

TECHNICAL SOLUTIONS FOR REDUCING NOISE LEVELS IN PUMPING UNITS

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Abstract:

The article studied the process of the impact of noise generated in pump units on workers and employees. For the research, the 22H/C pump unit at the ToshGRES pumping station was selected. The research was carried out in accordance with the requirements of Sanm and Q No. 0325-16 and GOST 12.1.003-2014, where the noise level was determined using the SMART SENSOR-586 sound level meter. The results showed that the noise level ranged from 65 to 101 dB, which is considered a critical value for workers and employees. The noise level in industrial production should be as follows: the acceptable level is 50–60 dBA, and the permissible level (constant noise) is up to 80 dBA. Based on the data obtained on the noise level of the pumping station, the incidence of occupational diseases among workers was studied. During the study, it was determined that 24 out of 43 worker illnesses were related to the noise factor. To reduce the noise level and create the most comfortable conditions for workers, a noise-absorbing sandwich enclosure covering the pump unit was installed. The sandwich enclosure reduced the noise level to the optimal range of 40–60 dBA. This, in turn, prevents the development of occupational diseases among workers and employees.

Keywords: pump, noise, diseases, sandwich enclosure, noise-absorbing materials.

1. Introduction

When According to the World Health Organization and the International Labour Organization, approximately 1.9–2 million people die each year due to work-related diseases and injuries. The main cause (81% of deaths) is non-communicable diseases resulting from workplace risk factors such as long working hours, exposure to hazardous substances, and psychosocial factors.

An analysis of global disease statistics and studies conducted for each case shows that one of the main reasons for the increasing incidence of occupational diseases among workers and employees is the

impact of industrial noise in the workplace.

According to the World Health Organization, the main causes of occupational deaths are related to working hours not meeting recommended standards, with more than 745,000 people dying each year from stroke and ischemic heart disease. Regarding occupational factors, specifically exposure to hazardous substances: approximately 450,000 people die from chronic obstructive pulmonary disease, and more than 350,000 people die from stroke and cardiovascular diseases caused by exposure to harmful substances. Worldwide, approximately 340 million occupational accidents are recorded every year [1].

Although the rate of work-related deaths decreased by 14% between 2000 and 2016, the total number of deaths remains very high.

High noise levels are present in almost all industries and are particularly characteristic of mining, coal, mechanical engineering, metallurgy, petrochemical, and forestry sectors. Exposure level: Hazardous working conditions related to noise (exceeding permissible limits) have been identified in 7.5% of workplaces. In some industries, such as the petrochemical sector, signs of noise-related effects on the auditory system have been detected in $19.6 \pm 1.0\%$ of workers [2]. Morbidity statistics (RF and general trends): In the structure of occupational diseases, approximately 46.3% of cases are attributed to physical factors (including noise). In this context, sensorineural hearing loss most often ranks first among occupational diseases. The highest levels of occupational diseases caused by noise are recorded in the following sectors: Mining and coal industry, mechanical engineering, metallurgy, and petrochemical industry [3], [4]. In industrial enterprises, significant signs of occupational noise exposure have been identified in 24.7% of compressor and pump unit operators and in 15.7% of maintenance technicians. From this perspective, it is of great importance to study the causes of occupational accidents and diseases at water management facilities in the Republic, to ensure that workplaces fully meet labor safety requirements, and to analyze the availability of modern safe technologies that guarantee safety for workers at these facilities [5].

2. Methods And Materials

For studying noise levels at pumping stations and conducting research on its reduction, the R01-45N pump unit at the ToshGRES pumping station was selected. The research was carried out in accordance with the requirements of SanM and Q No. 0325-16 and GOST 12.1.003-2014, where noise levels were measured using a SENSOR-586 sound level meter. To determine the noise level at the pumping station, four measurement points were selected, and at each point measurements were taken three times using a sound level meter. The average noise value was then calculated for each point and for the room as a whole. The experiments were conducted as follows. Experiment 1: The first measurement point was located near the entrance door of the pumping station (from the inside). Experiment 2: The second measurement point was in front of Pump 1. Experiment 3: The third measurement point was at the midpoint between the two pumps. Experiment 4: The fourth measurement point was located between the last pump in the station and the wall.



Figure 1. SMART SENSOR Digital Sound Level Meter AS 824 noise meter



Figure 2. Noise measurement points in the pumping station room

The registered diseases at the “ToshGRES” pumping station were analyzed based on the “List of Occupational Diseases in Uzbekistan,” approved by the Resolution No. 62 of February 8, 2022 of the Cabinet of Ministers of the Republic of Uzbekistan. The influence of noise levels on the occurrence of these diseases was also studied. Various methods and approaches for reducing noise levels at the pumping station were considered. In this process, different options were analyzed, ranging from the location of the pumping station to the use of soundproof and noise-absorbing panels, enclosures, casings, and other similar solutions. During the study, a sandwich enclosure was selected to reduce noise affecting workers at the pumping station. Depending on their composition, sandwich panels absorb sound waves, provide sound insulation, and help improve acoustic conditions. In the study of the sandwich enclosure, the sound-absorbing properties of each layer element, as well as their weight and cost, were also taken into account. The main objective was not only to reduce the noise level, but also to ensure minimal impact on the structural and technical dimensions and parameters of the room where the pump units are installed.

3. Results

Sound level measurements were carried out using the SMART SENSOR Digital Sound Level Meter AS 824 (Figure 1), which complies with the requirements of the international standard IEC 61672-3:2013. In this study, noise measurements were conducted according to the layout shown in Figure 2. The obtained results are presented in Figures 1 and 3. Based on the conducted measurements and results, it was found that the noise levels at the locations of the pump units are significantly higher than the permissible standard values. Noise causes constant irritation of the nervous system and disrupts the functioning of the central nervous system and the cardiovascular system [6]. Neuropsychological conditions have been observed to occur 2–3 times more frequently among workers operating in noisy environments compared to those working in quiet conditions [7], [8]. According to the SanPiN 0120-01 standards, the permissible noise level in industrial enterprises must not exceed 80 dB(A). If the noise level exceeds 85 dB(A), working hours must be reduced or the use of personal protective equipment becomes mandatory. In conditions of 90 dB(A) and above, employee rotation and rest regimes must be

strictly regulated [9], [10]. At the ToshGRES pumping station, the noise levels near the pump units are significantly higher than the permissible standards. According to sanitary rules and norms approved by the Ministry of Health, the permissible noise level in industrial enterprises should not exceed 80 dB. 80 dB(A) is the maximum permissible limit for continuous noise exposure. If the noise level exceeds 85 dB(A), working hours must be reduced or the use of personal protective equipment becomes mandatory. At noise levels of 90 dB(A) and above, employee rotation and rest schedules must be established [11], [12]. According to GOST 12.1.003-2014 standards, the noise levels at the pumping station were measured at different points using a special sound level meter. The measurements were carried out while the pump was operating under full load. The noise measurement device was placed at a distance of 0.5–1 m from the pump and at a height of 1.5–1.65 m, corresponding to the ear level of a worker operating in the pumping station. [13]. At each measurement point, the noise level was measured at least three times, and the results were recorded [86]. The obtained results are presented in Table 1 and Figure 3.

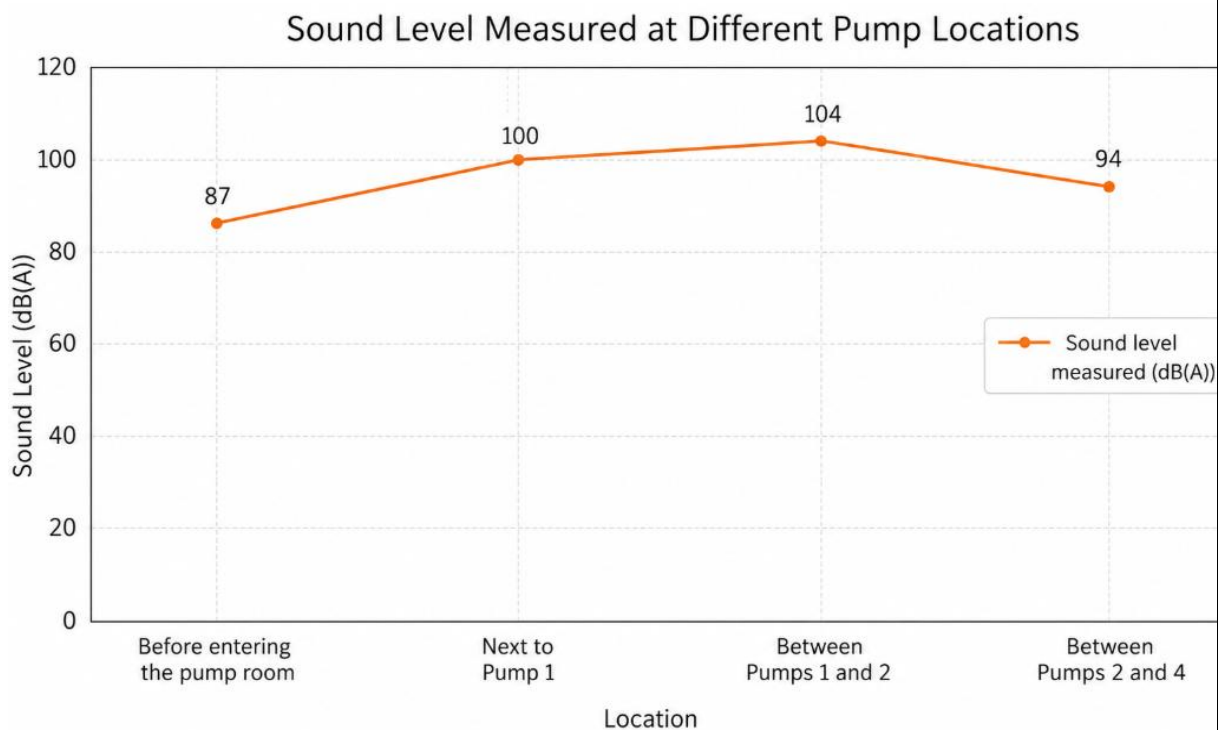


Figure3.Diagram of noise levels at the “ToshGRES” pumping station

Table 1. Noise Level Analysis of the Pump Unit Room

Measurement Variant	Front Door	Front of Pump	Between Two Pumps	End of Pump Row
1	87	104	103	93.8
2	87.2	100	104	94.0
3	86.8	96	105	94.2
Average Indicator	87.0	100	104	94
Standard Limit	65	85	85	85
Difference	+22	+15	+19	+9

As can be seen from the diagram, the noise level in the pump unit room of the pumping station is quite high. Therefore, the main objective is to develop a technical solution for reducing noise levels without making changes to the technological process or the structural design of the pumping station.



Figure 8: Noise measurement process (ToshGRES pumping station)

Noise Level Measurements at Pump Locations

Measurement Point	Location	Distance (m)	Noise Level (dB(A))	Status
Point 1	Before entering pump room	0	87	Above limit
Point 2	Next to Pump 1	3	100	High
Point 3	Between Pumps 1 and 2	6	104	Very High
Point 4	Between Pumps 2 and 4	9	94	High

From Table 1 and Figure 3, it can be seen that the noise levels at any point in the pump unit room of the pumping station exceed the established noise standards by 9 to 22 dBA.

Taking into account that these indicators cause serious harm to the health of workers operating in the pump unit room, the incidence of illnesses among the personnel of the pumping station was studied. The

study.

According to Appendix 8 of Order No. 300 dated 06.06.2000 of the Ministry of Health of the Republic of Uzbekistan, registered in the Ministry of Justice under No. 937 dated 23.06.2000, increasing noise levels contribute to the development of diseases such as tuberculosis, bronchitis, osteochondrosis, and cancer. Because in pumping stations, high levels of noise are generated due to mechanical vibrations of operating units, rotation of electric motors, and hydraulic processes. These vibrations and unfavorable working conditions (lighting, humidity) negatively affect not only the health of workers but also the overall productivity of production. ...prevents this. This noise creates an unfavorable acoustic environment inside the production building, negatively affects the health of service personnel, and reduces the efficiency of the technological process. Therefore, developing a special multilayer acoustic enclosure structure for pump units is considered one of the urgent engineering tasks.

To reduce the existing noise levels at the pumping station, various methods, approaches, materials, and structures were considered. In this process, not only the sound-absorbing and sound-reflecting properties of materials and structures were taken into account, but also their size, weight, and cost. As a result of the research, the sandwich enclosure option was selected as the most optimal solution.

The proposed acoustic enclosure is a protective casing that fully surrounds the pump unit and consists of the following main layers: 1. Metal frame 2. Outer metal sheet cladding 3. Mineral wool (stone wool) 4. Glass fiber insulation 5. Acoustic corrugated (or pyramid-shaped) foam 6. Ventilation openings and maintenance door As a result, the noise level ranged from 65 to 101 dB, which is considered a critical value for workers. The working distance was set at approximately 3 meters. This structure works on the principles of sound reflection, absorption, and reduction of noise transmission to the external environment. Before reaching this design solution, we conducted numerous experiments, and the materials and costs for the project are presented below. 1. Outer covering (black metal sheet): For this work, a 0.2 mm thick black metal sheet is required. A total area of 7.42 m² needs to be covered. If the average price per square meter is 200,000 UZS, the total cost for the sheets is approximately 1,500,000 UZS. 2. Angle bars (corner profiles): A total of 14 meters of angle bars are required for the frame of the structure. This calculation includes four pieces of 1.8 m, four pieces of 0.8 m, and four pieces of 0.9 m. If the price of one meter of angle bar is 75,000 UZS, the total cost for 14 meters is 1,050,000 UZS.

3. Wire mesh (reinforcement mesh): A 1-meter-wide mesh used in masonry construction is required in a length of 7 meters. Since the average price per meter is 40,000 UZS, the total cost of the mesh is 280,000 UZS.

4. Welding works (electrodes): Considering that 2 electrodes are used per meter of welding seam, a total of 32 electrodes are required to weld 16 meters. If the price of one electrode is 2,000 UZS, the total cost for all electrodes is 64,000 UZS.

5. The total internal volume of the noise-reducing and inner lining box is 2.83 m³. To fill it, the following materials are planned: stone wool- approximately 1.84 m³ of stone wool is required for the 3 cm thick section of the box. Pyramid foam: Similarly, for the 3 cm thick layer of pyramid-shaped foam, approximately 1.84 m³ of material is also required. Glass fiber insulation: To fill the remaining empty space, 0.675 m³ of glass fiber insulation is used. This structure is very convenient for us and is also considered efficient in terms of its design. Its cost is relatively low, and it is not heavy in terms of mass. In addition, it can be observed that its noise-reducing properties are also high.

If the internal part of the structure were filled with stone gravel, the construction would become excessively heavy and would also require significantly higher financial costs.

Based on the experiments, it was determined that in the structure we implemented, it is appropriate to fill the internal part with various sound-absorbing materials.

Experiments were conducted on a pump with dimensions of 1.8 m in length, 0.8 m in width, and 0.9 m in height. To reduce the noise level, the structure shown in Figure 13 was selected as the most effective solution. This structure requires relatively low financial costs, and its total weight is approximately 450–500 kg.

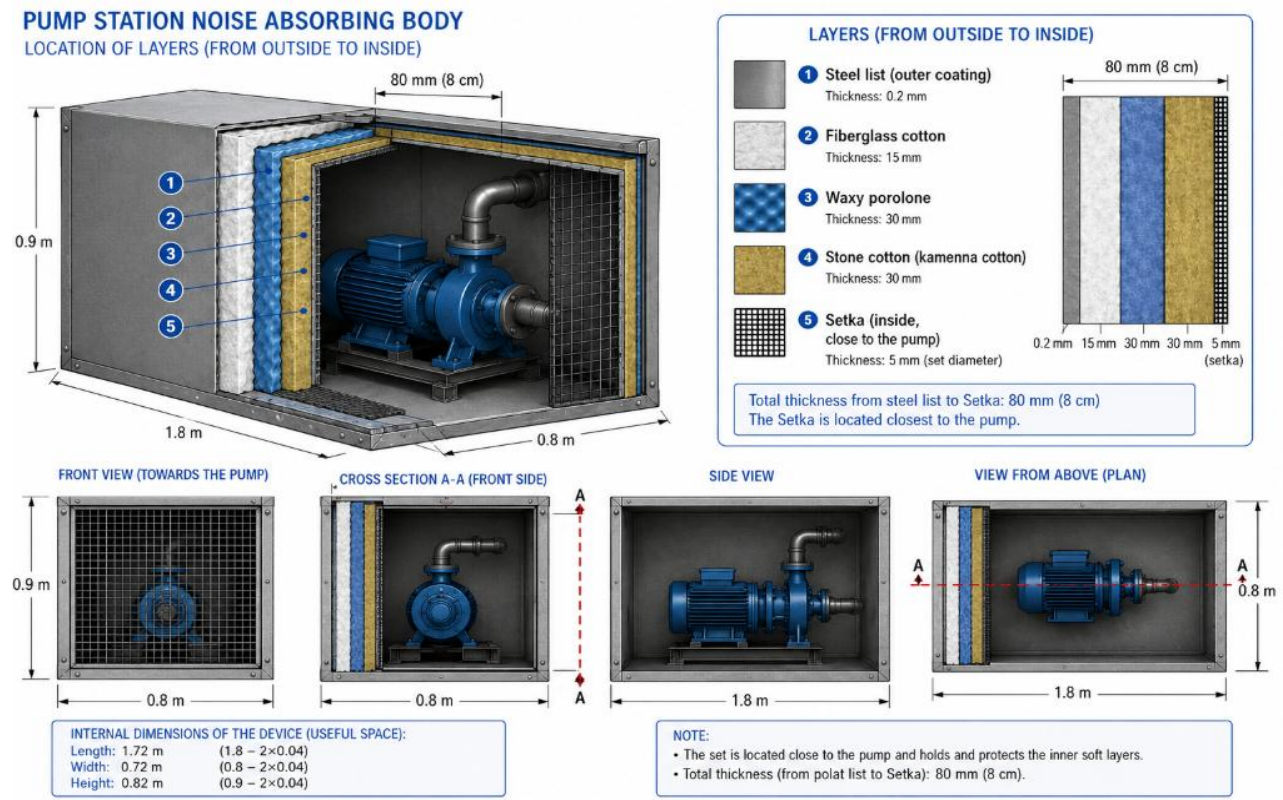


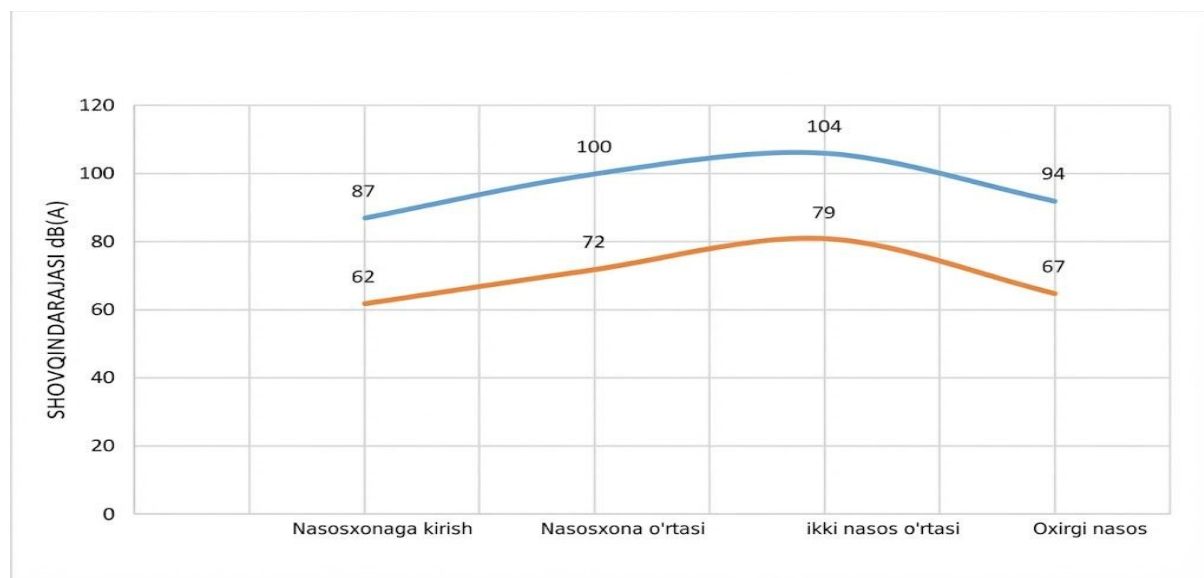
Figure 4. View of the proposed structure

Thus, the main principle of the proposed acoustic system in this study is the absorption of sound energy and reduction of resonance through a layered combination of materials with different densities and acoustic properties. This approach makes it possible to effectively protect the environment around the pumping station from noise.

To determine the effectiveness of noise reduction, it is first necessary to measure the noise level at the pumping station. For this purpose, it is recommended to use a sound level meter and measure the noise both at the source near the pump and in the room at a height of 1.20 m, in order to assess its propagation. If the sound level meter indicates a high value, measures are taken to localize and eliminate the noise source. At present, pumping stations are mainly constructed using reinforced concrete and concrete materials, which do not absorb noise but rather tend to amplify it. Therefore, it is practically impossible to eliminate noise completely in pumping stations; however, it is possible to prevent its propagation to the surrounding environment. In addition, attention should also be paid to the ceiling of the pumping station. According to the research of Russian scientist I.P. Eshmekeev, the use of a special acoustic design in the ceiling significantly reduces noise propagation. If the walls of the pump room are also

equipped with acoustic panels and noise-absorbing coatings, unfavorable conditions for both workers and the surrounding environment can be prevented [14], [15]. In this way, the following measures are recommended for reducing noise in pumping stations: a) Equip walls and ceilings with multilayer acoustic materials (polyurethane foam or mineral wool absorbers, acoustic coating, and air gaps). b) To reduce noise levels with minimal economic cost, it is necessary to localize the pump itself. c) Cover the walls and ceiling of the pump room with sound-absorbing materials. This approach makes it possible to effectively control the spread of noise generated at the pumping station and minimize its impact on working conditions inside the facility. Positive aspects of acoustic protection devices in production: The main advantage of acoustic noise protection devices is reducing workplace noise levels to within permissible limits. This helps to protect workers' health, reduce occupational diseases, and increase labor productivity. In addition, reduced noise improves the accuracy of technological processes and decreases the likelihood of safety situations. In addition, acoustic protection devices ensure compliance of the enterprise with sanitary and hygienic requirements, helping to prevent fines and compensation payments. In the long term, they increase economic efficiency and ensure the stability of production. Disadvantages of acoustic protection devices: Acoustic protection devices also have certain drawbacks. First of all, their design and installation require additional financial costs. In some cases, acoustic screens or enclosures may reduce the available production space and make technological maintenance more difficult. In addition, improperly designed devices may negatively affect ventilation and heat exchange. If the materials are not selected correctly, noise may not be sufficiently reduced, or the effectiveness may decrease over time. Therefore, when designing acoustic protection systems, technical, hygienic, and economic factors must be considered in a comprehensive manner.

Oichashjoyi Variantes	Door took	Pump took	Ikti pump crayfish pump and dev range	Soun	
Variantes	1	61	74	80	66
	2	62,2	71	78	68,5
	3	86,8	71	79	66,5
Medial koorsangić		62,0	72	79	67
Meyer		65	85	85	85
Standard limit					
Difference	-	-3	-13	-6	-18



Figure

5: Noise levels at the ToshGRES pumping station before and after acoustic treatment

From this graph, it is clearly visible that the noise level in the pumping station changes starting from the entrance (threshold) of the station. At the entrance to the pump room, the noise level is relatively low. In the next stage, i.e., towards the middle of the pump room, the noise gradually increases. The highest noise level is observed between the two pumps. This is associated with the simultaneous operation of the pumps and increased mechanical vibrations. For this reason, the noise reaches its maximum value precisely at this point. At the last pump section, the noise level decreases again. This can be explained by the attenuation of energy in the system and the presence of a wall in the area where the last pump is located, which acts as a sound-absorbing barrier. In conclusion, the noise level at the pumping station is not uniform but varies in a specific pattern, with the highest value observed between the two pumps. Therefore, it is considered appropriate to strengthen noise reduction measures specifically in this area.

4. Conclusion

As a result of the conducted research, the following final conclusions were reached regarding ensuring occupational safety at the pumping stations of “ToshGRES” JSC: When analyzing the existing working conditions at pumping stations, it was found that due to the complexity of technological processes and the long-term operation of equipment, noise and vibration levels are the main harmful factors. It was theoretically substantiated that at “Tash-gres” JSC the noise level significantly exceeds sanitary standards (80–85 dBA), reaching up to 95–105 dBA, which poses a serious risk to employees’ health, particularly affecting hearing and the nervous system. When experimentally studying harmful factors in the workplace (noise, microclimate, and illumination), it was found that 74% of occupational diseases are directly associated with unfavorable working conditions. During the study, a four-layer (metal, mineral wool, acoustic fabric, and foam) sandwich-type coating structure with high sound-absorbing properties was developed. Laboratory and field tests showed that this coating can reduce noise to 60–68 dBA, i.e., to a safe level. The economic efficiency of the proposed organizational and technical measures was calculated.

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