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Research Article

ANALYSIS OF ENVIRONMENTAL CONDITIONS IN METAL INDUSTRY

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Keywords

Environmental factors, Temperature, Noise, Humidity, Illumination, Productivity, Occupational health and safety.

Abstract

Environmental conditions have an essential importance in terms of occupational health and productivity in each sector. However, it is very difficult to keep environmental conditions within the specified ideal limits due to the processes carried out in the metal industry. Evaluating the environmental conditions constantly, defining precautions, and linking the consequences are critical to improve productivity of workers who work under improper conditions under time pressure. In this study aims to investigate the levels of critical environmental conditions such as heat, humidity, noise, and illumination for the metal industry in Eskisehir. An observation form is designed to record the data and a total of 92 measurements are taken for eight facilities that use sheet-metal forming machines such as hydraulic press, eccentric press, lathe, and guillotine shear. The analyze results of the data state that the temperature is 16.22-29.74 ° C (avg. 23.99 ° C), 22.99% to 54.92% (avg. 36.35), and the noise level 82.3-110.3 dB (A) (avg. 91.88 dB (A)) and the illumination is 33.2-902.7 lux (avg. 289.34 lux) for the facilities in concern.

METAL ENDÜSTRİSİNDE ÇEVRESEL KOŞULLARIN ANALİZİ

Anahtar Kelimeler

Çevre faktörleri, Sıcaklık, Gürültü, Nem, Aydınlatma, Verimlilik, İş sağlığı ve güvenliği.

Öz

Çevresel koşulları, her sektörde iş sağlığı ve verimlilik açısından yüksek derecede öneme sahiptir. Fakat metal sanayinde yapılan işlemler gereği, çevresel koşulların istenen düzeyde tutulması oldukça zordur. Sipariş yetiştirme vb. baskılar altında tehlikeli teçhizatlar ile çalışan işçilerin, uygun olmayan çevresel koşulların da etkisiyle verimlilik değişimlerinin değerlendirilmesi ve çevresel koşullar ile ilişkilendirilmesi atılması gereken önemli bir adımdır. Bu çalışmada, Eskişehir'deki metal sanayinin, en önemli çevre faktörleri olan gürültü, sıcaklık, nem ve aydınlatma yönüyle düzeylerinin tesbiti amaçlanmıştır. Verilerin alınmasını sağlayacak gözlem kayıt formu tasarlanmış ve Eskişehir'de metal endüstrisinde faaliyet gösteren ve hidrolik pres, ekzantrik pres, torna, giyotin makas gibi tezgahların yer aldığı 8 işletmede, toplam 92 adet ölçüm alınmıştır. Veri analizi sonucunda ele alınan işletmelerdeki sıcaklığın 16.22-29.74°C (ort. 23.99 °C), nemin %22.69-%54.92 (ort. 36.35), gürültünün 82.3-110.3 dB(A) (ort. 91.88 dB(A)) ve aydınlatma şiddetinin 33.2-902.7 lüks (ort. 289.34 Lüx) olduğu tespit edilmiştir.

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1. Introduction

In today's competitive world, it is important to use the resources in the best way to reduce costs, especially in small and medium-sized companies. Since, labor costs are critical among others, it is necessary to prepare the work environments so that they feel comfortable and workforce is used effectively (Sonmez, 2009).

Employees who work under poor conditions have less productivity because they do not feel comfortable. The environmental conditions such as illumination, ventilation, noise, heat, and humidity that does not meet the specified levels affect both physical and mental health of employees. These factors may also lead to accidents and occupational diseases.

Employee performance is affected by

- Endogenous Factors (age, gender, health status, work habit, work experience etc.) and
- Exogenous (Environment) Factors (climate, noise, illumination, vibration etc.).

It is not possible to change endogenous factors however, convenience to work and habits may develop over time. On the other hand, it is possible to take cautions for exogenous factors. Because environmental factors can cause an additional burden on workers.

Babalık (2016) state that the workers' feelings and performance directly depends on the environmental factors and summarizes the effects as;

- Illumination makes the job smooth and easy,
- The colors used in business environment affect the peace of mind,
- The climate contributes to both performance and peace,
- Noise and mechanical vibrations have various negative consequences, from disturbing to permanent damage, and
- Gas, steam, dust, and moisture can damage health.

Environmental conditions, such as preventing health threats caused by the work, facilitating information and understanding, preventing improper work, increasing job peace and keeping work at a bearable level should be kept in mind during workplace design.

Due to its importance, this study aims to determine the current levels of environmental factors such as noise, temperature, humidity, and illumination for eight facilities in metal industry. Second section provides the literature review and third section summarizes the environmental factors in concern and related ideal values. Fourth section explains how the study is conducted and results ,conclusions and directions for future studies are given in the last section.

2. Literature Review

A large number of studies have been conducted in different industries for different purposes, dealing with the analysis of environmental factors in the literature. However, the number of studies that solely address the analysis of environmental factors considering facilities in Turkey are very limited.

Gobba et al. (1988) consider illumination as an environmental factor to measure the fatigue levels of computer workers. The relationship between lighting conditions, screen reflections and contrast features and problems such as headaches, eye disturbances felt by employees are examined by evaluating the lighting.

Chen et al. (2003) investigate fatigue for electric arc melting workers and continuous casting workers in a steel plant and evaluated their physiological response to different levels of heat stress. Fifty-five men participated in the study. Workers' feelings of fatigue and physical discomfort are gathered through questionnaires. Workers are asked to conduct the same work in 25-28°C and 30-33°C temperature intervals on two different days and related data are recorded. Results indicate the slow working pace at high temperatures and the increase in heart rate. It has been also determined that workers suffered more from thirstiness in high temperatures.

Dawal and Taha (2006) investigate the relationship between job satisfaction and factors that affect work design in two automotive manufacturing companies in Malaysia. A basic work design model is proposed. The aim of the model is defined as to determine the factors that influence employees' perception towards their work. A set of multiple-choice questionnaires are developed and data are collected by interviewing with 170 employees at a production plant. The survey focused on job and environmental factors. The results show that there is a meaningful relationship between work and environmental factors and job satisfaction. Age, experience, and marital status are identified as to influence job satisfaction. Further, environmental factors, especially the surroundings, context dependence and the building's function, also had a significant impact on job satisfaction.

Juslen et al. (2007) study the effect of illuminance on the speed and the quality (percentage of errors) with which workers assemble electronic devices in an electronics factory in The Netherlands. The horizontal illuminance is defined as an alternative per work shift between 800 and 1200 lux. The first test is conducted during the summer and the second one during the winter. A significant effect of illuminance has been determined. With 1200 lux at the working plane, the speed of production in the summer is 2.9% higher than with 800 lux. In the winter it is 3.1% higher with the increased illuminance. However, no significant effect of the illuminance on the percentage of errors is identified.

Camkurt (2007) identify the factors that may cause accidents. As one of these factors, ergonomic environmental conditions appear at the forefront. It is emphasized that the poor design of noise,

illumination, temperature, and humidity have a potential to increase the risk of accidents at work.

Kahya (2007) investigates the effects of job characteristics (physical efforts and job grade) and working conditions (environmental conditions and hazards) on job performance. A total of 154 employees in 18 teams at a medium-sized metal company participated in the study. Seven criteria for task performance and 16 for contextual performance are used for measuring employee performance. The results show the substantial relationships between employee performance, job assessment, and environmental conditions. Poor workplace conditions (physical efforts, environmental conditions, and hazards) result in decreasing employee performance that include; following organization rules, quality, cooperating with coworkers to solve task problems, concentrating the tasks, creativity, and absenteeism.

Yumusak (2007) consider ergonomic environmental conditions as one of the factors affecting work stress in his study and conducted a survey study on 53 employees. It is concluded that suitability of environmental conditions has an affect relaxing and stress-reducing on employees.

Sönmez et al. (2009) examine the suitability of environmental conditions for 87 companies in the furniture sector in Ankara. Data considering illumination, ventilation, and heating systems are gathered from the managers of the relevant companies through questionnaires and face-to-face interviews. The results indicate that illumination level, heating system, climatic condition, prevention of noise, and cleaninness of environment does not meet the required levels companies.

Noweir et al. (2013) evaluate the progress of occupational safety and health in the manufacturing sector in Jeddah Industrial Estate (JIE), Saudi Arabia over a 20-years period. Their study conducted in 1990 is based on sampling of 52 plants employing 5830 workers and the study in 2010 consider 135 plants employing 18351 workers. In both studies, evaluation is performed by walk-thorough survey and using detailed survey forms. Temperature and noise levels are identified as the most uncomfortable environmental factors.

In the Dianat et al. (2016)'s study, the association between objective and subjective assessments of environmental ergonomic factors including noise, illumination and heat are assessed in three manufacturing plants. Data are collected from 130 workstations using questionnaire and physical measurements of the noise (noise dosimetry), lighting (task area illuminance) and heat (wet bulb globe temperature e WBGT) levels. Results illustrate that the recommended noise, illuminance, and WBGT levels are not met in about half of the workstations surveyed, that supported the low satisfaction levels with the environmental factors in the workplace. A considerable effect of the environmental factors is identified on perceived workers' job performance, safety and health.

3. Environmental Factors

Factors affecting working environment can be summarized in four groups (Kahya and Ozkar, 2014):

- Physical factors (thermal comfort, noise, illumination, vibration etc.)
- Chemical factors (dusts, gases and vapors, solvents etc.)
- Biological factors
- Psychosocial factors

The most common environmental (physical) factors considered for the metal industry are noise, temperature, humidity, and illumination.

3.1. Noise

Noise is defined as the sound that disturbs the human being (Babalık, 2016). It is the direct cause of hearing loss which is the most common permanent occupational disease. If enough time is not spent in a sufficiently quiet environment after exposure to a high degree of sensation, the next noise exposure may continue on the previous one because damaging effects of noise on ear is cumulative. It is one of the most dominant environmental conditions in the sectors where processes executed by use of noisy machines.

Noise also has negative effects on work performance regarding cognitive abilities, memory, motor skills, and level of perception (Sanders and McCormick, 1993). Noise is influential on people's nervous system and hearing. Noise weakens employee concentration, reduces attention and reaction capacities. Discomforts such as fatigue, sleeping disorders, headaches, circulatory symptoms may occur. The most important effect of noise is hearing loss. The duration of exposure to noise determines the severity of the illness besides frequency, intermittent or persistent illness, person's age, and vulnerability.

It has been proven that people exposed to high levels of noise tends to have permanent and high blood pressures. Sabancı and Sümer (2011) summarize the physiological effects as follows;

- Growth in pupils,
- Increase in thyroid hormone production,
- Increase in heart rate,
- Increase in adrenaline production,
- Increase in the production of corticotrophin (stress-increasing hormone),
- Contractions in the stomach and abdomen,
- Increase in muscle reactions, and
- Shrinkage in blood vessels.

In the workplace, the severity of noise annoyance differs from person to person; 90% of people show normal behavior, 5% are resistant, and 5% are very sensitive. The noise level in the workplace also increases the possibility of deafness. As a criterion of ear damage, the probability of hearing loss of 25 dB or more in the region of 350-2800 Hz at different noise levels (Lr = 80 dB - 115 dB) is shown in Figure 1.

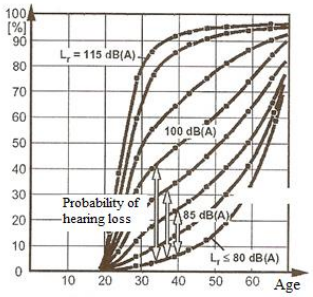


Figure 1. Probability of Hearing Loss as a Link to Working Time (Babalık, 2016)

The bottom curve on the figure is L_r <80 dB, whereas an employee has hearing loss due to old age. As the sound level increases, the risk of hearing loss from noise increases, and people are confronted with a greater risk of hearing loss at an earlier age. For example; one of the two groups starting work at 20 years of age will work in a noise level of 85 dB(A) and another group will operate in a 100 dB(A) noise environment. When they reach the age of 35 after 15 years, those working in 100 dB(A) noisy environment will have 40% probability of permanent deafness while the other group will have 10% deafness probability. The higher the noise intensity in the working environment, the greater the risk ratio; at 105, 110 and 115 dB(A), the danger of permanent deafness after a short period of work is demonstrated.

The International Labor Organization (ILO) has adopted 85 dB(A) as the warning limit and 90 dB(A) as the hazard limit, because the noise level above 85 dB(A) has effects such as temporary and permanent hearing loss (Sabancı and Sümer, 2011). According to the 5th item of the Noise Regulation (Number: 28721, accepted on 28 July 2013), maximum exposure action values are determined as (LEX, 8hour) = 85 dB(A) or (Ptepe) = 140 Pa, [137 dB(C) re. 20 µPa]. For this reason, it is necessary to take the precautions stated in Table-1 depending on the noise level in the workplaces.

Table 1. Noise Level Related Measures (Kahya and Özkar, 2014)

Noise Level (dB(A))	Precaution
00-85	There is no need to take precautions at noise levels of 85 dB (A) under the Noise Regulation.
85-90	Use of ear protectors reduces noise exposure by 20 dB (A). If the workshop noise level is 90 dB (A), the worker will hear 60 dB (A), which is not possible to cause hearing loss.
90-120	The headphone reduces the effect of noise by 30 dB (A). If the workshop noise level is 120 dB (A), the worker will hear 80 dB (A), which is not possible to cause a hearing loss.
120-130	A special helmet must be used to protect the skull from sound vibrations.
130-	Special overalls should be used to protect the internal organs.

3.2. Heat

The most important climatic factor temperature, affects the body temperature, as well as the heart rate, breathing oxygen intake, and even weight loss.

Sabancı et al. (2012) summarize the effects of high temperature as follows;

- Pulse is elevated,
- Increased sense of irritability,
- Blood circulation accelerates,
- Sweating is increasing,
- The loss of salt and liquid comes into play,
- Heat cramps
- Thirst sensation
- Attention is reduced, and
- Physical and mental efficiency decreases, number of errors and accidents increase.

The temperature above the specified level usually lead to fatigue and drowsiness causing distraction and error. It is stated that there is a significant increase in work accidents at 38˚C and at 19˚C (Güler, 2004).

Heavy physical activity increases the heat production of the organism. Since the highest efficiency in physical activity is around 25%, at least 75% of the energy consumed is converted into heat. In addition to the heaviness of work, the heat produced by the body also increases. In order for the worker to feel better, s/he has to give out the generated heat, which is achieved by lowering the ambient temperature.

The performance of the employee changes according to the effective temperature. After the effective temperature exceeds 25˚C, the performance begins to decrease considerably. At 33˚C, the performance value descents to half. When ambient temperature decreases, performance degradation in heavy work is more than the decrease in light work (Figure-2) (Babalık, 2016). For example, when the temperature is 26˚C, the performance loss is 4% at the office works, 10% at the lightweight works, 20% at the medium-weight works, and 44% at the heavy works.

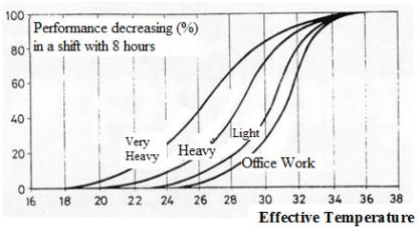


Figure 2. Change in Performance Due to Effective Temperature

Temperature and humidity conditions, for the comfortable climatic environments in various workplaces are presented in Table 2 (Babalık, 2016).

Table 2. Ideal Temperature and Humidity Conditions

Type of Work	Temperature (°C)			Humidity (%)		
	Min	Opt	Maks	Min	Opt	Maks
Office Work	18	21	24	40	50	70
Light Work (Sitting)	18	20	24	40	50	70
Light Work (Standing)	17	18	22	40	50	70
Heavy Work	15	17	21	30	50	70
Very Heavy Work	14	16	20	30	50	70
Work in high Temperature (With Radiation)	12	15	18	20	35	60

3.3. Humidity

An amount of water vapor is always present in the air and it is required for health.

Absolute Humidity: The amount of water vapor in the unit amount of air. Unit is expressed in gr/cm^3.

Relative Humidity: Indicates what percentage of the absolute humidity in saturated air at the same temperature. At a given temperature, the unit volume is the ratio of the amount of water vapor in the air to the amount of water vapor that must be present in the saturated air at that temperature.

Some workplaces have high humidity due to the process (i.e., textile etc). In such environments, working becomes much more difficult when the temperature is high as well.

High relative humidity;

- Makes worker feel exhausted at high temperature,
- It gives a feeling of chills at low temperatures.

Therefore, the relative humidity should be reduced as the temperature rises. The optimum relative humidity for the workplace is suggested between 40% and 60%.

- If the relative humidity falls below 40%, this is called "dry air". In these conditions, there may be drying and gashing in the throat and nose.
- If the relative humidity exceeds 60%, sweating becomes difficult or even impossible, and therefore body temperature increases (Babalık, 2016).

The humidity level in the environment affects how hot the person actually feels. Particularly at high temperatures, it plays a role in sweating and evaporation. Low levels of humidity in the air makes evaporation easier. The effect of ideal humidity level on human health can be more clearly understood if it is thought to be a measure to protect the body's core temperature. Considering only ambient temperature measurement is often insufficient, because humidity also determines how much the person feels the ambient temperature. Therefore, it is necessary to evaluate the temperature together with the effect of humidity.

3.4. Illumination

Illumination is defined as lighting practices that are designed for an environment where objects within it are visible properly (Sabancı and Sümer, 2011). In many areas of life, the sun is enough as a light source. However, additional lighting sources are needed for the work hat are executed indoors or at night (Sanders and McCormick, 1993).

A good illumination not only increases the speed of production but also is a key factor for the health, safety, and effectiveness of the worker. Improper illuminated environments may cause eye disorders, accidents, and material losses further leading to slowing down the production. Inadequate lighting, especially in places where sensitive operations are done, reduces the productivity of the employees and increases the costs (Sönmez, 2009; Ilıcak, 1988).

Illumination affects physiological functions such as nervous system, breathing, digestion, hormone secretion as well as proper vision (Babalık, 2016). The performance level of a task is usually influenced by the composition of visual, cognitive, and motor activities. Sanders and McCormick (1993) state that the more the visual need in a task, the greater the impact of the illumination on performance. Therefore, as the sensitivity of the work increases, the requirement of better illuminatation also increases. For example, the assembly of a sensitive part or manufacturing of a measuring instrument, may require up to 2000 lux lighting. This is a need to perceive very small details.

The minimum illumination intensities compiled from the TS EN 12464-1: 2011 standard for different locations and works are presented in Table 3.

Table 3. Minimum Illumination Intensity

Workplace	Work	Illumination (Lux)
Circulation zones in the building	Corridor and circulation areas	100
General areas such as resting areas, sinks and first aid areas in the building	Toilets, bathrooms, shower and clothes changing rooms	200
	Infirmary rooms	500
Metal casting	Casting molds	200
Industrial activities and handicrafts related to metalworking	Welding	300
	Coarse and / or medium machining: tolerances> 0,1 mm	300
	Fine and precise machining with machine; grinding: tolerances <0.1 mm	500
	Sheet metal working: thickness> 5 mm	200
	Working with sheet: thickness <5 mm	300
	Mounting (rough)	200
	Surface preparation and painting	750
	Equipment storage and storage areas Packaging areas	200
	Packaging areas	300
Offices	File and photocopy rooms etc.	300
	Writing, tape, reading and data processing	500
Education / Training buildings - schools	Classrooms and practice rooms	300
	Black, green or white boards	500
	Computer rooms	300
	Teacher rooms	300

Improper lighting causes attention loss/decrease to the employee, fatigue or detection errors. On the other hand, work accidents are usually resulted from great loss of attention and fatigue. For this reason, the issue of lighting in workplaces is so crucial that it can be vital in many cases, which should be carefully considered (Güler, 2004).

4. Method

An observation form is designed to record the current values of the environmental factors for the sheet-metal processing facilities in Eskişehir. Noise, temperature, humidity, and illumination that are the most common environmental factors in the metal industry are considered. The observation form includes sections for worker information (duty, age, education level, experience), machine information (type, size, process name), measurement time and values for 4 environmental factors. The suitability of the form design is tested by taking 15 measurements at 3 manufacturing companies and then final version is designed as to satisfy well understanding.

The focus of the study is the machines that are commonly used in metal industry workbenches such as hydraulic press, eccentric press, guillotine shear, and lathe. For each machine in concern, measurements are made in 3 different time slots (morning, noon, and evening) in a day by use of a multifunctional (Extech Instruments EN300) Environmental Meter device illustrated in Figure-3. To enable consistency, a measurement at a location is replicated 10 times and three measurement locations are defined as an arc with the machine in the center (Figure-4).

Figure 3. Extech Instruments EN300

Figure 4. Measurement location for a machine

The measured values (temperature, humidity, light and noise) are recorded on the desined form. With approximately 2 minutes interval, the average of all factors and then general (daily) average for each factor is calculated. Five undergraduate students are assigned during the fall and spring semesters and two students are assigned in the summer semester in 2016-2017 for the measurements. The first 3-4 measurements in each establishment are made with authors and students. A total of 92 measurements are taken for 8 manufacturing facilities.

5. Results

Some of the information regarding the considered machines and the workers working on these machines are given in Table-4. For the male workers who work on machines in concern, the average age is 41.10

(standard deviation 8.39) years and most of them (75%) are in the age range of 30-50 years. Half of the workers are primary and/or secondary school graduates. The average experience at work is 8.49 years and 66% have 1-21 years of experience. 59 (64%) of the measuring machines are hydraulic (hydraulic and eccentric), the others are guillotine shears, lathe, grinding and drilling. 33 (33%) of the machines are automatic.

The distribution of the environmental conditions measured for 92 machines are summarized in Figure 5. Measured noise level (dB(A) is given in Figure 5.a;

- Average: 91.88
- Standard Deviation: 5.68
- Minimum: 82.3
- Maximum: 110.3

The noise level varies between 82-110 dB(A) and 90% is above 85 dB (A). It is clear that the noise level in metal industry is quite high in consideration with the highest exposure value, 85 dB(A), in the relevant regulation.

Table 4. Survey participants and machine information

Category	Attribute	Frequency
Age (year)	00 - 19	1
	20 - 29	7
	30 - 39	31
	40 - 49	38
	50 - 59	13
	60 -	2
Education	Primary school	33
	Secondary / Primary	12
	High School / Vocational High School	43
	Associate	2
	Bachelor Degree	1
	No answer	1
Experience (year)	0 - 0,9	14
	1 - 4,9	26
	5 – 9,9	14
	10 – 14,9	21
	15 – 19,9	4
	20 – 29,9	9
	30 -	2
	No answer	2
Machine Type	Eccentric Press	30
	Hydraulic Press	29
	Guillotine Shears	8
	Drill	5
	Lathe	7
	Milling	3
	stoning	6
	Other	4
Machine Working Type	Automatic	33
	Manual	59

Temperature level (°C) is given in Figure 5.b;

- Average: 23.99
- Standard Deviation: 2.90
- Minimum: 16.22
- Maximum: 29.74

Workplace temperature is closely related to outdoor temperature and season. In the autumn and summer seasons, the workplace temperature is determined to be higher (~27°C) during summer and lower (~24°C) during the winter months (Table 5).

Humidity (%) is given in Figure 5.c;

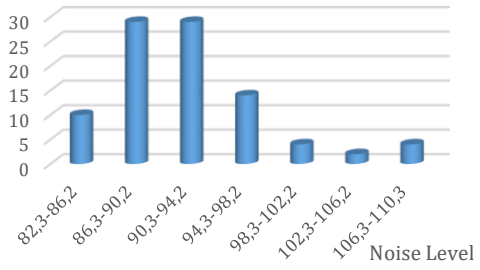
- Average: 36.35
- Standard Deviation: 7.26
- Minimum: 22.69
- Maximum: 54.92

The humidity is measured as 30% in autumn and winter, 36% in the spring and 46% in summer. In 90% of operations are done under the humidity condition lower than 50% (dry air). This rate can cause drying and gashing in the throat and throat during operations.

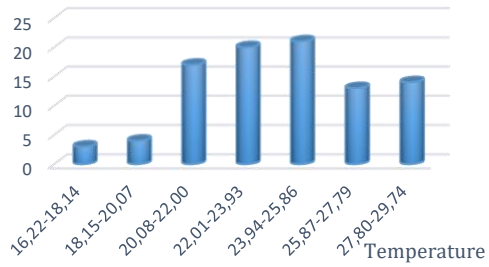
Illumination intensity (Lux) is given in Figure 5.d;

- Average: 289.34
- Standard Deviation: 188.26
- Minimum: 33.2
- Maximum: 902.7

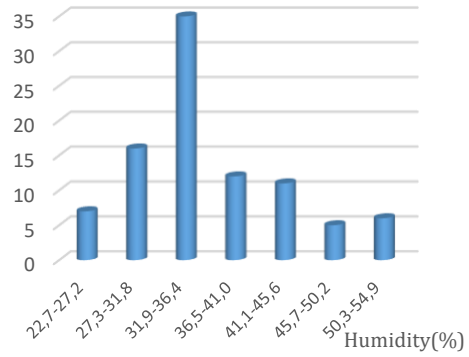
According to EN 12464-1: 2011 Standard, the lighting intensity for the operations of pressing and metal working is 300 Lux. 65% of observed jobs is done below this value. The main problem of low illumination is that it may cause to accidents. Illumination intensity is higher in winter and spring.



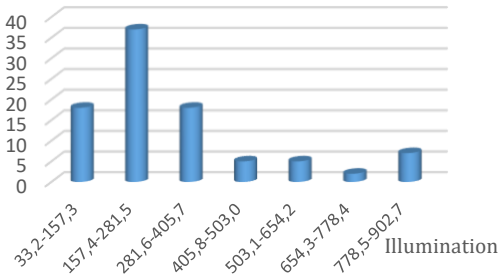
a. Noise (dB(A))



b Temperature (°C)



c. Humidity (%)



d. Illumination (Lux)

Figure 5. Environmental Conditions

Table 5. Seasonal changes in environmental conditions

Season	Temperature (°C)	Humidity (%)	Illumination (Lux)
Autumn	26,52	30,74	390,18
Winter	22,19	30,46	442,52
Spring	23,70	35,76	244,07
Summer	26,56	46,03	271,75

6. Conclusions

This study aims to assess the environmental factors in terms of noise, temperature, humidity, and illumination for the facilities in metal industry. 92 measurements are taken in total from machines in 8 manufacturing facilities. By analyzing the data, levels and distributions of environmental factors are determined.

The machines in concern are the classical machines that require mechanical information and workers who work on these machines should be graduated from machine or metal program of the vocational high school. About half (45%) of the workers working in the facilities in concern are primary and/or secondary school graduates. The workers with low education level and older worker who have been recruited many years ago are identified to be the most experienced ones. When these workers' experience periods are investigated, it has been seen that almost half of them have less than 5 years of experience and 20% of them have less than one year of experience. As expected, almost all the the vocational high school graduates were hired in last 15 years while 65 % of them don't have more than 10 years of experience. It is expected that, workers who have higher level of education, can be more succesful during such in-service trainings as occupational health and safety, quality assurance, creativity etc. Therefore, it is recommended that workers with vocational high school graduates should be assigned to the critical machines such as presses, scissors, and lathes.

The noise level varies between 82 and 110 dB(A), and 90% is above 85 dB(A). Considering that the highest exposure value in the relevant regulation is 85 dB(A), the noise level in metal industry is very high, so it is imperative that all workers in the workshop, not just those working on the machine, use their protective equipment. Noise levels for the machine types in concern are given as follows:

- Eccentric press: 93.41 dB(A)
- Hydraulic press: 92.01 dB(A)
- Guillotine shear: 92.39 dB(A)
- Grinding: 93.21 dB(A)
- Turning: 89.39 dB(A)
- Drill: 87.41 dB(A)

It is clearly seen that, the noise level is higher at the machines where the operations such as cutting, drilling and grinding are performed on the sheet-metal. Depending on the automation level of the machines, the noise level also changes. The noise level is measured as 93.40 dB(A) in the automatic machines and 91.07 dB(A) in the manual ones. It can be stated that the noise level in automatic machines is usually higher due to the higher production rate.

The temperature around the machine is obtained as 23.99°C (Standard Deviation: 2.90). Presses, guillotine scissors, etc. are light/medium-weight operations standing and the optimum temperature for these work is 18°C (17-22°C). While most of the works are done above 18°C, half of them are done above 24 ° C. During autumn and summer, the workplace temperature is determined as higher than 27°C. Therefore, it is expected that the climatic condition may reduce the productivity around 30%. It is possible to enable workshop temperature within the specified limites by using an air conditioning system. However, purchasing an air conditioning system may cause fixed costs (purchase and installation price, annual maintenance) and operation (energy) costs. Therefore, more analysis is required to obtain optimum temperature level by considering labor costs and cooling costs.

The assessment of environmental conditions is critical in the metal industry. However, there are limited number of studies in the accessible literature. The results generated in this study basically attract attention to the noise levels, climatic conditions and illumination. The results discussed by Chen et al.

(2003) that investigate melting and casting workers in the steel industry (temperature 30-32 °C, noise level 84-89 dB(A) and illumination intensity 16.2-194 Lux) and Dianat et al. (2016) in the metal industry (temperature 26 °C, noise level as 83 dB(A) and illumination intensity 140-180 Lux) are also consistent with the industry in concern. It is suggested to periodically conduct measurements for the facilities that are in high risk.

It is known that employees who do not feel comfortable in environmental conditions above or below standards have lower productivity levels. Illumination, ventilation, temperature, humidity, and noise not only affect the physical and mental health of nut also may cause accidents at work and occupational diseases in the long term.

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Conflict of Interest

No conflict of interest was declared by the authors.

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