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RESEARCH ARTICLE

EVALUATION of OCCUPATIONAL HYGIENE MEASUREMENTS with REGARD to EMPLOYEES in a LIMESTONE QUARRY

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ABSTRACT

Although working environments have become safer with the developing technology, there are still negative effects on the health of employees. It is very important to detect these negative effects and take the necessary precautions. For this, occupational hygiene measurements should be made. Employees in the mining sector are exposed to physical and chemical risk factors depending on the type of work they do. Mining is a very dangerous business line where occupational diseases and occupational accidents occur. In this study, occupational hygiene measurements were made in a limestone quarry located in Sakarya region, physical and chemical risk factors that the working personnel are exposed to were investigated and evaluations were made in terms of occupational health and safety.

Keywords: *Dust, Illuminance, Limestone quarry, Physical and Chemical Factors, Noise, Vibration, Thermal Comfort*

1. INTRODUCTION

Working life contains different risk factors in itself. Many employees either die or become permanently disabled due to these risk factors. It is of great importance to evaluate these risk factors and to take the necessary precautions in workplace environment. When risk assessment is performed in workplaces, the physical and chemical risk factors in the working environment should also be taken into consideration. Evaluations should be made by performing ambient and personal exposure measurements to lay down the physical and chemical risk factors existence. The limit values determined by the legislation should be taken into consideration while evaluating the occupational hygiene measurements in the workplace. Necessary precautions must be taken to keep the measurement values in the working environment under the limit values determined in the legislation. Mining sector is one of the most dangerous business lines that occupational diseases and work accidents occur as a result of exposure to the physical and chemical risk factors. Therefore, ambient measurements should be performed in terms of occupational health and safety and necessary measures must be taken due to the obtained results.

In a study relevant to the subject, Albayrak [1] carried out occupational safety ambient measurements at the Greton marble facility. In the selected facility, a risk assessment was performed by using the indoor measurement results obtained from measurements of noise, lighting, thermal comfort and dust. In the study onducted by Okşar [2], existing detrimental factors in a travertine quarry and factory were investigated. As a result of the measurements, values of environmental factors such as dust, noise, illuminance and thermal comfort were evaluated and suggestions were made to ensure that they do not affect the health of the employees. In the study carried out by Dolmaz [3], measurements of physical risk factors such as lighting, thermal comfort, noise, dust and vibration were performed in an exporter marble cutting and polishing facility and the results were interpreted by using L matrix and Fine Kinney risk analysis methods. In the study, it was determined that, luminous intensity was very low at night shift, there was a relative unfavourableness in the hot-cold balance of thermal comfort conditions, short-term noise values were far above near the ST machine, formation of dust was very low and forklift operator was exposed to very high vibration. In their study, Onder et al. [4] carried out measurements to determine the temperature and humidity increase in a fully mechanized underground mine in Türkiye and calculated the temperature and humidity changes in the mine air. In the study, they also analyzed the acceptability of climatic conditions according to EN ISO 7243:2017 by comparing them with the limit values given in the literature. Erol et al. [5] measured noise levels of some machines that operated in a mechanized underground mine. The lowest, highest, avarage and equivalent noise levels of machines and noise levels that the employees can be exposed to were calculated. The results obtained were evaluated pursuant to the noise regulation. In the assessment, it was determined that noise levels were over the exposure limit value (87 dBA) for the pneumatic perforator, over the exposure action value (85 dBA) for the shearer-loader, and between the lowest and the highest exposure action values (80-85 dBA) or under the lowest exposure action value (80 dBA) for other excavation and transportation vehicles. In another study, Doğan et al. [6] performed whole body vibration exposure measurements of drivers and operators working in various mining enterprises operating within the borders of Sivas province. The results obtained were evaluated pursuant to the national and international standards. In their study, Onder et al. [7] collected noise mesurement samples from three mining fields, including launder, opencast and underground mines between 2004 and 2007 in order to evaluate the equivalent noise levels from mining enterprises. The data obtained from measurement studies were evaluated by using one-way analysis of variance and Tukey’s multiple comparison method. In another study by Erdem et al. [8], hand-arm vibration exposure measurements were performed for employees that work in various mining enterprises and evaluations were made pursuant to relevant regulations. The highest vibration value, equivalent vibration acceleration, total exposure score, hourly exposure score, vibration acceleration frequency, access time for exposure action value and access time for exposure limit value were calculated. In the study carried out by Şensöğüt [9], noise sources and levels encountered in mines, effects of noise on employees and suggestions to reduce these effects were given. A mine example in Türkiye was given in the study. In the study by Erol et al. [5], noise and vibration values that machine operators exposed to in an underground mine were measured and the results were evaluated within the scope of regulation. In the study, it was determined that the results were under limit values designated by regulation for all of the operators who use ear protectors. It was also determined that pneumatic

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perforator operator was exposed to the highest noise and hand-arm vibration values. In the study, vibration values of machines were also measured as well as vibration exposure of operators. It was emphasized that the diversity of vibration values between crawler Jumbo and rubber wheeled Jumbo were changed due to the road roughness, engine vibrations and machine movements. In their study, Onder et al. [10] investigated dust related occupational diseases in open-pit lignite mine. Primarily, dust measurements were carried out and subsequently employees were gone through physical examinations. The data set obtained was categorized by considering the occupation, age, experience and dust exposure level of the employees. A hierarchical loglinear model was established to investigate the factors in the occurence of diseases while logistic regression analysis was performed to determine the possibility of worker exposure to dust. According to the logistic regression analysis, it was determined that the most risky occupation group was operators, followed by drivers, field personnel and technical personnel. It has been found that the probability of operators to get dust related occpuational diseases is approximately 2 times more than other occupation groups.

In this study, occupational hygiene measurements were performed in a limestone quarry located in Sakarya region, risk factors that employees were exposed to such as illuminance, thermal comfort, noise, dust and vibration were investigated and evaluations were carried out in terms of occupational health and safety.

2. WORK SITE

The work site located around Karakaya village in Pamukova district of Sakarya province. Site location map is given in Figure 1. The limestone quarry works in one shift and produces 2200 tons per day [11].

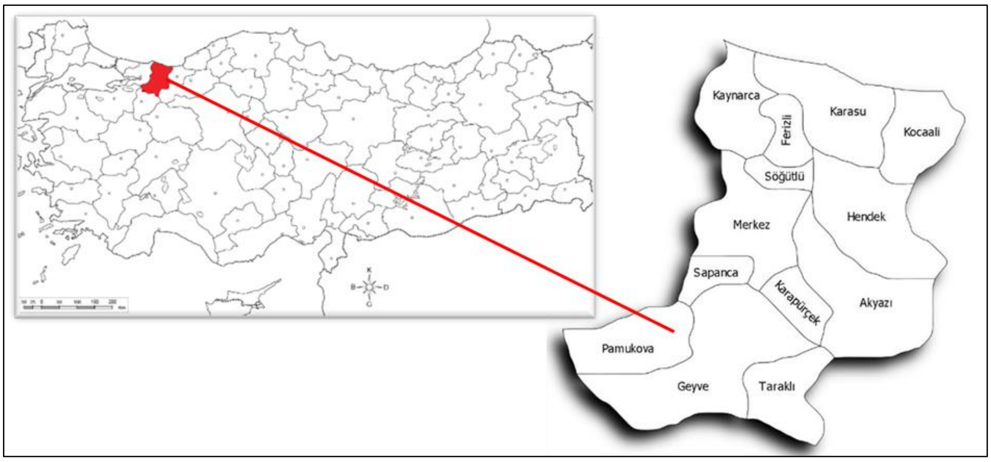

Figure 1. Site location map.

3. MEASUREMENT PARAMETERS

3.1. Illuminance

Illuminance is the application of light to provide a clear visual perception of objects in an environment at intended standards. Depending on type of the work and size of the area that will be illuminated; one of the contrivances such as general lighting, local lighting with support of general lighting or only local lighting is used [1]. General lighting is the illuminance that needed to meet the demands between specific criteria in a whole volume. In addition to general lighting, significant emphasis, orientation or other luminous intensity may be needed. Lighting the local regions in these required sections is called local lighting. Local lighting is sometimes used to create the required luminous intensity in places where general lighting is not sufficient. Local lighting can sometimes be used to emphasize any object or to give an aesthetic appearance. Solutions should be generated to meet all expected requirements and settlement and usage area of objects should be specified uniformly to offer the most proper lighting solution in a volume. In order to offer the most suitable lighting solution in a volume, the layout and usage areas of the objects should be well determined and solutions should be produced to meet all the needs expected from them. With the purpose of meeting general requirements, local lighting should definitely be taken into consideration with general lighting [12]. While creating the most proper working environment in terms of illuminance, daylight should be utilized as much as possible. In cases where daylight is not sufficiently utilized, an artificial lighting system should be established. The use of daylight and artificial lighting systems together and in a balanced way is the most appropriate solution in terms of applicability [13]. Luminous intensity and its distribution in the space have a great impact on the employee’s ability to perceive and perform a visual task quickly, safely and comfortably. As the lighting intensity increases, the finer details of the work are noticed. Studies have shown that high lighting intensity increases concentration and motivation, and as a result, employee performance increases. Since the level of making mistakes of the employee will decrease, there is a decrease in the work accidents caused by lighting in businesses with high lighting intensity. Workplaces should be adequately illuminated by daylight. If the daylight cannot be used adequately or in night works, appropriate and sufficient lighting is provided with artificial light. TS EN 12464-1: 2013 and TS EN 12464-1.2011: 2012 standards are taken as basis in the illumination of workplaces. Lighting systems in workplaces and passageways should be positioned in such a way that they do not pose a risk of accident. In case of failure of the lighting systems, an emergency lighting system, which is connected to a separate energy source, should be installed to provide sufficient lighting in places where there is a risk of accident [14]. Some values are recommended for the lighting of the workplaces in order to provide a suitable lighting that will not cause eyestrain, create dangerous situations and not disturb the employees. These values are; 80-170 lux for rough works, 130-350 lux for medium fine works, 350-700 lux for fine works and 700-1000 lux for very fine works [1]. It is known that artificial light is at an intensity of 200-300 lux in home environments, and 500 lux in well-lit workplaces. Required luminous intensity values in some areas and works in workplaces; corridor and storage areas are 100 lux, office work is 500 lux, surface preparation and painting is 750 lux, assembly, quality control and color control are 1000 lux [15]. The intensity of light emitted by daylight varies between 50000-100000 lux [16].

3.2. Thermal Comfort

Thermal comfort refers to the fact that most of the employees continue their physical and mental activities comfortably in their working environment in terms of certain climatic conditions such as temperature, humidity and air flow velocity. If the thermal comfort conditions are insufficient in the working environment, some problems and discomfort begin to be felt. As a result, there is a decrease in work efficiency [17]. Creating a suitable working environment is possible by considering factors such as light, hygiene, temperature, cleanliness, humidity, sound and vibration. Especially in winter and summer, works such as construction, machine assembly, piping, welding, which are done outside and often need to be completed in a limited time, bring important occupational health and safety risks [18]. Some measures that can be taken in the workplace can bring thermal comfort conditions to a better level. Since the ambient conditions of each business may be different, the measures to be taken will also be different. There are four factors that affect thermal comfort. These; temperature, humidity, velocity of air flow and thermal radiation. An increase or decrease in air temperature negatively affects the harmony of employees with their work. There is a high temperature problem in the industry in general. Excessive heat in the person causes fatigue and drowsiness. The human body keeps the central nervous system and internal organs at a constant temperature depending on the ambient temperature. The human body provides the necessary heat balance with the constant heat exchange with the external environment. The body temperature, which is usually 36,5 °C, is kept in balance by burning nutrients with oxygen in cold weather, and by sweating in hot weather. However, maintaining the body's heat balance in this way is limited [19]. It is essential that the thermal comfort conditions in the workplaces do not disturb the employees and do not adversely affect the physical and psychological conditions of the employees. It is ensured that the temperature of the working environment is suitable for the working style and the power consumed by the employees. Resting, waiting, changing rooms, showers and toilets, dining halls, canteens and first aid rooms are kept at a sufficient temperature according to their intended use. Vehicles used for heating and cooling are placed in such a way that they do not disturb the employee and do not pose a risk of accident, their maintenance and controls are carried out. TS EN ISO 7243 and TS EN ISO 7730 standards can be used to measure and evaluate thermal comfort conditions in workplaces. In case of continuous work in very hot or very cold environments and if this situation cannot be changed, measures should be taken to protect the employees from hot and cold [14]. The basic components of thermal comfort can be expressed as personal, environmental and external factors. While personal factors are expressed as metabolism level and thermal resistance of clothing, external factors can be expressed as nutritional status, age, gender, body shape and health of the employee. Environmental factors are air velocity, air temperature, relative humidity and mean radiant temperature [20].

According to the standards (TS EN ISO 7243 and TS EN ISO 7730), which will be taken as an example in determining and measuring thermal comfort, dissatisfaction is evaluated in two stages. One of these stages is PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied) values obtained as a percentage to the determined PMV value correspond to the dissatisfaction values. In working environments where the temperature is high, the WBGT (Wet Bulb Globe Temperature) index specified in the TS EN ISO 7243 standard is calculated. The standard ISO 7243 provides limit values for the thermal environment according to WBGT, and limit values are determined based on metabolic rates for persons acclimatized and unacclimatized to heat [4]. The WBGT value is calculated by a measurement method that includes air temperature, humidity, air velocity and radiant

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temperature values [21]. WBGT as the evaluation criterion of the thermal environment; It is an environmental thermal stress index associated with three different temperature indices. The WBGT index combines dry bulb temperature, wet bulb temperature under natural ventilation condition and black globe temperature [22]. The 3 sensors of the thermal comfort device are the nature wet-bulb temperature sensor (Tnw), the globe temperature sensor (Tg) and the dry air temperature (Ta) (dry-bulb temperature) sensor. These temperature values are used to determine the degree of heat stress that the person is exposed to in the working environment, to prevent heat damage and to determine how to reduce heat stress [21].

3.3. Noise

Noise is briefly defined as unwanted sound that undesirable and has a negative impact on people. Noise is a sound spectrum with an arbitrary structure [23]. This definition considers noise more as an event that reduces the feeling of comfort. However, the definition in occupational health is different. In the convention decision on noise and vibration published by the ILO in 1977 (no:148); There is a definition as “the term noise covers all sound which can result in hearing impairment or be harmful to health or otherwise dangerous”[24]. In other words, noise is an important environmental pollution consisting of unwanted sounds, which negatively affects people's hearing health and sense, disrupts their physiological and psychological balance and reduces work efficiency [25]. Noise is an environmental pollutant consisting of undesirable sounds with a random sloppy spectrum, which disrupts the hearing health of the workers and negatively affects the hearing sense, disrupts the balance of the organism physically and psychologically, causes reductions in working performance, changes the good characteristics of the environment by reducing or destroying the pleasantness and calmness [11]. Noise is an environmental pollution that negatively affects the hearing health of employees, disrupts the physiological and psychological balance of the person and reduces work efficiency [5]. Hearing loss is examined in two ways as temporary and permanent. Temporary hearing loss is the most common condition in the literature. Temporary loss of hearing sensitivity is defined as temporary threshold shift or listening fatigue. In cases where the level of exposure is high and the hearing system reaches its old features, it is mentioned that hearing loss becomes permanent if it is affected by noise again. Physiological effects of noise include stress, increase in blood pressure, changes in heart rate, circulatory disorders, acceleration of respiration, dilation of pupils, and tensions in the muscles. Psychological effects such as nervous breakdown, fear, discomfort, uneasiness, and fatigue are also observed [26]. In addition to reducing the working efficiency of the person, high noise levels also have effects such as inability to understand the sounds heard [5]. The regulation on the protection of employees from noise-related risks within the scope of Occupational Health and Safety No 6331 states the minimum requirements to be taken in order to protect employees from health and safety risks, especially hearing-related risks, that may occur as a result of exposure to noise. In this regulation, daily exposure level ($L_{EX,\ 8\ hours}$) [dB(A) re. 20 µPa] refers to the time-weighted average of all A-weighted noise exposure levels for an eight-hour working day, including the highest sound pressure and instantaneous pulsed noise, as defined in the TS 2607 ISO 1999 standard. The weekly noise exposure level ($L_{EX,\ 8\ hours}$) represents the time-weighted average of A-weighted daily noise exposure levels for a week consisting of five eight-hour working days, as defined in the TS 2607 ISO 1999 standard. In this regulation, the lowest exposure action value is ($L_{ex,8\ hours}$) is 80 dB(A), the highest exposure action value ($L_{ex,8\ hours}$) is 85 dB(A) and the exposure limit value is ($L_{ex,8\ hours}$) is 87 dB(A) [27]. According to the regulation, the effect of ear protectors is not taken into account in the exposure action values. If the risks that may arise from exposure to noise cannot be prevented with the necessary precautions, the employer must keep the ear protection equipment ready for the use of the employees when the minimum exposure action values are exceeded. When the highest exposure action values are reached or exceeded, the employer ensures that the ear protection equipment is used by the employees and monitors this situation. The employer makes every effort to ensure the use of hearing protection equipment and checks the effectiveness of the personal protection measures taken in accordance with the regulation. The exposure of the employee cannot exceed the limit values in any way. In case the exposure limit values are exceeded despite taking all control measures as per the regulation, the employer immediately takes all necessary measures to reduce the exposure below the limit values. The employer determines the reasons for exceeding the limit values and reviews and rearranges the measures taken to prevent its recurrence.

3.4. Dust

Dust is a term used for solid particles of various sizes and is always in a mixture with air or another gas. Dust is formed by the separation of substances into small particles as a result of mechanical processes. These processes lead to the formation of dust in different sizes, from small particles that can hardly be seen even with a microscope, to large ones that can be seen with the naked eye. Dust is generally smaller than 1 mm in diameter, suspended in the air or precipitated over time [28]. The grain sizes of dust particles are generally below 300 µm. The size of the dust particles with low specific gravity can be up to 1 mm. The particle size of respirable dust is below 60 µm. Dusts that reach the alveoli through respiration and cause lung dust diseases called pneumoconiosis are called “fine dust”. These dust particles are between 0,5-5,0 µm [29]. The smallest dust particles visible to the human eye are about 50 µm [30]. Therefore, harmful dust suspended in the air cannot be visually detected. About 80% (by mass) of respirable dust in mine air is smaller than 1 µm and only 4% is greater than 4 µm. This ratio is almost the same for dust in the lungs of patients who died of pneumoconiosis [30]. The degree of damage suffered by those working in a dusty environment varies depending on the duration of work in the dusty environment, the composition of the dust, the amount of dust, the distribution of the dust particle size and the personal sensitivity to the dust [28]. The particle size distribution of the dust is an important factor. However, dust smaller than a certain size causes various dust diseases. Dust particles larger than 5 µm is captured by the respiratory organs and expelled over time. For this reason, the size of the dust that can penetrate the alveoli the most is important. The sizes known as respirable dust are between 0,2-0,5 µm, but in practice, dust particles below 5 µm are considered harmful [28]. Dust has an important place in the industry and mining sector in terms of occupational health and safety today. While dusty air harms the health of the workers, on the other hand, it decreases the work efficiency, increases the cost and affects the economy. In addition, powders that cause pneumoconiosis cause chronic lung tissue damage and respiratory function losses [31]. Occupational branches and workplaces where dust is most common are drilling, blasting, grinding, crushing works, mines, tunnel and road construction works, porcelain, brick, tile manufacturing, cement, marble and welding works, iron and steel, sandblasting, transportation and storage. The amount of dust allowed is determined in a way that does not harm the health of the worker in case of working 8 hours a day, 40 hours a week. These values are known as threshold limit value (TLV), maximum allowed concentration (MAK), or time-weighted average (TWA). According to the dust control regulation, the employer ensures that dust measurements are made at periodic intervals determined as a result of the risk assessment [32]. The measurement results should be evaluated by taking into account the occupational exposure limit values given in the regulation. Necessary studies should be carried out to reduce the dust density below the limit values by methods such as preventing dust formation in dusty workplaces, eliminating dust at the source without dispersing into the working environment or suppressing dust. Total dust is powders that affects the entire respiratory system, including respirable dust, 50% of which has an aerodynamic diameter below 80-100 microns. Respirable dust, on the other hand, is defined as amorphous or crystalline dust with an aerodynamic diameter of 0,1 to 5,0 microns, and fibrous dust with a diameter of less than 3 microns and a length of at least 3 times its diameter. The devices used in dust measurement work on two principles: gravimetric and particle counting. In the gravimetric method, the total dust in a certain amount of air is separated, weighed and calculated in mg/m^3. In order to prevent errors that may occur due to the coarse grain effect, particles smaller than 5 microns are initially separated and weighed. Another method is the particle counting method. In this method, the dust collected on a glass plate is separated and those smaller than 5 microns are counted. The result is calculated in $particle/cm^3$.

3.5. Vibration

The oscillating motion of an object under the influence of internal or external forces is defined as vibration. When touching a vibrating surface or object, the person feels this vibration. Vibration is transferred to the human body through the contacting vibrating surface. There are two types of exposure: hand-arm vibration from hand-held tools with a handle and whole-body vibration transmitted from the seat or surface on a motorized machine [33]. Exposure to whole-body vibration usually occurs when a person is in contact with a vibrating surface. Whole-body vibration is mechanical vibration that, when transmitted to the entire body, poses a risk to the health and safety of the worker, causing discomfort, particularly in the lumbar region, and trauma to the spine. Hand-arm vibration is mechanical vibration that, when transferred to the hand-arm system of the person, poses a risk to the health and safety of the worker, and especially causes vascular, bone, joint, nerve and muscle disorders [34]. Vibration is described by its magnitude and frequency. The vibration magnitude is expressed in terms of vibration displacement (m), vibration velocity (m/s) or vibration acceleration (m/s^2) [35]. The magnitude of the vibration, the average value of the acceleration of the motion, is usually given as the square root of the sum of the squares of the frequency-weighted acceleration values (RMS) [32]. A frequency-weighted RMS average acceleration is measured from each vibration axis. This is expressed as a_{hw}. The value used to evaluate the exposure is the total vibration value combining the a_{hw} values in the X, Y and Z axes [35]. Calculation of a_{hw} value is given in Eq. 1.

$$a_{hw} = \sqrt{a_{hwa}^2 + a_{hwy}^2 + a_{hwz}^2} \qquad (1)$$

Evaluation of the exposure level in hand-arm vibration is based on the calculation of the daily exposure value A(8) normalized to an eight-hour reference period, expressed as the square root of the sum of the squares of the frequency-weighted acceleration values (RMS) (total value) and it is made according to the standards and the most up to date versions of these standards which are TS EN ISO 5349-1 "Mechanical Vibration – Measurement and Evaluation of Hand-Transmitted Vibration Exposure of Persons-Part 1: General Rules" and TS EN ISO 5349-2 "Mechanical Vibration – Measurement and Evaluation of Hand-To-Body Vibration Exposure of Persons – Part 2: Practical

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Guide for Measuring in the Workplaces" [34]. Exposure action and limit values for vibration are given in the Regulation on the Protection of Employees from Risks Related to Vibration. The daily exposure limit value for hand-arm vibration is 5 m/s^2 and the exposure action value is 2,5 m/s^2 for an 8-hour working period. Evaluation of the exposure level in whole body vibration, calculated as the highest (RMS) value defined in terms of continuous acceleration equivalent in an eight-hour period A(8) based on the calculation of the daily exposure value and it is made according to the standards and the most up to date versions of these standards which are TS EN 1032+A1:2011 "Mechanical Vibration – Testing of Moving Machines for the Determination of Vibration Emission Value" and TS ISO 2631-1 "Mechanical Vibration and Shock-Whole Body Vibration Exposure Assessment – Part 1: General Guidelines". For whole body vibration, the daily exposure limit value for 8 hours of work is 1,15 m/s^2 and the exposure action value is 0,5 m/s^2. Vibration damage depends on various factors such as individual susceptibility, severity of vibration, frequency of exposure, duration (years), insulation level, grip strength, body part affected by the resource and maintenance of tools used [36]. Hand-arm vibration can cause narrowing of the vessels, decrease in blood flow, loss of vascular flexibility, as well as disorders in nerves, muscles, bones and joints. Findings such as tingling, numbness, pain and whitening in the hand and arm, cramps in the shoulder and loss of strength in the wrist are grouped under the name of "Hand-Arm Vibration Syndrome" [35]. Although the frequency range in hand-arm vibration varies between 5-1500 Hz, it usually occurs between 125-300 Hz. The effect of whole body vibration is greater at the end of the 0,5 Hz – 100 Hz range [6]. Vibration exposure is expressed as the average of the exposure measured in m/s^2 over a given period of time (usually 8 hours). Whole-body vibration is shaking or jolting of the human body through a supporting surface (usually a seat or the floor), for example when driving or riding on a vehicle along an unmade road, operating earth-moving machines or standing on a structure attached to a large, powerful, fixed machine which is impacting or vibrating [37]. Whole body vibration can cause discomfort especially in the lumbar region and trauma to the spine.

4. OCCUPATIONAL HYGIENE MEASUREMENTS

4.1.Illuminance

In the lighting measurements, care was taken not to create an angle that would affect the measurements of device in a different direction during the measurement. Lighting measurements were made with the Extech-SDL-400 model device at 5 points, including the dining hall, kitchen, storehouse, bureau and main control room. In Table 1, the places and ambient conditions where the lighting measurements were made are given. In Table 2, the lighting measurements for the dining hall, kitchen, storehouse, bureau and main control room are given.

Table 1. Lighting measurement parameters [11].

No	Measurement location	Ambient Conditions			
		Temperature (°C)	Humidity (%Rh)	Air flow velocity (m/s)	Air pressure (kPa)
A-01	Dining Hall	24,2	48,9	0,1	90,70
A-02	Kitchen	24,6	48,7	0,1	90,70

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A-03	Storehouse	24,6	48,2	0,1	90,70
A-04	Bureau	24,3	48,1	0,1	90,70
A-05	Main Control Room	24.9	48.7	0.1	90.70

Table 2. Lighting measurements [11].

No	**Measurement location**	**Measurement (Lux)**	**Result**	**Limit Value (Lux)**	**Assessment**
A-01	Dining Hall	1009		200	Appropriate
A-02	Kitchen	304		500	Not Applicable
A-03	Storehouse	750		200	Appropriate
A-04	Bureau	2352		500	Appropriate
A-05	Main Control Room	3252		500	Appropriate

4.2. Thermal Comfort

The wet-bulb globe temperature change, called WBGT, which is one of the general principles related to thermal comfort measurements, is all of the experimental changes that show the heat stress on which the worker is affected. It is a method that allows an effective diagnosis and measuring the heat stress that the employee is affected by in hot environments. The WBGT index is based on the work of the employee between a certain period and is the effect of the heat generated on the employee during this work on an average employee. This index usually combines two combined parameter measures, nature wet-bulb temperature (tnw) and globe temperature (tg), and in some cases it combines air temperature (ta) (dry bulb temperature) which is a basic parameter measure. The metabolic rate can be approximated by measuring the oxygen consumed by the worker, or from reference tables. Due to the nature of the WBGT change, it will be sufficient to estimate the metabolic rate according to the reference table. Work/rest cycles for unacclimated and acclimated individuals are determined by estimating the reference values in the reference value chart of WBGT and WBGT heat stress index according to the specified standard. Reference values of WBGT are given in Table 3.

Table 3. Reference values of WBGT [22].

Metabolism level	**Metabolism rate (M) (W·m-2)**	**Reference values of WBGT(°C)**			
		Good heat acclimation		Bad heat acclimation	
0	M<117	33		32	
1	117<M<234	30		29	
2	234<M<360	28		26	
		Can't feel the air flow	Feel the air flow	Can't feel the air flow	Feel the air flow
3	360<M<468	25	26	22	23
4	M>468	23	25	18	20

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In the thermal comfort measurements of the personnel working at the measurement point, metabolic rates and clothes of the employees were determined according to the work they did and included in the calculations. Thermal comfort measurements were made with a Delta ohm-HD 32.3 model device. Thermal comfort measurement locations, pre-measurement determinations and outdoor conditions are given in Table 4, and thermal comfort measurement results are given in Table 5.

Table 4. Thermal comfort measurement locations, pre-measurement determinations and outdoor conditions. [11].

		Outdoor conditions				**Pre-measurement determinations**			
No	**Measurement location**	Temp. (°C)	Humidity (%Rh)	Air flow velocity (m/s)	Air press. (kPa)	Clothes	Clo Value	Activity for Met. ratio	Met. Value
A-01	Dining Hall	24,5	48,7	0,1	90,70	Pants T shirt Shoe Sock	1	Standing Work	1,20

Table 5. Thermal comfort measurement results [11].

		Parameters				**WBGT**	
Measurement Point	**Measurement Location**	**WBGT**	T_g	T_{nw}	T_a	**Reference Value Acclimated Person**	**Reference Value Unacclimated Person**
TK-01/ Standing Work	Dining Hall	28,60	26,89	26,55	26,64	30 °C	29 °C

4.3. Noise

Noise measurements were carried out as workplace environment measurements and personal noise exposure. Care was taken not to make any noise that would affect the measurement during the measurement. The device was calibrated before each measurement. While Svantek-Svan971 model device was used for ambient noise measurements, Svantek SV104 model was used for personal exposure measurements. Information about ambient conditions in personal noise exposure and ambient noise measurements is given in Table 6. The measurement results of personal noise exposure are given in Table 7, and the results of ambient noise measurements are given in Table 8.

Measurements of personal noise exposure were carried out on 4 employees, including loader operator, truck driver, greaser and crusher operator, with an 8 hour exposure Svantek SV104 model noise dosimeter. Measurements related to personal noise exposure are given in Table 4.7.

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Ambient noise measurements were carried out at the main control room, dining hall and bureau. Measurements of ambient noise are given in Table 4.8. Ambient noise measurements were made taking into account some principles. If the residual noise level is lower than the measured sound pressure level in a value of 10 dB or more, no correction is made. The measured value is valid for the source under test. If the residual noise level is lower than the measured sound pressure level in a value of 3 dB or less, no correction is allowed. In this case, the measurement uncertainty is high. If the residual noise level is lower than the measured sound pressure level in a value between 3 to 10 dB, the corrected sound pressure level is used. The corrected sound pressure level can be calculated with the formula: $\mathrm{Lcorr} = 10\,\mathrm{Log}(10^{\mathrm{Lmeas}/10}\text{-}10^{\mathrm{Lresid}/10})$ In this formula, Lcorr indicates the corrected sound pressure level, L_{meas} indicates the measured sound pressure level, and L_{resid} indicates the residual noise level.

Table 6. Ambient conditions in ambient noise and personal noise exposure measurements [11].

No	Measurement Location/Person	Ambient Conditions			
		Temperature (°C)	Humidity (%Rh)	Air flow velocity (m/s)	Air pressure (kPa)
KG-01	Loader Operator	24,1	48,9	0,1	90,70
KG-02	Truck	24,9	48,7	0,1	90,70
KG-03	Greaser	24,5	48,2	0,1	90,70
KG-03	Crusher Operator	24,6	48,1	0,1	90,70
OG-01	Main Control Room (1.Measurement)	24,2	48,9	0,1	90,70
OG-02	Main Control Room (2.Measurement)	24,6	48,7	0,1	90,70
OG-03	Main Control Room (3.Measurement)	24,6	48,2	0,1	90,70
OG-04	Bureau (1. Measurement)	24,3	48,1	0,1	90,70
OG-05	Bureau (2. Measurement)	24,9	48,7	0,1	90,70
OG-06	Bureau (3. Measurement)	24,5	48,9	0,1	90,70
OG-07	Dining Hall (1. Measurement)	24,6	48,7	0,4	90,70
OG-07	Dining Hall (2. Measurement)	24,6	48,7	0,3	90,70
OG-08	Dining Hall (3. Measurement)	24,5	48,9	0,5	90,70

Table 7. Personal noise exposure measurements [11].

No	Measurement Location/Person	Measurement (dB(A)
		Lex,8h
KG-01	Loader Operator	77,2
KG-02	Truck	80,8
KG-03	Greaser	85
KG-04	Crusher Operator	74,6

Table 8. Ambient noise measurement results [11].

Measurement No	Measurement Location	Measured(dB(A))				Corrected(dB(A))
		L_{min}	L_{max}	L_{meas}	L_{resid}	Lcorr
OG-01	Main Control Room 1. Measurement	61,8	106,8	86,8	65,7	86,5
OG-02	Main Control Room 2. Measurement	69,7	106,6	83,4	65,7	83,4
OG-03	Main Control Room 3. Measurement	55,4	101,2	86,2	65,7	86,2
OG-04	Bureau 1. Measurement	62,5	97,1	76,3	64,4	76,3
OG-05	Bureau 2. Measurement	61,8	79,2	71,5	64,4	70,5
OG-06	Bureau 3. Measurement	54,6	91,6	72,6	64,4	71,8
OG-07	Dining Hall 1. Measurement	54,9	81,0	65,6	61,6	63,3
OG-08	Dining Hall 2. Measurement	55,0	87,0	68,9	61,6	68,0
OG-09	Dining Hall 3. Measurement	54,5	96,5	68,1	61,6	66,9

4.4. Dust

A.P.Buck Lp-5 Libra Plus dust sampler was used to determine the dust and dust exposure in the working environment by gravimetric method. Total dust and respirable dust measurements are made differently. Respirable dust is based on dust particles smaller than 5 microns, while dust particles smaller than 80-100 microns in diameter are taken as the basis for total dust. Respirable dust can reach the alveoli and cause lung diseases called pneumoconiosis. Ambient conditions for dust measurements are given in Table 9.

In Table 10, occupational dust exposure limit values of some substances are given according to the Dust Control Regulation. In this regulation, in order to prevent the risks that may arise from dust in the workplaces, the procedures and principles are determined regarding the precautions to be taken in order to control dust in terms of occupational health and safety and to ensure that the workers in these works are protected from the effects of dust. In Table 11, the results of personal respirable dust concentration measurements made in the limestone quarry and the total measurement results are given.

Table 9. Ambient conditions in dust measurements [11].

No	Measurement location/person	Ambient conditions			
		Temperature (°C)	Humidity (%Rh)	Air flow velocity (m/s)	Air pressure (kPa)
KST-01	Loader Operator	24,2	48,9	0,1	90,70
KST-02	Truck	24,6	48,7	0,1	90,70
KST-03	Greaser	24,6	48,2	0,1	90,70

KST-04	Crusher Operator	24,3	48,1	0,1	90,70
FÖ-01	Crusher	24,9	48,7	0,1	90,70
FÖ-02	Filling Field / Stone Loading	24,5	48,9	0,1	90,70
FÖ-03	Dining Hall	24,6	48,7	0,4	90,70
FÖ-04	Compressor Room	24,6	48,7	0,3	90,70
FÖ-05	Control Room	24,5	48,9	0,5	90,70

Table 10. Occupational dust exposure limit values of some substances according to the Dust Control Regulation [32].

Material Name	**Total Dust Amount TWA/ZAODA (mg/m^3)**	**Respirable Dust Amount TWA/ZAOD (mg/m^3)**
Calcium Carbonate (Marble)	15	5
Calcium Carbonate (Limestone)	15	5
Calcium Hydroxide	15	5
Calcium Silicate	15	5
Calcium Sulphate	15	5
Magnesite	15	5

Table 11. Personal respirable dust concentration and total measurement results [11].

No	**Measurement Location/Person**	**Measurement Value (mg/m^3)**	**Limit Value (mg/m^3)**
KST-01	Loader Operator	0,258	5
KST-02	Truck	0,208	5
KST-03	Greaser	0,350	5
KST-04	Crusher Operator	0,567	5
FÖ-01	Crusher	0,958	15
FÖ-02	Filling Field / Stone Loading	2,833	15
FÖ-03	Dining Hall	1,333	15
FÖ-04	Compressor Room	2	15
FÖ-05	Control Room	1	15

4.5. Vibration

In the study, vibration measurements were made with Svantek SV38 and SVANTEK SVAN SV-106 Model devices. Hand-arm and whole body vibrations of the jaw crusher operator, truck driver and loader operator were measured. The ambient conditions of vibration measurements are given in Table 12. Hand-arm and whole body vibration values are given in Table 13.

Table 12. Ambient conditions of vibration measurements [11].

No	**Measurement**	**Ambient conditions**

	location/person	Temperature (°C)	Humidity (%Rh)	Air flow velocity (m/s)	Air pressure (kPa)
TT-01	Jaw Crusher Operator	24.5	48.9	0.1	90.70
TT-02	Truck Driver	24.6	48.7	0.3	90.70
TT-03	Loader Operator	24.5	48.9	0.5	90.70

Table 13. Hand-arm vibration and whole body vibration measurement results [11].

No	**Measurement**		**Measurement Results**				**Assessment**	
	Location/person	**Type*** *	a_{hwx} (m/s^2)	a_{hwy} (m/s^2)	a_{hwz} (m/s^2)	a_{hw} (8h)* (m/s^2)	Daily Exposure Limit Value (8h) (m/s^2)	Daily Exposure Action Value (8h) (m/s^2)
TT-01	Jaw Crusher Operator	HAV	0.205	0.249	0.198	0.384	5	2,5
TT-02	Truck Driver	HAV	0.001	0.001	0.001	0.006	5	2,5
TT-03	Loader Operator	HAV	0.0003	0.000261	0.000286	0.00049	5	2,5
TT-01	Jaw Crusher Operator	WBV	0.119	0.113	0.270	0.270	1,15	0,5
TT-02	Truck Driver	WBV	0.216	0.172	0.280	0.303	1,15	0,5
TT-03	Loader Operator	WBV	0.215	0.386	0.269	0.541	1,15	0,5

∗ Evaluated according to exposure times. ** Hand-Arm Vibration (HAV), Whole Body Vibration (WBV)

5. RESULTS and SUGGESTIONS

According to article 10 of the Occupational Health and Safety Law No. 6331, the employer is obliged to ensure that the necessary controls, measurements, examinations and researches are carried out in order to determine the risks which the employees are exposed to in terms of occupational health and safety. Noise, vibration, dust, insufficient or excessive lighting and thermal temperatures in the working environment can cause temporary health problems and occupational diseases in employees. In order to prevent these health problems and occupational diseases, the degree of physical and chemical risks in the working environment should be measured. Measures to be taken against these risks can be revealed more easily as a result of these measurements. According to the lighting measurement results in the facility where the study was conducted, considering the values specified in the regulations and standards, the value of lighting measurement made in the kitchen section was 304

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lux. Considering that the limit value should be 500 lux, some precautions should be taken in the kitchen section. Local illuminators can be placed in the kitchen section. Instead of the few yellow bulbs in the kitchen, white bulbs close to daylight can be used. Light sources with uniform illumination can be used which have the same level of illumination throughout the work surface and at sufficient distance intervals. It is essential that thermal comfort conditions are in a way that does not disturb the employee in the working environment and does not adversely affect their physical and psychological conditions. The working environment should be suitable for the way of working and the effort spent by the employees. According to the thermal comfort measurement results made at the facility, there are no parts that do not meet the recommended values of 29°C. Only in the standing study in the kitchen, the value is 28,6°C. This is a factor due to both the temperature of the stove and the steam of the food. In this part, a more ideal temperature can be reached with a suitable ventilation. Based on the minimum exposure action value of ($L_{ex,8\ hours}$) 80 dB(A), the highest exposure action value of ($L_{ex,8\ hours}$) 85 dB(A) and the exposure limit value of ($L_{ex,8\ hours}$) 87 dB(A) specified in the regulation on the protection of workers from noise-related risks, ambient noise was measured as 86,5 and 86,2 dB(A) in the measurements made in the crusher main control section. The highest exposure action value of 85 dB(A) was exceeded. Covering the crusher with materials that will provide sound insulation in the crusher plant will reduce the noise rate. For personnel working in the main control room, exposure can be prevented by covering around of the control room with sound insulation material and also by ensuring that the personnel use earplugs. The dust measurement results were evaluated according to the limit values specified in the Dust Control Regulation, which was published in the Official Gazette of the Republic of Türkiye dated 05.11.2013 and numbered 28812. According to the measurement results of Respirable and Total Dust Exposure of Persons at the facility, the limit values specified in the regulation were not exceeded. The hand-arm and whole body vibration measurement results were evaluated according to the Regulation on the Protection of Employees from Risks Related to Vibration. In this regulation, the exposure limit value for hand-arm vibration is 5m/s² for 8 hours of operation and the exposure action value is 2,5m/s². In the same regulation, for whole body vibration, the exposure limit value is given as 1,15 m/s² during the 8-hour working period and the daily exposure action value is 0,5 m/s². Considering the vibration acceleration parameter (A(8)) in the measurements made, the 8-hour whole body vibration value of the loader operator is 0,541 m/s². In 8 hours of operation, the daily exposure action value of 0,5 m/s² for whole body vibration was exceeded. In order to minimize the vibration exposure of the operators and increase the working efficiency, vehicle driving training should be given, periodic maintenance of the vehicles should be done and the vibration caused by the work machine should be reduced.

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