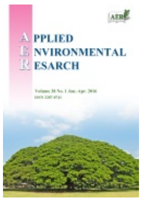
App. Envi. Res. 41(1) (2019): 38-45

Applied Environmental Research

Journal homepage: http://www.tci-thaijo.org/index.php/aer



Assessment of Hearing Loss among Workers in a Power Plant in Thailand

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Article History
Submitted: 1 February 2018/ Revision received: 7 May 2018/ Accepted: 10 May 2018/ Published online: 20 February 2019

Abstract

Noise exposure in the working environment is a major cause of hearing impairment for workers; an audiogram hearing threshold level above 20 dB is considered irregular. In this study, audiometric data were analyzed with the objective of assessing hearing loss among power plant workers based on their age, noise exposure level, years of working, and work characteristics. A cross-sectional study was conducted to assess hearing level data for 672 workers reserved by the Health Care Unit of the power plant. The most recent audiometric data presented during 2013-2015 were used in the statistical analysis at 5 % level of significance. It was found that the most dominant frequency with reference to age and work experience is the test frequency at 4,000 Hz. The most prominent suffering significant hearing loss for both ears is the age group of 50-60 years, consistent with more than 35 years of working. The most significant exposure level is noise level at 81-84 dBA for the left ear only. The work characteristics were found to be the most significant factor affecting hearing loss in both ears. The t-test reveals no significant difference in hearing loss in both ears at all test frequencies. Hearing loss is found to occur at 4,000 and 6,000 Hz; therefore, there is a necessity to implement noise control measures specifically for each work group. Although there is an educational and training program in the power plant, all workers should still be educated continuously on how to use hearing protection equipment correctly to enhance awareness of the hazards of noise to hearing. Periodic audiometry should be performed to early detect noise-induced hearing loss specifically the notch occurring at 4,000 and 6,000 Hz, together with engineering control in order to reduce unwanted sound.

Keywords: Audiometry; Hearing loss; Industrial noise; Noise exposure; Power plant

Introduction

Industrial noise is a major health problem in many industries because noise-induced hearing loss (NIHL). For the human ear, the most sensitive sound frequencies lie in the range of 1,000-4,000 Hz. In industry, excessive noise exposure, which is over 85 dB A per 8 hours a day, is frequent, and can lead to both auditory and extra-auditory effects. The most significant effect is NIHL- hearing damage caused by prolonged exposure to excessive noise [1]. Another detrimental effect is to interfere with communication and concentration, resulting in unsafe working conditions. Annoyance is a third undesirable effect, affecting workers' mood and wellbeing [2].

Prolonged exposure to excessive industrial noise may cause a range of neurobehavioral changes, psychological stress, and discomfort in daily life without showing overt signs and symptoms of acute or chronic disorders [3]. The nature and extent of damage caused by industrial noise depends on several factors, including loudness, frequency, continuity, variation with time, time of occurrence, information content, origin of the sound, recipient's state of mind and individual temperament, and background noise level. According to the World Health Organization, excessive exposure to noise can lead to many health problems, including auditory stress, physical reactions such as elevated blood pressure, heart rhythm and muscle contractions, increased production of adrenaline and other hormones, irritability, stress, insomnia and anxiety [4].

Power plants are among the noisiest workplaces, with a large number of workers exposed to noise levels between 80-90 dB, according to routine noise monitoring [5]. Within such plants, major sources of noise include steam turbine generators (STG), combustion inlet filter house, and the exhaust stack or heat recovery steam generator (HRSG). All these result in NIHL as a serious and pervasive occupational health issue in power plants. However, there are few studies of NIHL among workers in power plants. One such study found that the prevalence of NIHL among maintenance workers and product workers from thermal power plants and combined cycle plants of the Electricity Generating Authority of Thailand (EGAT) was 3.4 per 100 [6]. A study in a hydroelectric power plant demonstrated that workers were routinely exposed to noise levels in the range of 95-110 dBA at frequencies of 2,000-8,000 Hz. Within the first 10 years of exposure to such noise, hearing loss was found, including an audiometric notch at 4,000 Hz [7]. This 4,000 Hz frequency is obviously of most concern for industrial hygienists when assessing workers' hearing related to occupational noise exposure [8].

Audiometry is essential to confirm any hearing discrepancy because of the unreliability of physical tests of hearing, such as the whispered voice or the finger-rub test. Screening audiometers for workers normally test at octave band frequencies, with a range between 500 and 2,000 Hz to test speech, and 3,000-6,000 Hz for loss of high frequency hearing. The most common method for assessment of hearing loss is pure-tone audiometry, performed at frequencies of 250 to 8,000 Hz. An audiogram hearing threshold level above 20 dB at all frequencies is considered unusual [9]. Audiometric testing programs provide practice guidelines to identify NIHL, advising that: "Assessing the low and high frequencies separately takes account of the fact that NIHL preferentially affects the high frequencies, with hearing loss beginning characteristically around 4,000 Hz before spreading to the lower frequencies as the 4,000 Hz loss progresses (the 4,000 Hz dip)". From our own knowledge, although NIHL occurs among workers of power plants, there are still few studies directly targeting workers in power plants. Therefore, the main purpose of this study is to define hearing threshold levels (HTLs) based on audiometric data of power plant workers in different working characteristics. In order to better understand the characteristics of hearing impairment, specific groups were defined where peaks of hearing loss were found using different statistical methods.

Materials and methods

A cross-sectional study was conducted to investigate hearing thresholds covering 672 workers at a power plant. The research protocol to analyze the audiometric data was reviewed and approved by the Ethics Committee of Thammasat University No.3 (COA No.288/ 2560). Samples were obtained by purposive sampling. The audiometric data were taken from the Health Care Unit of a power plant in Thailand and all data were controlled according to the American National Standards Institute (ANSI) standard, by a certified audio technician. The audiogram at frequencies 3,000, 4,000 and 6,000 Hz were used to assess a possible notch due to exposure to different noise levels. From the existing data collected by the power plant, the samples were divided into four age groups: ≤ 30, 31-40, 41-50, and 51-60 years, eight work experience groups: 0-5, 6-10, 11-15, 16-20, 21-25, 26-30, 31-35, and > 35 years, three exposure levels: ≤ 80, 81-84, and ≥ 85 dB A, and ten work characteristics base on their work location, so-called Similar Exposure Groups (SEGs). Sound Level Meters, Larson David model LXT1, were used for measuring actual noise levels which workers were exposed to. Sound level meters was set to "A" frequency weighting, "Slow" time response, and “5” exchange rate in order to take several measurements at different locations within the workplace. Noise contour maps were then created, and combined with information on worker location throughout the day to estimate individual exposure levels.

The latest audiometric data presented during the period 2013-2015 were used in the statistical analysis using SPSS Statistics version 23 for Windows. The statistics used in this study were as follows: Descriptive statistics were used to describe characteristics of respondents; a Generalized Linear Model ANOVA was used to calculate mean differences, and the t-test was used to analyze any different audiograms between left and right ears, with significance set at 0.05.

Results and discussion

Audiometric data of 672 individuals, sampled between 2013 and 2015 were taken from the Health Care Unit of the power plant. The sample comprised 655 males and 17 females. According to the data of workers in the power plant, 58 % of the respondents were 51-60 years old, 56 % had more than 31 years of experience, and 87 % of the samples were exposed to noise levels higher than 80 dB A. All data were used to assess high frequency notches at 3,000, 4,000, and 6,000 Hz caused by exposure to different noise levels. These frequencies are typically found in the workplace and have been well documented as contributing to hearing loss [7]. The sample respondents were separated into four age groups, eight work experience groups, three noise exposure levels and ten work characteristics based on their work location, as depicted in Table 1. Progressive hearing loss in both ears at high frequencies was found in long-term workers in the power plant.

As shown in Figure 1, the audiogram reveals a bilateral hearing threshold with no hearing loss below the low frequency range (500-2,000 Hz), and notches at 4,000 and 6,000 Hz, followed by a slight recovery at 8,000 Hz. Average hearing levels of the entire samples at 500, 1,000 and 2,000 Hz were above the average at 3,000-6,000, within the normal range, and the hearing threshold level at 8,000 Hz is typically better than the deepest part of the “notch”. This pattern is associated with the audiogram of NIHL [10], which is documented as initially appearing as a threshold shift at frequencies of 3,000-6,000 Hz in pure-tone audiometry [11]. In addition, it is widely confirmed that with exposure to extensive band, steady noise, or impulse noise, the first sign of hearing impairment is typically a dip or notch in the audiogram maximal at 4,000 Hz, with recovery at 6,000 and 8,000 Hz [12].

Table 1 Sample characteristics in mean hearing threshold level at 3,000, 4,000 and 6,000 Hz

Factor	Hearing threshold level in decibel (dB HL)					
	3,000 Hz		4,000 Hz		6,000 Hz	
	Right	Left	Right	Left	Right	Left
Age (years)						
≤ 30	16.13	17.41	16.75	18.44	17.83	18.16
31 - 40	17.50	19.44	18.33	20.56	20.00	20.00
41 - 50	21.82	22.21	27.95	27.92	26.75	26.10
51 - 60	29.68	30.47	36.47	36.98	37.75	36.33
Work experience (years)						
0 - 5	15.92	17.39	16.41	18.70	18.04	18.21
6 - 10	16.59	18.18	18.64	17.73	17.73	17.95
11 - 15	21.67	20.83	16.67	20.83	19.17	24.17
16 - 20	16.88	16.88	21.25	21.25	23.75	18.75
21 - 25	22.07	22.55	27.17	27.77	25.54	26.09
26 - 30	22.39	23.84	30.43	30.29	30.65	28.99
31 - 35	29.37	30.00	36.00	36.19	37.27	35.74
> 35	31.03	31.55	38.09	39.12	38.81	37.42
Exposure level (dBA)						
≤ 80	26.67	28.38	32.82	34.99	35.22	34.70
81 - 84	24.34	24.40	29.61	28.82	30.00	28.07
≥ 85	25.86	26.95	31.37	32.57	31.83	31.49
Work characteristic						
Group A	26.11	36.56	38.33	47.67	39.44	42.11
Group B	28.68	28.40	33.77	33.77	36.04	31.70
Group C	25.00	24.92	31.17	30.51	32.30	30.12
Group D	23.58	23.77	27.96	28.64	30.43	29.44
Group E	26.46	27.69	31.77	32.85	31.42	31.35
Group F	23.16	24.66	28.42	29.27	28.63	28.76
Group G	21.98	21.04	27.71	25.21	25.52	23.65
Group H	26.96	31.30	35.00	38.91	33.70	34.57
Group I	30.80	31.40	36.20	41.40	41.76	42.20
Group J	29.33	29.83	33.50	22.17	34.00	33.83

Note: Group A: Chemical & Environment; B: Civil; C: Operator Thermal Plant; D: Operator Combine Cycle Plant; E: Mechanical Maintenance; F: Electrical Equipment and Instrumentation Maintenance; G: Planning; H: Repair Parts; I: Security; J: Office and services.

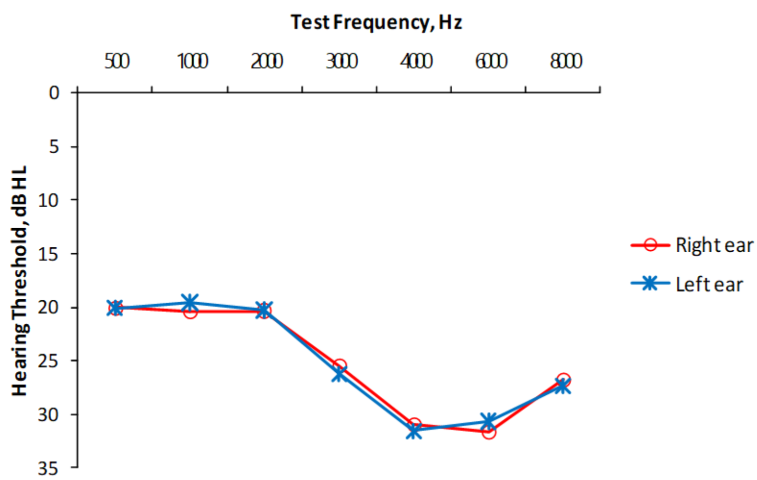

Figure 1 Mean of hearing threshold levels with detail in test frequencies.

The results indicate that the mean of hearing threshold level is in the frequency range of 3,000-6,000 Hz for the whole samples, and that hearing impairment seems to occur primarily at frequencies of 4,000 and 6,000 Hz. It is possible that the audiogram variability is higher at 6,000 Hz than 4,000 Hz as the 6,000 Hz notch is temporary, and potentially occurred [13]. This is caused by an interchangeably 6,000 Hz and 4,000 Hz notch transformation.

Consequently, audiometric variability, though known to exist, does not seem to have a consistent effect at 6,000 Hz. As a further confounding factor, a notch at 6,000 Hz has been detected in individuals exposed to impulse noise [14]. Although the 4,000 Hz notch is a well-established clinical sign and may be valuable in confirming the diagnosis of occupational hearing loss, the 6,000 Hz notch is variable and of limited diagnostic value.

Table 2 shows average binaural hearing level at 500-2,000 Hz, 3,000-6,000 Hz and 8,000 Hz and a sensorineural hearing insufficiency that begins at higher frequencies (3,000 to 6,000 Hz). The null hypothesis assumed that there is no significant difference between left and right ears with respect to hearing level. A two-tailed t-test was conducted and found that there was indeed no significant difference between left and right ears ($p > 0.05$), associated with the study of Kerketta et al. [15], which studied the hearing loss among workmen at open-cast chromite mines. The t-test also reveals no significant difference in hearing loss between both ears due to age, work experience, noise exposure level and work characteristic at all test frequencies. Considering the audiogram separately between lower and higher frequencies and taking into account the fact that hearing loss among workers in the power plant preferentially affects the higher frequencies, hearing impairment typically commences at around 4,000 or 6,000 Hz before becoming evident at lower frequencies. This study confirmed the prevalence of hearing loss at 4,000 and 6,000 Hz of power plant workers, attributable to industrial noise exposure; this far exceeded the hearing loss at lower frequencies critical to the ability to understand speech. This finding is consistent with earlier reports by May 2000 [10] which presented the criteria for a diagnosis of hearing loss due to audiometric examination with bilateral deficits most prominent in the 3,000-4,000 Hz range often with a typical “notch" or upturn at 8,000 Hz.

Analysis of multiple comparisons of means by the Gabriel method as demonstrated in Table 3 reveals that the test frequencies at 4,000 and 6,000 Hz are found to be the most significant test frequencies for the right ear; the maximum hearing loss at 5 % level of significance is suggestive. The test frequency at 4,000 Hz was found to be the most influential frequency with respect to age (50-60 years) and work experience (> 35 years), the frequency of 6,000 Hz was related to work characteristics, but no specific frequency was found to be significant for exposure level. Similarly, the study reveals that the most dominant frequency for the left ear was 4,000 Hz with reference to all factors (age, work experience, exposure level and work characteristics). The analysis also revealed that the age group 50-60 years and workers with more than 35 working experience suffer the most significant hearing loss in both ears. The noise level at 81-84 dBA is found to be the most influential exposure level. Furthermore, the work characteristic was found to be the most significant factor affecting hearing loss in both ears. The influential subgroups of work characteristic for right ear are group F; Electrical Equipment & Instrumentation Maintenance and group G; Planning. Meanwhile, group C; Operator Thermal Plant, group D; Operator Combine Cycle Plant, group F; Electrical Equipment and Instrumentation Maintenance and group G; Planning, were the most significant subgroups for left ear hearing loss. The finding clearly indicates that the severity of hearing impairment depends on the specific characteristics of noise in each working environment [16].

The results of this study also suggest that hearing loss of workers in the power plant develops first at high frequencies, with no significant difference in hearing loss between left and right ears. Because high frequency hearing loss alters reception of consonant sounds, it reduces speech recognition [17]. In addition, high-frequency hearing loss may be a precursor to further hearing loss affecting mid- and lower-spectrum speech frequencies. Regardless of the exact cellular mechanism, several phenomena related to loud noise do appear to be well established. However, there are other contributing factors such as genetics, age [18], certain infections, birth complications, trauma to the ears, and certain medications or toxins that can all cause hearing loss [19]. Hence, these factors should be considered while conducting research.

Table 2 Hearing level (dB HL) between left and right ears of the whole samples

Hearing threshold level (dB)	500-2,000 Hz		3,000-6,000 Hz		8,000 Hz	
	Mean	SD	Mean	SD	Mean	SD
Right ear	20.27	9.08	29.31	15.29	26.74	19.00
Left ear	19.99	8.22	29.47	14.33	27.36	19.04
p value	0.063		0.217		0.094	

Table 3 Most influential test frequencies and significant subgroups

Factor	Most significant frequency	*P value*	Significant Sub-group	*P value*
Right ear				
Age	4 kHz	< 0.001	50 - 60 years	< 0.001
Work experience	4 kHz	< 0.001	> 35 years	< 0.001
Exposure level	-	-	-	-
Work characteristic	6 kHz	0.009	Group G	0.012
			Group F	0.024
Left ear				
Age	4 kHz	< 0.001	50 - 60 years	< 0.001
Work experience	4 kHz	< 0.001	> 35 years	< 0.001
Exposure level	4 kHz	0.002	81 - 84 dB A	0.005
Work characteristic	4 kHz	< 0.001	Group G	0.001
			Group F	0.006
			Group D	0.007
			Group C	0.014

Note: Group C; Operator Thermal Plant, D; Operator Combine Cycle Plant, F; Electrical Equipment & Instrumentation Maintenance, G; Planning,

Conclusions

Hearing loss is found to occur initially at 4,000 and 6,000 Hz among workers in the power plant in Operator and Maintenance positions, particularly in workers aged 50-60 years or with more than 35 years work experience, or with exposure to noise level at 81-84 dBA. Because hearing loss due to noise is irreversible, early detection and appropriate preventive intervention is critical. Therefore, workplaces where sound levels are an average of 85 dB or higher average for more than eight hours must implement programs to preserve the hearing of workers. There is a strong necessity to implement noise control measures specifically for each work group. All workers should be trained and motivated to use hearing protection equipment correctly to reduce hazards of noise exposure. Workplaces must provide free hearing protection devices such as earplugs and earmuffs to workers as well as systematically implement appropriate engineering control measures to reduce noise exposure. Early diagnosis of NIHL can prevent hearing loss from worsening to impact on speech frequencies; periodic audiometry should therefore be employed to identify early hearing loss, particularly at the notch frequencies of 4,000 and 6,000 Hz. Where the noise cannot be controlled through elimination of the source or substitution of quieter instruments or processes, engineering controls should be applied such as redesigning machinery or equipment, constructing sound barriers and enforcement of use of hearing protection equipment.

Acknowledgements

The authors are grateful to the staff of the Health Care Unit of the power plant and also to the workers participating in this project.

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