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Proposal of a method for assessment of acoustic risk

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Abstract

The non-auditory impacts of noise are defined using quantitative factors in this work. The suggested methodology is illustrated and applied in specific working areas. The consequences of acoustic risk evaluation are not just auditory, but also non-auditory, and the probability also includes the subliminal values of noise exposure. The non-auditory impacts of noise are relevant predominately in the life environment. The proposed method deals with the working environment primarily with respect to Directive no. 89/391/EEC on occupational safety and health protection and Act no.124/2006 on occupational safety and health protection

Keywords: noise, acoustic risk management, non-auditory effects of noise.

Introduction

Noise is statistically defined as one of the most damaging factors in the work environment. The Labour Code states that an employee has the right to fair and satisfactory working conditions and the ensuring of safety and protection of health at work. Legislative provisions in the field of safety and protection of health regarding the risk factor noise only take into consideration the damage to hearing resulting from noise or noise interference. No prescriptive and legislative document exists which would set limit values regarding the non-auditory effects of noise exposure; therefore, experimental measurements of the non-auditory effects of noise are published in this article with the aim of proposing a method of managing acoustic risk.

Algorithm for risk management

Risk management represents a process of studying and monitoring what can cause damage at a workplace in the form of physical injury or damage to health (Pačaiová, Sinay & Glatz, 2009).

This process is possible to describe schematically in the following points:

- a description of a system and identification of dangers and threats, defining of possible consequences (e.g. damage to health),
- an estimate of risk and its evaluation,
- the setting of corrective measures with the goal of reducing risk.

Risk analysis also identifies the probability and range of consequences a negative event following from a given work or other activity. Risks are then estimated on the basis of the identified dangers. With the assessment of risk by an analysis of threats, the seriousness of the estimated size of the risk is assessed and the necessity to reduce it is evaluated. A component of risk management of the basis of its assessment is the proposal of measures, their implementation and the monitoring of their effectiveness (Pačaiová, Sinay & Glatz, 2009).

With estimates of the probability of damage, it is necessary to take these viewpoints into consideration (TNI ISO/TR 14 121-2. 2009):

- the endangered persons,
- the type, frequency and duration of a threat – estimating the consequences requires that the long-term effect also be noted,
- the relationship of exposure and its effects – the relationship between the working of the danger and its effects in any dangerous situation must be considered. It is also essential to take into consideration a threat that is activated and its synergic effect,
- human factors, e.g. the interaction of persons, education, the degree of fatigue, ergonomic viewpoints, etc.

The conditions for the origin of damage, which can be an injury but also damage to health that has a chronic character with a long-lasting course, are depicted in Figure 1. Dangerous situations, during which damage originates in consequence of cumulative working during a certain period (the non-auditory effects of noise), need to be resolved in a different way than situations during which sudden unexpected damage occurs. The probability of damage arising depends on the cumulative exposure to the threat. Therefore, the exceeding of a certain level or measure above which the cumulatively working can cause damage to health can be considered as a dangerous event. Several exposures with different time durations and relevant doses can create an overall dosage, e.g. with hearing loss the dosage depends on the noise levels.

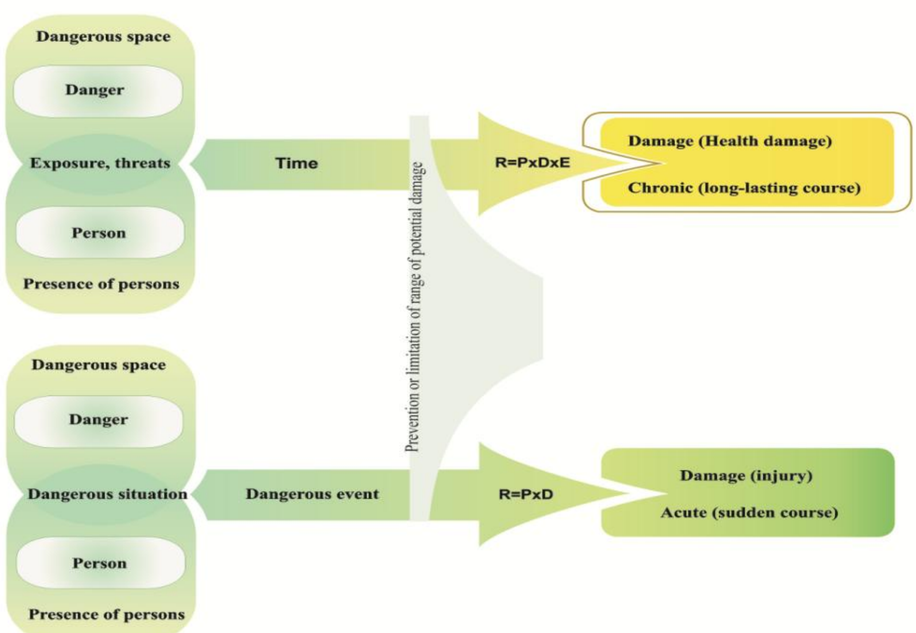

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Figure 1 - Conditions for the origin of damage

The first step in risk assessment is the identification of threats. The aim of threats identification is the creation of a list of threats that enable possible accident scenarios to be described on when and how damage may arise in a given threat. This work is focused on one group of threats, the threat from noise, Table 1.

Table 1 - Example of threat from noise

Type or group of threats	Examples of threats	
	Source [a)]	Potential consequences [b)]
Threat from noise	○ cavitation ○ drawing off of air ○ leak of gas at great speed ○ production process (impacts, cutting, etc.) ○ moving parts ○ rough surface ○ unbalanced rotating parts ○ whistling of pneumatic equipment ○ worn parts	○ discomfort ○ inattention ○ loss of balance ○ permanent damage to hearing ○ stress ○ buzzing in the ears ○ fatigue ○ interruptions during communications ○ increased accident rate ○ cardiovascular problems

[a)] one source of threat can cause several potential consequences

[b)] with any group of threats several potential consequences can be associated with several sources of threat

The method of risk assessment is proposed specifically for the reason of long-term noise exposure (even sub-limit noise values), which can later lead to chronic damage to health. From the long-term perspective, this can lead to non-auditory effects of noise that is necessary to capture in the beginning phase, for which the method proposed in this work can serve as an instrument.

The assessment of acoustic risks consists of a basic method for risk assessment, which is described in standard STN EN ISO 14121 – 2 Safety of Machines. Risk Assessment. Part 2: Practical instructions and examples of methods – Risk Matrix. The assessment of acoustic risks is made up of two Risk Matrices. The first is the matrix of auditory risks ($R_{audit.}$) and the second is the matrix of non-auditory risks ($R_{non\text{-}audit.}$). A risk matrix is a two-parametric register of the probability of a negative event and its consequence originating. The limits of probability in $R_{audit.}$ and $R_{non\text{-}audit.}$ are created by legislative limit values of exposure to noise (Regulation of the Government no.115/2006 Coll. on minimum health and safety requirements for the protection of employees from risks associated with exposure to noise). Consequences are set by subjective feelings, or by quantitative values of non-auditory effects. For example, in the case of irritation of the automatic nervous system (an increasing heart activity, the working of the internal organs, raised blood pressure and increased hormonal secretions) or in the case of the endocrine system, this is the release of catecholamine or cortisol with raised noise levels.

This proposed method for the assessment of acoustic risks is also applied in practice, where the non-auditory effects of noise were quantitatively described using the heart-rate, that is the impact of noise on the cardiovascular system. The software processing of the developed method in the spreadsheet program Microsoft Excel for Microsoft Windows is in Fig. 2.

Possibilities for determining the integrated values of acceptable risk:

- the acceptability of the vibro-acoustic environment can be assessed as the tolerable measure of the load by unfavourable conditions of the simultaneous working of noise and mechanical oscillation in the work environment,
- the vibro-acoustic acceptability of the environment can be evaluated according to the criteria of subjective interruption, interference with the activity of a person or performance, safety of the work and protection of health or with their free combination. Another possibility for assessing acoustic risk is application of the equation:

$$R = f\,(R_1 \dots \dots \dots \qquad (1)$$

$$R = f\,(R_{audit.}, R_{non-audit.}) \qquad (2)$$

$$R_{acoust.} = [R_{audit.} + R_{non-audit.}]f \qquad (3)$$

$$R_{acous.} = \left[\begin{pmatrix} P_1 D_{1audit.} & \cdots & P_1 D_{3audit.} \\ \vdots & \ddots & \vdots \\ P_6 D_{1audit.} & \cdots & P_6 D_{3audit.} \end{pmatrix} + \begin{pmatrix} P_1 D_{1non-audit.} & \cdots & P_1 D_{3non-audit.} \\ \vdots & \ddots & \vdots \\ P_6 D_{1non-audit.} & \cdots & P_6 D_{3non-audit.} \end{pmatrix}\right] f$$

$$f = (t_{ex.}/t_{8hrs.}) \quad (min.)\,, \quad D_{non-audit.} = \sum D_i \qquad (4,5)$$

whereby:

$R_{acoust.}$ - acoustic risk,

R_{audit}. - acoustic risk with auditory effects,

$R_{non-audit.}$ - acoustic risk with non-auditory effects,

P - probability of exposure of a person to noise,

D_{audit}. - consequence of acoustic load on human hearing organ,

$D_{non-audit.}$ - consequence of acoustic load on a person: non-auditory consequences, which are more difficult to identify, $D_{non-audit.}$ e.g. cardiovascular, neurological, digestive consequence and others.

f - weight of exposure coefficient,

t_{8hrs}. - 8-hour work day = 480 min.,

t_{ex}. - time of exposure to noise in minutes, min. 60 min.

The measuring of noise in the individual experiments was performed using a manual 2250 noise analyser. The measured noise was recorded in BZ 5503 software. The measuring of EKG took place using a portable system for EKG examination and the measured EKG readings were recorded in the software OMRON ECG Viewer. Quantitative assessment of the non-auditory effects of noise was done using the proposed method of acoustic risk assessment.

Experimental measurement of the non-auditory effects of noise no. 1

The measuring was performed during work activities – work with woodcutting equipment. An upper shaping machine with a nominal power of 1400 W was worked with. A sample of young people aged from 21 to 28 years old, 60% of whom were men, took part in the measurements. By filling out a questionnaire, it is possible to state that the research sample of people has no significant health problems, and the BMI index ranged between 18.5 – 24.9, which is normal where health risks are minimal due to overweight, or underweight. The majority of the respondents are not taking any medicaments, and only one respondent smokes. From evaluation of the questionnaires, no factor that would impact the measured results is evident.

Experimental measurement of the non-auditory effects of noise no. 2

During this measurement, the level of exposure to noise and the impact of noise on a professional assistant is determined by measuring the noise of work tasks (operations). The work day of a professional assistant consists of the following operations:

a) work with students, or lectures and exercises – duration of 5 hours,

b) lunch, break – 1 hour,

c) work with computers, preparation and study – 2 hours.

Experimental measurement of the non-auditory effects of noise no. 3

In this case, the level of exposure to noise of a worker when cutting and shaping boards in a woodcutting workshop is determined by measurements of the noise of working tasks (operations) in the meaning of standard STN ISO 9612 Acoustics: Setting of noise exposure in the work environment. Technical method.

The work day consists of the following operations in the order presented:

a) planning of work (non-noise),

b) two cycles of cutting and shaping or grinding of boards,

c) lunch (a part of the work day),

d) planning of work (non-noisy),

e) two cycles of cutting and shaping or grinding boards and connecting them and glass – putting it into the final product – carpentry work**.**

Experimental measurement of the non-auditory effects of noise no. 4

Experimental measurement no. 4 was performed at a work site. It involves maintenance of a railway wagon, the turning of wheels. Measuring ran in line with standard STN ISO 9612 "Acoustics [46]. The setting of noise exposure in the work environment. Technical method".

The work day consists of the following operations in the order presented:

a) planning of work (non-noisy),

b) cycle of grinding and turning the wheels of a railway wagon,

c) lunch (a part of the work day),

d) cycle of shaping, grinding and turning the wheels of a railway wagon, cleaning the workplace.

Evaluation of experimental measurementst

Determining the exposure to noise at individual work sites was performed in line with standard STN ISO 9612; the calculated values are recorded in Table 2. Likewise the results of EKG records are a part of Table 2. The acoustic risk was calculated in the software processing the proposed method for assessment of acoustic risks also concerning the non-auditory effects of noise, Figure 2.

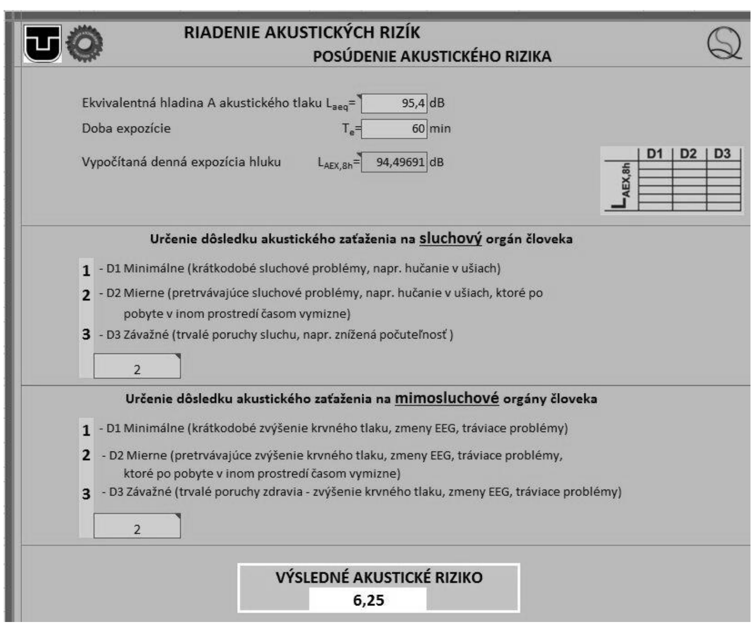

Figure 2 - Application of the assessment of acoustic risk in experimental measurement no. 1 in the created software

Table 2 – Assessment of the experimental measurements

Experimental measurement	**Measured values of noise exposure**	**Measured EKG**	**Comparison with legislative regulation NV no. 115/2006 Coll.**	**Acoustic risk R= {1-75}**
Experimental measurement no. 1: measuring of 20 respondents in a noisy operation	Non-noisy environment: $L_{A,eq}$ = 44.8 dB Noisy environment: $L_{A,eq}$ = 95.4 dB	From the testing it follows that a difference between heart rate of the respondents before movement in the noisy environment and during their time in the noisy environment is demonstrable, with a growth in values, which means that the heart rate of respondents increased during the operation of noisy equipment.	It is not possible to set legislative values of exposure due to the experiment of a young sample of people for the purpose of identifying the impact of noise on human heart activity.	R = 6.25 (low risk)
Experimental measurement no. 2 - measuring of work tasks (operations): personal assistant	$L_{A,ex8h}$ = 61.2 dB	From EKG records it is possible to state that during the work shift the heart rate increased in 100% of cases. The EKG measurement was done in young professional assistants who have no health problems recorded. It is important to note that no deviations occurred in the EKG curves.	Action values of exposure $L_{A,ex,8h}$ = **50** dB	R = 12.5 (medium risk)
Experimental measurement no. 3 - measuring of work tasks (operations): work in a woodcutting workshop	$L_{A,ex8h}$ = 90.7 dB	From EKG records it is possible to state that during the work shift the heart rate increased. The EKG measurement was done in a young worker who has no health problems recorded. It is important to note that no deviations occurred in the EKG curves.	Limit values of exposure $L_{Aex,8h,L}$ = 87 dB Upper action values of exposure $L_{Aex,8h,L}$ = 85 dB Lower action values of exposure $L_{Aex,8h,L}$ = **80** dB	R = 37.5 (significant risk)
Experimental measurement no. 4 - measuring of work tasks (operations): repair of a railway wagon	$L_{A,ex8h}$ = 86.9 dB	Despite the fact that the worker is used to, or his body is adapted to, the higher noise level, during measurement an increase in the worker's heart activity during his time in the noisy environment was recorded and at the same time also the heart rate after completion of working activities was higher than it was initially. It is important to note that deviations of the EKG curve occurred after completion of the noisy operation – J-curve, which means an irregular heart rate.	Limit values of exposure $L_{Aex,8h,L}$ = 87 dB Upper action values of exposure $L_{Aex,8h,L}$ = 85 dB Lower action values of exposure $L_{Aex,8h,L}$ = **80** dB	R = 31.25 (significant risk)

Note: After consultation with a cardiologist the final evaluation was that noise can have an impact on the cardiovascular system on the basis of measurements, by an increased heart frequency.

A graphic depiction of the measured results is in Figure 3. From the graph, it follows that the sublimit values of noise exposure also have from the viewpoint of long-term effects, or cumulation, negative consequences on the human organism (non-auditory consequences).

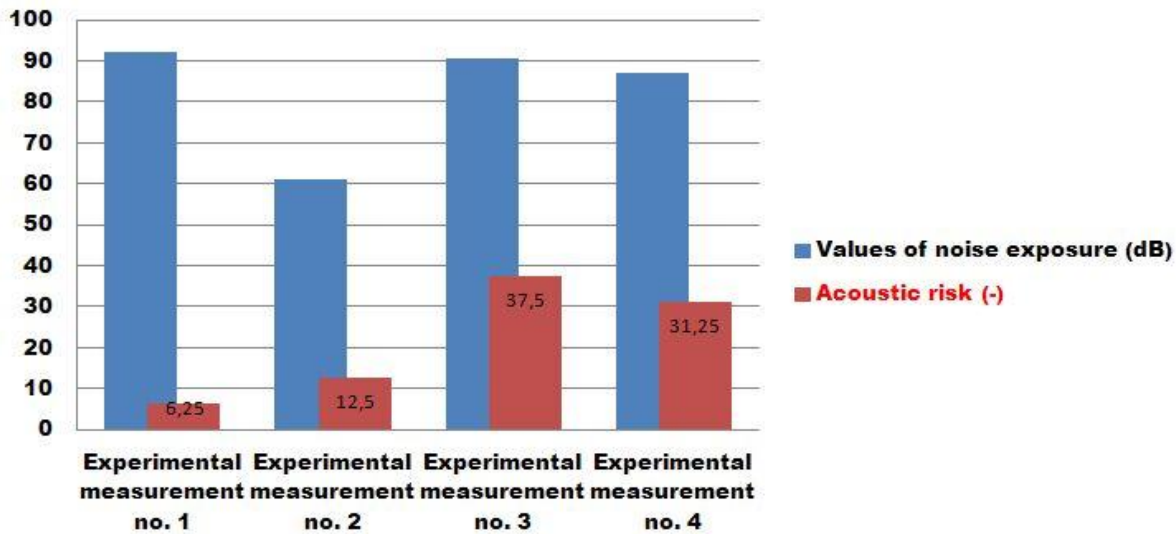

Figure 3 - Evaluation of experimental measurements

Conclusion

Regulation of the Government no.115/2006 Coll. sets the requirements of occupational safety for employees in association with exposure to noise at the workplace and for prevention of risks and threats that arise or may arise in association with exposure to noise, especially to prevent damage to hearing. The given government regulation does not include non-auditory effects; therefore, in the scope of this work measurements of non-auditory effects of noise were carried out. Even an unsurpassed standardized limit of noise exposure can represent an increased risk of non-auditory effects of noise. For minimizing this risk, it is necessary to pay attention to this issue and to propose relevant measures – a methodology of assessment of non-auditory effects of noise, which is the goal of further research.

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VEGA 1/0150/15 "Development of methods of implementation and verification of integrated systems for safe machines, machine systems, and industrial technologies.”

References

Pačaiová, H., Sinay, J., Glatz, J., (2009). Bezpečnosť a riziká technických systémov, SjF TU V Košiciach, 2009, ISBN 978-80-553-0180-8, 246.

STN ISO 9612 (01 1623) Akustika. Stanovenie expozície hluku v pracovnom prostredí. Technická metóda. Apríl 2010.

TNI ISO/TR 14 121-2 Bezpečnosť strojov. Posudzovanie rizika. Časť 1: Praktické návody a príklady metód, SÚTN, 2009.

Biography

Michaela Balážiková has been working as a docent at the Technical University of Kosice, Faculty of Mechanical Engineering, Department of Safety and Quality Production. Graduated in 2000 at the Technical University of Kosice, Faculty of Production Technologies, in the field of study: Mechanical Engineering, specialization: Corporate Ecology. Professional specialization is Systems of the safety control and health protection at work, Safety of technical systems Prevention of large industrial accidents, Risk management of acoustic risks. Other information: Cooperation with industry, Team member of 3 scientific projects granted by the Structural Funds, three national projects and one project granted by the 7th FP - iNTeg-Risk, more than 50 articles published in the conference proceedings and professional journals and two university textbooks.