Hz to 21 kHz was used for the measurement of sound pressure levels.

The SLM in the integrating mode samples the sound data at regular intervals of time to find out the rms and peak values of the time varying sound pressure level. It can also compute a single continuous sound pressure level (SPL) that would produce the same acoustic energy as the actual time varying sound signal, over the measurement period. This average value of SPL, the Equivalent Sound Pressure Level (L), is calculated in decibel as

$$L_{eq} = 10\log_{10}\left\{\frac{1}{(t_2-t_1)}\int_{t1}^{t2}\frac{p_{(t)}^2}{p_0^2}dt\right\} \text{dB}$$

Where t,

= the start time of measurement

= the end time of measurement

= the instantaneous sound pressure of the sound signal and

= 2 x 10''^{5} N/m^{2}, the reference sound pressure

The System 814 uses the A-weighting network to modify the SPL in order to obtain the same loudness as perceived by the human ear. The equipment then provides the L_{eq} value of the A-weighted sound level for the measurement period.

Table 1. Description of Chetak and Pratap Helicopters

Paramet er	Chetak (Allouette III)	Pratap (Mi-8)
Engine	Single - 649 KW RPM : 33,500 held constant-nt by governor (±200)	Twin - 1267 KW RPM : 1200
Rotor system	Main rotor : 3 blades RPM - 353.2 Tail rotor : 3 blades	Main rotor : 5 blades RPM -192 Tail rotor : 3 blades
Capacity	Passengers : 5	Passengers : 24

Microphone Calibrator. A Type 1 L precision Microphone Calibrator (Larson Davis Model CAL 200) capable of generating sound pressures of 1 Pa and 10 Pa (SPLs of 94.0 dB and 114.0 dB respectively) at a frequency of 1000 Hz was used for the calibration of System 814.

Helicopters used for the study. On-ground and in-flight sound measurements were carried out at AFA, Hyderabad and at ASTE, AF, Bangalore on Chetak (Allouette III) and Pratap (Mi-8) helicopters. The physical characteristics of these two helicopters are given in Table 1.

On-Ground Sound Measurements

The System 814 was configured in the integrating SLM mode. The time constant of the detector and the frequency weighting were set to 'Slow' and 'A' respectively and the instrument was set to store the L_{eq} value automatically every l/8th of a second during the measurement period. On-ground sound was measured from eight locations around the two helicopters with the engine(s) at maximum rpm and the rotors engaged. The locations were at angular separations of 45° along the circumference of a circle of radius 10 m from the axis of the main rotor, as shown in Fig 1. 0 represents the location in front of the aircraft along the longitudinal axis while 180° represents the position behind the tail rotor. Sound data was collected for more than 10s from each location. **In-**

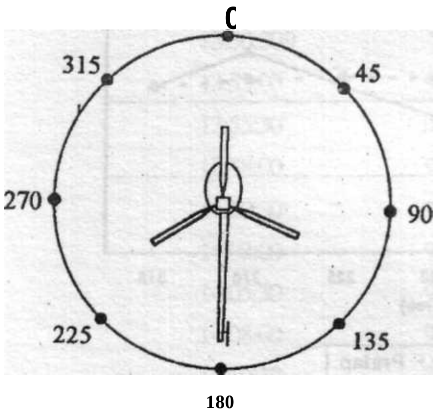

Fig 1. On-ground sound measurement locations

Flight Sound Measurements Chetak and Pratap helicopters were flown for one sortie each for acquiring in-flight sound data. The System 814 was set to the integrating mode with the time constant of the detector and the frequency weighting set to 'Slow' and 'A' respectively. The equipment was positioned inside the cockpit at the ear level of pilot. A-weighted sound data was acquired continuously at intervals of 2 min 30 s. The L value, the maximum rms (L) value and the peak sound level were calculated for each of these intervals from start up to switch off of the engine(s). The sortie-profile showing the event versus time for sorties undertaken by Chetak and Pratap helicopters are given in Tables 2 and 3. Continuous sound data was recorded for 58 min 28 s for Chetak and 1 hr 10 min 20 s for Pratap helicopter. Acquired data was then downloaded to a computer for analysis.

Table 2. Event vs. time of flight of Chetak helicopter

Event	Time (hr: min: s)				
Startup	13	17	: 02 to 13	S C	12
Max rpm	13	21	14		
Taxy	13	22	: 57 to 13	24	49
Pickup/hover	13	26	: 00 to 13	27	00
Take off	13	27	02		
60 Knots	13	27	05		
60 to 90 Knots	13	31	30 to 13	57	05
Autorotation	14	00	08		
Approach	14	08	51		
Transition	14	10	23		
Touch down	14	11	00		
Switch off	14	14	38		

Results

On-Ground Sound Measurements

The maximum L values of A-weighted
eq °
sound levels recorded during the ground run from the different locations around the two helicopters

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Table 3. Event vs time of flight of Pratap helicopter

s	Time (hr		: min : s)
Startup	11	07 :	21 to 11 :
Max rpm	11	11 :	44
Taxy	11	12 :	17
Hover	11	16 :	15 to 11 :
150kmph	11	20 :	20
20° bank	11	24 :	10
60 kmph	11	37 :	15
lOOkmph	12	13 :	40
60 kmph	12	14 :	30
Transition	12	14 :	30
Switch off	12	17 :	41

are given in Table 4 while a graphical representation of these sound levels are shown in Figure 2.

Mapping of on-ground sound levels along a circle of 10 m radius around Chetak helicopter with the rotors engaged and the engine running at max rpm shows that maximum L_c values of 113.9 and 112.7 dB(A) were recorded at the locations 135° and 270 while the minimum L values of 93.1 and 95.9 dB(A) were recorded at 0° and 180" locations respectively. For Pratap helicopter, a maximum L value of 108.3 dB(A) was recorded at 0° position while the other locations had more or less similar sound levels.

Table 4. Maximum L_{eq} values of A-weighted sound levels for various locations around Chetak and Pratap helicopters

Location (degree)	Maximum values of A-vveighted sound level in dB(A)	
	Chetak	Pratap
0	*93.1*	*108.3*
45	*107.7*	*106.4*
90	*107.6*	*105.9*
135	*113.9*	*106.6*
180	*95.9*	*105.7*
225	*103.9*	*106.3*
270	*112.7*	*105.3*
315	*103.8*	*103.7*

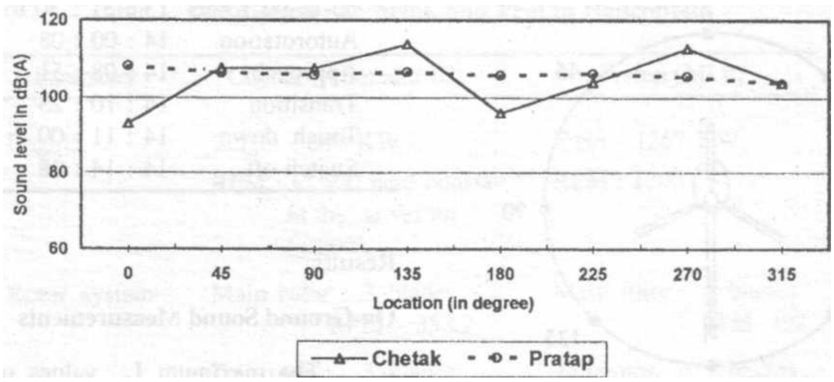

Fig **2.** Maximum L values of A-weighted sound levels around Chetak and Pratap helicopters

In-Flight Sound Measurements

Interval-wise break-up of L, L_{eq} and peak L_{max} values of A-weighted sound levels inside the Chetak cockpit during the sortie are given in Table 5. The average value of A-weighted sound level for the various sub-intervals during the measurement period varied between 92.4 and 101.5 dB (A). Similarly L_{max} and peak values are in the range 98.1 to 108.6 dB (A) and 109.8 to 129.4 dB (A) respectively. The L and L values of A-weighted $_{eq}$ $_{max}$ sound levels in relation to time of the sortie for the same helicopter are graphically illustrated in Figure 3.

Table 5. Interval-wise break-up of L, L and peak values of A-weighted sound levels eq⁷ max

Time of sortie (hr : min : s)	A-weighted sound level in dB(A)		
	L_{eq}	L_{max}	Peak
13:18:00	92.4	98.1	109.8
	97.9	99.7	113.0
13:20:30			
	98.5	100.1	113.5
13:23:00			
	100.7	103.7	116.0
13:25:30			
	98.6	101.7	120.6
13:28:00			
	99.1	102.7	129.4
13:30:30			
	101.5	108.6	124.4
13:33:00			
	98.8	102.6	117.6
13:35:30			
	100.1	102.9	115.2
13:38:00			
	99.1	102.5	116.7
13:40:30			
	99.8	103.8	123.6
13:43:00			
	101.2	103.7	117.4
13:45:30			
	100.6	103.2	114.4
13:48:00			
	7.6	101.0	113.3
13:50:309			
	98.5	102.3	118.3
13:53:00			
	100.2	101.9	1165
13:55:30			
	97.5	102.1	119.5
13:58:00			
	982	103.2	124.4
14:00:30			
14:03:00	97.2	101.4	116.9
14:05:30	97.8	101.8	113.6
14:08:00	98.3	100.1	116.4
14:10:30	98.6	1045	117.6
14:13:00	96.1	99.2	1125

In-flight L_{eq}, L_{max} and peak values of A-weighted sound levels inside the Pratap cockpit during the sortie for different intervals are given in Table 6. It can be seen that the L_{eq}, L_{max} and peak values inside Pratap for the different intervals ranged between 91.8 to 98.6 dB (A), 94.5 to 108.6 dB (A) and 111.5 to 124.7 dB (A) respectively. L_{eq} and L_{max} values recorded for the different sub-intervals in relation to actual time of flight for Pratap helicopter are shown graphically in Figure 4.

Table 7 gives the overall summary of the two sorties viz., duration, L, peak and percentile distribution (L_n) of A-weighted sound levels recorded for the two helicopters. L_n is that level of sound which has exceeded for 'n' percent of the total measurement duration. The maximum values of A-weighted peak for Chetak and Pratap helicopters were 129.4 and 124.7 dB(A) respectively while the maximum L_{max} value for both the helicopters were 108.6 dB (A). The maximum value of L_{max} for Pratap was recorded during the landing phase while for Chetak it was registered during flight. The percentile distribution of A-weighted sound levels indicate that for one-third of the sortie duration (L_{3333}), the sound levels were in excess of 99.3 and 94.4 dB(A) inside Chetak and Pratap cockpits respectively. The analysis also shows that for two-third of the sortie duration (L^ „), the sound levels were in excess of 97.6 and V DO. Of 93.2 dB (A) for Chetak and Pratap, respectively.

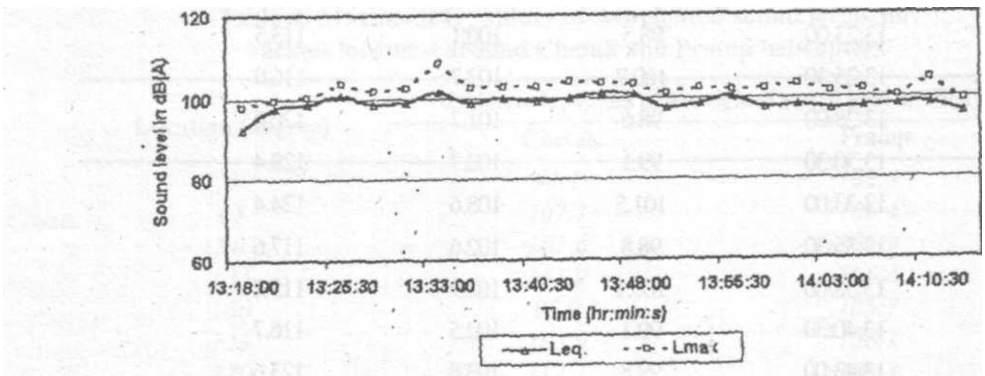

Fig. 3: Leq and Lmax values of Chetak helicopter vs Time of flight

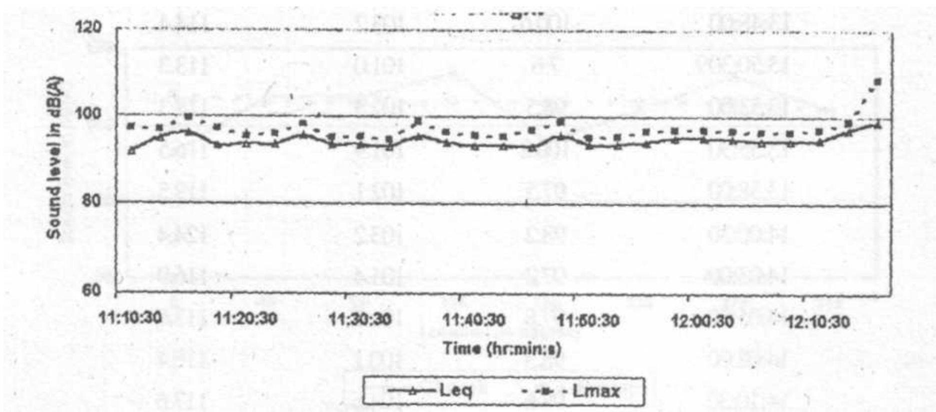

Fig. 4: Leq and Lmax values of Pratap helicopter vs Time of flight

Table 6. Interval-wise break-up of L, L and peak values of A-weighted sound levels for Pratap helicopter during the sortie

Time of sortie	*A-weighted sound level in dB(A)*		
(hr : min : s)	L_{eq}	L_{max}	*Peak*
11:10:30	**91.8**	**97.8**	**115.4**
	94.7	**96.7**	**117.1**
11:13:00			
	96.1	**99.4**	**114.3**
11:15:30			
	93.3	**97.0**	**113.2**
11:18:00			
	93.4	**95.3**	**113.0**
11:20:30			
	93.6	**95.8**	**116.1**
11:23:00			
	95.5	**98.0**	**114.7**
11:25:30			
	93.5	**94.9**	**112.6**
11:28:00			
	93.6	**95.3**	**111.9**
11:30:30			
	92.9	945	**111.5**
11:33:00			
	95.2	**98.5**	**116.7**
11:35:30			
	94.1	**96.2**	**113.9**
11:38:00			
	93.1	**95.6**	**1135**
11:40:30			
	93.1	**952**	**114.1**
11:43:00			
	92.9	**96.9**	**118.2**
11:45:30			
	95.5	**98.6**	**114.0**
11:48:00			
	93.4	**95.1**	**112.8**
11:50:30			
	93.6	**95.2**	) **112.2**
11:53:00			
	93.6	**95.2**	**112.2**
11:55:30			
	' 95:9	**96.7**	**113.4**
11:58:00			
12:00:30	**95.0**	**96.9**	**112.1**
12:03:00	**94.7**	**96.6**	**115.9**
12:05.30	**94.3**	**96.3**	**112.7**
12:08:00	**94.2**	**962**	**113.6**
12:10:30	**94.6**	**96.7**	**118.6**
12:13:00	**96.8**	**98.7**	**119,9**
12:15:30	**98.6**	**108.6**	**124.7**

Table 7. Summary of in-flight sound data and percentile distribution of sound levels inside the cockpits of Chetak and Pratap helicopters

Helicopter	Duration (hrnin)	Max L_{max} [dB(A)]	Peak [dB(A)]	Percentile values in				dB(A)	
				^1.67	^8.33	^33.33	30.00		
Chetak	00:58	10S.6	129.4	102.9	101.3	99.3	98.3	97.6	94.8
Pratap	01:10	103.6	124.7	97.6	96.2	94.4	93.7	93.2	91.7

The percentile distributions of L_{max} values of A-weighted sound levels for six levels from $L_{1.67}$ to L_{90}, during the two sorties are shown graphically in Figure 5. The figure clearly shows that the rms value of sound levels inside the cockpits of Chetak and Pratap helicopters were consistently higher than 90 dB (A).

Discussion

Noise is believed to act as a general stressor and possibly to have some effect on task concentration and performance efficiency. Extremely intense noise, be it continuous or impulse, can cause immediate damage to hearing. High frequency hearing is lost first, although the loss progresses to lower frequencies later and generally becomes greater in magnitude with increase in age. Although its causes are incompletely understood, it is believed to be brought about by deterioration of the inner ear, nerves to the brain and possibly cortex.

The effects of noise on human beings can be broadly divided into two: physiological and psychological effects. [4] Physiological responses, both auditory and non-auditory, involve changes in physiologic mechanisms or functions attributed to noise. One of the most important physiological effects of noise of sufficient intensity is to rise

Fig 5. Percentile distribution of A-weighted sound level inside Chetak and Pratap cockpits the threshold of hearing by a direct action upon the hair cells of the organ of Corti. This elevation of threshold may be temporary (Noise Induced Temporary Threshold Shift, NITTS) or permanent (Noise Induced Permanent Threshold Shift, NIPTS). The general consensus is that noise, at least at levels in the audible frequency spectrum which are tolerable in practice according to accepted standard criteria, has no untoward or permanent physiological effects upon man provided that the hearing is fully protected [5]. However, noise induced auditory pain occurs almost independent of frequency at sound levels of 130 to 140 dB and above.

In most countries, the trading relation between exposure time and sound level is based on 'equal energy rule' so that if 90 dB(A) for 8 hr is assumed as the acceptable limit, then for every halving of exposure time, overall level can be increased by 3 dB. Some countries have taken a less cautious approach by advocating 5 or 6 dB as appropriate halving factor. The United States' Occupational Safety and Health Administration (OSHA) Standards uses a 5 dB trading relation with 90 dB (A) for 8 hr per day in a 5 days/week working environment as the permissible noise exposure limit [6]. However, most countries place an upper limit on the peak SPL of 140 dB for any single exposure to loud noise as high intensity sound extend the physical response of the ear beyond its 'elastic limit'. If we go by the permissible noise exposure limits advocated by the United States' OSHA Standards, then without any ear protective devices, the daily noise exposure level will have to be limited to 100 dB(A) for 2 hr, 105 dB(A) for 1 hr and so on for conservation of hearing.

Mapping of sound levels during ground run at max rpm of the engine(s) with the rotors engaged, revealed that the L_{eq} value of A-weighted sound level for Chetak had maximum values at 135° location while for Pratap the max L^ was registered in front of the cockpit at 0° location. These maximum L_e values were around 110 dB (A). If one goes by OSHA Standards, the permissible duration, of noise exposure at this level for 5 days a week gets limited to 30 min per day.

Sound at levels high enough to cause damage to hearing is also undesirable as it creates other health problems, interferes with performance of task or produces annoyance. Sound below hazardous levels may still affect performance, cause annoyance or produce mental fatigue [7]. Man's perceptions, judgments, attitudes and opinions influence psychological response to noise. However, the effects of noise on cognitive and sensorimotor performance remain unclear and very complex. There have been many experiments and field surveys concerned with task efficiency at work, but no unequivocal simple generalization about the effects of noise on behavior have been drawn. Some of the studies have reported detrimental effects; a somewhat smaller number, beneficial effects; and a great many, no effects at all [8].

Intelligible communication between aircrew and air traffic controllers is essential during flight. The successful transmission of spoken messages or other auditory signals depends primarily upon the microphone picking up signals satisfactorily from the sender and an earphone or loudspeaker delivering the message without undue masking or distortion to the listener. The difficulty of understanding speech heard over communication a system in aerospace operations is quite common, even for a practiced listener. Extraneous acoustical noise picked up by the communication system can add to aircrew's difficulty in deciphering the message. Distortion can also result when high intense noise levels force the speaker to raise his voice. On the receiving end, the ground crew may have to increase the volume in their headsets, which could be hazardous over long duration exposures.

The maximum A-weighted rms value (L)
° v max'
of sound level recorded during the two representative sorties of Chetak and Pratap helicopters was 108.6 dB (A). The percentile distribution of A-weighted sound levels inside the helicopters indicate that for one-third of the sortie duration, the rms value of sound levels were in excess of 99.3 and 94.4 dB(A) for Chetak and Pratap respectively. For two-thirds of the sortie duration, the sound levels were in excess of 97.6 and 93.2 dB (A) while 90% of the time it was more than 94.8 and 91.7 dB (A) respectively for the two helicopters. At 95 and 100 dB (A) noise levels, OSHA Standards permit only 4 hr and 2 hr

exposure per day over a 5 days/week. When many sorties are undertaken on the same day in these types of helicopters, the unprotected aircrew within the cockpit is liable to be subjected to hazardous noise levels.

Summary

1. Mapping of A-weighted sound levels around Chetak and Pratap helicopters were carried out with the engine (s) at maximum rpm, at eight positions at angular separation of 45° at a radius of 10 m from the axis of the main rotor. The maximum L_{eq}values averaged over l/8th s were 113.9 & 108.3 dB (A) respectively for Chetak and Pratap helicopters.

2. In-flight sound data was recorded continuously inside the cockpits of Chetak and Pratap helicopters during two representative sorties. The A-weighted L_{eq}, L and peak values inside Chetak helicopter

max r 1

for intervals of 2 min 30 s varied between 92.4 and 101.5 dB(A), 98.1 and 108.6 dB(A) and 109.8 and 129.4 dB(A) respectively. Similarly, the A-weighted L, L and peak values

1=1 **eq** **max** r

inside Pratap for the different intervals ranged between 91.8 and 98.6 dB (A), 94.5 and 108.6 dB (A) and 111.5 and 124.7 dB (A) respectively.

3. The maximum L value recorded for the

max

a helicopter during the two representative sorties was 108.6 dB (A) while the maximum values of A-weighted peak were 129.4 and 124.7 dB (A) respectively for Chetak and Pratap.

4. The A-weighted sound levels at the pilot's ear were in excess of 99.3 and 94.4 dB (A) inside Chetak and Pratap cockpits respectively for one-third of the sortie duration. For two-thirds of the sortie duration, the sound levels were in excess of 97.6 and 93.2 dB (A) for Chetak and Pratap respectively.

5. The A-weighted sound level was always more than 90 dB (A) for both the helicopters on-ground as well as in-flight.

Conclusion

The ground crew and aircrew of Chetak and Pratap helicopters are likely to get exposed to A-weighted sound levels of hazardous magnitude (above 90 dB(A)) and as such they must adhere to mandatory use of efficient and properly fitting ear protective devices for hearing conservation.

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