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ARTICLE

Evaluation of Individual and Environmental Sound Pressure Level and Drawing Noise-Isosonic Maps Using *Surfer V.14* and *Noise at Work V.5.0*

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ABSTRACT

Noise pollution is one of the common physical harmful factors in many work environments. The current study aimed to assess personal and environmental sound pressure level and project the sound-Isosonic map in one of the Razavi Khorasan Paste manufacture using Surfer V.14 and Noise at work V.5.0. This cross-sectional, descriptive study is analytical that was conducted in 2018 in the Paste factory that contains Canister, production and Brewing unit. Following ISO 9612:2009, Casella Cel-320 was used to measure personal sound pressure level, while CEL-450 sound level meter (manufactured by Casella-Cel, the UK) was employed to assess environmental sound pressure level. Statistical analyzes was done using SPSS V.18 and Linear Regression test. The sound-isosonic maps were projected using Surfer V. 14 and Noise at work V.5.0. The results of assessing personal sound pressure level indicated that the highest received dose (172.21%) and personal equivalent sound level (87.36 dBA) were recorded for workers in the Canister unit. According to results of measuring of the environmental sound pressure level, out of 16 measurement stations in this unit, overall 87.5% were regarded as danger and caution areas. The lowest and highest sound pressure levels in this units were 61 dBA and 92 dBA that belong to Brewing and Canister units respectively. Results indicate Over 75% of the Canister and production units had a sound pressure level greater than 85 dBA and these two units were regarded as the most dangerous area in terms of noise pollution. It is therefore necessary to implement noise control measures, apply hearing protection program and auditory tests among workers in these units.

KEYWORDS

Sound pressure level; personal sound; environmental sound; sound map; isosonic map; surfer; noise at work

1 Introduction

Noise is the most common and physically damaging factor worldwide. The workplace noise is generally unpleasant, unwanted and unavoidable, and there is no significant relationship between its pressure amplitudes, frequency and wavelengths. This type of noise (that have no significant relationship between its characteristics (pressure, frequency, and wavelength ranges)), is abundantly produced and emitted in the industry [1]. The advancement of all aspects of science and industry, as well as the use of industrial machinery and equipment have caused overproduction of noise that in turn has affected many industry workers [2].

In the United States, more than 30 million workers are exposed to hazardous noise and 7.4–10.2 million industrial workers are at risk of noise induced hearing loss [3,4]. In Michigan City of the USA, there are about 86,000 people with work-related hearing loss. Despite the fact that it is 100% preventable, hearing loss is a most common occupational disease in the United States [5], so that, $200 million in damages were paid in 1990 for noise induced hearing loss [6]. The ratio of the population exposed to environmental noise of over 65 dB has increased from 15% to 26% in Europe over the past 10 years [7].

From an industry point of view, noise is produced by factors such as, structural and mechanical nature of machines, amount of mechanical part depreciation, the improper performance of moving machinery parts, high flow rate in channels, inappropriate foundation and consequently the structural vibration of machine [8].

Excessive noise causes physiological effects such as hypertension, adrenaline production, increased risk of heart attack, and changes in respiratory rate and amount of consumed oxygen, effects on the auditory system, and increased gastric and intestinal activity, and other psychosocial, social and economic complications. It also affects the individuals' performance and efficiency and interferes in verbal communication and understanding warning signs, and individuals' safety and performance [9,10]. However, even if people understand the noise, it will be difficult to hear the sound of conversation because the masking phenomenon reduces their ability to hear the conversation sound in the workplace. In such circumstances, disruptions in conversation process in the workplace may affect the staff performance [11], and thus it impedes the process of receiving instructions and messages between two people who work together in the workplace, and causes work process disruptions and increases risk of accidents in the workplace due to impaired understanding of conversations between two coworkers in an emergency [12].

Results of a research by Atmaca et al. [13] on assessing industrial noise and its effects on humans in several factories indicated that 61% of workers suffered from neurological disorders and 31% also suffered from hearing disorders. In this regard, Hakimi et al. [14] conducted a research in the outer space of the new unit of Sarcheshmeh copper mine in Kerman with an aim to model rate of noise in the unit in order to determine the best method for the noise control using Sound Plan software and they estimated noise level of 20 dB by placing a module in the air outlet.

The paste manufacturing plant has machines in the canning, production and shearing units that each emit different levels of noise at salons and causes high noise pollution. Since there is no study on the assessment of individual and environmental sound pressure level and drawing isosonic maps in this plant, and due to the increasing progress of industry and industrial technology, it is necessary to investigate risk factors of work environment, including physical hazardous agents and particularly harmful noise in the plant; hence, the present study was designed with the following objectives:

1. Assessment of individual workers' sound pressure levels.
2. Assessment of environmental sound pressure level.
3. Drawing noise and isosonic maps (parallels) using Surfer software.
4. Drawing noise and isosonic maps using Noise at work software.
5. Determining hazardous, warning and safe places at different locations of canning, production and shearing units.

2 Materials and Methods

2.1 Case Study and Sampling Method

The selected industry was a paste production plant. In general, due to the noise pollution, three canning, production and shearing units were selected for the study. In canning unit in a length of 42 m and width of 13 m, swing scissors, rolling, welding, welding dye spraying, marking, and flanging machines were working and produced a lot of noise. In the production unit, there were washing and steam machines, and two conveyors in two rows with 2-meter distance from each other in a hall of 49 meters in length, 14 meters in width, and 6 meters in height, each of which could in turn be the main source of noise production in that hall. In the shearing unit, there were a total of three machines for packing paste cans that produced high noise. The length and width of the unit were 14 and 5, respectively.

The industry had 80 to 120 workers who worked in two 8-hour shifts. 60 workers worked in three studied units in the morning and afternoon shifts and were selected to measure individual sound level. The environmental sound pressure level was also measured in canning, production and shearing units.

2.2 Research Design

The present descriptive cross-sectional and analytical study was conducted in the canning, production and shearing units of a paste production plant in Razavi Khorasan province in 2018. The general stages of study were as follows: 1-Measurement of 8-hour equivalent sound level in individuals and calculation of equivalent dose, 2-Measurement of environmental sound pressure level in each unit, 3-Drawing noise-isosonic maps using Surfer V.14 and Noise at work V.5.0 software, 4-Identifying hazardous, warning and safety areas for all three units.

2.3 Measurement

2.3.1 Measurement of Equivalent Sound Level (Individual Sound Level)

The equivalent sound level was evaluated by noise dosimeter (Casella, Model Cell-320) and standard ISO 9612. The calibrator Cel-110/2 was used to calibrate the dosimeter before measurement [15,16]. As individuals were working continuously in the units (except for 2 h of rest), their individual equivalent levels in the site were measured for 6 h. Workers also left the site for rest in the hall during breaks; and their noise equivalent levels were measured and recorded for 2 h. The calculation of equivalent dose by workers and measurement of the eight-hour equivalent level are presented as follows [17]:

Measurement of equivalent dose by workers

Dosimetry was the most reliable method for measuring and evaluating the worker exposure. According to the Iranian exposure standard, the individuals' dose percentage can be calculated according to equivalent levels in the site and lounge as follows [18]:

$$D(\%) = 12.5 \sum_{i=1}^{n} t_i anti \log\left(\frac{SPL_i - 85}{10}\right) \tag{1}$$

Measurement of the 8-hour equivalent sound level

The following equation was used to measure the 8-hour equivalent sound level in studied units [18]:

$$L_{eq}.8h(dB) = 10Log\left[\frac{1}{8}\sum_{i=1}^{n} t_i \times 10^{\frac{LP_i}{10}}\right] \tag{2}$$

Leq.8h: 8-hour equivalent sound level (dB)

ti: Duration of relevant exposures (hr)

LP_i: Measured equivalent sound level in lounge and workplace (dB)

2.3.2 Measurement of Environmental Sound Pressure Level

The sound level meter, model CEL-450 made by Casella- Cel Company of the UK, in the frequency distribution network A and at slow speed was used to measure the environmental sound pressure level at desired points. This level meter was calibrated before any measurement by calibrator Cel, Model 110/2. In the first phase of study, environmental sound meter was done according to standard ISO 9612:2009 [15,19] and ISO 11200:2014 in order to determine noise pollution levels in the units and identify main sources of noise production [3,20]. In the study, the studied units were divided into equal squares (5×5 m^2) and centers of the squares were considered as measurement points. Since the environmental noise is continuous and there are low noise changes due to the time in this industrial complex, the noise was measured at each point for at least three times and the average of these three readings was considered as the noise level in the station. According to the research purpose, which was the assessment of noise pollution in baking unit of complex, the network A was selected as the measured level of sound level. Microphone direction was towards the position of participants' head without their presence according to standard ISO 9612:2009. The microphone of sound meter had a distance of about 1.55 ± 0.075 m from the ground level. In cases where the considered square was located on a device or location that was not measurable, that point was considered as the blind spots and was eliminated from the sum of measurement points. In the research design, locations such as the device location in canning room and workers' lounges were considered as blind spots [15,21].

2.3.3 Drawing the Noise and Isosonic Zoning Map

Noise-isosonic maps are conventional methods of drawing in the provision and assessment of workplace noise. These maps indicate different areas of a workshop based on desired areas for the Sound Pressure Level. The workshop was first divided into grid places with identical dimensions (canning and production halls: 5×5 m^2 and shearing hall: 2×2 m^2) and center of each area was considered as a station for measuring sound pressure level. After the measurement, the results were entered into the station plan of plant and then into the Surfer v.14 and Noise at work V.5.0 software in a file format (input data). In the next step, noise-isosonic maps were drawn according to three ranges of sound pressure level (referred below). In isosonic maps, points with equal levels are connected, and isosonic curves are drawn. Like topographic maps, the lines show sound pressure level ranges [17,22].

- Safe zone (SPL ≤ 65 dBA) in green
- Warning zone (65 < SPL ≤ 85 dBA) in yellow
- Hazardous zone (SPL > 85 dBA) in red

2.4 Data 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 Results of Equivalent Sound Level Measurement

Tab. 1 presents results of the 8-hour equivalent sound dosimetry. The highest dose belonged to canning workers at 172.21%; hence, workers of this unit had the highest eight-hour individual exposure level (dBA: 87.36).

3.2 Results of Environmental Sound Pressure Level Measurement

Tab. 2 presents the environmental sound pressure levels, number of stations, blindspots, and station classification in terms of sound pressure levels. Minimum sound pressure level of 61 dBA belonged to the shearing unit; and the maximum sound pressure level of 92 dBA belonged to the canning unit. Most of measurement stations were in the production unit; and most of blind spots were in canning unit. 77.77% of production unit stations were in red and 22.23% were in yellow.

Table 1: Results of individual sound pressure level measurement (n = 60)

Unit name	Number of workers	Presence places (Hours)		Individual equivalent sound level (dBA)		Equivalent dose (%)	8-hour equivalent sound level (dBA)
		Site	Rest hall	Site	Rest hall		
Canning	28	6 h	2 h	88.60	67	172.21	87.36
Production	24	6 h	2 h	86.50	67	106.34	85.27
Shearing	8	6 h	2 h	84	67	95.91	82.78

Table 2: Results of environmental sound pressure level measurement

Unit name	N	B.S	Min.S (dBA)	Max.S (dBA)	N > 85 dBA		65 < N ≤ 85 dBA		N ≤ 65 dBA	
					Percent	No.	Percent	No.	Percent	No.
Canning	16	8	63	92	12.5	2	25	4	12.5	2
Production	18	–	84	90	77.77	14	22.3	4	–	–
Shearing	14	–	61	84	–	–	50	7	50	7

Note: N = Number of stations; B.S (Blind spots) = Number of blind spots; Min.S (Minimum SPL) = Minimum Sound Pressure Level; Max.S (Maximum SPL) = Maximum Sound Pressure Level.

3.3 Results of Drawing Noise and Isosonic Maps

3.3.1 Noise-Isosonic Map by Surfer V.14

Fig. 1 shows the noise-isosonic map of plant units. Three units- canning, production and shearing, are shown by mentioning sources of sound production and identifying hazard, warning and safe points. The maximum sound pressure level belonged to canning unit; and the maximum area of hazard belonged to the production unit.

3.3.2 Noise-Isosonic Map by Noise at Work V.5.0

Fig. 2 shows the noise-isosonic map of the plant units by determining hazardous, warning and safe points. The locations of machines are also shown in the following figure.

As shown, the result of figure is a color zoned and factory-level map of the plant with safe, warning and hazardous areas. The hazardous area is significantly important for noise control measures.

4 Discussion

The present study aimed to evaluate individual and environmental sound pressure levels and draw noise-isosonic maps by Surfer V.14 and Noise at work V.5.0 in a paste production plant of Razavi Khorasan province in 2018. Results of dosimetry of all workers in the units indicated that the mean 8-hour equivalent levels of workers were 87.36, 85.27 and 82.78 dBA in canning, production and shearing units, respectively. The results indicated that the canning unit was the most hazardous unit in terms of equilibrium level. The mean equivalent levels of workers were 3.6 and 1.5 dB higher than the permissible level in canning and production units respectively, while the mean levels were lower than the recommended level for the shearing unit. The equivalent doses were 172.21%, 106.34%, and 95.91% in canning, production and shearing units, respectively; and the equivalent dose of canning unit was

1.72 times higher than the limit (Tab. 1). Number of stations with sound pressure levels of higher than the permissible level (greater than 85 dBA) was higher in the production unit. Furthermore, number of safe stations (less than 65 dBA) was greater in the shearing unit. The minimum sound pressure level was 61 dBA, and the maximum was 92 dBA and they belonged to the shearing and canning units respectively. The highest number of measurable stations as well as the highest number of blind spots with 18 and 8 stations belonged to production and canning units respectively (Tab. 2). There are three red, yellow and green zones in the canning unit. There are only yellow and green zones in the shearing unit. The most hazardous units were canning (due to high sound pressure levels) and production (due to high hazard range) units (Figs. 1 and 2).

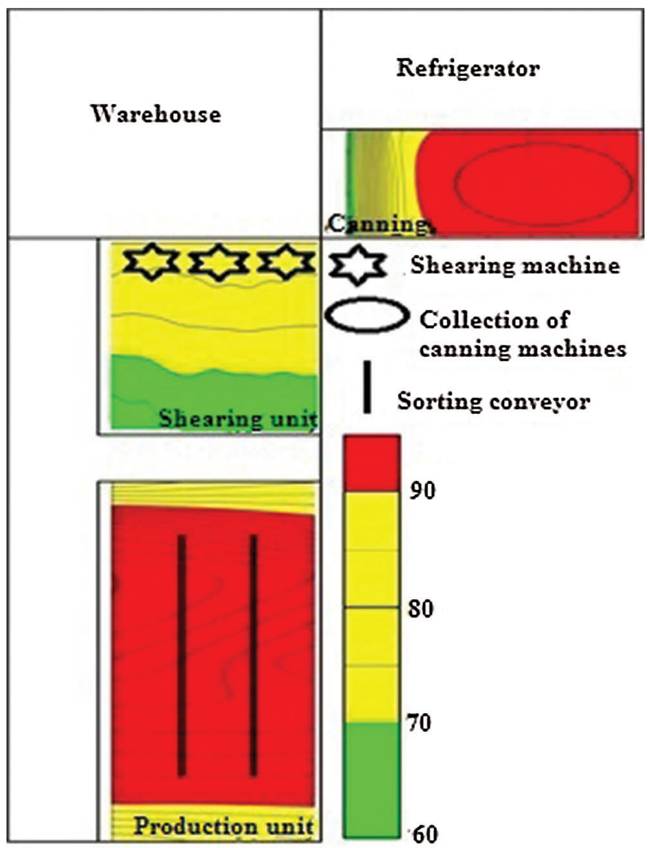

Figure 1: Noise-isosonic map of canning, production and shearing units by Surfer software

In a study by Forouharmajd et al. [23] with an aim to evaluate the environmental sound and drawing noise map in the metal melting industry by Surfer software, results indicated that the highest sound pressure level belonged to the electric arc furnace with 109 dB level. According to results of noise maps, the electric arc furnace was identified as the source of sound production in the industry. In the present study, canning unit machines were the main factors of noise production in the plant. With an aim to determine the pattern of workers' exposure to noise in a steel industry by Surfer software, Hojati et al. [16] concluded that 56 percent of all measured stations were within the hazardous range. According to the noise map, the maximum sound levels were 112.2 dB and 97 dB in the electric arc and ladle furnaces respectively. In the present study, 77% of the production unit and 12.5% of the canning unit were in hazardous zone and are greatly in the warning zone.

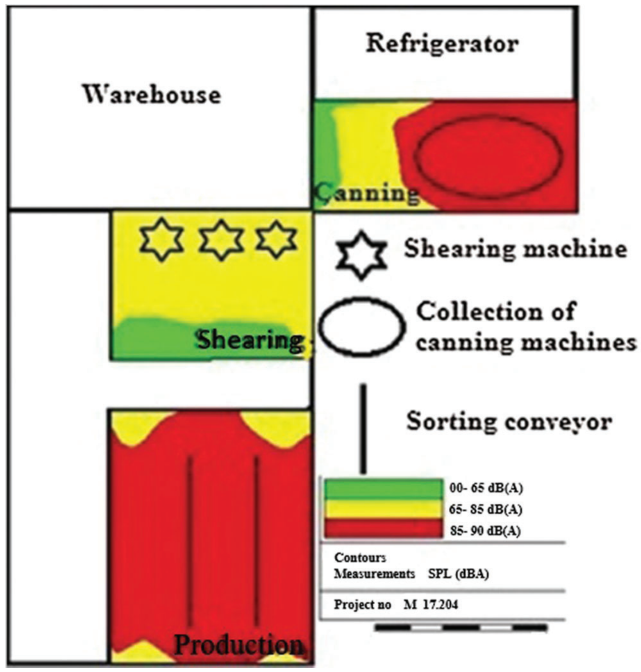

Figure 2: Noise-Isosonic map of canning, production and shearing units by *Noise at work* software

Golmohammadi et al. [24] investigated sound emission characteristics of point sources and presented a sound control scheme for three sources (compressors, pumps, and control valves) of the Isomax and Control Unit I of Refining Company of Tehran in 2009, and their results indicated that weight pressure levels and maximum sound pressure of sources exceeded the recommended limit. Results of Golmohammadi's study were consistent with results of the present study, so that the noise level of the plant was higher than the permissible level and had created a wide hazard range for workers. Zare et al. [18] also found that cutting, sewing, and carving workers had excessive noise levels. In a study titles "the Evaluation of individual and environmental sound pressure levels and drawing noise maps at the shoe factory", they also examined environmental sound pressure levels; and a total of 3 major factory units, and 32.3% of measured stations were in the risk range (above 85 dBA). The maximum sound pressure level was 88 dB in skiving and creaser unit, 89 dB in the injection unit, and 93 dB in cutting, sewing and lasting unit. In the present study, the canning and production workers had noise levels of greater than the permissible level, and a total of 33.34% of measured stations had levels of above 85 dBA. The maximum sound pressure level was 92 dB in canning unit, 90 dB in production unit, and 84 dB in shearing unit.

Results of a study by Muraviev et al. [25] on characteristics of produced sound by metal melting complex equipment in Russia indicated that sound pressure level of equipment such as an electric arc furnace in bending was 113 dB in a distance of 15 meters; and the furnace was considered as the main source of sound production. In the present study, the highest sound pressure level belonged to caning and production units. Maximum sound pressure levels of the units were 92 and 90 dBA, respectively. In another study by Golshah [26] for investigating engineering control methods in Isfahan Petrochemical Complex, results indicated that the mean sound pressure level was above the permissible limit in most units of the industrial complex; and the produced sound was mainly due to the movement of relevant fluids and plumbing as well as the rotation of engines and compressors in the refining operation. Golshah's results were consistent with results and sources of sound production in the present study.

Strengths of the present study included the use of two software for drawing noise-isosonic maps and the small number of such studies on this field. The imitations and problems of project included the non-cooperation of some people and also the need for permission from units.

5 Conclusion

The results of assessing the individual exposure of units indicated that people were exposed to continuous noise of higher than the permitted level. Given the percentage of exposure to noise in the canning unit (172.21%), the unit remained the most hazardous unit in terms of noise pollution levels. Furthermore, the environmental sound pressure level was higher than the standard limit in the hall compared to the other two units. Therefore, the sound technical control in canning unit, and the Hearing Protection Program implementation for workers should be the top priorities of the industry. In additions, both of the software were equally in the same precisions. Their results of the noise-isosonic maps show the noise pollution zones correctly.

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