Assessing Individual and Environmental Sound Pressure Level and Sound Mapping in Iranian Safety Shoes Factory

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Abstract: - Noise is regarded as a major physical hazard in work environments. The current study aimed at investigating environmental sound pressure level and sound mapping in an Iranian safety shoes production factory in 2017 using Surfer V.13. This cross-sectional, descriptive-analytical study was conducted among 3 units of a safety shoes production factor. Casella noise dosimeter (Cel-320) was used to measure individuals' exposure to noise, while 450 Casella-Cel sound level meter (manufactured in England) was utilized to assess environmental sound pressure level. The collected data were then fed into Surfer V.13 to draw the isosonic map. The results of assessing individuals' exposure showed that workers in the cutting, stitching, and stuffing unit had excessive exposure to noise (over 85.76 dB, which is the standard limit). The results of measuring environmental sound pressure level also showed that 32.3% of the measurement stations were located in the danger zone (with sound pressure levels greater than 85 dBA). The highest sound pressure levels measured in Lewis and lineage, injection, and cutting, stitching, and stuffing units were 88, 89, and 93 dB, respectively. Based on the obtained results, the cutting, stitching and stuffing is in dire need of engineering controls and working, trafficking, and stopping limitations.

Keywords: - Noise, environmental sound pressure level, sound map, surfer

1. INTRODUCTION

Noise and Vibration is a major hazard in work environments [1] and is regarded as a serious challenge in many work settings across the world. Exposure to excessive noise may result in hearing loss, caused by mechanical and metabolic changes in the internal ear. Mechanical damages happen in external cells [2,3].

In the United States, over 30 million workers are exposed to dangerous noises and 7.4-10.2 million industrial workers are in danger of hearing loss caused by occupational noise. Only in Michigan, around 86 thousand individuals suffer from work-related hearing loss. In fact, hearing loss is one of the most common diseases in the US despite the fact that it can be prevented [4,5]. In 1990, 200 million dollars were paid to workers as indemnity for their hearing loss [6]. Over the past 10 years, the proportion of the population that are exposed to environmental noises louder than 65 dB has increased from 15% to 26% [7].

In Germany, around 4 to 5 million workers (which constitute 12% to 14% of the country's population) are exposed to excessive sound pressure levels according to WHO standards. The majority of work-related activities are accompanied by a proportion of noise; however, some of these activities are performed with excessive sound pressure levels. Although the available data for developing countries is limited, it seems that the average sound pressure level in such countries is on the rise because of the industrialization process [8].

With regard to industrial equipment, several factors can cause excessive noise including the structural and mechanical nature of the machine, the amount of depreciation of mechanical parts, inappropriate performance of moving machinery parts, high velocity of fluid flow in canals, and inappropriate foundation which leads to structural vibration of the machinery [9,10].

In a typical safety shoes production factory, there are several machines – including gear press machine, atom press machine, heavy Lewis machine, leather foot machine, sanding machine, stamping machine, Lewis machine, injection machine, etc. – which can generate excessive noise. To date, no published study has attempted to assess environmental sound pressure level and draw the sound- map in a safety shoes production factory. On the other hand, this industry is making a constant, significant progress. It is therefore incumbent upon researchers to study risk factors in such environments, especially physical factors like noise. As a result, the present study aimed at:

1. Assessing individual sound pressure level of workers.
2. Assessing environmental sound pressure level in different units of the factory.
3. Drawing the sound map and issuance noise map for these units.
4. Determining danger zones, caution zones, and safe zones in the factory.

2. MATERIALS AND METHODS

2.1. Participants and industry selection

This cross-sectional, descriptive-analytical study focused on the safety shoes production industry. A total number of 75 workers (50 males and 25 females) in a safety shoes factory participated in the research. They all worked in the same work shift (from 7 A.M to 3 P.M). The target sample was determined by census sampling. The participants had a mean age of 32.42 ± 8.26 years and a mean body mass index of 24.74 ± 2.65 kg/m2.

2.2. Measurements

2.2.1. Measuring individual sound pressure levels

Sound dosimetry is the most reliable procedure for measuring individuals' exposure to noise since it will stay with the worker and records all noise exposures during the entire shift. This is an accurate procedure because dosimetry takes into account all instances of workers' exposure to noise during a shift and assesses a particular workers' exposure to noise using equivalent balance. Casella noise dosimeter (Cel-320) was used to gauge individuals' noise exposure [11,12]. The workers were involved in work-related activities for six hours during their shift (they had a break time of two hours in the shift). Thus, their individual exposure to noise was measured for 6 hours in their work place. During the break time, the workers exited the working site and rested in another hall. Their exposure to noise in these two hours was also measured and recorded.

2.2.2. Measuring environmental sound pressure level

A sound level meter (CEL-450) (manufactured by Casella-Cell of England) was exploited in the A frequency distribution network using the slow mode velocity to measure environmental sound pressure level. In the first phase of the study, environmental auditing was performed according to standard procedures proposed by ISO 9612:1997 and ISO 11200:2014 to determine the amount of noise pollution in different units and identify the main sources of noise generation [13,14]. The studied units were divided into 5×5 m2 squares, with the centers of these squares being selected as the measurement spots [15]. If the center of the square was positioned on a machinery which made measurement impossible, it was regarded as a blind spot and removed from further analysis. In the current study, areas like office buildings, control rooms, chemical and injection units, and storage departments were blind spots.

2.3. Drawing the Isosonic map

Isosonic mapping is a common way of expressing and assessing noise in the work environment. Isosonic maps are used to demarcate various zones in a workshop based on their sound pressure level. In order to draw these maps, the workshop were first divided into various square zones with equal areas (5×5 m2), with the center of each square being the measuring spot for sound pressure level. Then, the measurement results were inserted into the factory plan with various measurement stations and the output was fed into Surfer V.13 in the format of an input file. Subsequently, isosonic maps were drawn in the light of three sound pressure level zones (mentioned below). In isosonic maps, the spots which have the same sound pressure level are connected to each other, hence creating isosonic curves. Similar to topographic maps, these lines indicate three sound pressure level zones.

- Safe zone (SPL< 65 dBA) demonstrated in green
- Caution zone (65 < SPL ≤ 85 dBA) demonstrated in yellow
- Danger zone (SPL > 85 dBA) demonstrated in red

The output was a colored map indicating safe, caution, and danger zones, with the last one being the area which needs utmost attention in terms of noise controlling procedures [16].

ETHICAL CONSIDERATIONS

Ethical approval was obtained from the Ethics Committee of Kerman University of Medical Sciences (ID: IR.KMU.REC.1396.1110). All participants signed a consent form.

STATISTICAL ANALYSIS

The collected data were fed into SPSS (version 22) followed by conducting descriptive data analysis, i.e. mean and standard deviation for quantitative variables.

3. RESULTS

3.1. The results of measuring individual sound pressure level

Table 1 contains the results of sound dosimetry and sound pressure level for the 8-hour period. It is observed that the highest dose (119.5%) was recorded in the cutting, stitching, and stuffing unit. The workers in this unit had the highest individual exposure to noise (85.76 dB).

Table 1. The results of measuring individual sound pressure level **(**n=75**)**

Unit	Number of workers in the shift	Duration of stay in each place (hour)		Equivalent Sound Pressure Level (dBA)		Received dose (%)	8-hour Equivalent Sound Pressure level (dBA)
		Working site	Resting hall	Working site	Resting hall		
Lewis and lineage	20	6	2	83	65	48.25	81.78
Injection	10	6	2	80	65	24.25	78.8
Cutting, stitching, and stuffing	45	6	2	87	65	119.5	85.76

3.2. The results of measuring environmental sound pressure level

Table 2 illustrates sound pressure levels, number of stations, blind spots, and station divisions based on the range of sound pressure level. It is observed that the lowest sound pressure level (57 dBA) was recorded in the injection unit, while the highest one (93 dBA) was registered in the cutting, stitching, and stuffing unit. The largest number of stations with excessive sound pressure level (over 85 dBA) is located in the cutting, stitching, and stuffing unit. On the other hand, the largest number of stations with sound pressure levels below the standard value (85 dBA) belongs to the injection unit.

Table 2. The results of measuring environmental sound pressure levels

Unit	Number of workers in the shift	Number of measurement stations	Number of blind spots	Minimum sound pressure level (dBA)	Maximum sound pressure level (dBA)	Stations with SPLs greater than 85 dBA	Stations with SPLs between 65 and 85 dBA	Stations with SPLs smaller than 65 dB**A**
						Percentage	percentage	percentage
Lewis and lineage	20	65	0	74	88	32.3	67.7	-
injection	10	28	8	57	90	32.1	32.1	35.8
Cutting, stitching, and stuffing	45	68	40	75	93	39.7	60.3	-

3.3. The results of drawing the isosonic map

The following images show the hall maps in which the noise generating sources and caution/danger zones are demarcated.

Image 1 shows the Lewis and lineage hall, which has an area of 112 m2 and contains 20 workers. The machinery location (brand stamping, Lewis machine, and lineage machine) is demonstrated in the sound map.

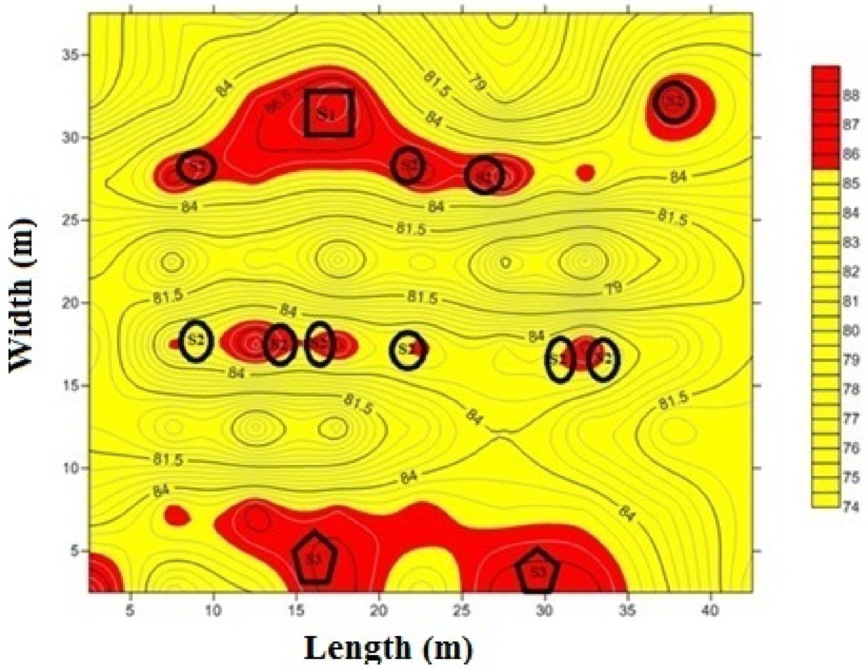

Figure 1. The map of the Lewis and lineage hall

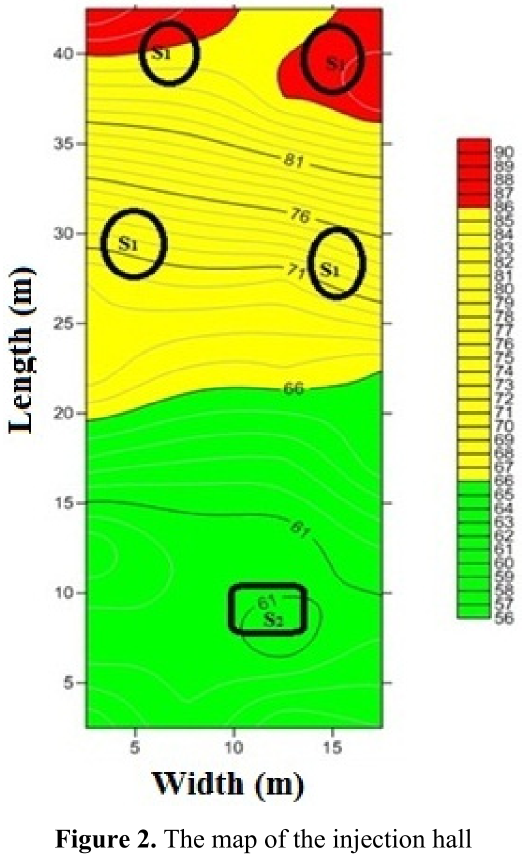

Figure 2. The map of the injection hall

The following figure shows the injection unit, which has an area of 800 m^2 and contains 10 workers.

The machinery location (automatic and manual injection machines) is demonstrated in the figure.

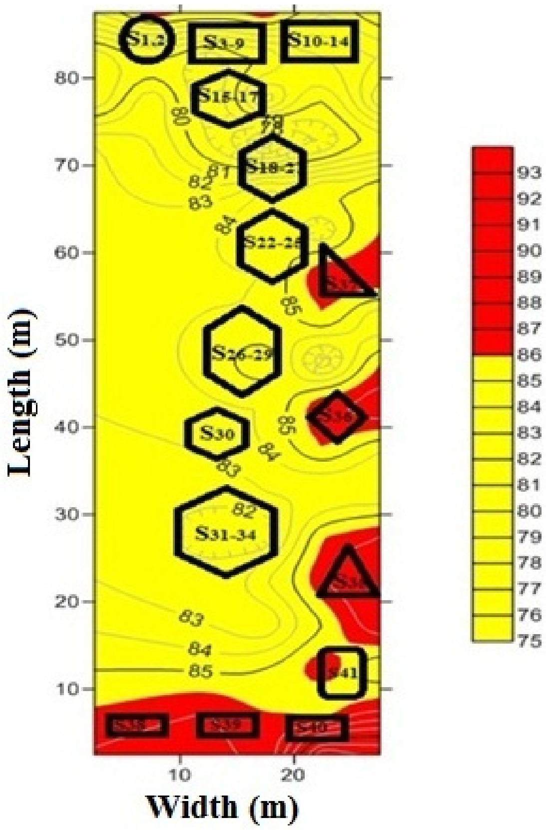

Figure 3. The map of the cutting, stitching, and stuffing hall

Figure 3 shows the cutting, stitching, and stuffing hall. The areas of the three units are 600, 896, and 96 m^2 respectively. In total, 45 workers work in this hall. The number of the machinery and their location (gear cutting machine, molding machine, stitching machine/sewing machine, stapler machine, tweaking machines, pneumatic press machines, drying machines, and sanding machines) are indicated in the figure.

4. DISCUSSION

This study sought to assess individual/ environmental sound pressure level and draw the sound map of a safety shoes production factory. Since people are exposed to various levels of sound during an 8-hour shift, the best way for measuring individuals' exposure to noise is assessing sound pressure level during the whole 8 hours. The results indicated that the 8-hour sound pressure level for various units including Lewis and lineage, injection, and cutting were 81.78, 78.8, and 85.76 dB, respectively. Accordingly, the highest sound pressure level (85.76 dBA) was recorded in the cutting, stitching, and stuffing unit, hence being the most dangerous unit for workers. People working in the Lewis and lineage unit received a dose of 48.25%, while those working in the injection unit received a dose of 24.25%. Also, workers in the cutting, stitching, and stuffing unit received a dose of 119.5%.

Aliabadi et al. (2015) measured environmental sound pressure level and individual exposure in a steel factory. Dosimetry measurement showed that the received doses in the cast iron, furnace, crystal, filter bag, and cooling tower respectively were 2.9, 2.82, 2.4, 2.3, and 1.8 times greater than the standard level. Furthermore, the major noise pollution was recorded in furnace [17]. In the current study, workers' received doses in Lewis, injection, and cutting were 48.25%, 24.25%, and 119.5%, respectively. Thus, the received does in the cutting unit was 1.2 times greater than the standard limit. The main noise pollution was registered in the case of cutting unit (pneumatic and punching machine) with a sound pressure level of 87 dBA, followed by the Lewis unit (brand stamping) with a sound pressure level of 86 dBA.

In this study, environmental sound pressure level was measured in three major halls including Lewis and lineage, injection, and cutting, stitching, and stuffing, which had the largest number of noise generating sources. The overall results of measurements obtained from 161 stations showed that 94 stations (58.4% of machinery) were located in the caution zone, with the majority of such machinery being located in the Lewis and lineage hall (44 stations) and cutting, stitching, and stuffing hall (41 stations) in that order. In addition, sound pressure levels higher than 85 dB were recorded in 57 stations. The results revealed that a major proportion of dangerous sources are located in the cutting, stitching, and stuffing and Lewis and lineage halls. The lowest recorded sound pressure level (57 dBA) belonged to the injection hall, whereas the highest one (93 dBA) was observed in the cutting, stitching, and stuffing hall (Table 2). Based on the obtained sound maps, the highest sound pressure level in the Lewis and lineage hall (88 dBA) belonged to the Lewis machine (map 1), while the maximum sound pressure level in the injection hall (89 dBA) was recorded for the automatic injection machine (map 2). Additionally, the highest sound pressure level in the cutting, stitching, and stuffing unit (90 dBA) was registered for pneumatic, drying and sanding machine. Thus, these machines are the major sources of noise generation (map 3).

Foruharmajd et al. (2015) assessed environmental sound pressure level and drew the sound map of a metal melting factory using Surfer. The results indicated that the highest pressure level (109 dBA) was recorded for the electric arc furnace. Furthermore, studying sound maps revealed that the electric arc furnace was the major source of noise generation in the factory [18]. Muraviev VA et al. (2013) examined the noise generated by metal melting machinery in a Russian factory. They concluded that the electric arc furnace had a sound pressure level of 113 dB as recorded in a distance of 15 meters from the machine. They argued that this machine was the main noise generating source [19]. In the current study, the highest sound pressure level (87 dBA) was recorded for pneumatic and punching machine in the cutting unit.

Hojati et al. (2015) aimed at finding the noise exposure pattern among workers of a steel factory using Surfer. The results showed that 56% of measurement stations were located in danger zones. Studying the sound map also revealed that the highest sound pressure levels were recorded in the electric arc furnace (112.2 dBA) and pathetic furnace (97 dBA) [20]. Omer Ahmad H et al. (2012) also investigated workers' exposure to noise in two steel factories. They showed that the sound pressure level in 17 measurement stations were between 76 and 110 dBA, with 10 stations having sound pressure levels greater than 85 dBA [21]. In the present study, measurements were conducted in 161 stations of the selected units (Lewis and lineage, injection, and cutting, stitching, and stuffing). The results showed that 35.4% of the stations had a sound pressure level greater than 85 dB, hence being located in the danger zone.

5. CONCLUSION

In terms of individuals' exposure to noise, workers of the cutting and Lewis units have the greatest amount of exposure. More specifically, the recorded SPL in the cutting and Lewis units were 85.75 dB and 81.78 dB, respectively. It is therefore necessary to design and execute hearing protection plans among these workers. The results of environmental measurements revealed that, in 35.4% of measurement stations, SPL exceeded the standard level (85 dB). The highest SPL (93 dB) was registered in the cutting, stitching, and stuffing unit. Also, managerial and engineering controls should be exercised more seriously in the cutting, stitching, and stuffing unit in comparison with other units.

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REFERENCES

[1] Gillich G.R., Gillich N., Chioncel C.P., Cziple F., (2008), Legal aspects concerning the evaluation of pollution effects due to vibrations in urban areas, *J. Environ. Prot. Ecol,* 9, 465–473.

[2] Vekteris V., Strishka V., Ozarovskis D., Mokshin V., (2015), Experimental Investigation of Behavior of Fine Particles in Acoustic Air Flow, *Rom. J. Acoust, Vib*. 12, 57.

[3] Tiuc A.E., Vasile O., Usca A.-D., Gabor T., Vermesan H., (2014), The analysis of factors that influence the sound absorption coefficient of porous materials, *Rom. J. Acoust, Vib*. 11, 105.

[4] Nassiri P., Zare S., Pour M.R.M.E., Pourbakht A., Azam K., Golmohammadi T., (2017), Assessment of the Effects of Different Sound Pressure Levels on Distortion Product Otoacoustic Emissions (DPOAEs) in Rats, *Int. J. Occup. Hyg*, 8, 93–99.

[5] Nassiri P., Zare S., Monazzam Pourbakht M.R., A., Azam K., Golmohammadi T., (2017), Evaluation of the effects of various sound pressure levels on the level of serum aldosterone concentration in rats, *Noise Heal*, 19, 200.

[6] Monazzam M.R., Nadri F., Khanjani N., MR G.R., Nadri H., Barsam T., Shamsi M., Akbari H., (2012), Tractor drivers and bystanders noise exposure in different engine speeds and gears, *J. Mil Med*, 14, 149–154.

[7] Lercher P., (1996), Environmental noise and health: An integrated research perspective, *Environ, Int*. 22, 117–129.

[8] Concha-Barrientos M., Steenland K., Prüss-Üstün A., Campbell-Lendrum D.H., Corvalán C.F., Woodward A., Organization W.H., (2004), Occupational noise: assessing the burden of disease from work-related hearing impairment at national and local levels.

[9] Golmohammadi R., Monazzam M.R., Nourollahi M., Nezafat A., Momen Bellah Fard S., (2010), Evaluation of noise propagation characteristics of compressors in tehran oil refinery center and presenting control methods, *J. Res. Health Sci*, 10, 22–30.

[10] Safari Variani A., Ahmadi S., Zare S., Ghorbanideh M., (2018), Water pump noise control using designed acoustic curtains in a residential building of Qazvin city, *Iran Occup Heal*, 15(1), 126–35.

[11]Zare S., Nassiri P., Monazzam M.R., Pourbakht A., Azam K., Golmohammadi T., (2016), Evaluation of the effects of occupational noise exposure on serum aldosterone and potassium among industrial workers, *Noise Health*, 18, 1.

[12]Nassiri P., Zare S., Monazzam M.R., Pourbakht A., Azam K., Golmohammadi T., (2016), Modeling signal-to-noise ratio of otoacoustic emissions in workers exposed to different industrial noise levels, *Noise Health,* 18, 391.

[13]Zare S., Nassiri P., Monazzam M.R., Pourbakht A., Azam K., Golmohammadi T., (2015), Evaluation of Distortion Product Otoacoustic Emissions (DPOAEs) among workers at an Industrial Company exposed to different industrial noise levels in 2014, *Electron, Physician*, 7, 1126.

[14]Nassiri P., Zare S., Monazzam M.R., Pourbakht A., Shirali G., Savari R., Ahmadiangali K., Salehi V., Abadi L.I.G., Dehaghi B.F., (2016), A Model to Determine the Level of Serum Aldosterone in the Workers Attributed to the Combined Effects of Sound Pressure Level, Exposure Time and Serum Potassium Level: A Field-Based Study, Assessment, 27, 9.

[15]Thiery L., Ognedal T., (2008), Note about the statistical background of the methods used in ISO/DIS 9612 to estimate the uncertainty of occupational noise exposure measurements, Acta Acust, *United with Acust,* 94, 331–334.

[16]Golmohammadi R., Aliabadi M., (1999), *Noise and vibration engineering*, Daneshju.

[17]Aliabadi M., Darvishi E., Shafikhani A., (2015), Assessment of the environmental sound level and the noise exposure in a steel Industry.

[18]Forouharmajd F., Shabab M., (2015), Noise Pollution Status in a Metal Melting Industry and the Map of Its Isosonic Curve, *Jundishapur J. Heal, Sci*, 7.

[19]Muraviev V.A., Madatova I.G., (2013), Study of the noise characteristics of industrial equipment on the grounds of a metallurgical complex, *Metallurgist*, 56, 731–735.

[20]Hojati M., Golmohammadi R., Aliabadi M., (2016), Determining the Noise Exposure Pattern in a Steel Company, *J. Occup. Hyg, Eng,* 2, 1–8.

[21]Ahmed H.O., (2012), Noise exposure, awareness, practice and noise annoyance among steel workers in United Arab Emirates, *Open Public Health J*, 5, 28–35.