Global Journal of Engineering and Technology Advances

eISSN: 2582-5003

Cross Ref DOI: 10.30574/gjeta

Journal homepage: https://gjeta.com/

(Review Article)

Occupational noise induced hearing loss and vibrations exposure and its determinants in oil & gas industry in India: A review article

Vikas Mahalkar [1, *], Sanjay Kumar [2] and Sanjeev Singhal [3]

[1] Senior Medical Officer, Occupational Health Centre, Institute of Petroleum Safety, Health & Environment Management (IPSHEM)- ONGC, Goa.
[2] General Manager- Support Manager, IPSHEM- ONGC, Goa.
[3]Executive Director, Head of Institute, IPSHEM- ONGC, Goa

Global Journal of Engineering and Technology Advances, 2022, 11(01), 036–044

Publication history: Received on 25 February 2022; revised on 30 March 2022; accepted on 01 April 2022

Article DOI: https://doi.org/10.30574/gjeta.2022.11.1.0063

Abstract

Occupational Noise Induced Hearing Loss and Whole Body Vibrations are the common hazards in modern industries. Noise is the insidious of all industrial pollutants, involving every industry and causing severe hearing loss in every country in the world. It has been suggested that 12% or more of the global population is at risk of hearing loss from noise. A study published in American Journal of Industrial medicine showed in Oil and Gas extraction sector of the U.S 14% of the overall noise-exposed workers and 28% of the noise-exposed workers in the Natural Gas Liquid Extraction had hearing loss. Left untreated, hearing loss can lead to communication difficulty, social isolation, stress and fatigue. It is additionally associated with depression, cognitive decline, dementia, falls, and mortality. Workers with hearing loss face challenges to their personal safety, are at higher risk of injury. Vibration reported a significantly higher prevalence of tingling, numbness, paresthesia (18.2%); pain in finger, wrists, arms, etc. (31.7%); stiffness in hand (13.6%); and hyperhidrosis (48.5%) among drillers. Whole-body vibration and segmental vibration need to be studied separately because they are measured and evaluated using different standards. They also require different control measures and have differing effects on the human body. The clinical presentation of HAVS in India is not the classical VWF. Subclinical manifestations and dose- response relationships need to be worked out for HAV and WBV in Indian miners. The review paper intends to throw light on these silent killers in the form of occupational hazards leading to serious non-curable permanent health impediments/ disabilities in Oil & Gas industry.

Keywords: Occupational Health (OH) Hazards in petroleum industry; Noise Induced Hearing Loss, NIHL; Whole Body Vibration (WBV); Prolonged Vibration Exposure

1 Introduction

Occupational Noise Induced Hearing Loss and Whole Body Vibrations are the common hazards in modern industries. These hazards are a cause of concern as they cause occupational diseases and deaths worldwide, which significantly affect the quality of life of the employees and increase the global burden of non-communicable diseases (NCDs) [1].

According to WHO non-communicable diseases (NCDs) make up 70% of the occupational health risks. This should not be overlooked as many workers are persistently challenged by occupational hazards.

Noise and Whole Body Vibrations are the most common work-place hazard in most Oil and Gas industries.

* Corresponding author: Vikas Mahalkar
Occupational Health Centre, Institute of Petroleum Safety, Health & Environment Management (IPSHEM)- ONGC, Goa.

Noise is the insidious of all industrial pollutants, involving every industry and causing severe hearing loss in every country in the world. Exposure to excessive noise is the major avoidable cause of permanent hearing impairment. Oil and Gas developmental (E&P) activities generate noise. Following are the operations of the E&P industry which generate high level noise [1].:

- Airborne Surveys
- Seismic Operations for Oil and Gas exploration and discovery
- Construction activities (such as construction of rigs, pits etc.)
- Drilling and Production of oil & gas.
- Transportation of oil

Whole body vibrations & Segmental Vibration are also a common hazard of the Oil and Gas development (E&P) industries. The frequent use of hand held vibrating tools on offshore platforms like grinders, needle guns, impact wrenches air drills and chipping hammers is the reason for the common health hazard of Hand Arm Vibration Syndrome (HAVs), a type of segmental Vibration Syndrome [13].

2 Noise-Induced Hearing Loss (NIHL)

2.1 Introduction to NIHL

Noise-induced hearing loss (NIHL) is an irreversible damage of cochlear hair cells of the inner ear. It may be represented as partial or complete hearing loss of the patient. It has been long recognized more as an occupational disease after the advent of the Industrial Revolution. Noise-induced hearing loss, when associated with noise exposure at workplace is called Occupational Noise-induced hearing loss (ONIHL) [2].

2.2 Prevalence of Noise induced hearing loss

It has been suggested that 12% or more of the global population is at risk of hearing loss from noise. Though global estimates are scarce, and methods vary widely, the prevalence of noise exposure at work (i.e., the percent number of cases at a given time) has been reported to be approximately 15% in Canada (Feder et al., 2017), 20% in European Union and 20% in Australia.

Table 1 Noise levels in different industries

Industries	Range (dBA)
Textile industries	102-114
Pharmaceutical firms	93-103
Fertilizer plants	90-102
Oil and natural gas complex in Bombay high	90-119
Road traffic in Ahmedabad city	60-102
Surface rail traffic	90-102
Metro rail	70-111
Air traffic	90-112

While some evidence indicates that occupational exposure to high levels of noise may be slowly decreasing in the developed world, whereas workplace noise is increasing in the developing countries like India as developing economies shift from an agriculture to a more industrial base.

Studies carried out by the National Institute of Occupational Health, India, showed that sound levels at Oil and Natural Gas complex at Bombay High were very high (90-119 dBA). Hearing test data collected by British Columbia employers in Oil and Gas drilling sector between 2012 and 2017 show that the percentage of workers who showed signs of Noise-induced hearing loss increased from 33 percent in 2012 to 45 percent in 2017 [2].

A study published in American Journal of Industrial medicine showed in Oil and Gas extraction sector of the U.S 14% of the overall noise-exposed workers and 28% of the noise-exposed workers in the Natural Gas Liquid Extraction had hearing loss.[4].

2.3 Causes of Occupational Noise induced hearing loss and difficulty faced by affected people

Noise exposure is the primary reason behind cause of primary cause of preventable hearing loss. Noise exposure at work is responsible for a 16% of disabling hearing loss in worldwide [5].

Left untreated, hearing loss can lead to communication difficulty, social isolation, stress and fatigue. It is additionally associated with depression, cognitive decline, dementia, falls, and mortality.

Workers with hearing loss face challenges to their personal safety, are at higher risk of injury (with the inability to hear alarms or having difficulty in judging the direction of sound sources), and are more likely to be underemployed.

Simply put Occupational Noise induced hearing loss (ONIHL) can have substantial negative impact on the quality of life of employees affected by it.

2.4 Symptoms of Noise-induced hearing loss (NIHL)[10].

Noise-induced hearing loss is associated with damage to the hair cells in cochlea which results in partial or complete hearing loss of the patient. The hair cells in the cochlea are responsible for initiating the neural impulses that carry information to the brain regarding the sounds. The human cochlea has one row of inner hair cells (sensitive to lower frequency) and three rows of outer hair cells (sensitive to higher frequency). The amount of direct hair cell damage depends on the intensity of sound [10].

Exposure to noise at sub traumatic levels exhibits a temporary shift in hearing sensitivity that returns to normal with time away from hazardous exposure.

However, higher sound levels damage the outer hair cells, stereo cilia, further destruction of intercilial bridges and recovery takes longer. An even higher level of sound leads to collapse of stereocilia and hair cell is permanently damaged.

If the outer hair cells are not properly functioning, a greater stimulation is required to initiate a response, which is perceived as hearing loss. Once damaged the auditory sensory cells cannot repair themselves nor can any medical procedure restore normal functioning.

Table 2 Grading Of the Hearing Impairment [10].

Grade of impairment	Corresponding audiometric ISO value	Performance	Recommendations
0 - No impairment	25 dB or better (better ear)	No or very slight hearing problems. Able to hear whispers	Nil
1 - Slight impairment	26-40 dB (better ear)	Able to hear and repeat words spoken in normal voice at 1 m	Counselling. Hearing aids may be needed
2 - Moderate impairment	41-60 dB (better ear)	Able to hear and repeat words spoken in a raised voice at 1 m	Hearing aids usually recommended
3 - Severe impairment	61-80 dB (better ear)	Able to hear some words when shouted into the better ear	Hearing aids needed. If no hearing aids available, lip reading and signing should be taught
4 - Profound impairment including deafness	81 dB or greater (better ear)	Unable to hear and understand even a shouted voice	Hearing aids may help understand words. Additional rehabilitation needed. Lip reading and sometimes signing essential. No treatment available.

Grades 2, 3 and 4 are classified as disabling hearing impairment. The audiometric ISO values are averages of values at 500, 1000, 2000 and 4000 Hz

2.5 Diagnosis of NIHL

Audiometry is a standard test to detect and evaluate hearing loss. Audiometry is used to determine the auditory threshold of an individual to pure tones of 250-8000 Hz and sound levels between 10 (the hearing threshold of intact ears) and 110 dB (maximal damage).

The patient should not have been exposed to noise during the previous 16 h to eliminate the effects of a temporary threshold shift. Air conduction is measured by ear phones placed on the ears, while bone conduction is measured by placing a vibrator in contact with the skull behind the ears.

Each ear is evaluated separately and test results are reported on a graph known as an audiogram. Comparison of air and bone conduction allows classification of hearing loss as conductive or sensorineural.

2.5.1 The audiogram in case of NIHL is characterized by an onset of hearing loss at 4000 Hz, visible as a dip in the audiogram

As exposure to excessive noise level continues, neighboring frequencies are progressively affected and the dip broadens, intruding into neighboring frequencies. NIHL is usually bilateral and shows a similar pattern in both the ears. The difference between the two ears should not exceed 15 dB at 500, 1000 and 2000 Hz and 30 dB at 3000, 4000 and 6000 Hz, respectively.

2.5.2 Best practices of the Hearing Conservation Program

The most effective way to prevent NIHL is to protect the worker from hazardous noise at the workplace.

Hearing protectors should be used when engineering controls and work practices are not feasible for reducing noise exposure to safe levels. A personal hearing protection device is a device designed to reduce the level of sound reaching the eardrum. Ear muffs, ear plugs and ear canal caps are the main types of hearing protectors. To select hearing protectors, we should consider the following:

- The workers who will be wearing them.
- The need for compatibility with other safety equipment.
- Workplace conditions such as temperature, humidity and atmospheric pressure.

A variety of style should be provided so that workers may select a hearing protector on the basis of comfort, ease of use and handling and impact on communication. Each worker should receive individual training in the selection, fitting, use, repair and replacement of hearing protectors.

Table 3 OSHA's / Indian Factories Act (Schedule II) Permissible Exposure Limits for Noise in Air:

Sr.	Exposure Intensity	Permissible Duration
1.	82-85 dBA	16 hours
2.	90 dBA	8 hours
3.	95 dBA	4 hours
4.	100 dBA	2 hours
5.	105 dBA	1 hours
6.	110 dBA	30 mins
7.	115 dBA	15 mins
8.	More Than 115 dBA	0 Mins

The most common excuses reported by workers for not wearing hearing protectors include discomfort, interference with hearing speech and warning signals and the belief of workers that there is no control over an inevitable process that causes hearing loss.[10].

Given adequate education and training, workers can realize the crucial importance of wearing hearing protectors.

2.5.3 Vibrations Exposure Hazard

Introduction to hazards of Vibrations [13].

Vibration is defined as oscillatory motion. Oscillatory displacement involves alternate velocity in one direction and then a velocity in the opposite direction. This change of velocity means that the object is constantly accelerating, first in one direction and then in the opposite direction. The oscillatory motion from a source, e.g., a vehicle or a tool, may be simple harmonic sine wave or a multiple wave complex differing in frequency and acceleration; or a random non- repeating series of complex waves.

The human responses to vibration depend on the part of the body that is exposed. There are two broad types of vibrations that workers are exposed to, Vibrations can be classified as 2 types based on mode of transmission:

- Hand Transmitted Vibration: When vibrations transmit from tools to the hand-arm system it is referred to as Hand-transmitted vibration (HTV). Hand-arm vibrations occur in employees who use regularly the hand-held machines.
- Whole body Vibration: Whole body vibrations are mechanical vibrations transmitted to the body via buttocks or back in case of sedentary work , via feet in case of work done standing or the head and back while working in supine position

Prevalence of vibration related health hazards

In India prevalence of vibration hazard related health problems are hardly documented. Dasgupta and Harrison studied 66 drillers and 35 blasters as control subjects from limestone mines. They reported a significantly higher prevalence of tingling, numbness, paresthesia (18.2%); pain in finger, wrists, arms, etc. (31.7%); stiffness in hand (13.6%); and hyperhidrosis (48.5%) among drillers as compared to blasters. The prevalence of ulnar neuropathy and soft tissue wasting in hands was also significantly higher among the drillers. They concluded that complaints of neurological symptoms in the musculoskeletal problem accounts for nearly 70 million visits to doctors.

Although the problems these workers faced was not only caused by the exposure to vibration (it also included wrong posture, repetitive motion etc. i. e. Ergonomic Problems) the role of vibrations in causing Work-related musculoskeletal disorders (WRMSDs) cannot be neglected [11].

In 2008, according to the survey conducted by National Hazard Exposure Worker Surveillance (NHEWS) (Australia) reported that overall:

- 24% percent of workers were exposed to vibration at workplace
- 43% of workers were exposed to HAVs, 38% to WBVs, 17% to both
- 27% of workers reported that they received training
- Large percentage of workers in smaller workplaces reported they were not provided with any vibration control measures

Whole-body vibration and segmental vibration need to be studied separately because they are measured and evaluated using different standards. They also require different control measures and have differing effects on the human body.[17].

Hand and Arm Vibration Syndrome (HAVs) / Segmental Vibration Syndrome

Jackhammers are used both in opencast and underground mines; and the operators, popularly known as drillers, are regularly exposed to hand-arm vibration (HAV). Vibrating hand tools like hand drills, chipping machine, riveting guns; control systems of modern large drill machines, locomotive handles; and hand-held grinders, scrapers, etc., are other sources of HAV exposure in mines.

Regular exposure to vibration causes both vascular and neural disorders. Involvement of arms manifest as vibration-induced white finger (VWF) or hand-arm vibration syndrome (HAVS). In 1911, Giovanni Loriga of Italy first reported HAVS among stone cutters using pneumatic hammers on marble and stone blocks.

They suffered from finger-blanching attacks similar to the digital vasospastic response to cold or emotional distress, described by Raynaud in 1862. Later in the U.S, it was found to result from daily use of vibrating pneumatic hand tools (air-hammers) by workers in limestone quarries of Indiana.[16].

The clinical symptoms for HAVs

- Tingling and/or numbness in the finger(s) initially - similar to but not same as Carpel Tunnel Syndrome.
- As the exposure continues, the appearance of a single white or blanched fingertip occurs - usually, but not always - in the presence of cold.
- With further exposure, these attacks increase in number, intensity and duration, especially in cold conditions. In the later stages, HAVS attack will occur in all seasons. Simultaneous combination of vibration, cold and nicotine (from smoking) are particularly harsh since all three tend to act as synergistic vasoconstrictors. Later stages of HAVS are generally irreversible.
- In extreme and rare cases, the loss of blood supply to the fingers can lead to gangrene, which may require amputation.

The existence of sensory and vascular components in HAVS led to the adoption of the Stockholm grading based on the subjective history supported by the results of clinical tests to classify the severity.[14].

Table 4 Stockholm workshop scale for classification of hand- arm vibration syndrome

White Finger Syndrome due to Raynaud's phenomenon		
Stage Grade		**Description**
0	-	No attacks
1	Mild	Occasional attacks affecting only the tips of one or more fingers.
2	Moderate	Occasional attacks affecting distal or middle (rarely also proximal) phalanges of one or more fingers.
3	Severe	Frequent attacks affecting all phalanges or most fingers.
4	Very severe	As in stage 3, with trophic changes in the finger tips.
Sensory neural effects		
0 SN	-	Exposed to vibration bur no symptoms.
1 SN	-	Intermittent numbness, with or without tingling.
2 SN	-	Intermittent or persistent numbness, reduced sensory perception.
3 SN	-	Intermittent or persistent numbness, reduced tactile. Discrimination and or manipulative dexterity.

Whole Body Vibration

The most pronounced long-term effect of whole-body vibration is the damage to the spine. In the spinal region is the most frequently affected is the lumbar part, where spinal deformation, lumbago and sciatica can develop. Other organs systems, such as peripheral and autonomic nervous, vestibular, vascular, digestive and reproductive organs are also liable to be affected [15].

Damage to the body from exposure to vibration depends on:

- Length of exposure time
- The frequency of vibration, Magnitude
- Amplitude

Vibration transmitted to the body through the supporting surfaces such as feet, buttocks or back is known as whole-body vibration (WBV). There are various sources of WBV in the mining industry, such as the seat-transmitted vibrations from dumper, dozer, shovel, backhoes, load-haul-dump vehicles (LHD), road graders, etc.;

WBV transmitted through feet while standing on or moving near vibrating machines like various types of crushers, vibrating screen or while operating certain types of loaders/ drilling rig, operating from standing on centrifuge tank, mud pump, and shale shakers.

There is strong epidemiological evidence that occupational exposure to WBV is associated with an increased risk of lower back pain, sciatic pain and degenerative changes in the spinal system, including lumbar intervertebral disc disorders.

Symptoms of Whole Body Vibration

There is a shortage of conclusive evidence to establish 1) The probability and extent of vibration-induced injury and 2) a definite dose-response relationship between whole-body vibration and injury or health damage. Results from epidemiological studies, subjective data, biodynamic models and knowledge of the physical properties of the body reveal ill effects of WBV. These constitute:

- *Diseases of spinal column*

These are very common and associated with long-term exposure to whole-body vibration. The back is especially sensitive to the 4-8 Hz vibration range. WBV exposure has been linked to severe lower back pain (lumbar spine) and degeneration, bucking/ slipping of the lumbar discs. Chronic exposure to WBV takes some time before lower back problems develop. Poorly designed vehicle seats, awkward postures and manual cargo handling in addition to WBV exposure tend to aggravate lower back pain symptoms. There is a higher risk of varicose veins, menstrual disorders, proneness to abortion and hyperemesis gravidarum in women exposed to WBV. Further, there is a distinct increase in blood volume during the phases of ovulation and menstruation [16].

- *Digestive system diseases*

Are often observed in persons exposed to whole-body vibration over a long period of time. This is due to resonance movement of the stomach at frequencies between 4 and 5 Hz.

- Prolonged exposure to whole-body vibration at frequencies below 20 Hz affects cardiovascular system and results in hyperventilation, increase in heart rate, oxygen intake, pulmonary ventilation and respiratory rate

3 Conclusion

- There is lack of awareness about vibration hazard and its ill effects. This needs to be rectified.
- The exact number of Oil mine workers occupationally exposed to vibration is not known. Estimated number may be in lakhs.
- There is an urgent need to investigate the population suffering from vibration exposure above safe limits and its ill effects on their health.
- The clinical presentation of HAVS in India is not the classical Vibration induced White Finger (VWF). Subclinical manifestations and dose- response relationships need to be worked out for HAV and WBV in Indian miners.
- Indian mining legislation is not specific enough to develop a definite strategy for evaluation and control of occupational vibration. Specific rules based on Indian data need to be framed.
- Vibration monitoring should be made mandatory for all semi-mechanized and mechanized mines.
- The effective way of reducing hazards of the vibrations is through precautions. Precautions against hazards of vibration:
  - Do routine medical check-ups of employees for the early detection of HAVS
  - Limit time spent by employees with vibrating tools/vibrating surface
  - Ensure the vibrating equipment are well maintained to reduce excess vibration

- Creating awareness among employees.
- Use of protective equipment's like vibration damping seats, vibration damping pads etc.

- Noise is the hazardous industrial pollutant causing severe hearing loss in workers of every country in the world. The workers in industries like mining, construction, printing, saw mills, crushers, etc are at risk. Workers are exposed to high levels of noise throughout their lifetime of work, but there are very few NIHL studies in India to show its prevalence.
- Awareness should be created among workers about the harmful effects of noise on hearing and other body systems by implementing education and training programs.
- Research studies are needed to know the exact prevalence of NIHL among various industries in India.
- A national program should be established considering the amount of damage the NIHL causes to the quality of life of workers. The effective way of controlling NIHL is noise level reduction and protecting the worker from hazardous noise at the workplace. The various option of noise level reduction include may include:
  - The first and simple way to control the noise is through insulation.
  - Regular maintenance and observance of equipment to reduce the noise by replacing bearings and tightening of all loose part which can vibrate and create extra noise.
  - Choosing a quieter manufacturing process and equipments where possible (e.g. DC Engines, Bush bearing)
  - Putting silencers on the exhaust of the various flow machines.
  - Operating equipments at optimum level rather than at higher levels which increases the noise levels.
  - The precautions that must be taken from both the sides of the employee and the employer
  - Frequent monitoring of sound levels in where there is consistent high sound level.
  - Providing the workers with various type of hearing protection devices, PPEs as well as training in the selection, fitting, use, repair and replacement of hearing protectors.
  - Creating awareness among the employees about Noise-induced hearing loss(NIHL)
  - Frequent mandatory audiometric testing of employees for early detection.
  - The workers must also try to reduce the noise level during their off working hours when not necessary.

Compensation

Nearly 3 billion dollars has been paid in the U.S as compensation for NIHL in the last 2 decades.

In India, it was in 1996 that the first case got compensation, although, it was compensable since 1948 through the Employees State Insurance Act (1948). Awareness must be created among workers about the harmful effect NIHL could have on their lives.

Way Forward

In the past 20 years, curative treatment of NIHL and HAVS have been explored but as yet no promising results have been found. As they are irreversible once occurred, the best approach is prevention through taking precautions, implementing standard rules and regulation, expansion of training programs to create awareness and periodic mandatory health checkups for early detection of these diseases.

Compliance with ethical standards

Acknowledgments

The authors are grateful to the Oil & Natural Gas Corporation's top management, Board Members/ Executive Committee Members especially Director (Onshore)- Incharge HSE, ONGC for encouraging for conceptualization of this paper. Corresponding Author also wish to acknowledge GM- Support Manager & ED-HoI, Institute of Petroleum Safety, Health & Environment Management (IPSHEM), ONGC, Goa for their constant guidance and support.

Disclosure of conflict of interest

The authors declare no conflict of interest.

Limitation of Study

No standard published data available on Whole body Vibration & Occupational Noise induced hearing loss in India.

References

[1] Wang et al. Sex differences in noise-induced hearing loss: a cross sectional study in China *Biology of Sex Differences.* 2021; 12: 24.

[2] Kumar R, Sharma R, Kumar V, Khan AA. Relation of work stressors and work related MSDs among Indian heavy vehicle drivers. Indian J Occup Environ Med. 2021; 25: 198-203.

[3] Stedman TL. Stedman's Medical Dictionary. Baltimore: Williams and Wilkins. 1990.

[4] Nelson Dl, NelsonRY, Concha-Barrientos M, Fingerhut M. The global burden of occupational noise-induced hearing loss. Am j Ind Med. 2005; 48(6): 446-58.

[5] Mrerna R, Ylikoksi M, Makitie A, Pirovola U, Ylikoski J. Occupational noise-induced hearing loss reports and tinnitus in Finland. *ActaOtolaryngol.* 2007; 127(7):729-35.

[6] Lynch ED, Kil J. compound for the prevention and treatment of noise-induced hearing loss.DrugDiscov Today 2005; 10(19): 1291-8.

[7] Thai T, Kucera P, Bernatik A. Noise Pollution and Its Correlations with Occupational Noise-Induced Hearing loss in Cement Plants in Vietnam. Int J Environ. Res. Public Health. 2021; 18: 4229.

[8] Mukkamala N, Parmar L, Kumar P. Musculoskeletal disorders in tyre manufacturing workers. Indian J Occup Environ Med. 2021; 25: 133-7.

[9] Ramita KL, Ankita T, Alankruta RV, Anitha CT. A cross-sectional study on occupational health and safety of municipal solid waste workers in Telangana, India. Indian J Occup Environ Med. 2021; 25: 169-77.

[10] Nandi, Subroto S, Sarang V, Dhatrak. Occupational noise-induced hearing loss in India" *Indian journal of occupational and environmental medicine*. 2008; 12(2): 53-6.

[11] Occupation Safety & Health Administration, a federal Regulatory Agency of USA Official Website [https://www.osha.gov/noise/hearing-programs last accessed on 31.03.2022.].

[12] Bogadi-Sare A. Djelovnje opcih vibracija: nedovoljno poznat zdravsteni problem [The effect of whole-body vibration: an unrecognised problem]. *Arhiv za higijenu rada I toksikologiju*. 1993; 44(3): 269-279.

[13] Victorian Trades Hall Council for Occupational Health & Safety in Autralia official Website page on effects of Vibration Hazard [https://www.ohsrep.org.au/effects_of_vibration last accessed on 31.03.2022.].

[14] Kumar R, Sharma R, Kumar V, Khan AA. Predictors of Whole-Body Vibration Exposure among Indian Bus and Truck Drivers. J Phys Conf Ser. 2021;1854(1).

[15] Srivastava A, Mandal B. Risk from vibration in Indian mines. Indian J Occup Environ Med. 2006;10(2):53.

[16] Singh H, Prakash C, Singh A, Singh S, Singh LP. Investigation of occupational whole-body vibration exposure among Indian tractor drivers. Int J Hum Factors Ergon. 2018;5(2):151.

[17] Ravinder Kumar RS, , Vikas Kumar1 AAK. Relation of Work Stressors and Work-related MSDs among Indian Heavy Vehicle Drivers Ravinder. Indian J Occup Int Med. 2019;23(1):8–13.