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Evaluation of Noise Levels in Flour Factories in Terms of Occupational Health and Safety

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Abstract

This study aims to determine the daily noise exposure levels in flour mills and evaluate the effects on the health and safety of workers. The study measured the equivalent sound pressure levels of workers exposed in two flour mills operating in Konya province in dBA. The factories include machines with high noise levels, such as sifters, sieves, and rollers. A Type-2 class sound pressure level meter was used in the measurements taken in accordance with ISO 9612: 2009 standard. Based on the measured values, the A-weighted equivalent sound pressure levels were determined, and the daily personal noise exposure levels were calculated taking into account the working hours. It was determined that the equivalent sound pressure levels and the daily individual noise exposure levels of the workers were in the range of 88.2-97.7 dBA and 87.9-97.4 dBA, respectively, and above the minimum daily personal exposure limit (80 dBA) specified in the legislation. As a result of the study, it was evaluated that the noise in flour mills can negatively affect the health and safety of workers as well as their job performance.

1. Introduction

With the Industrial Revolution that began in Europe and America in the 18th century, there were significant changes in production methods and technology, and the era of machinery, which is synonymous with the Industrial Revolution for industrial production, began. Machinery made it possible to use machine power instead of human power and to produce based on machines, thereby increasing production speed, reducing costs, and improving product quality. The first mechanization occurred in the weaving, mining, manufacturing, transportation, and energy sectors, and soon thereafter, it was seen in all other sectors. Many countries worldwide aimed to replace human power with machine power and achieve this through shorter processing times and lower labor costs with the Industrial Revolution [1]. Machinery has made significant progress in production methods and technology, but along with these progressions, some problems have arisen. One of the most important of these problems is noise. Noise is a natural result of mechanization and is a frequent problem in production facilities, factories, industrial areas, vehicles, and other industrial areas. The level of noise in these areas is high, and this high noise can create some health risks for workers.

Noise, one of the machine factors negatively affecting worker health caused by technological advancements, is generally defined as an unwanted, disturbing, and annoying sound. However, according to the International Labor Organization (ILO) 148 agreement on noise and vibration published in 1977, noise is defined as "all sounds that can cause hearing impairment or be harmful or dangerous in any other way" [2]. The effects of noise on human health can be grouped into physiological and psychological effects. The most obvious example of a physiological effect is temporary or permanent hearing loss. In addition, some effects such as increased blood pressure, cardiovascular system disorders, increased heart rate, and sleep disorders can also occur. Research has shown that the psychological effects of noise are more widespread than physiological effects. It has been found that noise can lead to changes in character depression and

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prolong the time it takes for the body to return to its normal state after being ill [3].

According to the Ministry of Labor and Social Security, it has been determined that hearing loss due to exposure to noise constitutes 10% of occupational diseases. However, while many occupational diseases can be treated, some hearing losses cannot be treated [4].

Flour factories are one of the most important work environments where workers are exposed to noise. Flour factories are industrial facilities that produce flour. In these facilities, grains such as wheat, barley, and oats are cleaned, ground into different sizes, and finally turned into flour. In this section, grinding, sifting, rolling, and other operations are carried out. The grinding machine separates the grain into pieces and opens up the surfaces of the particles. The sifting machine separates the small particles, cores, and other waste inside the flour using air currents after grinding. The rolling machine improves the size and shape of the particles inside the flour. The production process of wheat flour generally consists of the stages of raw material procurement, storage, cleaning, washing and rolling, grinding, screening, and storage. The cylinders called rollers in which the grinding process is carried out, the screw conveyors that perform product transfer between processes, the cleaning screens, and the distribution and washing sections are the regions that contribute heavily to noise exposure during this process [5].

Turkey is one of the most suitable countries for grain production in terms of climate and geography [6]. According to TUIK data, approximately 17.7 million tons of wheat were produced in Turkey's 160,615,720 hectares of grain production area in 2021 [7].

Today, there are approximately 621 factories with a production capacity of 24.5 million tons actively producing in Turkey, and these workplaces have a total of 13,710 employees, including 2,899 technical personnel [8]. In 2021, the flour sector had exports of $1.14 billion and imports of $2.67 billion, and the industry, which has a trade deficit of $1.53 billion and imports more than twice its exports, is a net importer. In 2021, the most exported products in the flour sector were wheat flour exports of 3,002,557 tons, wheat bran exports of 123,924 tons, and wheat exports of 3,946 tons, while the most imported products in 2021 were wheat imports of 7,819,217 tons, wheat bran imports of 1,490,419 tons, and wheat flour imports of 12,936 tons. The flour sector, which has a significant trade volume, imports a large amount. In 2021, of the $17.18 billion in food and agriculture imports, $2.67 billion, or 15.5%, was made with wheat, wheat bran, and wheat flour [9].

It can be seen from these statistics that the sector's importance to the country's economy is obvious. However, high production volumes bring high levels of automation. If necessary occupational health and safety measures are not taken, severe physical risk factors to workers' health may arise.

Machines used in flour production facilities are high-level noise sources. Workers who work near these machines can experience hearing problems due to exposure to high noise levels. Long-term exposure to noisy areas can result in Noise-Induced Hearing Loss (NIHL) in workers. The noise levels of flour mills can also cause damage to workers at similarly hazardous levels [10, 11]. The dynamic nature of the food industry and its high employment opportunities in Turkey show that occupational health and safety are of utmost importance for the food industry in Turkey. When investigating the hazards related to occupational health and safety in flour factories, one of the factors that we need to pay attention to is noise.

It is necessary first to determine the noise levels emitted by the machines used in flour factories, which contribute significantly to the country's economy and are continuously updated with technological developments, in order to examine the adverse effects on human health and work efficiency. Only a few studies examine the noise levels in flour factories from an occupational health and safety perspective. Some of these studies are described below.

In a study conducted by Narasimhan et al., 2022, it was found that 107 workers in rice and flour factories in the state of Tamil Nadu, South India, were exposed to high levels of noise due to machinery in the workplace and experienced hearing loss [12]. In another study conducted by Nimgde et al., 2018 to evaluate occupational noise exposure of 65 flour mill workers in the city of Chandrapur, India, it was found that approximately 70% of the workers had hearing problems, and around 23% experienced constant headaches at work [13]. In a study conducted by Mohammadizadeh et al., 2015 on noise exposure for workers in various sections of a flour factory in Lamerd, Iran, values above the legal limits were detected, and it was reported that there was a relationship between the workers' age and the occurrence of hearing loss [14]. In this study, noise level measurements were taken in various sections of two flour factories in Konya, and the effects on the factory workers were analyzed.

2. Materials and Methods

The noise measurements were conducted in two flour mills operating in Konya province. After obtaining the necessary permissions from the authorities of the flour mills, the environmental measurements taken in the operations were included in the evaluation. The noise

measurements in the study were performed in the pneumatic, electric, sorter, and milling units, which were reported to have the highest noise levels in the flour mills.

The measurement of noise and sound is a broad subject and includes specific techniques. The sound types, spectral forms, time-dependent variables, and many other elements, along with the characteristics of the noise and the sounds planned for measurement, can greatly vary. Therefore, if the equipment used for the measurement is not selected according to the conditions and the purpose, there may be incorrect or misleading results [15].

Therefore, all measurements were carried out on January 4, 2022, by the rules under the "Regulations on the Protection of Workers from the Risks of Noise," which was published in the Official Gazette No. 28721 and became effective. During the measurements, the wind speed, humidity rate, temperature, and pressure of the working environment were taken into consideration. According to the TS EN ISO 9612 standard, task-based measurements were carried out by taking at least three measurements for each different task of the personnel carrying out the measurement. In work-based measurements, the total measurement time described by the standard is taken according to the number of personnel exposed to homogeneous noise. In full-day measurements, measurements are taken with a dosimeter for three full days (8 hours) and reported by calculating the results. In task-based measurements, the SPL meter, a type of hand-held sound level measurement device, is generally used, while in work-based and full-day measurement strategies, a dosimetric sound level measurement device, the Dosimeter, is used [16].

The noise measurement in this study was conducted based on the TS EN ISO 9612 standard, with job-based measurements being carried out and both stable short-term and unstable full-day measurements being conducted based on the TS 2607 ISO 1999 standard. In order to determine the noise level that workers in a flour factory are exposed to, EXTECH SL 355 devices, also known as personal dosimeters, which can both measure an individual's exposure level and the noise level of the work environment, were used [17]. Before starting the measurements, the noise measurement device was calibrated by a firm accredited by TÜRKAK with AB-0113-K and according to the TS EN ISO/IEC 17025-2017 standards. The measurements were made by the device attached to the workers and designed for these measurements. Equivalent SPL (LAeq) values were calculated using Equation (1) using the obtained SPL dBA values. The durations (Tm) for each task were determined by observing the occupational activities of workers in the flour factories where measurements were taken and by conducting face-to-face interviews with them [8].

$$L_{P,AeqT,m} = 10\log\left[\frac{1}{I}\sum_{i=1}^{I} 10^{0,1xL_{P,AeqT,mi}}\right] \quad (1)$$

$L_{P,AeqT,m}$: LAeq for task m, dBA

i: Task sample number

I: Total number of task samples

m: Task number

$$L_{Ex,8h,m} = L_{p,AeqT,m} + 10\log\left[\frac{\bar{T}_m}{T_0}\right] \quad (2)$$

$L_{Ex,8h,m}$: LAeq for task m contributing to the daily noise exposure level, dB(A)

$\bar{T}_m$: Effective duration of the working day for task m, h

T_0 : Reference duration, 8 h

Daily personal noise exposure levels were calculated with Equation (3).

$$L_{Ex,8h} = 10\log\left[\sum_{m=1}^{M} \frac{\bar{T}_m}{T_0}\, 10^{0,1xL_{P,AeqT,m}}\right] \quad (3)$$

$L_{Ex,8h}$: Daily noise exposure level normalized to nominal eight h working day, dBA

M : Total number of tasks

The study made comparisons and evaluations based on the two flour factories and production units, considering the measured and calculated noise parameters. The parameters were summarized with graphs and figures, including standard deviation values. The possible effects of daily noise exposure values on the workers were evaluated and discussed, taking into account the 2003/10/EC directive of the European Parliament and Council (minimum levels of health and safety requirements for workers' exposure to physical agents).

3. Research Outcomes

This study determined that the equivalent weighted sound pressure level (Leq) in the flour factories measured was between 85.9 and 98.3 dBA, and the daily exposure level (LEX) was between 85.7 and 98.0 dBA. Upon examination of the Leq, Lmax, and LEX values determined in both flour factories, it was observed that the values found are similar to each other (Table 1).

Table 1. Leq, Lmax, and LEX values of the sections of the Flour Mills (Task-based)

	F1			F2		
Units	**Leq,8h (dBa)**	**Lmax (dBc)**	**LEX**	**Leq,8h (dBa)**	**LcPeak (dBc)**	**LEX**
Purifier Section	97.5±3.1	138.5±3.1	97.2±3.1	91.1±3,0	133.4±3.0	90.8±3.0
Sieve Section	85.9±2.0	112.4±2.0	85.6±2.0	90.5±2,0	116.4±2.0	90.2±2.0
Pneumatic Section	86.0±2.3	119.0±2.3	85.7±2.3	98.3±3,0	137.8±3.0	98.0±3.0
Waltz Section	97.2±3.3	137.3±3.3	96.9±3.3	98.3±3,1	139.4±3.1	98.0±3.1
Average	91.6±2.6	126.8±2.6	91.3±2.6	94.5±2,7	131.7±2.7	94.2±2.7

In the two flour factories, when the average of each section is considered, it has been determined that the Leq values in the sections of the factories vary between 88.2 dBA and 97.7 dBA, and the LEX values vary between 87.9 dBA and 97.4 dBA (Table 2).

Table 2. Average Leq, Lmax, and LEX values (Task-Based) for sections of Flour Factories

Units	**Leq,8h (dBa)**	**Lmax (dBc)**	**LEX**
Purifier Section	94.3±3.0	135.9±3.0	94.0±3.0
Sieve Section	88.2±2.0	114.4±2.0	87.9±2.0
Pneumatic Section	92.1±2.6	128.4±2.6	91.8±2.6
Waltz Section	97.7±3.2	138.3±3.2	97.4±3.2
Average	91.6±2.6	126.8±2.6	91.3±2.6

While the sifting sections contain the highest average Leq (97.7 dBA) and LEX values (97.4 dBA), the sifting sections contain the lowest Leq (88.2 dBA) and LEX values (87.9 dBA) (Table 1, Figure 1).

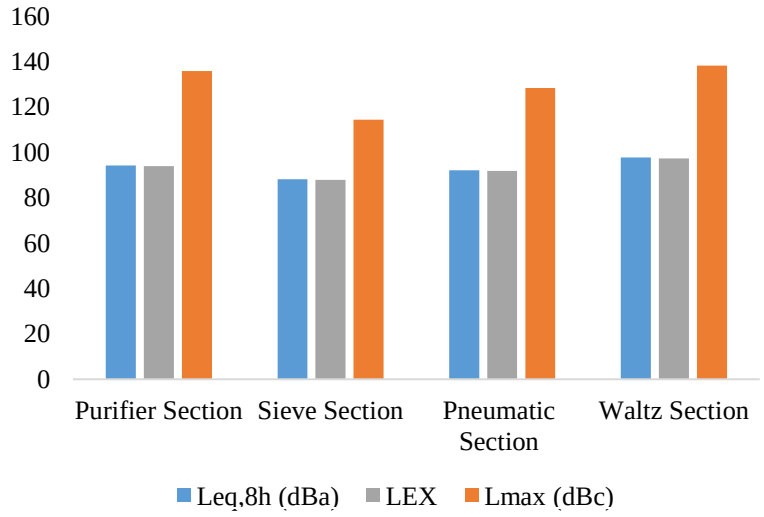

Figure 1. Average Leq, Lmax, and LEX Levels of Flour Factories

According to the 6331 Occupational Health and Safety Law, the obligations that employers and employees must comply with are clearly specified, and the aim is to eliminate the risks that arise from hazards in the working environment [18]. One of the most significant of these risks is noise. According to the Regulation on the Protection of Employees from Noise-Related Risks, published in the Official Gazette No. 28721 on July 28, 2013, and entered into force, Personal Protective Exposure Action Values and Noise Exposure Limit Values are given below.

1) Personal Protective Exposure Action Values and Noise Exposure Limit Values

a) Lowest Protective Exposure Action Values (LEX, 8 hours) = 80 dB(A) or (Ppeak) = 112 Pa [135 dB(C) re. 20μPa] (calculated as 135 dB (C) with reference to 20μPa).

b) Highest Protective Exposure Action Values (LEX, 8 hours) = 85 dB(A) or (Ppeak) = 140 Pa [140 dB(C) re, 20μPa].

c) Exposure Limit Values (LEX, 8 hours) = 87 dB(A) or (Ppeak) = 200 Pa [140 dB(C) re, 20μPa].

2) The protective effect of personal ear protective equipment should be considered when determining exposure to noise.

3) The effect of ear protectors is not considered in Protective Exposure Action Values.

4) In jobs where daily noise exposure shows significant variations from day to day, Weekly Noise Exposure Level can be used instead of Daily Noise Exposure Level in applying Exposure Limit Values and Protective Exposure Action Values. In such jobs:

a) The weekly noise exposure level, determined by sufficient measurement, does not exceed the 87 dB(A) exposure limit value.

b) Appropriate measures are taken to minimize the risks associated with these jobs.

Measurements taken at two flour factories located in Konya have resulted in noise levels exceeding the Personal Exposure Action Values and Exposure Limit Values given above. The values measured, taking into account the expanded measurement uncertainty, are not in line with the values in the aforementioned regulations when evaluated based on the limit values.

The Leq values in the waltz sections of the factories with codes F1 and F2 have been calculated to be 97.2 dBA and 98.3 dBA, respectively. The waltz sections are designed for grinding of grains and contain machines that work with crushing, cutting, and pressing forces to grind the product to the desired size. These machines are referred to as crushing and smooth rolls. The crushing rolls have gears, and the smooth rolls have a flat surface and drums covered with sandpaper, which are high noise sources due to friction. In both flour factories, it has been determined that there were oversights during the periodic maintenance of the roll machines, and the waltz section is the most high-risk section in terms of noise exposure.

The Leq values of the purifier sections in factories with the codes F1ve F2 have been calculated as 97.5 dBA and 91.1 dBA, respectively. The purifier sections are the areas where the grain is separated from straw, ears, and other foreign matter, and they contain large-sized and vibrating metal sieves and machines with engines that are high noise sources. It has been determined that there were shortcomings in the periodic maintenance of the sorter machines in both flour factories, and the purifier sections are the second highest risk areas in terms of noise exposure.

The Leq values of the pneumatic sections in factories with the codes F1ve F2 have been calculated as 86.2 dBA and 92.3 dBA, respectively. The pneumatic sections are the areas that transport grain to be ground to the upper levels, and they contain pneumatic pipes, gravity pipes, elevators, carriers (such as chain, screw, or belt conveyors, etc.). The noises of these carrier elements are high noise sources. It has been determined that there were shortcomings in the periodic maintenance of the pneumatic elements in both flour factories, and the pneumatic sections are the third highest risk areas in terms of noise exposure.

The Leq values in the sieve departments of the five F1ve F2 coded factories have been calculated as 85.9 dBA and 90.5 dBA, respectively. These departments are sections where large-scale screening machines with an oscillating shape are located to ensure that the particle size of the grain is the same after being ground into flour and the flour is homogeneous. These machines are also a high noise source, especially due to vibrations. Neglect of maintenance of the sieve units in both flour factories has been determined, and the sieve departments are the least risky in terms of noise exposure.

Noise, one of the most important harmful factors affecting workers' attention, fatigue, and work capacity, should be reduced in these departments to safety limits. Engineering control, which involves surrounding the noise source and is referred to as engineering control, can be taken as the first measure [19]. The second effective engineering measure is to separate the worker and machine with an acoustically designed cabin or barrier [20]. Management control can also be achieved by regulating break times and work frequency to limit worker exposure [21]. The last measure to be taken should be to provide the worker with personal protective equipment (headphones, earplugs, etc.).

Neither of the noise control methods has been applied in the two flour factories investigated to reduce noise. Without taking the necessary precautions, noise will

continue to have a negative impact on human health from a physiological, physical, and psychological perspective. Many studies have reported that different noise levels have negative effects on workers, such as thought, decision-making, learning, calculation, and hand-eye coordination [22, 23]. Noise can also reduce the productivity of workers. Grandjean (1988) reports that the decrease in productivity starts at 50-60 dB based on laboratory studies [24].

According to the results of the study, workers in all sections of flour factories (8 hours a day) are working in highly noisy conditions. The indoor SPL values of the factories were found to be between 70 and 89 dBA. Based on the Leq values measured, it can be seen that all workers in the flour factories are under health risks. In addition, no measures have been taken regarding the noise in the flour factories studied, and almost no measures have been taken for the health and safety of workers. The workers are untrained and have a very low awareness of work health and safety, so they work with very low-risk perception.

The cost of work accidents and occupational diseases is higher than the cost of preventing them [25, 26]. Taking this into account, efforts should be made to reduce the noise generated by the machine by taking precautions against risks at the source and in the environment in sections where the noise levels are high. In addition, it is also thought that outdated and poorly maintained machines can also be a negative parameter in the high noise levels. When the majority of the working environment poses a threat to the worker's health, instead of eliminating the source, it is preferred to provide the worker with personal protective equipment, which is the last operation that needs to be done instead of the first operation.

Generally speaking, it can be seen that the environmental measurements exceeding acceptable levels that can pose a threat to the health of the workers with regard to noise have been taken in both evaluated factories. Although reducing the source of factors such as noise in the field of occupational health and safety cannot be zeroed, it is accepted as the principle of reducing them. It is necessary to install new generation machines that reduce these factors in production facilities. If technology cannot reduce harmful factors at the source and in the working environment, emphasis should be given to personal protective equipment [27].

4. Conclusion and Suggestions

In this study, the noise levels were determined in one of the most important food industries in Turkey, flour mills, and the following main results were obtained:

• In both of the factories where measurements were taken, it was observed that the noise exposure in the production sections (sasör, vals, screening, pneumatic) was above the limit values determined in the relevant regulations.

• It is estimated that the noise exposure values of the workers in the regions where the production processes of the factories are carried out are high. This is the main reason that the workers are in a closed environment where machines that continuously and steadily produce noise are located for a large part of their working hours.

• It was observed that no structural measures were taken against noise in the working areas where the measurements were taken. It was also determined that earplugs or other protectors that reduce the impact of noise at the point where it reaches were not widely used in these work environments where noise directly affects human health and work performance.

• Working at high noise levels in flour factories negatively affects both health and reduces work efficiency and safety in the work being done. On the other hand, the worker contracting an occupational disease is a serious cost for both the worker, the employer, and the state.

• In work environments where noise is at a level that can have negative effects on human health and work performance, measures to reduce noise should be taken at the source of the noise, on the transmission path, or at the point where it reaches.

• The general approach to reducing noise exposures is to try to eliminate noise before it occurs, just like reducing other risks. If a solution cannot be found by focusing on applications such as isolation, replacing hazardous with non-hazardous, collective protective measures, engineering solutions, etc., personal protective equipment must be used as a last resort.

Contributions of the Authors

The first author has managed data collection and analysis processes; the second and third authors have made contribution in terms of visualization, original draft, and writing. All the authors have the same rate of contributions for preparing the paper. All of them read and approved the final form.

Declaration of Ethical Standards

The author of this article declares that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Conflict of Interest

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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