JRHS 2014; 14(1): 46-51

JRHS
Journal of Research in Health Sciences
journal homepage: www.umsha.ac.ir/jrhs

Original Article

A Passive Noise Control Approach Utilizing Air Gaps with Fibrous Materials in the Textile Industry

Mohammad Reza Monazzam-Esmaeelpour (PhD)[a], Zahra Hashemi (MSc)[b*], Rostam Golmohammadi (PhD)[c], Narges Zaredar (MSc)[d]

[a] *Department of Occupational Hygiene, School of Public Health and Center for Air Pollution Research (CAPR), Institute for Environmental Research (IER), Tehran University of Medical Sciences, Tehran, Iran*

[b] *Department of Occupational Hygiene, School of Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran*

[c] *Department of Occupational Hygiene, School of Public Health and Center for Health Researches, Hamadan University of Medical Sciences, Hamadan, Iran*

[d] *Department of Environment and Energy, Science and Research Branch, Islamic Azad University, Tehran, Iran*

ARTICLE INFORMATION

Article history:
Received: *09 June 2013*
Revised: *31 July 2013*
Accepted: *02 September 2013*
Available online: *19 October 2013*

Keywords:
Noise control
Textile industry
Absorbent
Technical control methods

*** Correspondence**
Zahra Hashemi (MSc)
Tel: *+98 611 3738269*
Fax: *+98 611 3738282*
E-mail: *z_hashemi26@yahoo.com*

ABSTRACT

Background: Noise pollution is currently a major risk factor in industries in both developed and developing countries.The present study assessed noise pollution in the knitting industry in Iran in 2009 and presented a control method to reduce the rate of noise generation.

Methods: The overall noise level was estimated using the network environmental noise assessment method in Sina Poud textile mill in Hamadan. Then, frequency analysis was performed at indicator target stations in the linear network. Finally, a suitable absorbent was recommended for the ceilings, walls, and aerial panels at three phases according to the results found for the sound source and destination environment.

Results: The results showed that the highest sound pressure level was 98.5 dB and the lowest was 95.1 dB. The dominant frequency for the industry was 500 Hz. The highest and lowest sound suppression was achieved by intervention at 4000 Hz equivalent to 14.6 dB and 250 Hz in the textile industry.

Conclusions: When noise control at the source is not available or insufficient because of the wide distribution of the acoustic field in the workplace, the best option is to increase the absorptive surface of the workplace using adsorbents such as polystyrene.

Citation: Monazzam-Esmaeelpour MR, Hashemi Z, Golmohammadi R, Zaredar N. A Passive Noise Control Approach Utilizing Air Gaps with Fibrous Materials in the Textile Industry. J Res Health Sci. 2014;14(1):46-51.

Introduction

Noise pollution is an underlying concern in social, administrative and industrial arenas. Its adverse effects on the environment, human beings, production, and even on the economy continue to grow. The textile industry is one of the oldest in the history of civilization because clothing is a basic human need after food. Exposure to noise in the modern textile industry is common and can cause temporary or permanent hearing threshold loss and other disorders depending upon the length of exposure, intensity, and frequency, as well as individual sensitivity. The most significant effect of noise pollution is hearing loss and hearing impairment.[1,2] Other effects include increased risk of accidents[3], increased stress, hypertension, increased heart rates, interfering with employee communication, sleep disturbance, behavior disorders[4], and psychological trauma.[5,6]

Atmaca et al[7] evaluated noise level and its physiological effect on workers of several industries in Turkey, including cement, steel, and textile industries. They found that the noise levels in all these industries were higher than 80 dB (A). In addition, 77.83% of workers in the industries were dissatisfied with their workplaces, 60.96% were suffering from anxiety, and 30.96% experienced some degree of hearing loss. Farouk et al[8] studied hearing loss in 70 workers in the textile industry in Turkey and found that the rate of hearing loss was 30% in the exposed group and 8% in the non-exposed group. Hearing loss increased as the level of noise increased and reached 73% in the 95 dB (A) range.

The National Institute for Occupational Safety and Health[9] took remedial action by covering the outside frame of stroke machinery with damping materials (EARC 2003). The result of this action was a 9 dB decline in noise. Monazzam et al[10] investigated noise control for spinning machines. In this study, a 2-3 dB reduction in noise was achieved using partial barriers mounted on the front of the spinning machinery. Mill et al[11] applied absorbent material for noise reduction to a weaving mill in 3 phases: applying absorbent material to the ceiling and walls, using of ceiling hangings, and improving the weaving machinery.

The textile industry in Iran dates back 4000 years and has been industrialized for more than 100 years. The large size of the workforce, the importance of the industry, and the effects of the noise pollution, are the importance and necessity finding techniques for reducing noise in the workplace.

The current study was performed in 2009 in a weaving factory and focused on providing technical strategies for noise control to reduce worker exposure to the recommended exposure limits. The unique focus of this study is to find strategies to reduce low frequency noise with the use of absorbent dampers as a solution to noise pollution.

Methods

The study was carried out in the weaving unit of Sina Poud textile mill in Hamadan. Initially, primary information was collected about the location of the noise sources and machinery mechanisms and architectural plans for the dimensions, size, and ceiling slopes. Maps of the main production hall, extensions maps, a map of factory noise sources, and information about the structures (area, material, thickness of walls and ceiling, doors, windows, and flooring) were also collected. The factory under study had dimensions of 41 × 30 × 5 m^3. It contained 35 weaving machines installed at uniform intervals. Ten operators monitored machine performance in three shifts; morning, evening, and night**.**

In the next step, noise measurement was done in the public areas to determine the distribution of sound pressure in the weaving unit. The study unit was divided into raster of equal dimensions (6 x 6 m); the center of each area was the measuring station. A total of 45 stations were determined in the study unit. A network was formed according to ISO 9612[12] using a sound level meter (TES 1385) with an analyzer that was calibrated using a standard calibrator (B & K, model 4231). The microphone faced the workers' heads and calibration was done in their absence, based on ISO 9612.[12] A sound level meter was set up 1.55 ± 0.075 m above the ground and ambient noise levels were recorded graphically and computationally using ARCGIS and the results were plotted graphically. To evaluate the frequency characteristics of the sound in the unit when workers were present and working, 8 representative stations were selected that had the highest worker traffic and a stopping-frequency analysis in was done for the network. The results from the noise analysis in the octave frequency were used to develop control techniques.

In this study, the emphasis was on reduction techniques along sound propagation pathways with a focus on the use of different absorbers at various phases. An estimation of noise reduction was calculated using the absorption coefficients for the material and absorbers at each phase (ceiling, walls, and spatial panels) separately and for a combination of eight frequencies. The results were processed using MATLAB and MS Excel.

Controlling strategies

Because of the uniform distribution and the large number of the dominant sources of ambient sound, the best technique to reduce the general noise in the unit is to survey the overall reduction in sound energy comprising direct and reflected sound waves. The most significant strategies in order of decrease in noise pollution were:

- use of adequate sound absorbers on practical surfaces
- use of spatial panels (practical absorber)

In the textile industry, the temperature and moisture in the work environment must be considered when selecting absorbers. In addition, durability, absorber lifetime, the aesthetic landscape, ease of installation must be considered.

The absorber that fulfilled these requirements the best for the ceiling was fire-proof polystyrene foam. This absorber had a thickness of 1 in and an area of 882 m^2. This thickness provides the highest absorption coefficient for the considered frequencies (250-500 and 1000 Hz); its area was determined according to ceiling dimensions. The absorber was mounted leaving a gap of 17.1 cm to better absorb low frequencies. A fulcrum was needed to attach the absorber to the ceiling, so a 35 mm shield with network dimensions of 50.5 × 50.5 was selected. The absorber for the walls was a fluffy loop carpet with a surface density of 1.4 kg/m^2 and a shaggy hemp layer with a surface density of 3 kg/m^2, with an area of 300 m^2. These dimensions were determined in consideration of the space needed to mount the absorber on the wall.

Spatial panels were used to enhance the absorption surfaces. An aluminum cylinder with a base radius of 30 cm and a height of 35 cm was selected and the fluffy loop carpet described above was mounted on the cylinder. A layer of carpet was also mounted inside the cylinder and covered the frame. One cylinder end remained uncovered to allow the inner surface of the cylinder to be part of the absorption area. The cylinder was hung from the ceiling using wire at a height of 1 m. The space between each two panels was 4 m in length and 3 m in width; overall, 100 panels were mounted on the ceiling.

Estimating the noise reduction

To estimate the amount of noise reduction, the surface absorption was calculated before mounting the absorber, considering the types of materials applied and the area in the study environment. To do this, the surface absorption was calculated using the Eyring equation [13] as follows:

$$\bar{\alpha}_t = \frac{\left(S_W \times \alpha_W + S_C \times \alpha_C + S_f \times \alpha_f\right)}{S_t} \qquad (1)$$

$$A = -S \times Ln\left(1 - \bar{\alpha}_t\right)$$

Where S_W is the area of the walls, a_w is the average absorption coefficient of the walls, S_C is the area of the ceiling, a_c is the average absorption coefficient of the ceiling, S_f is total area of the floor, and a_f is the average absorption coefficient of the floor.

The influence of distance can be ignored given the relatively uniform distribution of the noise propagation and source dispersion in the weaving environment. Overall, the reduction of noise level in such an environment can be calculated as[11]:

$$NR = 10\log\frac{A_2}{A_1} \qquad (2)$$

where A_2 is surface absorption after remedial action, A_1 is the surface absorption before remedial action, and NR is the noise reduction after remedial action.

Eq. 2 requires the calculation using Eq. 1 of the surface absorption before beginning the design. Surface absorption can then be estimated by controlling the design for space and type of material. The reduction on the overall noise level can be determined from the absorption of the two surfaces and Eq. 2. The design required 3 steps.

- *Step one:* Determining type of material, the absorption coefficient and surface dimensions.

The weaving unit was 41 m long, 30 m in width, and 5 m in height to the suspended ceiling. The floor is mosaic tile, the walls are 5 cm bricks and 30 cm of granite coping was installed along the floor line. The lateral surfaces of the machinery were galvanized sheet 1.6 mm thick and the suspended ceiling was aluminum with 1.6 mm galvanized skeins. The door was iron. Details of the acoustical properties of the material can be found in Cox [13].

- *Step two:* Determining the equivalent surface absorption coefficient before designing.

Given the materials type and area, the overall absorption coefficient of the study area in octave band frequencies is calculated using Eq. 1**.** The study unit surface absorption for the acoustic spaces is lower than the results of the acoustic spaces Sabine. The sound field is reflective and increases the sound. The Sabine calculation for this space reveals that, at a frequency of 1000 Hz, for example, the weaving unit in an overall area of about 3200 m^2 has a complete absorption rate equal to a space with an area of 53.7 m.

- *Step three:* Determining the type of materials and area required to reduce noise pollution.

The material suggested for the suspended ceiling is 1 in thick fire resistant polystyrene. The advantage of this product is that it can be produced in any shape and size. On the other hand, as shown in the results, the highest sound pressure level is at a 500 Hz, considered to be a low frequency. The absorber amplitude must be enhanced to improve absorption at this frequency. Free space between the absorber and the wall allows it to perform better, particularly at low frequencies. If the predominant frequency of the incoming wave equals 500 Hz, according to the formula, the wavelength of the sound would be 0.68 m. The highest absorption coefficient was measured as 1.4 λ in higher harmonic frequencies, and the lower absorption coefficient was 1.2 λ in higher harmonic frequencies. The sound wave had the highest absorption coefficient of 1.4 λ. By replacing the porous materials at 1.4 λ, higher absorption can be achieved considering the maximum speed of sound and motion of the material components.[13,14]

The absorber would be installed at a distance of 17.1 cm (1.4 λ) mounted on an aluminum shield holder with no space. The Delany and Bazley equation[1] was used to determine the absorption coefficient of absorber placed on a firm surface at a distance of 17.1 cm:

$$Z_{S_{i+1}} = -jz_i \cot(k_{xi} d_i) \qquad (3)$$

where $z_{S_{i+1}}$ is impedance at the bottom of the i+1 layer, k_{xi} is the wave number for the ith layer and d_i is the thickness of the layer. Impedance of the absorbent material is calculated using Delany and Bazley empirical formulations. In Eq. 3 is applied first to the air layer and second to the absorber layer. For the air layer:

$$z_{s1} = -j\rho_0 c_0 \, cot(kd_1) \qquad (4)$$

where k is the wave number for the air and d_1 is the air thickness. $\rho_0 c_0$ is the specific acoustic impedance of air (419 MKS rayls). For the absorbent layer:

$$z_{s2} = \frac{-jz_{s2} z_2 \cot(kx_2 d_2) + z_2^2}{z_{s1} - jz_2 \cot(kx_2 d_2)} \qquad (5)$$

where z_2 is the absorbent layer impedance determined by the Delaney and Bazely method.[14]

The flow resistance of the absorber was 20000 MKS rayls. The amount of absorption is shown in Figure 1.

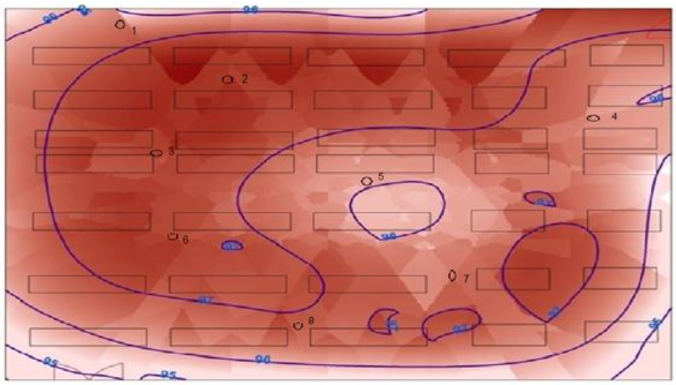

Figure1: Isosonic map and machinery position in the weaving unit dB (A)

Results

The results of measurement of background noise in the weaving unit showed that the highest and the lowest sound pressure levels were 98.5 dB(A) and 9.1 dB(A), respectively. Figure 2 shows the distribution of sound levels in the study unit.

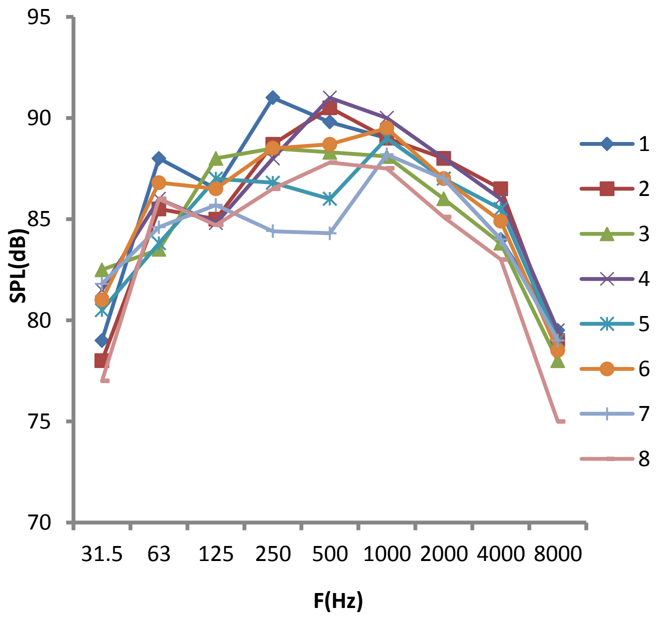

Figure 2: Frequency analysis diagram of different posts-weaving unit

In the weaving unit, the yarn produced in a previous stage is woven into fabric by machine. All machines are sources of sound pollution. The sound producing components were the reciprocating motion of the hasp, continuous and rapid motion of the head frame, and the beating and knocking motions of the comb.

The sound maps of the new weaving unit showed that the nearer the machinery and the entire unit overall had higher values than the allowed limit (95-97 dB). The position and distribution of the machinery, similar work processes and surface materials (often reflective) can be considered causes of the relatively uniform distribution of noise in the workplace. Figure 3 shows the frequency analysis of the different posts in the unit. The peak noise is at frequencies of 250-500 and 1000 Hz.

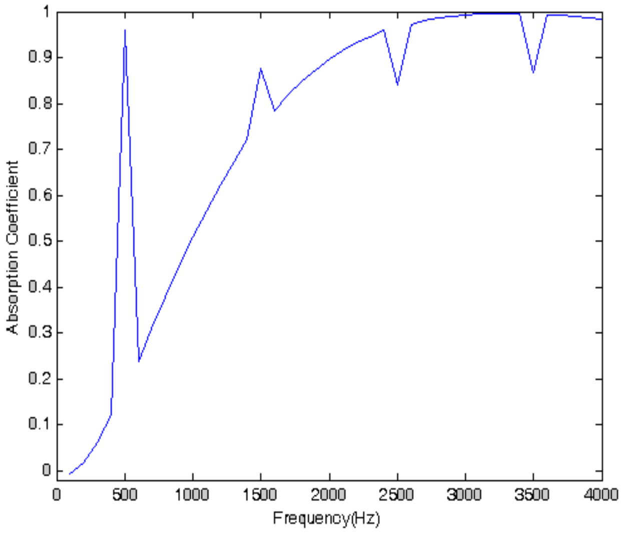

Figure 3: Acoustic response of the ceiling when is installed on a layer of air

As shown, although the ceiling frequency response under new design conditions improved as frequency increased, at a frequency 500 Hz, it suddenly increased because of the distance being one quarter of the predominant sound frequency wavelength. It is worth mentioning that the environmental measurements were done in octave bands, while the results were obtained in the narrow band. A correction was done and the absorption coefficients in the octave band were calculated considering the width of each octave band and averaging each bandwidth separately. The results for the new design are shown in Table 1.

Constraints for installing the fluffy loop carpet on the walls, such as the existence of several components, mechanical impact, machinery, and personnel traffic, this absorber was mounted directly on the walls to enhance the mechanical strength. Accounting for the skeins, doors and windows, and other issues, 300 m^2 of total a total of 710 m^2 of absorber can be used.

In addition, 100 panels made of fluffy loop carpet with a shaggy hemp layer and an aluminum frame was used on the ceiling. Results of acoustic properties of the weaving unit in the circumstances after designing are presented in Table 2.

The average reduction in sound level inside the weaving unit was estimated using Eq. 2 and the results are presented in Table 3. Figure 4 shows the results of comparison of sound pressure level in conditions before and after intervention.

Table 1: Overall absorption coefficient of ceiling and wall components

		Frequency (Hz)					
Material name	**Area (m^2)**	**125**	**250**	**500**	**1000**	**2000**	**4000**
Panel	50.26	0.2000	0.5000	0.6800	0.7200	0.6500	0.9000
1 inch polystyrene foam on an air layer to the thickness of 0.171 m.	882.00	0.0100	0.0500	0.2200	0.5300	0.8800	0.9700
Shield (metal)	348.00	0.0300	0.0070	0.0010	0.0006	0.0002	0.0002
General absorption coefficient of ceiling	1280.26	0.0200	0.0600	0.1800	0.4000	0.6000	0.7000
fluffy loop carpet (1.4 kg/m^2)with a shaggy hemp layer (3 kg/m^2)	300.00	0.2000	0.5000	0.6800	0.7200	0.6500	0.9000
Indoor hard surfaces	410.00	0.0300	0.0070	0.0010	0.0006	0.0002	0.0002
Overall absorption coefficient of the walls along with other indoor surfaces	710.00	0.1000	0.2000	0.2800	0.3000	0.2700	0.3800

Table 2: Acoustic properties of the weaving unit in the circumstances after designing

			Absorption coefficient					
Surface	**Material**	**Area (m^2)**	**125**	**250**	**500**	**1000**	**2000**	**4000**
Floor (no change)	Mosaic	1230	0.01	0.01	0.01	0.02	0.02	0.02
Ceiling (intervention Table 1)	Foam- panel- Arial layer	1280	0.02	0.06	0.18	0.40	0.60	0.70
Wall (intervention Table1)	Carpet- Brick	710	0.10	0.20	0.28	0.30	0.27	0.38

Table 3: Equivalent absorption coefficients, surface absorption and average sound level reduction after designing in octave-band frequencies

	Octave-band frequency (Hz)					
Quantity	**125**	**250**	**500**	**1000**	**2000**	**4000**
Equivalent absorption coefficient (%)	0.04	0.07	0.14	0.23	0.30	0.40
Absorptive surface (Sabine)	130.00	231.00	448.00	750.00	984.00	1191.00
NR (dB)	0.02	1.81	4.70	11.52	13.50	14.64

Discussion

Advances in technology require people to coexist unhappily with sound sources in a stressful environment. About 600 million workers are exposed to the occupational noise[16]. When the noise level exceeds allowable limits, it has harmful effects on the human body, including on hearing, the circulatory and nervous systems, on and work efficiency.[1-7]

From studies conducted on the textile industry, it can be concluded that the sound level in this industry is much above the allowable limit, particularly in the industrial units. Perlikowski[17] evaluated noise in a textile mill and reported that sound pressure level in different sectors varied from 95 to 104 dB (A), and highest sound level was recorded at 500, 1000 and 2000 Hz. Ni Chun-hui et al.[18] studied the relationship between blood pressure and exposure to the industrial noise in females working in a textile mill. The results from ambient sound measurement showed that noise levels were 80.1 dB (A) to 113.5 dB(A).

Atkama[7] in Turkey measured the volume in textiles industries at 99 dB, which is similar to the results for the present Study.

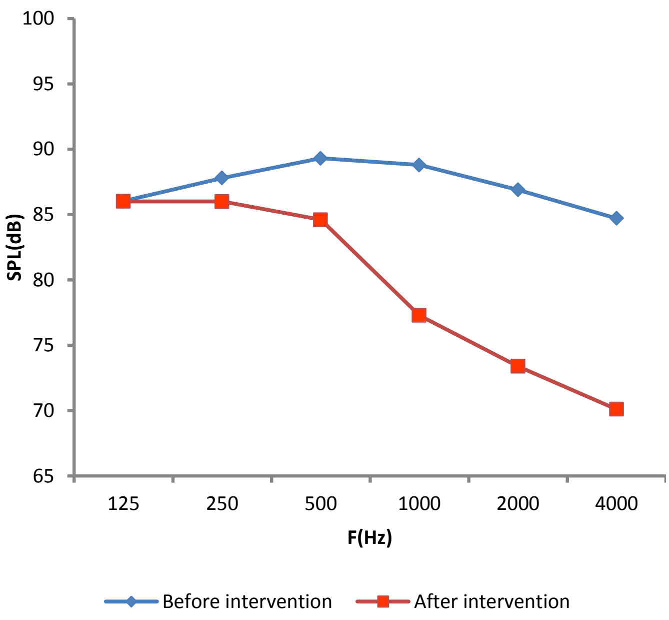

Figure 4: Comparison of sound pressure level in conditions before and after intervention

Noise has always accompanied the textile industry. Weaving mills have changed little change since the industrial revolution. The most common sound sources from the hasp, picking arm, and heald. The frequency spectrum of this process is usually of high frequency. Sound sources are difficult to remove, since they are inherent parts of the work process. A survey of the sound maps developed for a new weaving unit (Fig. 1), machinery location, and the overall study area suggests that it is higher than allowance limits (98 dB(A)) and the study area is considered to be 100% polluted. The results of the frequency analysis of the one octave band in the Lin network (Figure 2) showed that the main frequency comes from the weaving machines at 500 Hz. The Delaney and Bazely equation[14] was applied to determining the absorption coefficient.

The overall absorption was 0.05 (absorption coefficients of floor, ceiling, and walls) for the main frequency (500 Hz). The Sabine value for the area was 151.2 m^2.

The best way to control noise pollution is to implement control techniques at the source. This is not always applicable, especially for machinery in the operation phase. In the textile industry, sources are classified as surfaces (by dimension), machinery and mobile components of hard metal (iron and steel), and machinery arrangement throughout the study area. The perimeter of the machinery location was also important. A peripheral study determined that textile mills usually have a large area and a low ceiling, so there is no normal Sabine value for the acoustics in such rooms.

Factory buildings usually have little absorbent surfacing; as a result, absorption is insignificant. The present study found that the Sabine value or absorption surface can be modified by making changes in the interior industrial environment**.** Fire proof polystyrene absorbers 1 in thick were applied to the ceiling and fluffy loop carpet with a shaggy hemp layer was applied to the walls. Restricting factors in industry such as high temperatures, humidity, cost, efficiency, chemical and physical resistance to environmental factors, ease of installation, and the aesthetics of the design are factors that require consideration.

In the weaving unit, fire proof polystyrene absorber had an area of 882 m^2. The predominant frequency was in the low frequency range (500 Hz). To enhance the absorption coefficient, the polystyrene absorber was mounted on the ceiling leaving a gap. The highest absorption coefficient was 1.4 λ at higher harmonic frequencies, so the gap was 17.1 cm from the ceiling. Spatial panels are also an option to control noise and were applied in this study to increase the absorption surface. The panel was a cylinder 40 cm diameter at the base and 70 cm high; 100 panels were installed in the study area.

According to the calculations in the overall absorption coefficient of the ceiling (Table 1), the value of this parameter (a combination of panel, foam installed on the layer of the air, shield) at 500 Hz was 0.18. As expected, the highest absorption coefficient is related to 4000 Hz and the lowest one is at 125 Hz; because in sheet absorber, the highest coefficients correspond to the high frequencies and the lowest one are related to the low frequencies.

The skeins, doors and windows and other aspects of the weaving unit reduced the total absorber area to 300 m^2 out of a total of 710 m^2 in wall area. Table 1 shows that the overall absorption coefficient of walls for 500 Hz was equal to 0.28. The overall absorption coefficient of the weaving unit at 500 Hz was equal to 0.14. The absorption surface at the same frequency was 448 m^2, which is an increase of 2.8 times the conditions before the intervention. Overall noise reduction was calculated as a maximum of 14.5 dB at 4000 Hz and the least was 0.02 dB at 125 Hz. At the predominant frequency, noise reduction was 4.7 dB, which is below the allowable limit.

Mills et al.[11] applied absorber materials for noise reduction of weaving machines for three work phases on the ceiling, the walls and hung from the ceiling and also improved weaving machinery. He found that noise reduction at 1000-2000 Hz and 4000 Hz was much easier than at lower frequencies, which confirms the results of this study. Monazzam et al.[10] reduced noise about 2-3 dB by using partial barriers mounted in front of spinning machinery. From results of their study, it can be concluded that methods such as the use of a barrier are the most efficient in environments with high absorption coefficients. This finding confirms the results of the present study.

Differences in noise reduction at octave frequencies can be a result of several factors. Sheet absorber structure and the physics of acoustic waves cause differences in noise reduction for low and high frequencies. Since for low frequencies, sound waves have long wavelengths, the thickness of the sheet absorber is negligible compared to the wavelength of incoming sound. The majority of the sound passes through the absorber layer and collides with the wall behind the absorber, thus, the absorber only absorbs a small portion of the sound energy. At high frequencies, the wavelength of the sound is short and the thickness of sound absorber is able to absorb the sound energy. This was confirmed by the findings of Mills.[11] It should be noted that very little has been published on the types of absorbents used in industrial noise control.

Conclusions

One appropriate method for closed environments (most industries) is to correct the internal environment absorption coefficient using the absorption method for the base absorbent. This is most efficient for high frequencies but shows limited success at low frequencies. Increasing the thickness of the absorbent helps, but is not an economical alternative. The solution proposed in present study (leaving an air gap of varying thickness between the absorbent and the wall or ceiling surface) can remove this constraint and improve the performance of the absorbent at low frequencies.

Acknowledgments

The authors would like to Mr. Farhad Taleei for his support and cooperation during this study.

Conflict of interest statement

The authors have no conflict of interests to declare.

Funding

This study was financially supported by of Hamadan University of Medical Sciences. This article is part of MSc thesis in Occupational Hygiene.

References

1. Ahmed HO, Dennis JH, Badran O, Ismail M, Ballal SG, Ashoor A et al. Occupational noise exposure and hearing loss of workers in two plants in Eastern Saudi Arabia. *Ann Occup Hyg*. 2001;45(5):371-380.

2. Hwang SA, Gomez MI, Sobotova L, Stark AD, May JJ, Hallman EM. Predictors of hearing loss in New York farmers. *Am J Ind Med*. 2001;40(1):23-31.

3. Sprince NL, Zwerling C, Lynch CF, Whitten PS, Thu K, Gillette PP, et al. Risk factors for falls among Iowa farmers: a case-control study nested in the Agricultural Health Study. *Am J Ind Med*. 2003;44(3):265-272.

4. Niemann H, Bonnefoy X, Braubach M, Hecht K, Maschke C, Rodrigues C, et al. Noise-induced annoyance and morbidity results from the pan/European LARES. *Noise Health*. 2006;8(31):63-79.

5. Dalton DS, Cruickshanks KJ, Klein BE, Klein R, Wiley TL, Nondahl DM. The impact of hearing loss on quality of life in older adults. *Gerontologist*. 2003;43(5):661-668.

6. Kramer SE, Kapteyn TS, Kuik DJ, Deeg DJ. The association of hearing impairment and chronic diseases with psychosocial health status in older age. *J Aging Health*. 2002;14(1):122-137.

7. Atmaca E, Peker I, Altin A. Industrial noise and its effects on humans. *Pol J Environ. Stud.* 2005;14(6):721-726.

8. Shakhatreh FM, Abdul-Baqi KJ, Turk MM. Hearing loss in a textile factory. *Saudi Med J*. 2000;21(1):58-60.

9. National Institute for Occupational Safety and Health. NIOSH - Industrial Noise Control Manual. Process Plant Noise Control at the Plant Design Stage. NIOSH; 1978.

10. Monazzam MR, Nezafat A. On the application of partial barrier for spinning machine control: a theatrical an experimental approach. *Iranian J Environ Health Sci Eng*. 2007;4(2):113-120.

11. Mills RO. Noise reduction in a textile weaving mill. *Am Ind Hyg Assoc J*. 1969;30(1):71-76.

12. ISO-9612. Acoustics - guidelines for the measurement and assessment of exposure to noise in a working environment. International Organization for Standardization, 1997.

13. Cox TJ.Antonio PD. *Acoustic absorbers and diffusers theory, design and application*. New York: Spon Press; 2004.

14. Everst FA. *Master handbook of acoustics*. 4th ed. New York: McGraw-Hill; 2001.

15. Barron RF. *Industrial noise control & acoustic*. New York: Marcel Dekker; 2003.

16. BergerEH, Franks JR, Behar A, Casali JG, Dixon-Ernst C, Kieper RW. Development of a new standard laboratory protocol for estimating the field attention of hearing protection devices, Part 111, the validity of using subject- fit date. *J Acoust Soc Am*. 1998;103(2):665-672.

17. Perlikowski M. Noise suppressor for the textile industry. *Fibres Text East Eur*.2005;13(1):80-85.

18. Ni CH, Chen ZY, Zhou Y, Zhou JW, Pan JJ, Liu N, et al. Associations of blood pressure and arterial compliance with occupational noise exposure in female workers of textile mill. *Chin Med J (Engl)*. 2007;120(15):1309-1313.