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A. N. NIKULIN [1], *Associate Professor, Head of Technosphere Safety Department, Candidate of Engineering Sciences, anikulin@lan.spbgasu.ru*

[1] *Saint Petersburg State University of Architecture and Civil Engineering, Saint Petersburg, Russia*

DOSE ASSESSMENT OF INTERMITTENT NOISE EXPOSURE OF COAL MINERS

Dose assessment of intermittent noise exposure of coal miners is carried out. The effectiveness of selecting personal hearing protection equipment (PHPE) by the value of the equivalent sound pressure level and by the dose assessment is compared. The proposed dose assessment procedure allows taking into account the transmitted energy during the action of noise, estimating the total noise load and correlating the obtained values with the excited biological effects. Since the acoustic efficiency of the PHPE selected based on special evaluation of working conditions is insufficient to protect workers from the increased-level noise, selection of the PHPE based on the dose assessment is carried out to ensure safety.

It is found that the use of the PHPE selected according to the dose assessment can reduce the dose of noise received by miners during the shift down to allowable values. To ensure the safety of workers under the influence of the noise factor, the operators of mining and drilling machines should use the PHPE with an acoustic efficiency of 25 dB and 35 dB, respectively, which exceeds the acoustic efficiency of the PHPE selected from the special evaluation of working conditions by 10 dB.

The dependence of the absorbed noise dose of coal miners in the increased noise exposure on the acoustic efficiency of the PHPE is revealed.

It has been found that in order to prevent occupational diseases (sensorineural hearing loss) in underground miners, it is necessary to select the personal protective equipment for the hearing organ taking into account the dose assessment.

Keywords: *occupational safety and health, noise, coal mine, noise monitoring, noise impact assessment*
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Introduction

The most common hazard in mines is noise [1]. The sources of the industrial noise are the longwall systems, shearers and heading machines, winches, hoisting machines, drilling rigs, air drills and other equipment which generate intermittent noise higher than the standard noise level for operating areas [2–4].

The high-intensity noise exposure (over 80 dB) of a worker during the service can result in the partial or total loss of hearing and can cause occupational diseases [5, 6]. Depending on the duration and intensity of noise exposure, the temporal threshold shift (TTS) takes place in a greater or lesser degree [7–9]. The hearing threshold recovers after a weak effect. The periodic exposure to high intensity noise ends with the irreversible loss of hearing and in development of occupational disease of sensorineural deafness [10–12].

Research objective

Selection of personal hearing protection equipment for the operation in the conditions of intermittent noise uses the value of the equivalent sound pressure level [13, 14]. The equivalent sound pressure level is determined with regard to the energy deposition and the resultant biological change. The repeated effects on hearing organs when the noise load changes are neglected in this case [15].

The currently effective Special Workplace Evaluation Procedure and Special Underground Workplace Evaluation (approved by the Ministry of Labor and Social Protection of Russia, Orders Nos. 33 and N996n dated 24 Jan 2014 and 9 Dec 2014, respectively) omit the periodic nature of load exerted on hearing organs of a miner while the load periodicity induces much more severe decrease in the hearing threshold and develops occupational diseases [16].

The dose assessment takes into account energy transmitted during the action of noise, which makes it possible to evaluate the total noise level (by analogy with the dust level) and to correlate it with the excitative biological effects.

Eventually, given the intermittent noise exposure of personnel in coal mines, the equivalent sound pressure estimate per shift offers an incomplete rate of the noise exposure of a miner as the peak sound pressures are smoothed by the long periods of the allowable noise during the time of equipment maintenance or in the idle time [17]. **Figure 1** illustrates the acoustic pressure and the increased noise dose received by PT-48A air drill operator.

The industrial noise exposure reduces the labor efficiency and increases the risk of occupational diseases [18, 19]. A person exposed to an intense noise becomes more vulnerable to other hazards such as dust, illumination and severity of labor, which can raise the overall disease incidence by 10–15% [20].

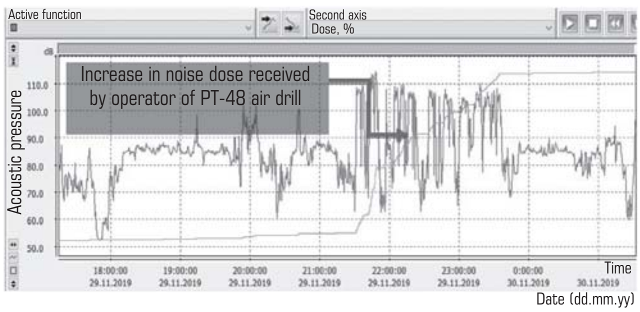

Fig. 1. Increase in noise dose in operation of PT-48A air drill (authorial approach)

Methods

The actual noise measurements using personal noise meters during working shifts of a driller and a miner revealed the time intervals of different noise load because of the impact of different noise sources. The identified noise sources made the major contribution in the overall noise exposure.

At the workplace of the driller and miner, the main noise sources within the shift are the mine diesel locomotive, cutter–loader 1GPKS and air drill PT-48A.

In the dose assessment, the sound pressure to agree with the intermittent noise level, exposure duration per shifty and the noise sources are determined for each time interval identified.

The noise dose received by each worker during the shift and per each time interval identified is assessed from the formula:

$$D = \sum_{i=1}^{n}(P_i)^2 t_i, \quad (1)$$

where D is the noise dose, Pa²·h; P_i are the sound pressures to meet the intermittent noise levels, Pa; n is the number of the exposure periods; t_i is the duration of the noise level, h.

The allowable noise dose is given by:

$$D_{alw} = P^2_{A_{eqv}} T = 1 \text{ Pa}^2\cdot\text{h}, \quad (2)$$

where D_{alw} is the allowable noise dose, Pa^2·h; $P^2_{A_{eqv}} = 0.2$ Pa is the allowable sound pressure with respect to the noise meter error A, to meet the allowable noise level of 80 dBA; $T = 8$ h.

The calculated minimum allowable dose (hearing threshold) is 0.32 Pa^2·h.

For calculating the noise dose received by miners in operation at the highest noise exposure due to different equipment, the sound decibels were converted to the sound pressure units of Pa^2. The obtained values of the sound pressure were multiplied by the action time of noise per the noise sources.

The calculated noise doses received by workers during the shift and per each time interval identified (in operation of separate types of equipment) are given in **Table 1**.

The analysis of measurements from the individual noise dosimeters shows that the major contribution to the noise load at the workplace of a driller is made by air drill PT-48A (53%) and by shearer 1 GPKS (20%). Regarding a miner, the contribution of these noise sources is 44% and 30%, respectively.

Figure 2 depicts the contribution of different noise sources to the impact exerted on a driller and a miner, as well as the exposure duration due to these noise sources.

Results

The implemented measurements and the data analysis yield that during operation of separate types of equipment, the noise level exceeds the allowable limits of the personal hearing protection equipment (PHPE) given to a driller in accordance with the Special Workplace Evaluation (SWE) and having the acoustic efficiency of 25 dB, which leads to the noise exposure of 1.91 Pa^2·h within a working shift while the allowable noise exposure is 0.32 Pa^2·h (Fig. 2a).

The noise exposure of a miner supplied with headphones with an acoustic efficiency of 15 dB as per SWE (Fig. 2b) during a working shift is 0.98 Pa^2·h.

Thus, the acoustic efficiency of PHPE selected based on SWE data is insufficient to protect mine personnel from excessive noise at the workplaces exposed to intermittent noise.

The application of the results can use the exponential approximation given by:

- for driller:

$$D = 80.416\, e^{-0.58a}\ (R^2 = 0.97); \quad (3)$$

- for miner:

$$D = 13.014\, e^{-0.177a}\ (R^2 = 0.94), \quad (4)$$

where a is the acoustic efficiency of PHPE.

The noise safety evaluation of mine personnel by using PHPE selected from the dose assessment shows that a miner and a driller need PHPE with the acoustic efficiency of 25 and 35 dB, respectively. Such-wise selected PHPE can reduce the noise exposure of mine personnel down to the allowable level during a working shift (**Fig. 3**).

Thus, for safety of coal mine personnel, PHPE should be selected from the data of the noise dose assessment.

Conclusions

First, the research has revealed a substantial deficiency of the noise analysis and evaluation by the equivalent sound pressure level as this method provides the smoothed peak noise during a working shift and neglects the repeated noise exposure which can provoke the hearing threshold shift and, then, the hearing loss.

Table 1. Calculated noise doses received by workers per shift and per each time interval identified

Job	Sound pressure, Pa	Noise dose per 8 h, Pa^2·h	Noise dose from air drill PT-48A, Pa^2·h	Exposure time of air drill PA-48A, h	Noise dose from shearer 1GPKS, Pa^2·h	Exposure time of shearer 1GPKS, h	Noise dose from diesel loco, Pa^2·h	Exposure time of diesel loco, h	Noise does from belt, Pa^2·h	Exposure time of belt, h
Driller 1	1.70	23.12	13.20	1.50	-	-	1.80	0.80	4.80	2.80
Driller 2	3.85	118.58	80.90	1.89	15.80	2.70	1.60	0.74	-	-
Driller 3	2.27	41.22	26.40	2.05	-	-	2.00	0.90	5.20	3.00
Average	**2.61**	**75.80**	**40.17**	**1.81**	**15.80**	**2.70**	**1.80**	**0.81**	**5.00**	**2.90**
Miner 1	0.96	7.37	3.50	1.10	2.30	2.50	1.06	0.50	0.00	0.00
Miner 2	1.02	8.32	4.20	1.30	2.30	2.40	0.98	0.60	0.00	0.00
Miner 3	0.80	5.12	1.50	0.60	1.68	2.00	1.60	0.60	0.00	0.00
Average	**0.93**	**6.94**	**3.07**	**1.00**	**2.09**	**2.30**	**1.21**	**0.57**	**0.00**	**0.00**

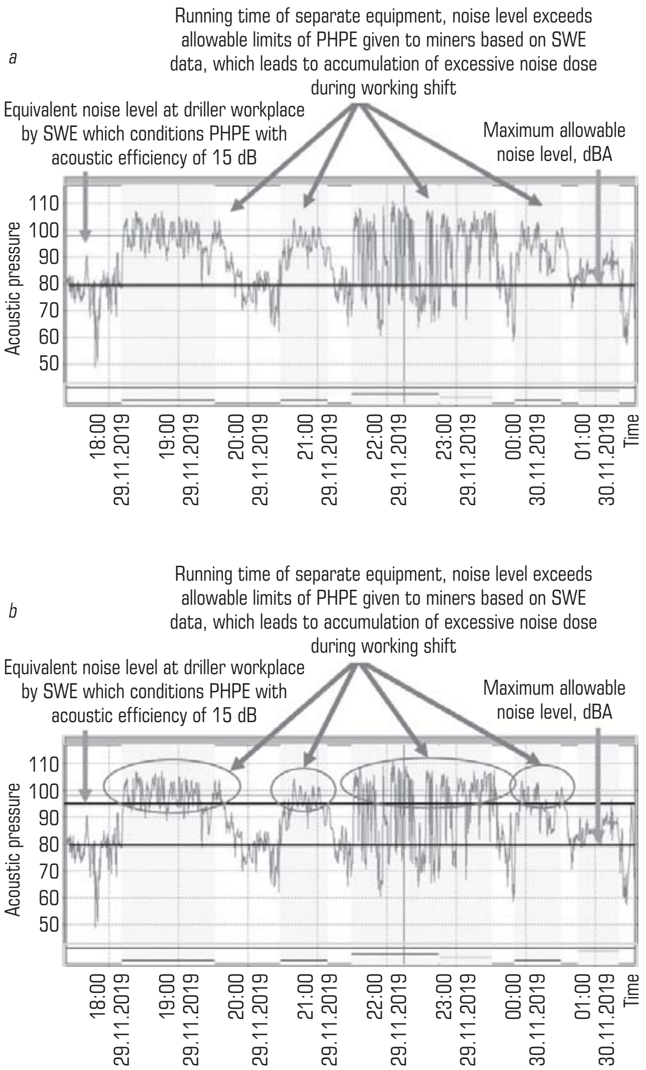

Fig. 2. Excessive noise exposure of driller (*a*) and miner (*b*) provided with PHPE based on SWE (authorial approach)

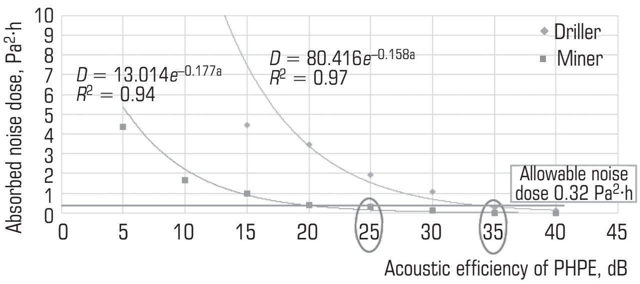

Fig. 3. Noise dose received by coal miner versus acoustic efficiency of PHPE (authorial approach):

1 – driller; *2* – miner

The overrun of the standard values leads to the permanent threshold shift. Regarding drillers, the average noise exposure exceeds 100 dBA, and the forecast reduction in hearing threshold is 7 dB in 5 years and 25 dB in 30 years, which means complete deafness.

Aside from that, the miners and drillers have the personal hearing protection equipment selected based on the Special Workplace Evaluation, which possess the acoustic efficiency of 15 dB and 25 dB, respectively. As a consequence of using such PHPE, the accumulated dose of noise received by the miners and drillers is 0.98 $Pa^2 \cdot h$ and 1.91 $Pa^2 \cdot h$, respectively, while the allowable noise dose is 0.32 $Pa^2 \cdot h$ for both jobs.

From the evidence of the accomplished research, PHPE has been selected by the dose assessment data: the miners and drillers need PHPE with the acoustic efficiency of 25 dB and 35 dB, respectively. The use of the personal protection equipment possessing the higher efficiency enables reducing the dose of noise received by the miners and driller during their working shifts down to the allowable level and enables prevention of occupational diseases of hearing organs.

The key research findings prove that:

—the measurement of the equivalent noise level as an average value per shift provides a deficient picture of noise exposure of a worker as the peak values of the sound pressure are smoothed by the long periods of weak noise exposure during the equipment maintenance time or in idle time;

—the safe operation environment of coal mine personnel requires selection of the acoustic efficiency of the personal hearing protection equipment from the dose assessment of the noise exposure;

—the mine personnel noise safety requires providing miners and drillers with PHPE having the acoustic efficiency of 25 dB and 35 dB, respectively.

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