sciendo DOI 10.2478/ntpe-2019-0098

2019
Volume 2
Issue 2
pp. 341-349

Evaluation of Noise Level at the Position of Water Cutter Operator at Selected Enterprise

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Date of submission to the Editor: 09/2019
Date of acceptance by the Editor: 11/2019

INTRODUCTION

Noise is any unwanted sound that can be harmful to the health of the worker, disruptive and increase the risk of an accident at work (Yulianto, Saadah, 2018). The data reported by the Central Statistical Office (CSO) indicate that noise is the most common threat among other risk factors occurring in the work environment. In 2018, there were 193.6 thousand people exposed to noise. employees, which accounted for 59.5% of all persons employed in conditions of danger related to the work environment (counted as many times as those factors were exposed). It should be emphasized that the number of employees exposed to noise was more than three times higher than the number of employees at risk of the second in terms of the frequency of occurrence of a harmful factor – dust to which 50.2 thousand were exposed people (15.4%) (Fig.1).

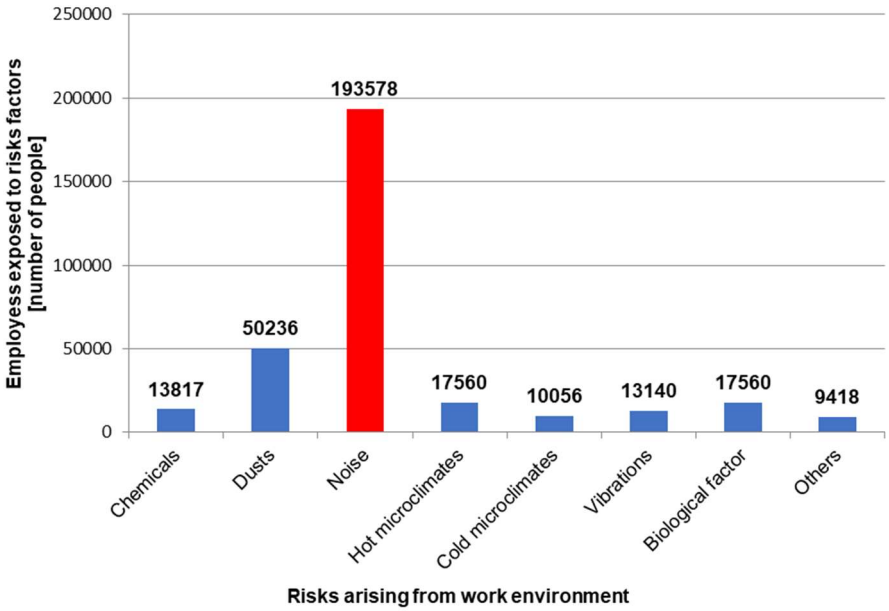

Fig. 1 Employees a exposed to the risks arising from work environment by physical health risk factors

Source: Working conditions in 2018 Statistics Poland

The highest number of people exposed to noise was reported, among others in the industrial processing section, in the section related to the production of metal products (Working conditions in 2018 Statistics Poland).

Due to the frequency range, the following are distinguished:

- infrasound noise – contains components with infrasound frequencies (inaudible) from 1 Hz to 20 Hz and low frequencies audible up to 50 Hz; it is also common to use low frequency noise for noise at frequencies from approx. 10 Hz to 250 Hz;
- audible noise – contains components with frequencies from 20 Hz to 16 kHz (some literature data give the range of 20 Hz-20 kHz, and some 16 Hz-16 kHz). The limits of the range of hearing are not strict and depend on the amplitude of acoustic vibrations, as well as on the human age and its individual characteristics;
- ultrasonic noise – contains in its spectrum components with audible and ultrasonic frequencies from 10 to 40 kHz (in some data 100 kHz is indicated).
- In accordance with the applicable legal provisions established in the Regulation of the Minister of Labour and Social Policy of 6 June 2014 on Maximum Permissible Concentration and Intensity of Agents Harmful to Health in the Working Environment (Journal of Laws 2014, item 817). and requirements specified in PN-N-01307:1994 exposure to noise in the work environment should be assessed on the basis of values of the following values:
- the noise exposure level related to the 8-hour daily working time or the noise exposure level related to the work week;
- maximum sound level A;
- peak sound level C.

Acceptable noise values due to the protection of hearing along with the interpretation of the occupational risk level for noise are presented in Table 1.

Table 1 Assessment of occupational risk related to noise and its acceptable level

Threat parameter	The level of risk		
	small	**medium**	**large**
Noise exposure level related to an 8-hour working day [dB]	$L_{EX,8h} \leq 80$	$85 \geq L_{EX,8h} > 80$	$L_{EX,8h} >$ **85**
maximum sound level A [dB]	$L_{Amax} \leq 109$	$115 \geq L_{Amax} > 109$	$L_{Amax} >$ **115**
peak sound level C [dB]	$L_{Cpeak} \leq 129$	$135 \geq L_{Cpeak} > 129$	$L_{Cpeak} >$ **135**

Souce: Zawieska, 2007

The methodology for determining individual values is described in the further part of the work.

Undeniably, the noise has a negative effect on the human body and can cause auditory and extra-hearing effects. One of the most common is the irreversible increase in the hearing threshold, i.e. permanent hearing loss (Wang et al., 2016, Wu et al., 2016, Jablonski et al., 2018). It results from a long-term employee's exposure to noise, with an equivalent A sound level above 80 dB. In addition, one-time noise exposure may also be the cause of permanent hearing loss if its peak sound pressure level exceeds 135 dB. In contrast, the extra-

hearing effects of noise on the human body rely on the action of noise as a stressor. Then it leads to disorders of the nervous, respiratory, circulatory, digestive and other organs (Dzhambov, Dimitrova, 2016, Hansen et al., 2017).
It should be emphasized that excessive sounds reduce speech intelligibility and negatively affect the perception of warning audio signals. This situation not only makes communication difficult, but above all increases the risk of accidents in a noisy work environment (http://archiwum.ciop.pl/1352.html, Zevitas et al., 2018).
In accordance with the requirements of Directive 2003/10/EC of the European Parliament of February 6, 2003 on protection against physical factors in the work environment, and in particular against noise, employer's responsibilities include:

- for noise levels of 80 dB (A) or above – providing exposed workers with access to appropriate hearing protection, without having to enforce their use;
- for noise levels of 85 dB (A) or above – equipping exposed workers with appropriate hearing protection, but it must strictly enforce their use. In addition, an exposure limit of 87 dB (A) has been set in the cited directive.

This is the upper limit of noise that can not be exceeded (Barač et al., 2018, Ullisch-Nelken et al., 2018).

MEASUREMENT METHODS

The subject of the research is the assessment of occupational exposure of the water jet operator to noise.
Noise measurements were carried out in accordance with the requirements contained in the standards:

- PN-N-01307:1994 Noise. Permissible noise values in the work environment. Requirements for making measurements;
- PN-EN ISO 9612:2011 Acoustics. Determination of occupational exposure to noise. Technical method.

The tests were performed for typical working conditions on a nominal work day and they included all significant acoustic events. During the measurement of noise, radios, tape recorders and other noise-emitting equipment were excluded, which is not related to professional activities.
Measurement of noise at workplaces was carried out in accordance with the applicable standards, at a distance of no more than 0.5 m from the ear of the employee serving the position, and in practice it was 1.7 m. Three measurements were taken for each operation.
The Laserliner Sound Test – Master decibel (Fig. 2) was used to test the noise level. It is located in the Laboratory of Work Safety and Hygiene, operating since 2013 at the Institute of Visual Arts and Security Engineering, Faculty of Production Engineering and Materials Technology, Czestochowa University of Technology.
The sound level meter is used to measure sound level with the frequency weighting filters based on the standard curves dB A and dB C as well as two time weighting factors (fast/slow). An internal memory stores the data measured

during long-term measurements and the internal interface enables real time logging on a PC (User manual SoundTest-Master).

1 – Microphone/Wind guard
2 – ON/OFF
3 – Max. function
4 – dB A, dB C/Record
5 – Time weighting/Memory readout
6 – Display lighting/Real time recording
7 – Adjust measuring range
8 – 9 V DC power supply connection
9 – DC/AC output
10 – Calibration screw
11 – PC interface
12 – Data transfer
13 – Analogue scale
14 – Time weighting
15 – Max. measuring range
16 – dB A/dB C
17 – Unit
18 – Record measured values
19 – Current measured value
20 – Time
21 – Min. measuring range

Fig. 2 The Laser liner Sound Test-Master

Souce: User manual Sound Test-Master

The basic functionalities of the device include:

- noise level measurement with frequency weight filter with dbA and dbC characteristics;
- selection of the time constant (fast 125 ms/slow 1 s) for optimization of fast-changing measurements;
- long-term registration (16,000 samples) or real-time data transmission;
- an analog indicator enabling visual assessment;
- settings and calibration in accordance with the standard noise level of 94 dB/1 kHz;
- sensitive electret microphone, capacitive with removable cover;
- transparent backlit display.

The technical parameters of the device are shown in Table 2.

The comprehensive assessment of noise included the designation of:

- maximum sound level A L A max [dB];
- peak sound level C L Cpeak [dB];
- noise exposure level related to the 8-hour work day LEX, 8h [dB].

The maximum sound level A L_{Amax} – it is the maximum effective value of sound level A. The parameter is used to assess short-term and pulse noise with high levels.

The maximum sound level A L_{Amax} is determined by the formula:

$$L_{A\,max} = \max_{i=1}^{n} \left(L_{A\,max_i}\right)$$

where:
L_{Amax} – the maximum sound level A for the i-th measurement,
i … n – number of noise measurements.

Table 2 Technical data

Manual measuring range	30 dB … 80 dB 40 dB … 90 dB 50 dB … 100 dB 60 dB … 110 dB 70 dB … 120 dB 80 dB … 130 dB
Automatic measuring range	30 dB … 130 dB
Accuracy	±1.5 dB
Dynamic range	50 dB
Test condition	94 dB, 1 kHz sinusoidal signal
Frequency range	31.5 Hz ... 8 kHz
Measuring interval Fast	125 ms, Slow: 1 s
Resolution of digital display 0.1 dB, Measuring rate:	2 measurements/second
Resolution of analogue display	1 dB, Measuring rate: 20 measurements/second
Microphone	Electret microphone
Data memory	16,000 measurements
AC voltage output	0.70 Vrms at full deflection, approx. 600 ohm output impedance
DC voltage output	10 mV/dB, approx. 100 ohm output impedance
Interface	Optoinsulated RS 232
Power supply	6 x 1.5 V AAA
Power pack connection	9 V DC, < 100 mV ripple, <= 150 mA current consumption
Operating temperature	0°C … 40°C (10% … 80% relative humidity)
Storage temperature	-10°C …60°C (10% … 70% relative humidity)
Dimensions (W x H x D)	80 x 245 x 35 mm
Weight (including batteries)	350 g

Source: User manual Sound Test-Master

Peak sound level C L_(C peak) it is the maximum instantaneous value of the C sound level. This parameter, like the maximum sound level A, allows to evaluate short-term and pulse noise with high levels.
Peak sound level C L_{Cpeak} is determined by the formula:

$$L_{C\,peak} = \max_{i=1}^{n} \left(L_{C\,peak_i}\right)$$

where:
L_{Cpeak} – peak sound level C for the i-th measurement
I … n – number of noise measurements

Noise exposure level related to an 8-hour working day $L_{EX,8h}$

Noise exposure level is a parameter that is used to assess the harmful effects on the auditory organ that changes during noise.
The noise exposure level related to the 8-hour daily working time (L_(EX,8h)) or work week (L_(EX,W)) is defined as the equivalent sound level A.
Noise exposure level related to an 8-hour working day $L_{EX,8h}$ is determined by the formula:

$$L_{EX,8h} = L_{A_{eq,T_e}} + 10\log\frac{T_e}{T_0}$$

where:
$L_{Aeq,Te}$ – equivalent sound level A for a daily exposure

T_e – exposure time [min], equal to the sum of the duration of activities in noise exposure
T_0 – reference time [min], for a daily exposure, 480 min is assumed.

Equivalent sound level A for a daily exposure

In a situation, an employee performs work on various machines that generate noise at different sound pressure levels, it is necessary to determine the risk that the employee affects him during the change of noise. Then calculate the equivalent sound level A. Equivalent sound level A is the level of sound A that, acting for the same time as noise with varying sound pressure level, carries with it the same energy and the same risk of hearing damage.
The equivalent sound level A for the daily exposure for several different activities in terms of noise exposure was determined by the formula:

$$L_{A_{eq,T_e}} = 10 \log \left[\frac{1}{T_e} x \sum_{j=1}^{m} \left(T_j \cdot 10^{0,1 \cdot L_{A_{eq,T_j}}}\right)\right]$$

where:
$L_{Aeq,Tj}$ – equivalent sound level A for the j-th action
j…m – number of activities in intensity for noise

RESULTS

The workplace of the waterjet operator is located in the production hall with cubic dimensions: length – 30 m; width – 12 m; height – 9 m. The object is heated by a central heating installation and meets the minimum temperature requirements at the physical work stations. The place of work is illuminated by daylight through the trained surfaces of the walls and in the ceiling. Additional lighting is provided by fluorescent lamps. The floor is even, uncluttered, dust-free and without any frets between the rooms. Employees have access to full sanitary and hygienic facilities.
Work at the operator's station takes place in a two-shift cycle, 8 hours for a work shift. The employee performs activities in accordance with the agreed work process, which consists of:

- support for the cutting plotter, material loading, supervision over the cutting process and collection of cut elements (300 min. for a change);
- auxiliary, transport and order work (90 minutes for a change);
- introduction of data regarding the cutting program to the machine control computer, preparation of documentation and hygienic and social breaks (90 minutes per shift).

Due to the fact that the employee performs various activities and tasks during the work shift, his exposure to noise is variable. Nine persons are employed in the enterprise under investigation as a water cutter operator, and there are no women or juvenile workers among them.
Table 2 presents the results of measurements of noise in the environment of a waterjet operator. The results are given with expanded uncertainty up to a confidence level of 95% and an expansion factor k = 2

Table 2 Evaluation of noise level at the waterjet operator station in the surveyed enterprise

No.	Action	T_m [min]	T_p [min]	Individual result [dB]	$L_{A_{eq,T_e}}$ [dB]	$L_{A\ max}$ [dB]	$L_{C\ peak}$ [dB]	$L_{EX,8h}$ [dB]
1.	Plotter support, material loading, supervision on the cutting process, receipt	300	5	83.4 84.01 83.9	83.8	90.3	111.2	82.2
2.	Auxiliary, transport and cleaning work	90	5	78.9 78.6 79.2	79.0	88.5	107.1	
3.	Computer support, keeping records, hygienic and social break	90	5	64.0 64.7 63.9	64.2	73.6	98.9	

Source: Own study

From the analysis of the results of noise measurements at the waterjet operator's station (Table 2), it can be stated that the level of exposure to LEX, 8h, is in the range of 82.2, which means that the limit value (85 dB) has not been exceeded and occupational risk related to the worker's exposure to the harmful factor is medium. The second analyzed parameter of noise exposure is the maximum sound level A L_{Amax}. This size was determined for all task groups being carried out and ranges from 73.6 dB (for activities related to computer operation, keeping records and hygienic and social breaks) up to 90.3 dB (for activities related to the process of cutting and loading and collection of material). The obtained results indicate that the permissible value (115 dB) has not been exceeded, and the occupational risk in this case is at a low level. The third rated size was the peak sound level C L_{Cpeak}, which has also been recorded for all groups of activities and ranges from 98.9 dB to 111.2 dB, and does not exceed the permissible value (135 dB), and the occupational risk is at a low level.
The work also determined the values of the equivalent sound level A, which range from 64.2-83.8 dB and for two groups of activities, i.e. (1) support for the cutting plotter, loading material, supervision over the cutting process and receipt of cut elements and (2) auxiliary works , transport and housekeeping, exceeded the limit value (65 dB).
In addition, it should be pointed out that the warehouse is located in the production hall, responsible for receiving, storing and recording materials and final products. Due to the location of workplaces, he is also exposed to noise. Taking into account the above, specific corrective and prophylactic actions should be recommended, which should include the installation of sound-absorbing screens, marking and marking noise-affected areas and equipping employees with personal protective equipment. Detailed proposals for actions are presented in the summary and final conclusions.

CONCLUSION

The following conclusions and final statements can be formulated on the basis of the analysis of the literature and the authors' own research:

1. The performance of any professional activity is related to the exposure of employees to various types of occupational hazards. The most common risk

factor in the work environment is noise, which affects over 50% of employees among all those employed in harmful conditions.

2. Noise is any unwanted noise, which negatively affects the body, causes discomfort and may be the cause of an accident at work. Therefore, the employer is obliged to periodically measure noise, if it occurs at the workplace, monitor the condition of the acoustic environment and implement preventive and preventive actions.
3. In Polish and European legal regulations and standards, the noise limit values are set, which can not be exceeded and which are respectively for:
   - noise exposure level related to an 8-hour work day $L_{EX,8h}$ – 85 dB;
   - maximum sound level A L_{Amax} – 115 dB;
   - peak sound level C L_{Cpeak} – 135 dB.
4. To measure the noise level at the waterjet operator's station, the SoundTest-Master decibel measuring instrument was used, which is located in the Laboratory of Occupational Safety and Health at Czestochowa University of Technology. The methodology of conducting the research corresponded to the standards described in the norms: PN-EN ISO 9612:2011 Acoustics. Determination of occupational exposure to noise. Technical method and PN-N-01307:1994 Noise. Permissible noise values in the work environment. Requirements for making measurements.
5. The conducted research indicates that the waterjet operator is exposed to noise generated primarily by the cutting plotter, but also computer equipment, metal objects hitting each other or various activities carried out at the workplace.
6. Noise measurements carried out indicate that its values do not exceed the acceptable levels for the protection of hearing. However, the value of the equivalent sound level A (65 dB) has been exceeded, which for:
   - plotter support, cutter plotter support, material loading, supervision of the cutting process and receipt of cut elements: 83.8 dB;
   - auxiliary, transport and order work is: 79.0 dB.
7. For the purpose of this work, the authors suggest using several types of protection measures by the company under analysis in order to maximally protect noise exposed operators. The collective protection measure may be portable acoustic screens that would divide the production hall into the working zones of the waterjet operator and the warehouseman. In this way, you will certainly be able to reduce the risk of exposing a warehouse employee to excessive noise pollution. In addition, all workers exposed to noise should be equipped with hearing protectors. An important prophylactic element will also be appropriate marking of zones in which noise occurs.

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Abstract.

The subject of this publication is to assess the exposure of the waterjet operator to the noise hazard. The publication presents basic information about noise in the work environment. Next, the procedure of noise measurement in the work environment was discussed and the results of tests carried out at the waterjet operator's station for three basic activities were presented, ie: (1) plotter support, supervision of the cutting process, loading and receiving material, (2) auxiliary, transport and cleaning, (3) computer service, keeping documentation, hygienic and social break. The noise level test included the determination of: the maximum sound level A $L_{A\,max}$, the peak sound level C L_{Cpeak}, the noise exposure level related to the 8-hour work day $L_{EX,8h}$. Based on the obtained measurement results, it can be stated that the exposure to noise at the station of the waterjet operator is at an acceptable level.

Keywords: noise, noise measurement, harmful factors, hazards in the work environment, waterjet operator