Defence Life Science Journal, Vol. 3, No. 3, July 2018, pp. 231-237, DOI : 10.14429/dlsj.3.12910

Implications and Prevention of Noise Hazards on Board Ships

Neeru Kapoor*, Kumar Vyonkesh Mani, Bhuvnesh Kumar, and Shashi Bala Singh

DRDO-Defence Institute of Physiology & Allied Sciences, Delhi-110054

**E-mail: neerukapoor0260@yahoo.com*

ABSTRACT

Seafarers are exposed to intense noise due to running of powerful gas turbines present in the engine room and in other compartments due to the operation of various sub systems that adversely affect their hearing acuity and proficiency. A large body of persons is employed in the shipping industry and it is of paramount importance to preserve and promote health in the work place. Hence, this particular study was undertaken with a view to precisely quantify the noise levels associated with the operation of turbine engines and examine the impact of exposure on hearing sensitivity of the individuals. The preventive measures that can control the adverse effects like the use of ear defenders, and, supplementation of carbogen, a mixture of 5 per cent CO_2 and 95 per cent O_2 were examined.

Keyword: Noise; Carbogen; Hearing thresholds; Temporary threshold shift

1. INTRODUCTION

Exposure to intense noise is known to cause damage to the hearing apparatus of man and it also implicates various non-auditory systems of the body through the secondary pathways[1-11]. In the defence and civil sectors, different types of machines, equipment, systems and processes, while in operation give rise to an environment full of noise. Majority of the work force deputed for the operation and maintenance of these machineries and systems are exposed to this environment repeatedly for several years and sustain hearing loss. Scientists from several countries have worked out the cause and effect relationship and formulated the damage risk criteria (DRC) with the objective to provide safety guidelines for continuous and impulsive noise[12-19]. This has also led to the determination of safe limits. As per the recommendations, continuous noise at work places should not exceed 90 dB 'A' for 8-hour work schedule if the work force is to be protected from adverse effects [20]. Protective measures have been recommended to protect the hearing sensitivity of individuals from the damaging effects of noise when the sound pressure level exceeds 90 dB 'A'[21-25].

The operation of different machines and noisy systems give rise to a variety of noise that differs in their quality as well as the intensity. Most of the machines used in the production process produce noise which is much higher in level compared to recommended upper safe limits. As regards the frequencies, different sources produce wide band noise with intense tonal components in some of them. Ships are powered by gas turbines that are fairly noisy and produce intense noise much beyond the level of human acceptability. This constitutes an auditory hazard. On account of the repeated and long-term exposure due to their deployment, the ship crew, particularly those working in engine room develop hearing loss. They frequently go to the room, check the operation and control parameters and return to the side room. Cramped space inside the engine room compartment makes the use of muff type of ear defenders difficult to use as these restrict the mobility inside the engine room[26]. In the other compartments also, the sound pressure levels (SPL) are often higher than acceptable and inflict their effects due to repeated exposures.

It is known that the ear is very sensitive to noise. Noise causes vasoconstriction in the cochlear blood vessels and reduces blood supply to the organ of corti. Hair cells are not able to respond proportionately to noise stimulus due to loss of sensitivity. Intense exposures may even lead to the loss of hair cells. Reduced O_2 supply as a result of vasoconstriction may be a basic mechanism for temporary threshold shift (TTS) induced by noise[27-35]. On the preventive aspect, recent studies in this Institute have shown that inhaling a mixture of 5 per cent CO_2 and 95 per cent O_2, known as Carbogen, for a brief period of 5 min effectively controls the effect of vasoconstriction by causing vasodilatation, which maintains the O_2 supply and increased metabolic demand. In other words, inhalation of Carbogen for a brief period of 5 min prevents the loss of hair cell sensitivity and thus it acts as a protective measure against the development of temporary threshold shift due to noise exposure and protects the hearing from permanent damage over time[36,37].

This study was undertaken with the objective to assess the potential of noise hazard to the ship crew and also the protective effect of inhalation of Carbogen for 5 min before and after the daily work schedule in the engine room and other compartments.

Received : 17 August 2017, Revised : 12 March 2018
Accepted : 22 March 2018, Online published : 25 June 2018

2. MATERIALS AND METHODS

In this study, 37 healthy naval personnel aged between 20 years to 34 years participated as subjects. They were furnished with the details of the study and their informed written consents taken prior to the commencement of the study that was duly reviewed and approved by the Human Ethics Committee of the Institute (Defence Institute of Physiology and Allied Sciences, Delhi, India). The participants were randomly divided into two groups. One group was administered the Carbogen mixture and termed experimental group (n=20), while the other group served as controls, not receiving Carbogen (n=17). The general details of the participants are briefly summarised in Table 1. The subjects did not use any ear defenders during the course of the study.

In a separate study, the hearing thresholds of a group of sailors comprising of 45 engine room crew and 11 non-engine room personnel was conducted in a quiet room near the harbour for assessing the effect of ship noise on the hearing acuity of the workers.

The sound pressure levels (SPL) and frequency spectrum of noise in the engine rooms and other compartments of the ships were monitored with the help of B & K Type 2230 Precision Integrated Sound Level Meter in conjunction with Type 1625 octave band filter, and, CEL Sound Level Analyser Type 573. The calibration checks were carried out daily before and after use of the instruments.

Two carbogen breathing systems were placed very close to the work place of the subjects. The audiometric evaluation of hearing status of the subjects was carried out using Grason Stradler GSI 61 Audiometer before their exposure to engine room noise and also before their grouping as experimental and control subjects. The pre and post exposure audiometry was carried out in the medical room of the ship. Two experiments lasting for 8 days and 16 days, respectively were conducted using these positive points. As per the scheduled programme, the experimental subjects inhaled the gas for a period of 5 min prior to entering the engine room for their duty. Simultaneously, one individual from the control group also resumed his duty in the engine room. This practice of administering of Carbogen and inducting individuals from both groups was followed for 8 days and 16 days, respectively during the period of sailing of the ships. The post exposure audiometry was carried out at the end of 8 days and 16 days of exposure.

Table 1. General characteristics of volunteers

Experiment	Groups	Age (Years)	Height (m)	Body weight (Kg)	BMI (Kg/m^2)
8 days exposure	Noise (Control) (n=9)	26.10±5.67	1.69±3.53	65.40±7.73	22.80±2.47
	Carbogen (Experimental group) (n=10)	28.20±3.46	1.67±3.83	61.40±9.07	21.97±2.75
16 days exposure	Noise (Control) (n=8)	22.44±1.89	1.67±2.39	63.90±3.92	22.40±1.08
	Carbogen (Experimental group) (n=10)	22.42±2.07	1.67±3.26	63.10±8.06	22.10±2.56

Plus or minus values are mean±SD.

3. RESULTS AND DISCUSSION

Volunteers from all groups were alike with regard to physical characteristics, age, height, weight and BMI with similar lifestyle. General details of participants are briefly summarised in Table 1.

The mean RMS sound pressure levels (dB) at different locations in the engine room in a stationary and sailing condition are presented in Table 2. As can be seen the SPL when the ships were stationary in harbour ranged from 81 dB - 89 dB in the forward and AFT engine room. During the sailing of the ships, the noise level increased substantially and ranged from 97.1 dB to 113.9 dB. Going from stationary to sailing condition causes sound pressure levels to increase from acceptable to highly damaging as per the DRCs. Based on the earlier noise measurements, ear defenders were recommended as a precautionary measure but on account of their limitation in attenuating sound as well as irritability and pain in auditory meatus during prolonged use[26], their use has not been found adequate. On account of the above limitations, these ear defenders have not found widespread acceptability/popularity by the engine room crew as per our current observations.

Table 2. Instantaneous sound pressure level (B) in the engine rooms of Indian Naval Ships

Location	Stationary (In harbour)		During sailing	
	Port side	Star board	Gas turbine 2	Gas turbine 4
Forward engine room	89.1	83.8	100.5	111.4
AFT engine room	81.9	82.0	97.1	113.9

The SPL in the different compartments the ships, recorded in stationary and sailing condition are depicted in Table 3. The noise levels in the Sailor's cabin, Officers' cabin, Officers ward room as well as operation room and other compartments ranged between 74.8 dB – 88.4 dB. These were within the safe exposure limit. During sailing, there was a substantial increase in the noise level in the AFT steering port (108 dB) with 24 dB increase, followed by MCR Table, operation and bridge rooms, where the sound pressure level increased by 8 dB to 14 dB. As seen, most of the values were within the safe limits when the ship was in the stationary phase. However, safe limits of exposure were exceeded in most of the compartments in sailing.

Frequency spectrum of noise in the compartments and engine room with engines running while in harbour or during sailing are presented in Figs. 1 and 2. While in harbour, the noise produced presented uniform level at different center frequencies starting form 20 Hz to 20 kHz in the commander's cabin. As seen from the figure, the sound pressure levels at the band of frequencies varied from 81.0 dB to 88.0 dB with a gradual decline towards higher frequencies starting from 6 kHz. The linear sound pressure level was 102 dB. During sailing, the noise level increased to higher magnitude ranging from 98 dB to 108 dB in the AFT engine room and from 88 dB to 104 dB in the forward engine room. The spectrum showed uniformity up to 5 kHz and thereafter a slight decline in sound pressure level. The noise level at each frequency in the forward engine room was higher than 100 dB while in the AFT engine room it was higher than 95 dB from 0.04 kHz – 5.0 kHz. The noise level is attenuated in the lower as well as higher frequencies in the forward engine room due to barriers.

Table 3. Sound pressure level (db) in the different compartments of Indian Naval Ships

Location/ Compartment	Stationary (In harbour)	During sailing
Jr. Sailors cabin	79.7 (76.4 ± 3.16)	85.7 (84.7 ± 1.6)
Sr. Sailors cabin	88.4 (84.75 ± 5.16)	88.5 (86.35 ± 3.04)
Officers cabin	81.5 (81.3 ± 0.28)	85.3 (83.9 ± 1.98)
Officers ward room	77.9	82.5
Captain cabin	74.8	82.2
Bridge	77.0	88.9
Operation room	76.6	91.0
M.C.R. Table	88.2	95.6
AFT steering port	84.1	108.3

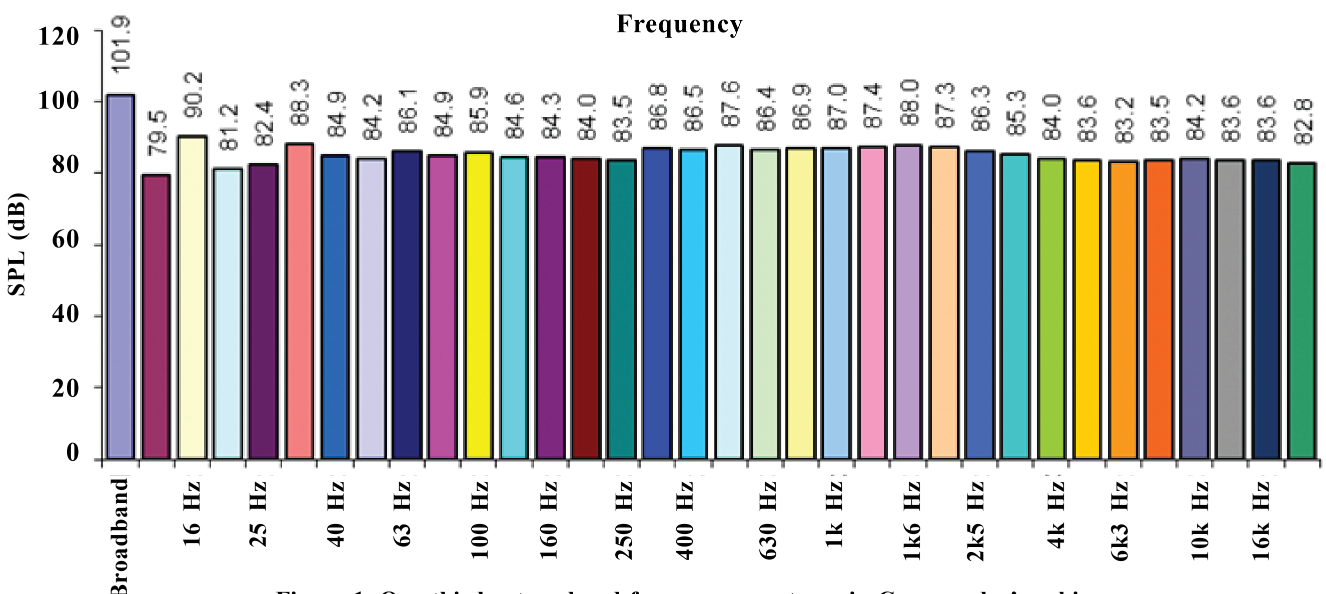


Figure 1. One third octave band frequency spectrum in Commander's cabin.

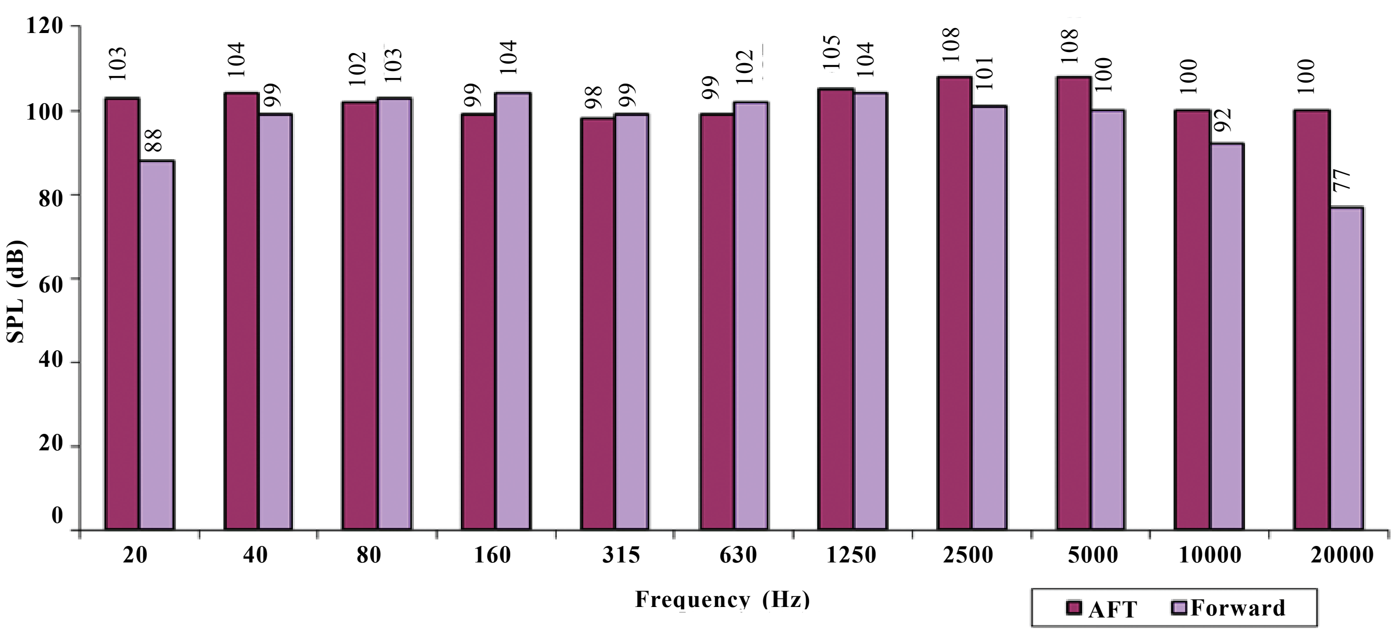


Figure 2. Frequency spectrum in the engine room of a ship during sailing.

Table 4 presents the audiometric tests conducted on the engine and non-engine room crew. On the basis of the hearing levels, the subjects were categorised as those having normal hearing (hearing level up to 25 dB), mild loss of hearing (hearing level between 26 dB - 40 dB), moderate hearing impairment (hearing level between 41 dB - 60 dB). Hearing levels higher than 60 dB were put as severe hearing impairment.

As seen from the Table 4, 73 per cent non-engine room crew presented normal hearing as against 24 per cent seen in the engine room crew. There were no incidences of moderate and severe hearing losses in the non-engine room crew.

Table 4. Percent distribution of hearing loss in different categories of exposed population

Category	Total Nos. (n)	Normal	Hearing impairment		
			Mild	Moderate	Severe
Non-engine room crew	11	72.7	27.3	0	0
Engine room crew	45	24.4	60.0	15.6	0

The frequency wise distribution of hearing losses among the ship crew indicated that the most affected frequencies were 4 kHz, 6 kHz, and 8 kHz. Hearing losses in the lower frequencies were not seen in the non-engine room crew, but many of the engine room crew presented hearing impairments in the lower frequencies below 1 kHz indicative of their prolonged repeated exposure to brief but intense noise affecting speech frequency range also.

Figure 3 presents the mean hearing level before and after 8 days exposure to noise to the control as well as experimental groups of subjects. The base line audiograms indicated higher hearing threshold at lower frequencies up to 750 Hz and the higher sensitivity and lower thresholds were recorded between 1.0 kHz to 4.0 kHz. The mean hearing level again increased to 22.5 dB at 6 kHz. Post exposure audiometry indicated elevated threshold of hearing ranging from 25 dB to over 30 dB, due to exposure to noise. The differences between pre and post audiograms were of almost equal magnitude between 2.0 kHz to 8.0 kHz. The average temporary threshold shift was 10 dB or higher beyond 2 kHz. Towards lower frequencies, the level of temporary threshold shift declined possibly due to the fact that lower audiometric frequencies are not much affected by noise exposure as in the case of higher frequencies[38,39]. A temporary threshold shift of 10 dB produced due to noise may not recover back to normal during the rest period and the residual temporary threshold shift over time may change into permanent threshold shift[40,41].

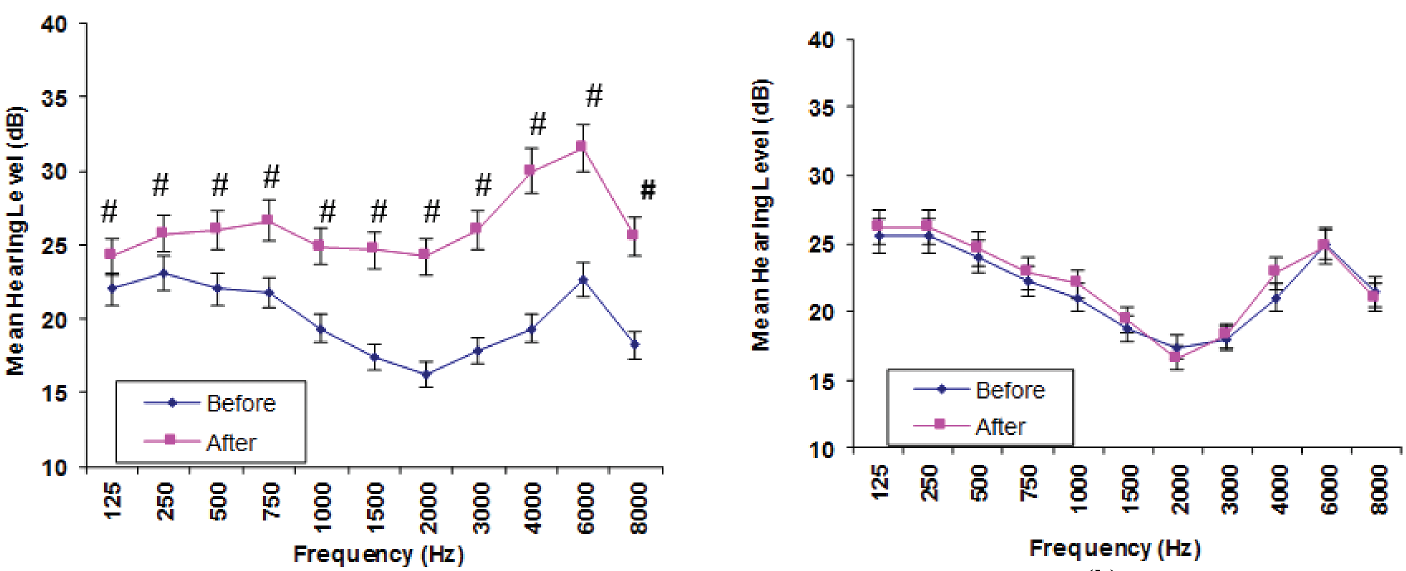
The group that received Carbogen as shown in Fig. 3(b) did not show any concernable difference between the pre and post exposure audiograms during the 8 days experimental duration.

The temporary threshold shift that developed during the 16 day exposure as shown in Fig. 4 in the control group followed almost the same course as seen in Fig. 3, i.e. temporary threshold shift of the order of 3.5 dB to approximately 10 dB developed between 1.0 kHz to 4.0 kHz. These differences were found to be significant ($p < 0.01$ and $p < 0.001$). In the Carbogen group of subjects as shown in Fig. 4(b), there was practically no temporary threshold shift development except at 2 kHz, where 2 dB difference was recorded. These results are in line with the findings of our laboratory experiments and also the studies conducted in the industrial environment of the army[36,37,42].

From Figs. 3 and 4, it can be conjectured that Carbogen inhalation before exposure to noise prevents the development of TTS and therefore it also controls the noise induced permanent threshold shift (NIPTS) which may set in over time.

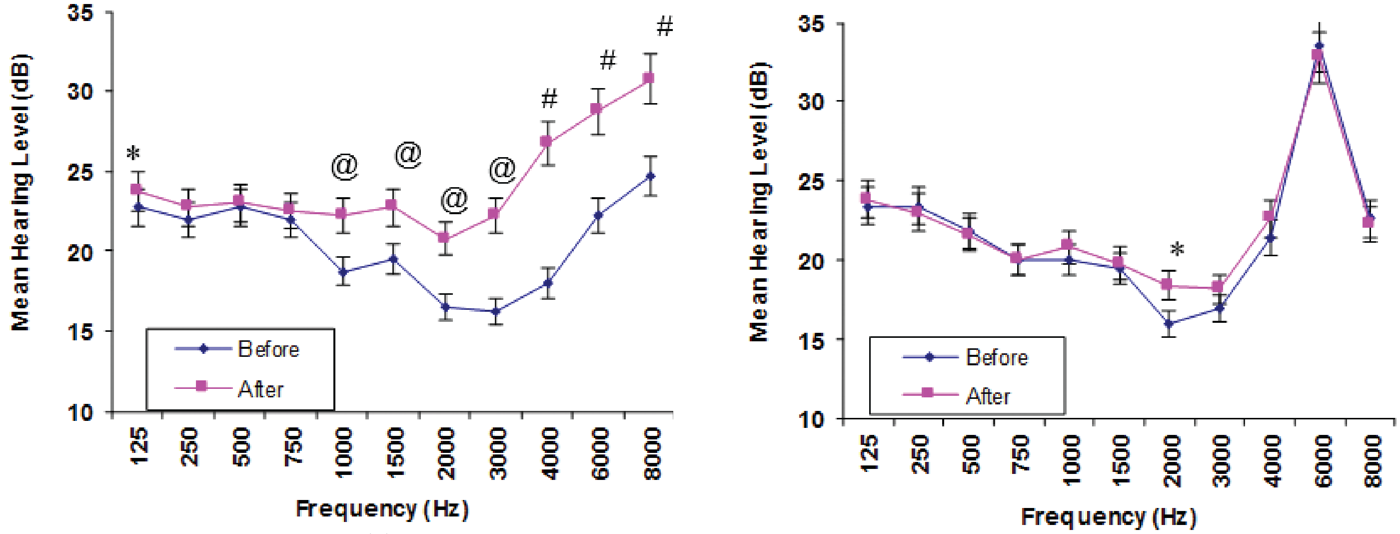
4. CONCLUSIONS

The prevalence of high level of noise in the engine room and other compartments of naval ships ranging from 97.1 dB -



#p<0.001 (a) (b)

Figure 3. Mean hearing level (dB) of left ear before and after 8 days exposure to noise (a) Control (n= 9), (b) Carbogen (n= 10) (Values Are: Mean ± SE)



*p<0.05, @ p<0.01, # p<0.001 (a) (b)

Figure 4. Mean hearing level (dB) of left ear before and after 16 days exposure to noise (a) Control (n= 9), (b) Carbogen (n= 10) (Values Are: Mean ± SE)

113.9 dB 'A', 82.2 dB and 95.6 dB 'A', respectively are higher as compared to the upper safe limit of 90 dB for 8 h exposure a day and exposures without hearing protection constitute a definite auditory risk.

Inhaling Carbogen (5 % CO_2 and 95 % O_2) by the engine crew for 5 min before occupational noise exposures during 8 days and 16 days of sailing of the ships indicated that carbogen renders almost complete protection from the development of hearing loss because the temporary threshold shift development due to prolonged exposures is almost negligible.

Conflict of Interest: No conflicts of interest.

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CONTRIBUTORS

Dr Neeru Kapoor obtained her PhD from Panjab University, Chandigarh. Currently working as Head of the Occupational Health Division at DRDO-Defence Institute of Physiology and Allied Sciences, Delhi. She has spearheaded research on hazards and ameliorating processes impacting human health and performance in noisy occupational environments and successfully pioneered indigenous design and development of efficacious interventions for safeguarding the hearing and optimize performance of our troops/soldiers.
Contributed to the concept & design of experiments, performance of experiments, analysis of data and writing of the paper.

Dr Shashi Bala Singh, obtained her PhD (Human Physiology) from All India Institute of Medical Sciences, New Delhi and DSc from Bharathiar University, Coimbatore. Currently working as Distinguished Scientist and DRDO-Director General, Life Sciences She was conferred with the *DRDO Scientist of the Year Award*, in 2010.
Contributed to the administrative processing for the paper.

Dr Bhuvnesh Kumar, obtained his PhD (Veterinary Medicine) from G.B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand). Presently working as Scientist 'G' and Director, DRDO-Defence Institute of Physiology and Allied Sciences, Delhi. Earlier he was Project Director of Low Intensity Conflicts to Counter Terrorism and Insurgency, and the Director, Project Monitoring at Directorate of General Life Sciences, DRDO HQrs, and Director, DIHAR.
Contributed to the administrative processing for the manuscript.

Mr Kumar Vyonkesh Mani did his MSc (Physics) from University of Delhi, Delhi. Presently working as a Scientist 'D' in Occupational Health Group at DRDO-Defence Institute of Physiology and Allied Sciences, Delhi. His research includes assessment of occupational noise and RF exposure to defence personnel and development of suitable protective devices.
Contributed to the measurement of noise parameters and analysis of data.