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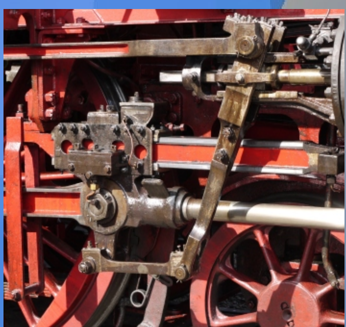

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C O N T E N T S

Personal noise exposure level and the impact on the employee's performance in the automotive industry

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Abstract: *In today's demanding market environment the companies need to deliver high quality product to their customers and in parallel to maintain an ergonomic workplace for their employees to increase the productivity. The purpose of this paper is determination of the personal noise exposure level caused by the machines and equipment installed in all organization units in an auto part production plant. The noise level was measured and analysed with noise measurements equipment – dosimeters and software tool at 25 measurement points across the plant. In addition, the strength between the variables, noise levels and concentration, is presented with correlation coefficient.*
***KEYWORDS**: NOISE LEVEL, PERSONAL EXPOSURE, AUTOMOTIVE INDUSTRY*

1. Introduction

The implementation of ergonomics design on the workplace can improve the productivity, safety, physical and mental well-being, and employee satisfaction. Many studies done in the past years have shown positive effects of adopting ergonomics principles to the work environment. It is very important that the production system designers should not be focused only on the productivity but also on providing comfortable workplace for the employees.

Many different factors have impact on the work environment: noise, vibration, lightening, heating, and cooling, air pressures, etc. The current research studies consider three types of effects of these factors: effects on employee health, comfort, and performance [1]. Continuous and dynamic interaction between people and their environment has its effects on personality. This can lead to a direct impact on performance and productivity as well as affecting the employee health and safety.

One of the key factors contributing to ergonomic workplace is the noise exposure level. Noise is defined as unwanted or harmful sound that can damage the hearing and cause many other adverse health effects. It can also be the cause of injuries at work. The effects can be short and long term. Short term effects of noise exposure are temporary hearing loss, stress, annoyance, difficulty in verbal communication and safety hazards [2]. The main long-term effect on employee's health from noise exposure is noise-induced hearing loss (NIHL) which cannot be remedied by medical treatment [3]. Noise-induced hearing loss is one of the most common occupational injuries, resulting in health problems for many workers and a significant social and economic problem. This includes lost jobs, higher absenteeism, lower employee performance, lost opportunities for promotion, and disrupted social relationships. In case there is a hearing loss, it can be the cause for an accident at the workplace [4].

Usually, the noise in the industry is caused by the machines and equipment used in the production process. This means that not only the employee who is operating on a specific machine is under noise exposure but also the employees operating in the same area or within the plant. The various types of equipment used by the manufacturing sector results in different noise levels due to the usage of plant equipment, and the operating speed of the machines. A large percentage of the labour force employed in a production plant is exposed to noise and according to literature research, a huge part of the production plants create noise that exceeds the permitted limits, and on average ranges between 70-118 dB.

Noise exposure in the workplace vary in the level, duration, and frequency. These parameters can be continuous, impulsive, or intermittent. The frequencies are rated as high or low frequencies. The goal in all industrial plants is to reduce the noise levels and eliminate the risk of noise-induced hearing damage.

Noise exposure is a complex combination of the sound levels to which an employee has been exposed and the duration of each of those noise levels. The focus is on the two variables: sound levels and duration. Equivalent sound level, Leq, t in dBA is the first of these. The simplest way to understand is as follows: In real life, sound levels constantly vary over time. They rise when the employee uses a power tool and shrink between operations, this means is constantly changing. Leq, t is a kind of "average" sound level for the entire period of exposure (working hours), which includes all "quiet" and "noisy" periods. It is defined as a constant sound level noise value that contains the same total A -long-term equivalent sound pressure level, expressed in decibels. While the real noise has a varying sound level, the equivalent has a constant level.

The negative effects caused by noise depend on the level of noise during the working hours. This means, as louder the noise becomes, it can cause damage for a short time. A 3 dB (A) increase of the noise level will produce twice as much energy and cause the same damage in half of the time compared to the noise level before this increase. For example, two minutes working in a noise level of 115 dB (a) can cause the same damage as eight hours working in a noise level of 90 dB. Long periods without exposure to noise in the workplace lead to a reduced risk of developing hearing impairment. As noise levels increase, the risk becomes greater. For example, exposure to a noise level of 90 dB (A) to 95 dB (A) represents a significantly risk of developing hearing damage.

Effective noise management in the industry is possible if the responsible team is focused on the following steps:

- regular risk assessment,
- corrective and protective measures and
- monitoring on the results of these measures.

The monitoring of the control measures is a necessary step to determine whether the measures are effectively implemented and provide adequate results for the employees. When the measures are implemented effectively, then the effects on the employees, such as unpleasant feeling, reduced concentration, injuries, and personal performance, will be eliminated or mitigate.

The following measures can be taken to improve the working conditions in relation to high noise exposure:

- application of equipment whit noise emission reduced to a minimum,
- adequate reconstruction of the workspace and installation of materials that enable better acoustics,
- regular maintenance of the machines and equipment,
- job rotation,
- provide personal protective equipment to the exposed employees.

While purchasing new equipment the industry should take in consideration the effect of the noise caused by the equipment as one of the sourcing criteria. This research is focuses on the analysis of personal noise exposure at different work positions in an auto part manufacturing plant and the effects on employee performance and productivity.

2. Aim and scope of the research

The purpose of the research is to determinate the levels of personal noise exposure from machines and equipment in all organizational units in a production plant, to identify the area in which the employees are most exposed to noise. In the organizational unit with the highest potential of noise exposure, the measurements will be performed to a higher number of employees. The personal noise exposure will be determined with the help of special instruments - dosimeters, which the employees should keep positioned closest to the ear during the day. The recorded personal exposure levels will then be processed using the software tool - Noise Safe.

Personal exposure to noise during a working day could have an impact on the employee performance. During the research, the type and degree of correlation between these two variables will be determined using correlation analysis. The analyses will show whether the exposure to noise in the production plant can be the reason for the drop of the employee concentration and a cause for injuries on the workplace. All this affects the productivity or performance of the company. The success of the company depends on the working conditions and the productivity of the employee.

3. Research methods

The research includes 75 employees working on 25 measurement points in a production plant, representatives from different organizational units: production, warehouse and maintenance. The criterion for selecting the employees is that they must be at their workplace for 8 hours and employed for longer than six months. The purpose of this study was shared with the participants and all of them voluntarily accepted to participate in conducting measurements of personal noise exposure, while the purpose of the study was first shared with them.

3.1. Measurement equipment – Dosimeters

Dosimeters are small devices that contain a microphone to capture personnel exposure to noise. The dosimeters used for the purpose of this research, CASELLA Dbadge2, satisfy the requirements according to IEC 61252 and in accordance with the requirements of IEC 61762-1: 2002 instrument class 1. The participants in this research will place the dosimeters on top of the shoulder without covering the microphone with clothing or other equipment. The procedure will be carried out in two different shifts, 6 hours per measurement, and repeated in at least three series per measurement point.

Before the dosimeters are distributed, the pilot group will receive instructions on how to use them. It is recommended to place them closer to the ear to capture the actual personal exposure levels. Before we put these instruments into use, we need to make sure that the battery is full and will last during the testing, as well as that they are placed in a suitable position without hindering the performance of the daily tasks of the employees. The software Noise Safe will be used to manage and collect the data from the dosimeters.

The Noise dosimeter which measures the noise level for several hours, calculates the cumulative noise level expressed as the application of a noise dose for a certain time in percentage [5].

3.2. *Questionnaire*

All the participants in the research filled a questionnaire for concentration check just after the end of the working hours. The results of the questionnaire will be used to determine the impacts of noise exposure on the employee performance. The questionnaire for each of the employees will be marked with an appropriate code, and the time required to answer is 2 minutes.

The results are manually collected and processed with statistical analysis. When the results of the questionnaire will be summarized, we can move on with statistical analysis and determining the dependence of the employee concentration and the levels of personal noise exposure.

3.3. *Statistical analysis*

As final step in the research a corelation analysis will be used for determining the dependence between two variables. Correlation Analysis is statistical method that is used to discover if there is a relationship between two variables/datasets, and how strong that relationship may be. A relationship between two variables, X and Y, exists if an increase of the first one is followed by an increase or decrease of the second variable. Depending on the direction, the relationship between two variables can be: positive or negative. A positive correlation result means that both variables increase in relation to each other, while a negative correlation means that as one variable decreases, the other increases. The relationship between the variables differs not only in direction, but also in strength (intensity).

Scatter diagrams are used to investigate the relationship between two variables which may be: quality parameter and factor affecting it, two quality characteristic, and two factors related to one quality characteristic. The procedure for creating these diagrams is carried out through several steps. The first step is monitoring and collecting pairs of data (x,y) for the dependence we want to investigate and calculation of the maximum and minimum values for x and y. For further explanation it is necessary to enter data such as: time intervals of the measurements, number of pairs of data, units of measurement used and the team performing the measurements. Results presented in a scatter diagram may show a different dependence.

To understand the relationship between the variables, the correlation coefficient needs to be calculated. This coefficient requires a table of data which displays the raw data, it's ranks, and the different between the two ranks. The constraint that this coefficient works under is $-1 \leq r \leq +1$, where a result of 0 would mean that there is no relation between the data. According to the obtained results for the degree of correlation, we can determine whether there is a correlation, positive or negative, and how strong the correlation is between the variables. The results at the end will be displayed graphically. This is the most widely used correlation analysis formula, which measures the strength of the 'linear' relationships between the raw data from both variables, rather than their ranks.

Having the data set of the personal noise exposure levels and the results of the questionnaire performed during the measurements the correlation coefficient will be calculated. The results will present the intensity of the relationship between these two variables and will give a direction for future actions.

Using a scatter graph is the easiest way of identifying any anomalies that may have occurred and running the correlation analysis twice (with and without anomalies) is a great way to assess the strength of the influence of the anomalies on the analysis. The regression equation representing how much y changes with any given change of x can be used to construct a regression line on a scatter diagram, and in the simplest case this is assumed to be a straight line. The direction in which the line slopes depend on whether the correlation is positive or negative.

The regression equation enables us to predict y from x and gives us a better summary of the relationship between the two variables. The regression equation can be used to find out what one variable is likely to be when we know the other.

4. Results

The measured levels of noise exposure in auto parts manufacturing plant have been obtained according to the ISO 9612-2009: Acoustics - Determination of occupational noise exposure method and have been normalized to 8 hours working day and the daily noise exposure level, LEX,8h, using the following formula: LEX, 8h = LAeq, Te + 10 log10 Te/T0 dB (A), where:

- Aeq, Te - measured equivalent noise level in dB (A) during Te,
- Te - daily duration of the employee's exposure,
- T0 - 8 hours reference time.

In Table 1 are presented the results of the personal noise exposure levels at 25 measurement points across 5 departments in the auto parts manufacturing plant. Due to the higher number of employees operating in Production 2 department, total 20 measurements were performed in this area.

Table 1. Personal noise exposure levels in an auto parts manufacturing plant

MP	Department	LEX, 8h dB
1	Maintenance	60.7
2	Maintenance	67.9
3	Maintenance	68.6
4	Warehouse	61.9
5	Warehouse	66.6
6	Production 1	67.0
7	Production 1	70.1
8	Production 1	70.3
9	Production 1	66.8
10	Production 2	76.4
11	Production 2	73.9
12	Production 2	71.0
13	Production 2	72.3
14	Production 2	71.1
15	Production 2	72.6
16	Production 2	76.2
17	Production 2	76.8
18	Production 2	74.2
19	Production 2	74.2
20	Production 2	71.8
21	Production 2	75.0
22	Production 2	79.6
23	Production 2	63.2
24	Production 2	64.2
25	Production 2	64.0

The results obtained from the monitoring of personal noise exposure vary depending on the work position in the plant. Considering the measured levels between 75-80 dB(A) regular control monitoring is required at the plant. From the previous research, we can expect that there is a correlation between the performance of the employees and the exposure to noise. For this purpose, a correlation analysis was performed using the results from the questionnaire (maximum score of 3; minimum score 0) and exposure levels in Table 1.

According to the corelation coefficient formula the dependence between the noise exposure levels and questionnaire score was calculated. Table 2 presents the parameters calculated based on the obtained results from the monitoring and the questionnaire. The correlation coefficient, r=-0.5, indicates moderate negative correlation between the two variables. When the noise exposure level increase than the concentration of the employees decreases.

Table 2. Correlation analysis parameters

parameter	noise exposure level	questionnaire score
average	69.8	1.24
min	50.1	0
max	79.6	3
R	29.5	3
r (correlation coefficient)	-0.5	

The relationship between the variables can be represented by a simple equation called the regression equation. In this context regression means that the average value of y is a function of x and it changes with x. The regression equation for the variables, noise exposure level and questionnaire score, is the following: $y=5.35-0.06x$

Two points are enough to define the line, three are better as a check. Having put them on a scatter diagram, we simply draw the line through them. Regression line show how the variable questionnaire score changes on average with the noise exposure level. This equation is very useful as we can identify what will be the expected questionnaire score when only the noise level is known.

5. *Discussion*

The results of this study indicate a moderate negative impact of the noise exposure levels on the employee's performance in automotive industry. In the available studies there is much debate as how the length of time an occupant is working under a single background noise condition can impact their performance and perception [6]. Prolonged exposure to noise at high intensity is associated with damage to the sensory hearing cells of the inner ear and development of permanent hearing threshold shift, as well as poor speech in noise intelligibility [7].

The noise in an automotive industry plant is generated from the production process. Machinery, equipment, and work practices are typically the sources of excessive noise in the workplace [8]. The implementation of noise control and other aspects of noise regulations place a financial and compliance burdens on employers. However, this should not discourage employers from implementing feasible engineering noise controls [9]. The employers should implement regular noise measurements and adopt adequate action plan to maintain health and safety workplace and hight product quality.

Pedro and Miguel [10] worked on research with a total of 434 industrial workers exposed to a noise level higher than 85dB (A). With the help of a questionnaire, the employees' perception of the exposure to high noise levels and the use of protective equipment was assessed. The analysis of the data with several variables showed that general risk recognition and personal efficiency have a significant role for employee's behaviour regarding the use of personal noise protection equipment. Furthermore, these results suggest that risk recognition should be considered as an essential issue in the design and implementation of Hearing Protection Programs.

To maintain a pleasant working environment, apart from noise, several factors have an impact and usually all of them are investigated individually. It is necessary to conduct further research for consolidating the impact of different factors to employee performance and propose preventive and corrective measure for risk mitigation or elimination.

6. *Conclusion*

According to the research work done in the field of personal noise exposure often the high exposure levels to noise cause negative effects to the employee health and productivity. This leads to a risk factor for hearing loss and reducing the quality and quantity of the products.

The results of this study performed in the automotive industry indicate that the levels of personal noise exposure vary depending on the work position in the plant. In general, the exposure levels are high and require regular control to avoid exceeding the industry limit levels and negative effects. The corelation between the exposure level and the employee performance is negative and indicates that there is a risk of lower performance while the noise exposure levels increase.

Therefore, the recommendations are to control the noise levels in the production facilities and keep them at the lowest possible level to enable a comfortable workplace and efficient production of quality products. Only with detailed measurements and risk assessment on the personal noise exposure level the companies can decide if there is need of additional protective measures.

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