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Evaluation of Noise Emission in a Textile Plant

Zekeriya DURAN[1], Mehmet GENÇ[2*], Tuğba DOĞAN[3], Bülent ERDEM[4]

[1]Department of Drilling Program, Sivas Technical Sciences Vocational School, Sivas Cumhuriyet University, Sivas, Turkey.
[2]Department of Drilling Program, Hekimhan Mehmet Emin Sungur Vocational School, Malatya Turgut Özal University, Malatya, Turkey.
[3] Department of Industrial Engineering, Engineering Faculty, Sivas Cumhuriyet University, Sivas, Turkey.
[4]Mining Engineering Department, Engineering Faculty, Sivas Cumhuriyet University, Sivas, Turkey.

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ABSTRACT: The textile industry is characterized by the use of complicated machinery in mass production methods in order to meet increased consumption demands. This situation brings with it some issues for the employees. Many of the machines used in the textile industry are operating at high noise levels. In this study, noise measurements taken from dyeing/finishing and weaving divisions in an integrated textile plant in Malatya city, Turkey were evaluated. Frequency distribution of dominant noise is also examined. Workers in the weaving division were exposed to higher levels of noise than those in dyeing/finishing. Accordingly, the noise level in weaving ranged from 99.2 to 101.1 dBA, while that in dyeing/finishing ranged from 77.1 to 79.3 dBA. It is also outside the 4000 Hz frequency zone, where the dominant frequencies of the maximum noise levels exposed by those working in the measured divisions fall in the middle frequency range to which the ear is most sensitive. Considering the frequency distribution, noise levels in the 4000 Hz region are calculated to be between 84.2 and 86.8 dBA in the weaving division and 60.0 to 61.9 dBA in the dyeing/finishing division. A noise histogram showed that noise in the weaving division had spread over a wider range than the dyeing/finishing division.

Keywords: Noise exposure, ⅓ octave band frequency, spectral analysis, frequency-noise relationship, textile plant.

1. INTRODUCTION

A negative working environment can lead to physical and mental health problems. Today, despite technological achievements, noise in the workplace stands up before us as a health problem. The textile industry is one of the most important locomotives of employment and foreign trade in Turkey. Production in the textile sector is based largely on human power. Workers employed in this sector may be exposed to significant noise in their workplaces.

Health is defined by the World Health Organization (WHO) "*a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity* " The purpose of occupational health is that of employees; maximizing and maintaining physical, mental, and

*Corresponding Author: mehmet.genc@ozal.edu.tr
ORCID number of authors: [1] 0000-0002-9327-8567, [2] 0000-0002-9950-0720
[3] 0000-0002-2628-4238,[4] 0000-0002-1226-9248

social well-being situations, placing them in jobs appropriate to their characteristics and risk factors in the workplace environment, ensuring protection from the risk factors harmful to health caused by working conditions and work environment. The working time of the employee in the workplace, the wage he received, the ways of paying wages, leave, etc. matters constitute the working conditions. The factors that are the sources of physical, chemical, biological, ergonomic and psychosocial factors that affect the health of the employee directly or indirectly, instantly or after a certain period in the production process constitute the working environment.

Sound can be measured and is an objective concept whose existence does not change depending on the person. Noise is a subjective concept. Noise can be defined as "unpleasant, unwanted, disturbing sound" [1]. Not every vibration in the ear is perceived as sound. Sound levels a human ear can detect are between 20 Hz and 20 kHz frequency limits [2, 3]. The human ear is not equally sensitive to all sound frequencies in this range, but is generally more sensitive to high frequency sound than low frequency sound. This sensitivity is greatest for sound frequencies between 2000 Hz - 5000 Hz. The frequency of sound to which the ear is most sensitive is 4000 Hz [4, 5].

A normal conversation is in the frequency range of 200 Hz - 10000 Hz. As can be seen, the frequency range to be examined is very wide and the use of fixed width bands is quite time-consuming in many cases. For this reason, the frequency range that should be examined in sound analysis is divided into sections called octave bands. 1/1 octave range is sufficient for analysis [6, 7]. There are different approaches in the literature to define the frequency ranges that the human ear can hear as low, medium and high. Frequencies below 200 Hz are low frequency sound, frequencies from 200 Hz to 2000 Hz are medium frequency sound and >2000 Hz frequency, high frequency sound [8]. Some researchers called sounds less than 200 Hz as low frequency sound [9-11]. Effective in personal protection, the noise intensity of the headphones; 30 dBA at low frequencies and 50 dBA at high frequencies. Similarly, polyurethane plugs placed in the outer ear canal are known to reduce by 25 dBA at low frequencies and 40 dBA at high frequencies [12].

Noise may cause hearing loss, nervous system and circulatory system disorders and disturbed hormonal balance. Another common negative effect of noise is sleep loss. It has also been stated that if one is exposed to noise for a prolonged time, it causes changes (dilatation) in heartbeat, blood pressure and respiration and it affects uric acid and lipid levels in the blood [13]. The potential negative effects of noise on human health are listed in Table 1.

Table 1. Noise levels and disturbances caused [14, 15]

Noise level	Sound pressure (dBA)	Effects on human health
1	30–65	Discomfort, anger, passion, sleep disturbance and concentration disorder, feeling of boredom
2	65–90	Physiological reactions; increased blood pressure, blood circulation disturbance, increased heart rate and breathing, decreased pressure in brain fluid, sudden reflexes, stress
3	90–120	Physiological reactions and headaches
4	120–140	Continuous damage to the inner ear, disruption of balance
5	>140	Serious brain damage, burst eardrum

The Occupational Safety and Health Administration of the USA (OSHA) sets the permissible exposure limit (PEL) of 90 dBA for all workers for an 8-hour day. But, where workers are exposed to a time-weighted average noise level of 85 dBA or higher over an 8-hour work shift,

OSHA mandates employers to implement a hearing conservation program in order to protect all workers in general industry. The "*Directive 2003/10/EC of the European Parliament and of the Council on the Minimum Health and Safety Requirements Regarding the Exposure of Workers to the Risks Arising from Physical Agents (Noise)*" [16] and the "*Regulation on the Protection of Workers from Risks Related to Noise*" issued by the Ministry of Labor and Social Security (MoLSS) both set the legal limits on noise exposure in the workplace, as follows [17]. It should be noted that the values are based on a worker's time-weighted average over an 8-hour day.

a) Lower exposure action values: ($L_{EX,8h}$) = 80 dBA or (P_{Peak}) = 112 Pa (135 dBC in relation to 20 μPa).
b) Higher exposure action values: ($L_{EX,8h}$) = 85 dBA or (P_{Peak}) = 140 Pa (137 dBC in relation to 20 μPa).
c) Exposure limit values: ($L_{EX,8h}$) = 87 dBA or (P_{Peak}) = 200 Pa (140 dBC in relation to 20 μPa)

In a study conducted to determine the noise level of the weaving and yarn divisions in three textile factories in the Çukurova Region, the relationships between noise and frequency were examined. It is stated that the sound pressure level emitted by weaving machines is 78.3 to 100.8 dB, and 74.7 to 90.3 for spinning machines. It was also stated that the sound pressure level emitted by weaving machines ranged from 87.7 to 98.1 dB at the frequency of 4000 Hz, which the human ear was most sensitive, and 81.2 to 88.8 dB in spinning machines. It was stated that while the equivalent noise levels emitted by weaving machines ranged from 97.1 to 105.5 dBA, these values were between 89.7 and 93.9 dBA for spinning machines [18]. In another study, the sound level in the environment where the looms were located varied between 86 - 96 dBA indicating to high noise levels. It was commented that 35 % of the employees working for 20 years in the current 96 dBA sound environment would be deaf, unless necessary and correct measures were taken [19].

The study of Talukdar where one-minute exposure to sound levels above 100 dBA was emphasized, provided supportive results. It was concluded that noise exposure could cause permanent hearing loss. Besides, it was emphasized that textile workers, particularly weavers, suffered from occupational hearing loss [20]. In another study, it was stated that with the technological development, the noise level in the textile industry became a serious issue and an important occupational hazard. In some textile factories the maximum noise level has increased up to 95 dB, and the noise level has increased by an additional 5 dB with the combination of many machines. In another study the noise level inside the coating facility of a textile factory was measured experimentally and a noise emission model was developed [21]. Noise measurements were taken by ISO 9612 standard from various units in a textile plant and isobaric noise curves were drawn in the SURFER package.

The sound pressure level in the cotton beating unit was 79 dBA to 87 dBA, the average sound pressure level of the carding machines was 86 dBA at the frequency of 1000 Hz. It was also stated that the highest sound pressure level and dominant frequency in mixing were between 80 dBA and 250 Hz, and 86 dBA to 95 dBA in the cotton spinning unit, respectively [22]. Noise level was measured and analyzed with the MATLAB package at a textile factory in Ethiopia. It was concluded that spinning and weaving divisions were potential sources of noise [23]. In a textile company operating in the city of Uşak, noise measurements were taken and a questionnaire was applied to the employees. After examining the data the noise level was determined as 97.08 dBA. Supported with the survey results it was concluded that high noise

level reached could lead to permanent hearing losses, poor performance and low productivity in the workplace [24].

This study aimed to evaluate the noise exposure of workers in a textile plant in Malatya City. For this purpose, noise measurements were taken at different divisions and ⅓ octave frequency analysis was performed. The study also entails corrective measure suggestions in the case of excessive personal exposure to noise.

2. MATERIAL AND METHODS

In the textile plant, noise measurements were carried out following TS EN ISO 9612-2009 "*Acoustics - Determination of acoustic-occupational noise exposure - Engineering method*" and TS 2607 ISO 1999 "*Acoustics - Determination of occupational noise exposure and estimation of noise-induced hearing impairment*". However, following the permit agreement with the workplace management upon taking noise measurements, the physical details of the workplace layout can only be given in a simple sketch (Figure 1). In the layout of the plant, the weaving division and the dyeing/finishing division were separated into insulated sections. Thus, the noise generated in each unit did not affect the other division.

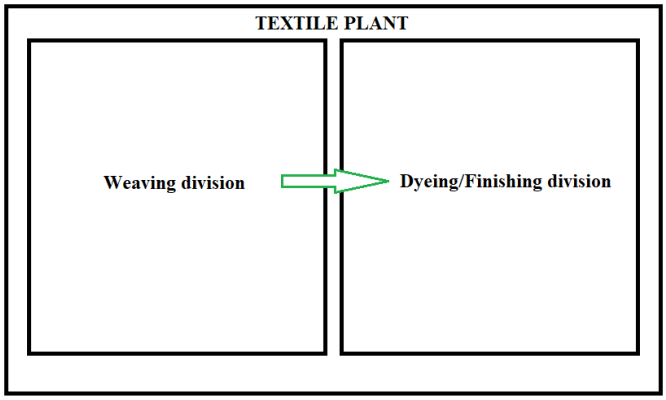

Figure 1. The textile plant layout.

The daily exposure level of employees ($L_{EX\text{-}8h}$) was calculated based on noise measurements taken in accordance with these standards. The root mean square (RMS) of the frequency-weighted sound pressure values was defined. The frequency-noise relationship was derived.

Noise measurements were carried out using a high-precision noise level measuring device suitable for all noise measurements included in the "*Regulation on the Assessment and Management of Environmental Noise*" by the Ministry of Environment and Urbanization [25]. The noise meter also meets the requirements stipulated in the IEC 61672-1: 2002 Standard and has an internal ⅓ octave band filter for frequency analysis (Figure 2). Noise measurements were made with A, C and Z (linear) frequency weighting by defining three different profiles.

Figure 2. Noise level measuring device used in studies [25].

3. RESULTS AND DISCUSSION

Noise measurements were taken in the dyeing/finishing division and weaving division of a textile plant, located in Malatya City. The sound pressure employees were exposed to was measured using A, C (peak) and Z-weighted filters. The noise parameters measured and calculated in accordance with the relevant standards are given in Table 2. The equivalent continuous sound level (L_{Aeq}) and the daily personal noise exposure ($L_{EP,d}$, $L_{EX,8hr}$) are given in Figure 3, where the minimum and maximum exposure action values and the exposure limit value are indicated. Evaluation of noise data has shown the following results.

a) A-weighted, C-weighted and Z-weighted $L_{EX,8h}$ in weaving division ranged from 99.2 dBA to 101.1 dBA, 100.4 dBC to 102.8 dBC and 100.6 dBZ to 103.1 dBZ, respectively.
b) $L_{EX,8h}$ in the weaving division is above the 85 dBA of the highest exposure action value specified in the relevant regulation.
c) There is a maximum of 1 dB difference between A-weighted, C-weighted and Z-weighted noise levels in the weaving division.
d) The dominant frequency of noise generated in the weaving division is around 1000 Hz.
e) There is a potential for workers in the weaving department to experience increased physiological reactions and headaches as a result of noise exposure.
f) A-weighted, C-weighted and Z-weighted $L_{EX,8h}$ in dyeing/finishing division ranged from 77.1 dBA to 79.3 dBA, 82.4 dBC to 84.6 dBC and 83.1 dBZ to 85.2 dBZ, respectively. Figure 3 illustrates noise levels during operations in various divisions of the textile plant.
g) $L_{EX,8h}$ in dyeing/finishing division is below the 85 dBA of the highest exposure action value specified in the relevant regulation.
h) Considering the $L_{EX,8h}$ in dyeing/finishing division, the sound pressure difference between A-weighted, C-weighted and Z-weighted exposures is 5 dB at maximum, while the difference between C-weighted and Z-weighted exposures is around 1 dB.
i) The $L_{EX,8h}$ in dyeing/finishing division is approximately 20 dBA higher than that in the weaving division.
j) The dominant frequency of noise generated in the dyeing/finishing division ranges between 400 Hz and 1200 Hz.
k) There is a potential for workers in the dyeing/finishing division to experience exaggeration of reflexes (hyperreflexia), physiological reactions, increased blood pressure, increased heart rate, increased breathing and low cerebrospinal fluid (CSF) pressure as a result of noise exposure.
l) Weaving division and dyeing/finishing division and noise histograms are given in Figure 4a and Figure 4b. The noise range in the dyeing/finishing division area is wider than the weaving division.
m) Considering the frequency-noise relationship given in Figure 5, it is revealed that the dominant noise levels are in the middle frequency range. Therefore, the noise levels in the 4000 Hz frequency region, where the human ear is most sensitive, range between 84.2 dBA to 86.8 dBA in the weaving division and 60.0 dBA to 61.9 dBA in the dyeing/finishing division.

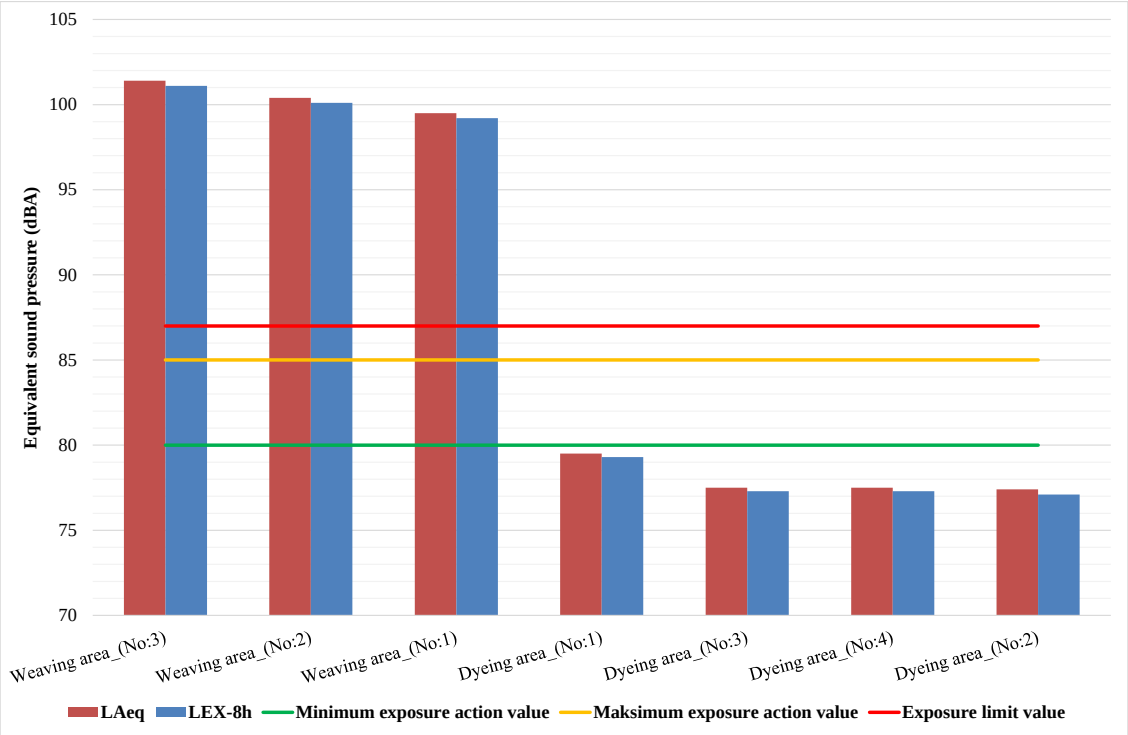

Figure 3. Noise levels during operations in the textile plant.

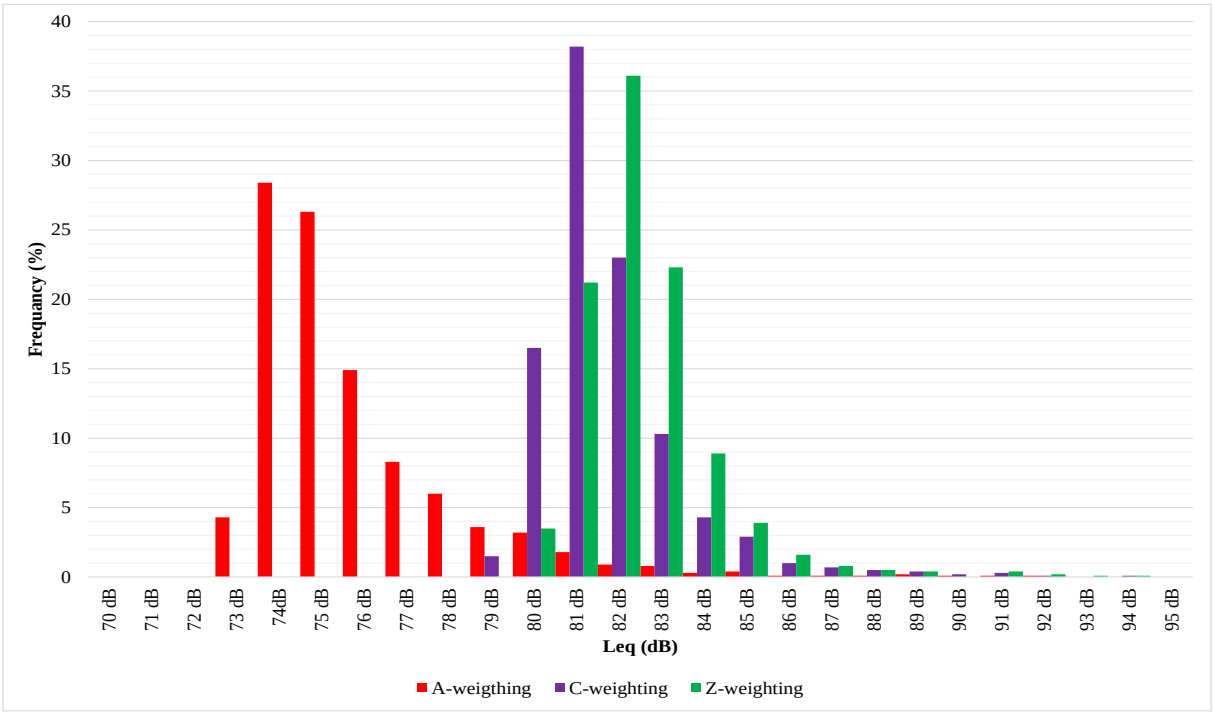

Figure 4a. Weaving division noise histogram

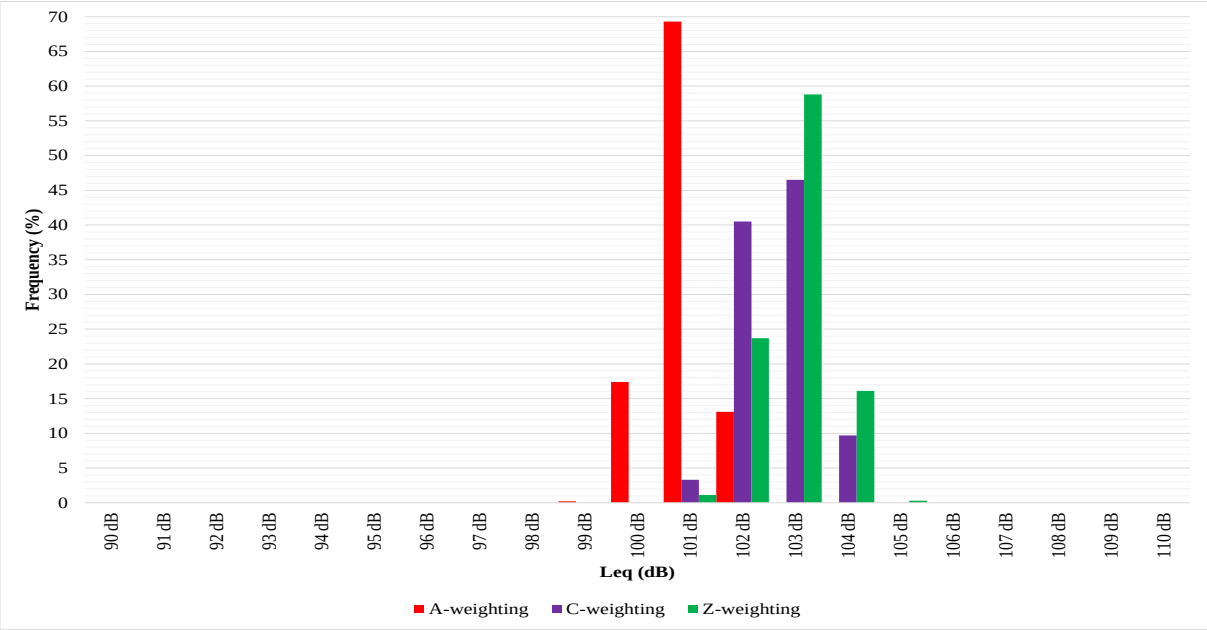

Figure 4b. Dyeing/finishing division noise histogram

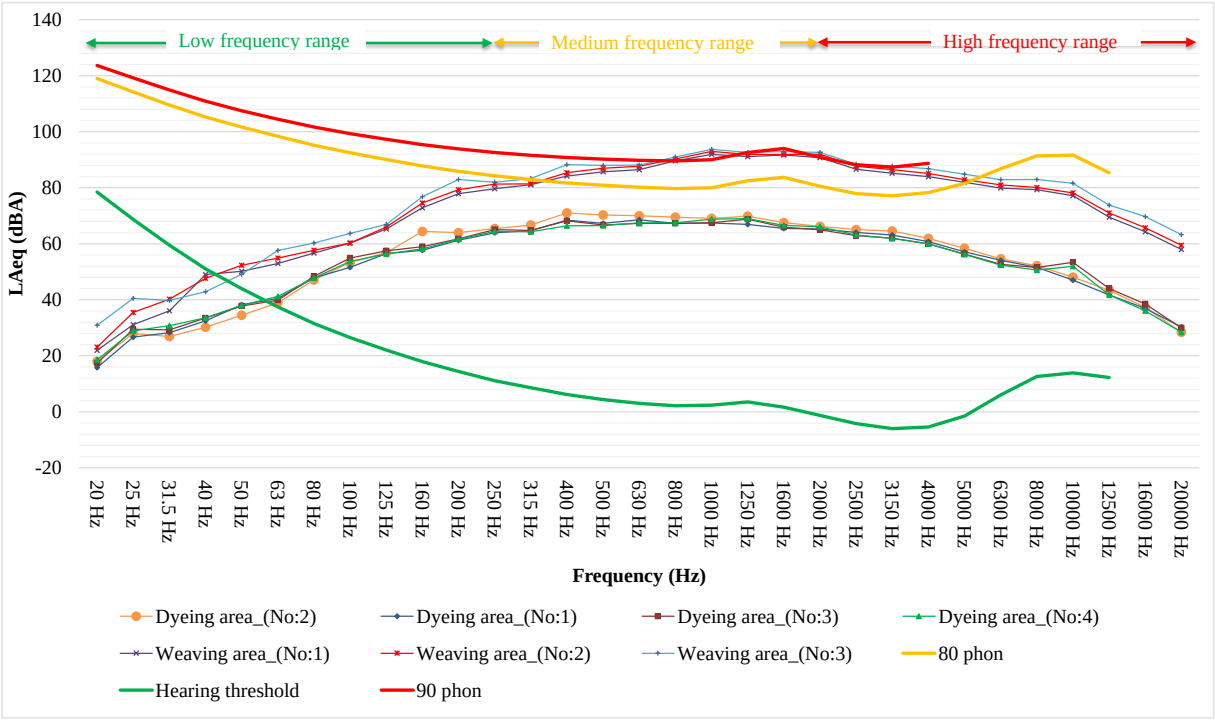

Figure 5. Frequency distribution of noise levels during operations of the textile plant.

4. CONCLUSIONS

In this study, noise measurements taken from the weaving division and dyeing/finishing division in a textile plant were evaluated. In the light of the evaluations, the following conclusions were reached.

a) The noise levels ranged from 99.2 dBA to 101.1 dBA in the weaving division, while in the dying/finishing division it ranged from 77.1 dBA to 79.3 dBA.
b) Personnel working in the dyeing/finishing division are not required to use personal protective equipment.
c) Personnel working in the weaving division, on the other hand, can only work for a maximum of 12 minutes without ear protectors in accordance with the relevant regulation. After this period, they should wear hearing protectors.
d) The dominant frequencies of noise to which the staff working in the textile plant are exposed to are lower than 4000 Hz, which the ear is the most sensitive.
e) Every effort should be made to reduce the noise level at its source in the weaving division. But, all ways to separate people from potentially damaging causes of noise are exhausted, workers must be provided with the correct personal hearing protectors. It must be noted that this equipment can be used as a temporary measure or the last resort.
f) The noise level in the weaving division is higher than 85 dBA, which is the highest exposure action value specified in the relevant regulation. Employees may experience hearing loss, hearing-related health problems and loss of productivity at work.

Table 2. Noise parameters for the textile plant

Division	Round of measurement	Average time mm:ss	Filter detector	L_{peak} (dB)	L_{max} (dB)	L_{min} (dB)	SPL (dB)	L_{eq} (dB)	SEL (dB)	L_{10} (dBA)	L_{50} (dBA)	L_{90} (dBA)	$L_{EX,8h}$ (dBA)	Working time (h)	Dominant frequency range (Hz)
Dyeing/finishing	1	05:04	A, Fast	102.2	88.4	77.2	79.2	79.5	104.4	81.4	78.5	77.6	**79.3**	<24.0	400-1250
			C, Fast	103.0	91.5	82.6	84.0	84.9	109.7	86.3	84.4	83.2	84.6		
			Z, Fast	102.8	91.6	83.2	84.6	85.4	110.3	86.8	85.0	83.9	85.2		
	2	05:27	A, Fast	103.5	92.4	73.5	75.5	77.4	102.5	79.5	75.6	74.2	**77.1**	<24.0	
			C, Fast	106.2	94.5	79.6	81.8	82.7	107.8	84.1	81.8	80.5	82.4		
			Z, Fast	106.9	94.7	80.3	82.3	83.4	108.5	84.7	82.7	81.3	83.1		
	3	05:06	A, Fast	99.3	86.7	74.8	76.8	77.5	102.3	79.4	76.6	75.4	**77.3**	<24.0	
			C, Fast	102.9	90.6	80.9	83.0	83.4	108.3	84.8	83.1	82.0	83.2		
			Z, Fast	104.0	91.1	81.7	83.9	84.3	109.2	85.7	84.0	82.8	84.1		
	4	05:04	A, Fast	106.0	93.3	74.8	76.7	77.5	102.3	78.2	76.9	76.0	**77.2**	<24.0	
			C, Fast	108.0	94.9	80.9	83.0	83.0	107.8	83.9	82.7	81.6	82.7		
			Z, Fast	108.0	95.0	81.6	84.3	84.0	108.8	85.2	83.7	82.4	83.7		
Weaving	1	05:05	A, Fast	114.7	100.3	98.5	99.5	99.5	124.3	99.9	99.5	99.0	**99.2**	0.3	1000
			C, Fast	115.3	101.6	99.8	100.7	100.7	125.5	101.4	100.6	100.0	100.4		
			Z, Fast	115.7	101.8	100.0	100.9	100.9	125.8	101.7	100.8	100.1	100.6		
	2	05:06	A, Fast	114.7	101.3	99.6	100.8	100.4	125.3	100.9	100.4	100.0	**100.1**	0.2	
			C, Fast	115.7	102.8	100.6	102.0	101.7	126.6	102.5	101.6	101.0	101.4		
			Z, Fast	116.1	103.0	100.8	102.2	101.9	126.8	102.7	101.8	101.1	101.6		
	3	05:04	A, Fast	116.9	102.8	100.0	101.1	101.4	126.3	102.2	101.4	100.5	**101.1**	0.2	
			C, Fast	117.7	105.0	101.4	102.6	103.1	127.9	103.9	103.1	102.1	102.8		
			Z, Fast	118.4	105.2	101.7	102.9	103.4	128.2	104.3	103.4	102.3	103.1		

NOMENCLATURE

dB : A relative unit of measure widely used in acoustics, electronics and communications.
dBA : A voice evaluation unit in which the human ear is particularly sensitive to medium and high frequencies.
dBC : A voice evaluation unit that correlates better with the human response to high noise levels.
dBZ : A voice evaluation unit implying no weighting (zero-frequency weighting) across the audio spectrum.
$L_{EX,\,8h}$: The sound exposure averaged over 8 hours ($L_{EP,d}$)
L_{max} : Maximum sound level
L_{min} : Minimum sound level
L_{peak} : Peak sound pressure
SPL : Sound pressure level
L_{eq} : Equivalent sound level
SEL : Sound exposure level
L_{10} : The noise level just exceeded for 10% of the measurement period
L_{50} : The noise level just exceeded for 50% of the measurement period
L_{90} : The noise level just exceeded for 90% of the measurement period

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