



## Evaluation of Noise Exposure in Gypsum Plant in Terms of Work Safety

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**Abstract.** Noise is one of the major physical risk factors for workers in the heavy industrial sector. Within the context of this study, the environments in which employees are located in a gypsum plant were determined, noise measurements were made according to the work they performed, the results were evaluated and frequency-noise relationships were revealed. According to this, while the highest noise was found in the crusher unit, administrative building personnel were exposed to the lowest level of noise. The regions exceeding the exposure limit value are packaging and stone crushing units. In the measured areas, the maximum noise levels exposed by the workers correspond to the medium frequency range and the minimum noise levels correspond to the low and high frequency ranges. The maximum noise level to which workers in all branches are exposed is in the frequency range of 250 Hz and 2500 Hz. The noise levels generated by the machines are in the wide frequency range, and the maximum sounds from the noise sources in the factory are defined as thin sound. As a result of the measurements made, it was calculated that the maximum noise levels, which are mostly exposed by the factory staff, are outside the frequency range where the human ear is most sensitive.

**Keywords:** Noise exposure,  $\frac{1}{3}$  octave band frequency, spectral analysis, frequency-noise relation, gypsum plant.

## Alçı Fabrikasında Gürültü Maruziyetinin İş Güvenliği Açısından Değerlendirilmesi

**Özet.** Gürültü Ağır sanayi sektöründe çalışanların maruz kaldığı önemli fiziksel risk etkenlerinden birisidir. Bu çalışma kapsamında bir alçı fabrikasında çalışanların bulunduğu ortamlar belirlenmiş, yaptıkları işe göre ayrı ayrı ölçümler yapıp, sonuçları değerlendirilmiş ve frekans gürültü ilişkileri ortaya çıkarılmıştır. Buna göre en yüksek gürültü taş kırma ünitesinde meydana gelirken idari bina personeli en düşük düzeyde gürültüye maruz kalmışlardır. Maruziyet sınır değerini aşan bölgeler paketleme ve taş kırma üniteleridir. Ayrıca ölçüm yapılan bölgelerde çalışanların maruz kaldığı maksimum gürültü düzeyleri orta frekans aralığına, minimum gürültü düzeyleri ise düşük ve yüksek frekans aralıklarına denk gelmektedir. Tüm şubelerde çalışanların maruz kaldığı maksimum gürültü düzeyi 250 Hz ve 2500 Hz frekans aralığındadır. Makinelerin oluşturduğu gürültü düzeyleri geniş frekans aralığında olup, fabrikadaki gürültü kaynaklarının çıkardığı maksimum sesler ince ses olarak tanımlanmaktadır. Yapılan ölçümler sonucunda fabrikadaki personelin çoğunlukla maruz kaldığı maksimum gürültü düzeyleri insan kulağının en hassas olduğu frekans bölgesinin dışında olduğu hesaplanmıştır.

**Anahtar Kelimeler:** Gürültü maruziyeti,  $\frac{1}{3}$  oktav bant frekansı, spektral analiz, frekans-gürültü ilişkisi, alçı fabrikası.

## 1. INTRODUCTION

While most people can hear sounds in the range of 20 Hz to 20000 Hz frequency, the human ear is not equally sensitive to all frequencies [1]. There are several approaches in the literature to describe the frequency ranges that the human ear can handle as low, medium and high frequency. Sounds lower than 250 Hz are called low frequency sounds, sounds between 250 Hz and 2000 Hz as medium-frequency sounds and those higher than 2000 Hz frequency are called high frequency sounds [2-4]. On the other hand, Brodin et al. [5] and Alves et al [6] described sound lower than 200 Hz as low frequency sounds.

High frequency sounds cause more hearing loss on workers than low frequency sounds [7, 8]. On the other hand, low frequency sounds create fatigue and lead to concentration disorders [9]. It is stated that the sounds in this frequency range may lead to serious problems such as loss of balance, pressure, high blood pressure, temporary memory loss, pressure on the ears, effects on the entire body, impaired cardiac rhythm and sleep disturbance [10-12]. High frequency sounds are expressed to have effects of high blood pressure, fatigue and hearing loss [13].

The primary noise-induced damage to the human health is temporary and permanent hearing loss. Persons exposed to high noise may experience a temporary hearing loss if the necessary precautions are not taken. Temporary hearing loss can be converted to permanent hearing loss if the period of stay in a noisy environment is prolonged for several years. The most sensitive hearing frequency range the ear has is about 4000 Hz [14, 15]. Therefore, even if the person gets away from the noisy environment and is unable to recover from hearing deficiency, the situation can result a long-term permanent hearing loss. This can indicate a permanent occupational disease [16]. Temporary or permanent hearing loss and the degree of loss are dependent on the level of exposure being affected, the frequency content, and the duration of the effect as well as the personal sensitivity.

Ear protectors, which are active in personal protection, are known to reduce noise intensity as much as 30 dB(A) in low frequency and 50 dB(A) in high frequency while polyurethane plugs placed in the outer ear path reduce noise intensity as much as 25 dB(A) in low frequency and 40 dB(A) in high frequency [7].

Since the frequencies of the sound sources are different, they will not steer properly if the sound waves are blocked by noise curtains. Low frequencies (long wavelengths) are more distorted when high frequencies (shorter wavelengths) are less distorted. Therefore, noise curtains are generally more effective in reducing high frequency sounds [1, 17]. Low frequency sounds are more difficult to block with barriers as they can pass directly through the obstacle and can be steered with relative ease. For this reason, thicker sound-absorbing materials are required to reduce the intensity of low frequency sounds compared to high frequency sounds [18]. It is also difficult and expensive to control low frequency sounds technically. Sound insulation in buildings is not practical, especially since it affects the design of modern buildings. Closing the noise source is a better option and will provide a more comprehensive solution. The noise levels in the machines producing low frequency sound can be reduced by using vibration absorbing fasteners [19]. Alptekin [20] suggests that the insulation type and wall thickness have no positive effect on sound absorption in high frequency sounds, that insulation material and wall thickness are effective on sound absorption in the frequency range of 200-600 Hz, and that frequency values of city noise are measured and insulation material be selected accordingly.

The highest exposure action value ( $L_{EX}$ , 8h) that workers are exposed to according to A-frequency weighting is 85 dB(A) and over [21-23].

## 2. FIELD WORK

### 2.1 Material and Method

In this study, noise exposure measurements were conducted in accordance with the following

standards; TS EN ISO 9612-2009 “Acoustics - Determination of occupational noise exposure - Engineering method” and TS 2607 ISO 1999 “Acoustics - Determination of occupational noise exposure and estimation of noise-induced hearing impairment”. In order to evaluate noise exposure, in both standards, based on the sound exposure averaged over 8 hours ( $L_{EX-8h}$ ), the square root of the arithmetic mean of the squares of the sound pressure values (RMS) was defined. Besides, the frequency-noise relation for assessing noise exposure has also been studied.

Measurements were conducted with a high sensitivity Class-1 Sound Level Meter and analyzer that complies with the Environmental Hazard Assessment and Management Regulation issued by the Ministry of Environment and Urbanization [24]. The sound meter meets the requirements stipulated in IEC 61672-1: 2002 standard and has an integral  $\frac{1}{3}$  octave band filter for frequency analysis. Noise measurements were performed

with A, C and Z (linear) frequency weighting by defining three separate profiles.

## 2.2 Noise Measurements

Noise measurements were made in a gypsum plant in Sivas. The measurements were analyzed by means of a packet program [25] used for noise-vibration analysis and the results are given in Table 1. The units and processes that are measured in the factory are given below: PLC room, administrative building, quality control laboratory, shift supervisor room, mechanical maintenance-repair workshop, mixer laboratory, mixer additive area, packing unit, packing bag control band, packing bag stacking operator, building chemicals packing unit, building chemicals mixer, stockroom and finished product loading area, forklift operator, stone crushing unit, stone crushing unit control room, wheel loader, mill and packing unit cleaning staff.

**Table 1.** Noise measurement results in gypsum plant.

Measurement place	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)	$L_{99}$ (dBA)	$L_{EX,8h}$ (dBA)	$\sigma$ (dBA)	Dominant frequency range (Hz)
1	08:56	A, Fast	109.4	84.5	56.2	61.3	66.5	93.6	70.1	60.5	57.3	56.2	66.2	2.1	400 - 630
		C, Fast	109.4	99.4	69.0	75.7	77.5	104.6	78.7	74.7	71.3	69.3	77.2	2.0	
		Z, Fast	114.8	107.0	72.6	79.3	84.5	111.6	83.3	79.0	75.5	73.0	84.2	2.0	
2	10:47	A, Fast	99.0	81.9	36.5	45.8	62.6	90.7	64.5	45.6	39.6	37.7	62.3	2.4	400 - 630
		C, Fast	99.0	85.7	57.6	64.6	69.2	97.3	72.2	64.0	61.0	58.6	68.9	2.0	
		Z, Fast	99.9	86.6	64.2	72.1	72.7	100.8	74.8	70.9	67.8	65.2	72.4	2.0	
3	10:24	A, Fast	111.6	92.2	49.3	65.4	74.4	102.3	76.9	62.5	52.0	50.2	74.1	2.3	400 - 630
		C, Fast	111.6	102.0	71.8	76.7	81.5	109.5	84.2	77.2	74.6	72.7	81.2	2.0	
		Z, Fast	120.4	112.7	79.2	83.0	87.7	115.6	87.8	83.9	81.8	79.9	87.4	2.0	
4	10:37	A, Fast	94.6	77.1	60.3	62.3	63.8	91.9	65.1	62.7	61.3	60.3	63.5	2.0	250 - 400
		C, Fast	94.6	83.1	70.8	73.4	73.9	102.0	75.0	73.5	72.1	71.0	73.6	2.0	
		Z, Fast	98.8	90.1	73.2	77.2	77.7	105.7	79.6	76.9	74.8	73.2	77.4	2.0	
5	10:11	A, Fast	106.6	93.7	77.0	80.3	81.2	109.1	83.6	79.6	78.0	77.3	81.0	2.0	400 - 800
		C, Fast	106.6	96.5	84.2	87.1	87.7	115.5	89.4	87.1	85.5	84.3	87.4	2.0	
		Z, Fast	109.2	99.9	85.4	88.6	89.1	117.0	91.0	88.6	86.9	85.6	88.9	2.0	
6	10:45	A, Fast	102.0	79.5	54.1	58.6	62.2	90.3	64.2	58.7	56.6	54.7	61.9	2.0	315 - 630
		C, Fast	102.0	93.7	71.0	76.9	81.7	109.7	85.8	78.3	74.3	71.9	81.4	2.0	
		Z, Fast	111.2	104.1	78.3	86.1	89.7	117.7	92.5	88.4	83.1	78.8	89.4	2.0	
7	10:04	A, Fast	112.0	97.2	74.9	78.0	80.3	108.1	83.7	78.2	76.8	75.6	80.1	2.0	630 - 1000
		C, Fast	112.0	98.8	84.7	89.4	89.2	117.0	90.8	88.9	87.2	85.9	89.0	2.0	
		Z, Fast	113.6	100.4	88.0	93.1	92.9	120.7	95.0	92.6	90.1	88.2	92.7	2.0	
8	10:04	A, Fast	115.4	100.3	82.3	87.4	88.6	116.4	91.1	87.3	85.2	83.4	88.3	2.0	630 - 1600
		C, Fast	115.4	101.1	90.3	93.9	93.7	121.5	95.1	93.4	92.0	90.7	93.4	2.0	
		Z, Fast	116.0	102.8	92.6	96.3	96.3	124.1	98.0	96.1	94.2	92.7	96.1	2.0	
9	10:40	A, Fast	111.4	96.5	75.5	81.9	82.1	110.1	84.6	80.4	78.2	76.8	84.4	2.0	500 - 800
		C, Fast	111.4	98.4	82.7	86.6	87.0	115.1	88.9	86.3	84.6	83.3	89.3	2.0	
		Z, Fast	111.8	99.0	84.8	89.8	89.5	117.6	91.6	89.0	86.7	85.1	91.8	2.0	
10	10:03	A, Fast	108.9	96.7	72.5	81.5	82.0	109.9	84.8	79.8	76.0	73.7	81.8	2.0	630 - 1600
		C, Fast	108.9	98.2	80.2	86.0	86.2	114.0	88.5	84.9	82.7	81.3	85.9	2.0	
		Z, Fast	110.5	99.2	83.0	88.6	89.0	116.8	90.9	88.5	86.1	84.0	88.7	2.0	
11	10:30	A, Fast	117.1	99.3	69.9	78.8	84.4	112.4	88.3	78.9	74.2	71.0	84.1	2.1	630 - 800
		C, Fast	117.1	107.9	76.2	82.8	88.5	116.5	91.2	83.9	80.1	77.4	88.3	2.0	
		Z, Fast	117.8	109.1	78.4	84.2	89.4	117.4	91.6	85.5	82.0	79.7	89.2	2.0	

Measurement place	Average time mm:ss	Filter, detector	L <sub>peak</sub> (dB)	L <sub>max</sub> (dB)	L <sub>min</sub> (dB)	SPL (dB)	L <sub>eq</sub> (dB)	SEL (dB)	L <sub>10</sub> (dBA)	L <sub>50</sub> (dBA)	L <sub>90</sub> (dBA)	L <sub>99</sub> (dBA)	L <sub>EX,ss</sub> (dBA)	σ (dBA)	Dominant frequency range (Hz)
12	10:15	A, Fast	110.4	94.5	64.5	71.8	77.6	105.5	80.1	75.8	68.1	66.8	77.3	2.1	630 - 1600
		C, Fast	110.4	100.7	73.6	79.3	82.6	110.5	84.3	81.0	77.5	74.7	82.4	2.0	
		Z, Fast	113.8	105.6	76.0	81.8	85.4	113.3	86.7	83.7	80.3	77.0	85.1	2.0	
13	10:20	A, Fast	113.2	98.9	62.5	74.9	82.8	110.8	86.8	76.7	68.0	64.1	82.5	2.1	1250 - 1600
		C, Fast	113.2	99.6	71.3	81.7	85.4	113.3	89.0	82.2	76.7	72.9	85.1	2.0	
		Z, Fast	113.5	100.0	72.9	83.3	86.5	114.4	90.0	83.7	78.7	74.9	86.3	2.0	
14	10:47	A, Fast	128.0	107.1	65.0	82.4	83.7	111.8	85.6	78.2	71.4	66.8	83.4	2.1	1250 - 2500
		C, Fast	128.0	119.3	77.8	87.6	95.6	123.7	98.0	91.2	85.2	80.7	95.3	2.1	
		Z, Fast	135.8	127.2	79.9	88.3	100.6	128.7	102.1	95.0	88.2	83.3	100.3	2.1	
15	10:05	A, Fast	128.9	110.5	76.5	91.9	92.6	120.4	94.5	90.0	86.4	84.5	92.3	2.0	315 - 1000
		C, Fast	128.9	116.3	87.1	97.6	98.8	126.7	100.0	96.9	93.8	91.6	98.6	2.0	
		Z, Fast	129.3	116.5	88.6	99.3	99.8	127.6	101.1	98.2	94.8	92.7	99.5	2.0	
16	10:02	A, Fast	111.0	86.7	55.3	62.1	65.1	92.9	66.3	59.4	57.5	56.0	64.9	2.0	500 - 1250
		C, Fast	111.0	101.0	70.8	78.2	80.0	107.8	81.8	78.2	74.4	72.0	79.7	2.0	
		Z, Fast	114.1	105.8	74.0	83.3	84.2	112.0	85.6	81.8	77.9	75.1	83.9	2.0	
17	10:34	A, Fast	108.8	83.2	59.3	65.8	67.6	95.6	70.7	64.1	61.5	60.0	67.3	2.0	250 - 500
		C, Fast	108.8	100.0	76.7	84.8	83.6	111.6	85.9	81.1	78.5	77.1	85.4	2.0	
		Z, Fast	113.6	107.1	78.8	90.0	88.8	116.8	90.9	84.3	80.8	79.2	88.5	2.1	
18	10:06	A, Fast	110.8	95.5	77.5	84.8	81.7	109.5	82.7	80.9	79.3	78.1	81.4	2.0	500 - 2500
		C, Fast	110.8	100.8	86.2	91.1	90.4	118.2	91.3	89.1	87.6	86.5	90.1	2.0	
		Z, Fast	111.4	101.6	88.1	93.1	92.5	120.3	93.8	91.5	89.6	88.3	92.2	2.0	
19	10:04	A, Fast	107.9	93.6	71.4	78.5	79.9	107.7	81.7	78.3	76.5	73.6	79.6	2.0	630 - 2500
		C, Fast	107.9	95.3	80.6	87.2	87.4	115.2	88.9	87.2	85.2	82.3	87.2	2.0	
		Z, Fast	109.6	98.6	83.6	91.3	91.5	119.3	93.8	91.0	88.2	85.3	91.2	2.0	

- |  |                                  |  |   |
|--|----------------------------------|--|---|
| 1 PLC room                               | 6 mixer laboratory               | 11 building chemicals packing unit             | 16 stone crushing unit control room     |
| 2 administrative building                | 7 mixer additive area            | 12 building chemicals mixer                    | 17 wheel loader                         |
| 3 quality control laboratory             | 8 packing unit                   | 13 stockroom and finished product loading area | 18 mill                                 |
| 4 shift supervisor room                  | 9 packing bag control band       | 14 forklift operator                           | 19 mill and packing unit cleaning staff |
| 5 mechanical maintenance-repair workshop | 10 packing bag stacking operator | 15 stone crushing unit                         |   |

The noise level generated in the work areas in the factory is collectively shown in Figure 1. The following results were obtained by evaluating the data.

- a) Administrative building personnel was exposed to the lowest level of noise while the highest noise was found in the stone crushing unit.
- b) Except for the staff in the PLC room, administrative building, quality control laboratory, shift supervisor room, mixer laboratory, building chemicals mixer, stone crushing unit control room, wheel loader, mill and packing unit cleaning, the other staff members in the study area were exposed to noise levels higher than the minimum exposure action value of 80 dB(A).
- c) Except for the cleaning staff, the staff in other studied areas were exposed to noise levels higher than the minimum exposure action value of 80 dB(A).
- d) Areas exceeding the exposure limit value are packaging and crushing units.

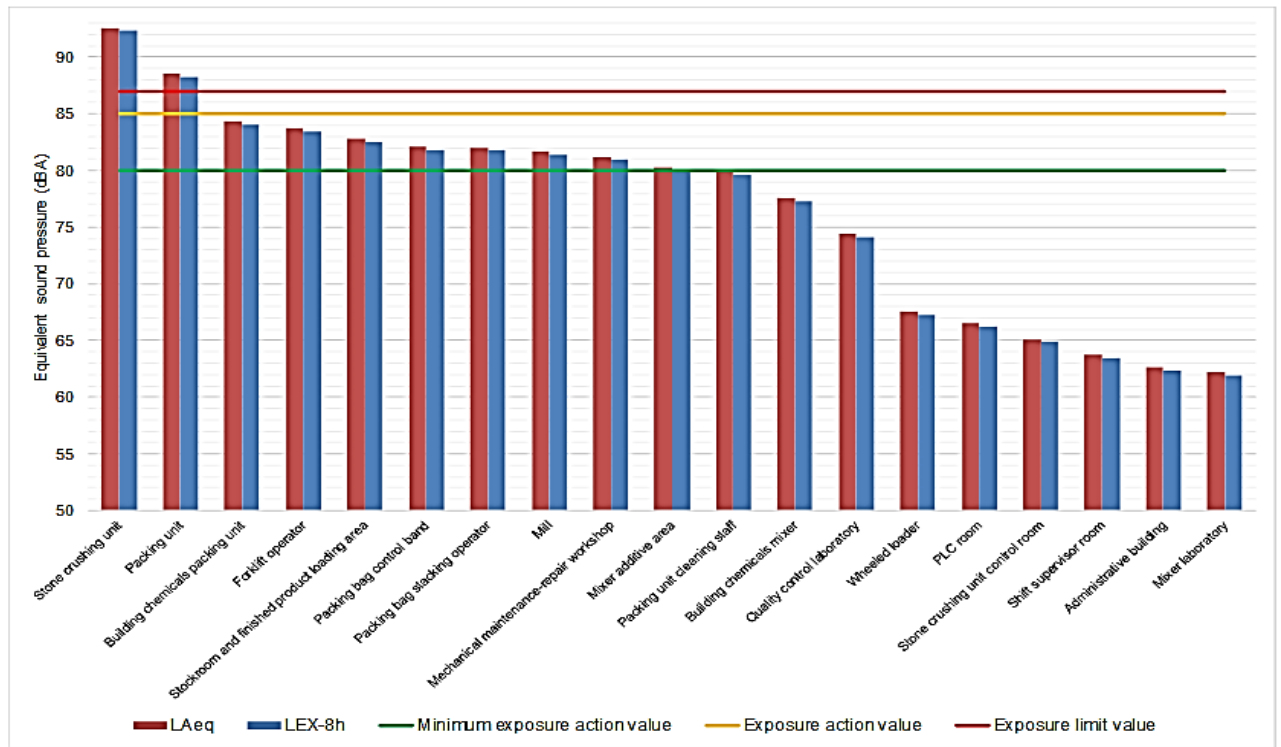


Figure 1. Noise levels during operations on all branches of the gypsum plant.

### 3. FINDINGS AND DISCUSSION

Within the scope of the study,  $\frac{1}{3}$  octave frequency-noise relations of the measurements performed in all branches were determined. The frequency-noise relationship in all operations is shown in Figure 2. The following results were obtained by evaluating the data.

- a) The dominant frequency ranges to which employees are exposed in all branches are varying (Table 1). Accordingly, there is no working area where the dominant frequency range is within the low frequency range. The predominant frequency ranges correspond to the medium frequency range and the minimum noise levels correspond to the low and high frequency ranges.
- b) The noise levels of the forklift operator and the packaging unit cleaning personnel are close to the frequency range that the human ear is sensitive to.
- c) The noise values in all the branches that are measured are in the wide frequency range.
- d) Employees at the gypsum plant cannot hear noise levels below about 40 Hz.
- e) The effective noise level ranges exposed by employees in all the branches that are measured correspond to the frequency ranges of the audiogram-hearing test analyzes.
- f) Sounds from noise sources at the gypsum plant can be described as subtle sound.
- g) Since the dominant frequency ranges of noise sources in the plant are not in the low frequency ranges, it is easy to reduce the noise intensity that workers are exposed to.
- h) The peak frequency of the crushing unit is 800 Hz and the LEX,8h is 92.3 dB(A) while the maximum noise level at the control room (gypsum plastered brick wall) in the same

place is 1250 Hz and the LEX,8h is 64.9 dB(A).

control room (PVC-coated wall) is measured as 500 Hz and the LEX,8h is 66.2 dB(A).

- i) The peak frequency of vibrations at the mixer doping zone is measured at 630-1000 Hz and LEX,8h is 80.1 dB(A), while the maximum noise level at the same control room (PVC-coated wall) is measured as 315-630 Hz and the LEX,8h is 61.9 dB(A).
- j) The peak frequency of vibrations at the mechanical maintenance-repair workshop is measured at 630 Hz and LEX,8h is 81 dB(A), while the maximum noise level at the PLC
- k) The noise sources in the factory show different behavior. Noise in the shift supervisor room, the mechanical maintenance-repair shop, the mixer doping area, the packaging unit, the packaging control band, the mill and the packaging cleaning personnel concentrates in the narrow gap while noise exposed to in other branches concentrate in the wider gap. An exemplary sound pressure histogram is given in Fig. 3 and Fig. 4.

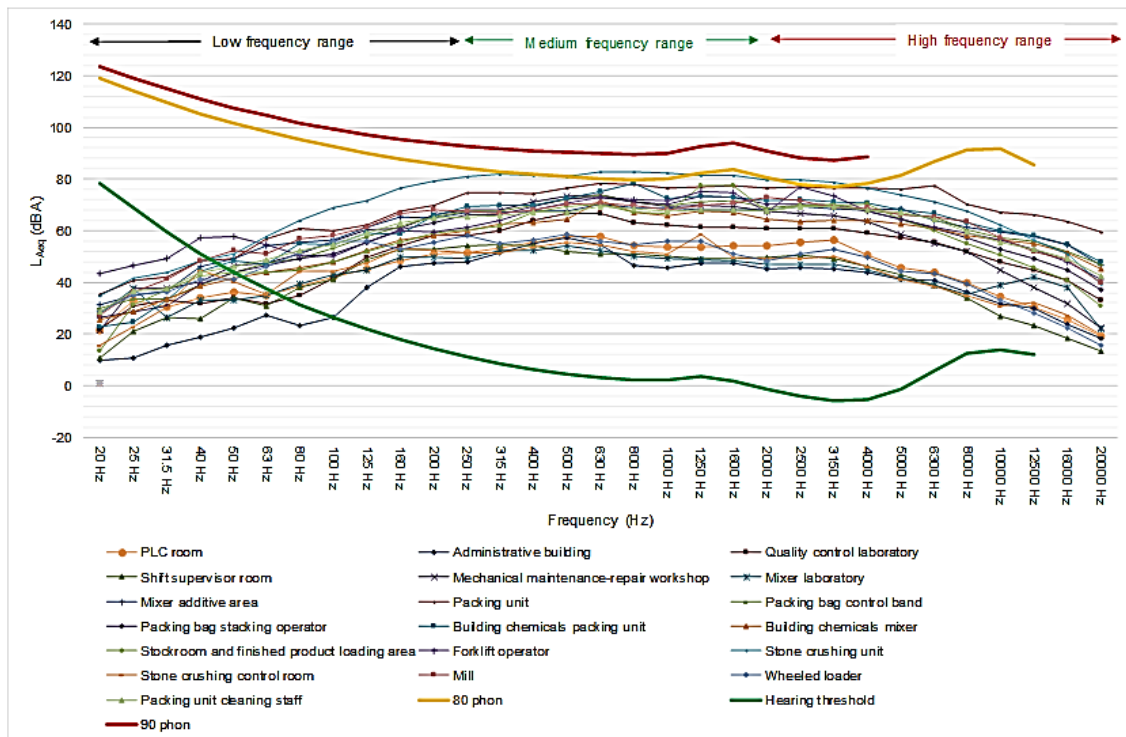


Figure 2. Frequency distribution of noise levels during operations on all branches of the gypsum plant.

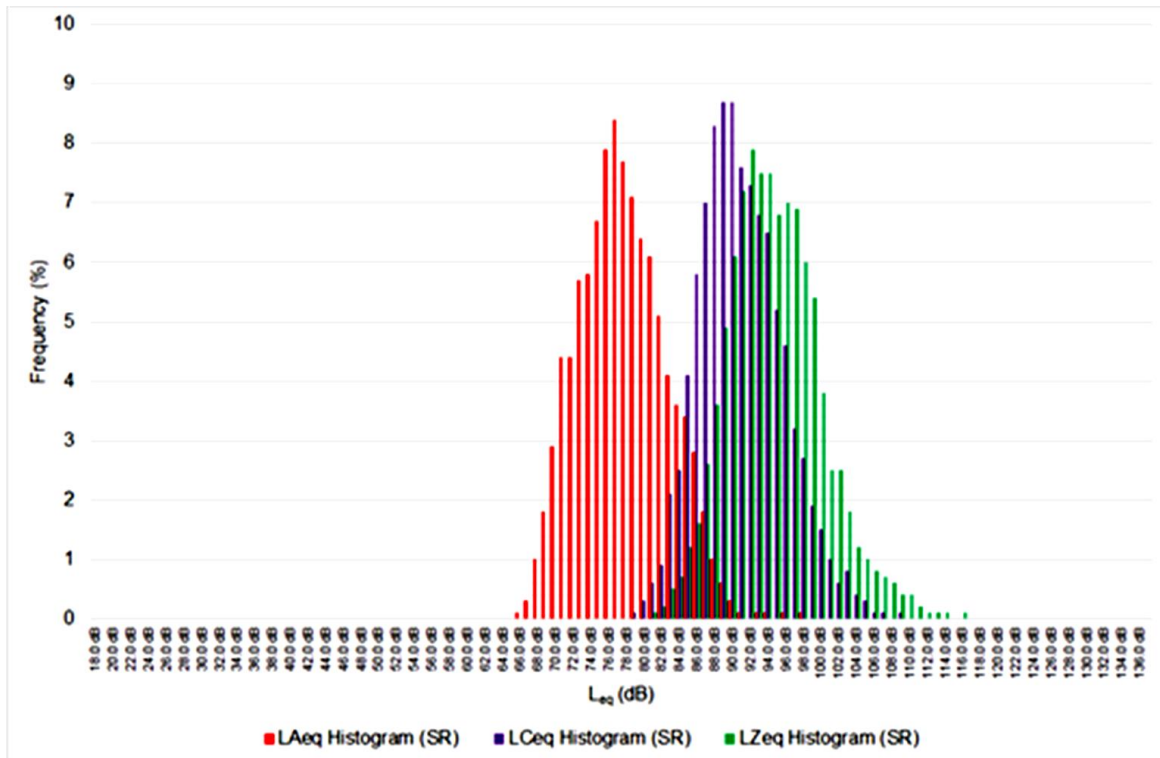


Figure 3. Forklift noise histogram.

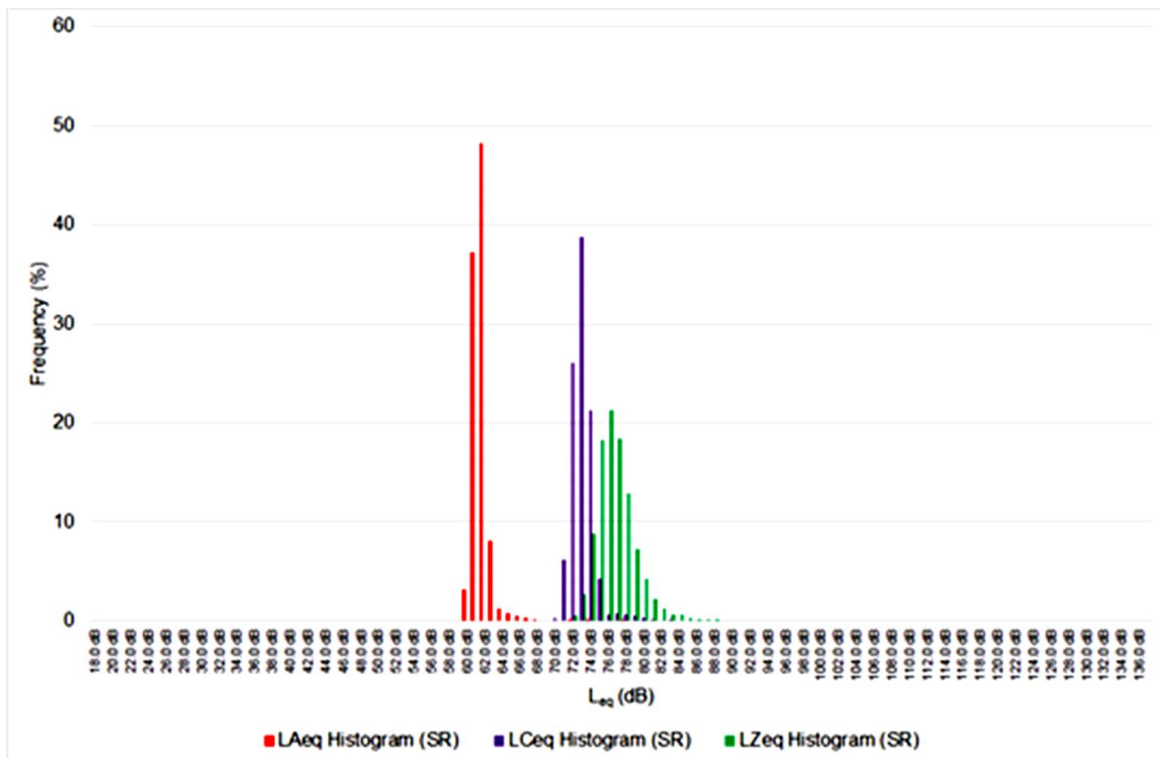


Figure 4. Shift supervisor room noise histogram.

#### 4. CONCLUSIONS

A total of 57 noise measurements were made for 19 different processes in all branches of the gypsum plant. The measurements were evaluated using an analysis package program. The branches where noise measurement recordings were done are PLC room, administrative building, quality control laboratory, shift supervisor room, mechanical maintenance-repair workshop, mixer laboratory, mixer additive area, packing unit, packing bag control band, packing bag stacking operator, building chemicals packing unit, building chemicals mixer, stockroom and finished product loading area, forklift operator, stone crushing unit, stone crushing unit control room, wheel loader, mill and packing unit cleaning staff. According to this, while the highest noise was found in the stone crushing unit, administrative building personnel were exposed to the lowest level of noise. Except for the staff in the PLC room, administrative building, quality control laboratory, shift supervisor room, mixer laboratory, building chemicals mixer, stone crushing unit control room, wheel loader, mill and packing unit cleaning, the other staff members in the study area were exposed to noise levels higher than the minimum exposure action value of 80 dB(A). Areas exceeding the exposure limit value are packaging and crushing units. The maximum noise levels exposed by the employees in all the branches that are measured corresponding to the medium frequency range and the minimum noise levels correspond to the low and high frequency ranges.

#### NOMENCLATURE

<b>dB</b>	: A relative unit of measurement widely used in acoustics, electronics and communications.
<b>dB(A)</b>	: A voice evaluation unit in which the human ear is particularly sensitive to medium and high frequencies.
<b><math>L_{EX, 8h}</math></b>	: The sound exposure averaged over 8 hours ( $L_{EP,d}$ )
<b><math>L_{max}</math></b>	: Maximum sound level
<b><math>L_{min}</math></b>	: Minimum sound level

<b><math>L_{peak}</math></b>	: Peak sound pressure
<b>SPL</b>	: Sound pressure level
<b><math>L_{eq}</math></b>	: Equivalent sound level
<b>SEL</b>	: Sound exposure level
<b><math>L_{10}</math></b>	: The noise level just exceeded for 10% of the measurement period
<b><math>L_{50}</math></b>	: The noise level just exceeded for 50% of the measurement period
<b><math>L_{90}</math></b>	: The noise level just exceeded for 90% of the measurement period
<b><math>L_{99}</math></b>	: The noise level just exceeded for 99% of the measurement period
<b><math>\sigma</math></b>	: Measurement uncertainty

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