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The “Engineer” publishes the most significant results of scientific and applied research carried out in universities of transport profile, as well as other higher educational institutions, research institutes, and centers of the Republic of Uzbekistan and foreign countries.

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Traffic flows on urban roads and their impact on public transport users

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Abstract: In this article shows the adverse health effects of industrial vibration on workers exposed to hand-transmitted vibration and whole-body vibration. Long-term exposure impairs the nervous, circulatory, musculoskeletal, and skeletal systems. Hand-transmitted vibration can cause Hand–Arm Vibration Syndrome, characterized by numbness, tingling, white-finger episodes, reduced grip strength, and musculoskeletal issues a progression confirmed. Whole-body vibration exposure, commonly experienced by heavy machinery operators, link to back and spinal disorders, fatigue, gastrointestinal issues, and potential cardiovascular complications. Also, the article gives protection measures based on occupational health regulations, including ERGONOMIC ENGINEERING CONTROLS, administrative practices like work-rest rotations and health monitoring, and use of anti-vibration equipment . These interventions align with European Directive 2002/44/EC, which mandates risk assessments and exposure monitoring. The study concludes that an integrated approach combining technical controls, organizational strategies, and personal protection is essential to mitigate vibration hazards and safeguard workers' health in industrial settings.

Keywords: transport, passenger transport, public transport sector, education, system

1. Introduction

Modern production processes are based on high technologies, and various mechanisms, equipment, and automated systems are widely used to increase labor productivity, improve product quality, and meet market demands. However, the human factor still plays an important role in these processes. Employees working in production are forced to work in various working conditions, and in some cases, they are exposed to factors that negatively affect their health. One such factor is vibration [1].

Vibration is a frequently repeated vibration of bodies or a medium. It occurs naturally in many mechanical devices, motor vehicles, electrical appliances, and production equipment. Workers working in workplaces, especially in heavy industry sectors, are more susceptible to vibration. In such conditions, long-term exposure can lead to serious health problems for workers, such as cardiovascular diseases, nervous system disorders, diseases of the musculoskeletal system, excessive fatigue, and constant stress [2].

According to international standards, compliance with occupational safety and sanitary and hygienic standards is one of the main requirements in production. However, practice shows that in many manufacturing enterprises, the impact of vibration on human health is still not sufficiently taken into account. A system of measures for the timely detection, assessment, and elimination of vibration risk factors has not yet been fully formed or the existing systems are not sufficiently effective. In this regard, the study and solution of this problem is a very urgent issue, especially in developing countries, including in the industrial sectors of Uzbekistan. The health and working capacity of the workforce directly affects the economic efficiency of the enterprise. If negative factors in the work environment are reduced, this will have a positive impact not only on the health of workers, but also on the overall efficiency of production. Therefore, the study, assessment, and development of effective mechanisms for preventing the impact of vibration arising in production processes is one of the important tasks facing modern science and practice [3].

Despite many technological achievements, the problem of protecting human health in the context of modern industrial development has not yet been fully resolved. To reduce the negative impact of vibration, control this factor, and ensure the safety of workplaces, it is necessary to introduce innovative technologies, intelligent monitoring systems, personal protective equipment, and ergonomic designs. At the same time, maintaining the health of workers under regular medical supervision is also an integral part of this issue [4].

The main goal of the research devoted to the topic is to identify various forms of vibration arising in the production process, analyze their impact on the health of workers, and develop measures aimed at reducing this problem. To achieve this goal, a number of scientific and methodological approaches were used, including experimental observation, statistical analysis, laboratory measurements, analysis of medical data, and modern monitoring tools. The study also compared foreign and domestic experience and analyzed the practical measures being implemented to reduce vibration based on advanced technologies [5]. Their effectiveness, impact on labor productivity, and economic advantages were considered. In the fight against vibration, the role of high technologies, in particular artificial intelligence, intelligent sensors, and analytical programs, is increasing [6].

2. Research methodology

The literature used in this study to study the impact of vibration arising in the production environment on the health of workers is based on various approaches and scientific schools. The analyzed scientific sources are mainly divided into two groups - studies created by national (Uzbek scientists) and international (foreign specialists).

The works of Uzbek scientists are largely based on practical observations, medical examinations, occupational safety standards, and experimental studies conducted in the

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existing production environment. For example, in his work, S.Kh. Turaev studied the effects of vibration on the human body through observations and laboratory measurements conducted under production conditions. They analyzed factors such as working conditions, physical properties of air, and equipment vibration frequency, determining the relationship with changes in workers' health [7].

Uzbek scientists typically use a hybrid methodology: in addition to medical and physiological data, technical measurements (vibration strength, frequency, transmission rate) are also used. They also rely on the local characteristics of the enterprise's conditions when developing recommendations for the implementation of innovative technologies.

Foreign scientists are mainly based on theoretical analysis, experimental research, and statistical modeling methods. For example, M.J. Griffin, in his work "Handbook of Human Vibration," analyzed the relationship between the human body and vibration from a biological, physiological, and physical point of view. Its methodology is based on experimental laboratory tests, ergonomic analysis, and statistical modeling, which is distinguished by its high scientific accuracy [8]. In studies conducted by such scientists as Bovenzi, Seidel, Palmer, the long-term effect of vibration was determined through long-term observations, medical diagnoses, and clinical experiments conducted on various working groups. They assessed the risk of vibration-related diseases based on the cohort method, weighted regression analysis, and healthcare statistics [9].

In international methodologies, in particular, when assessing the impact of vibration on the human body based on the ISO 2631-1:1997 standard, the types of vibration transmitted through the entire body and hand are distinguished. This approach has not yet been fully implemented in Uzbek research, but is based on internationally accepted norms [10].

Thus, while Uzbek scientists use an approach based more on practical enterprise conditions, relying on local medical and technical indicators, foreign scientists prefer a methodology based on large-scale statistical and theoretical research. The combination of both approaches serves to effectively study and prevent vibration hazards [11].

3. Results and Discussion

During this study, based on observations, measurements, and medical examinations conducted at several production enterprises, the impact of vibration on the health of workers was thoroughly analyzed. More than 100 workers working in metallurgy, machine building, cement production, and car assembly workshops were involved in the research. Information was collected on their working conditions, the availability of technical means, protective equipment, and their health status. The level of vibration was determined using special meters (for example, through vibrometers). According to the results, it was established that the level of vibration in some workshops is 1.5-2 times higher than the established sanitary and labor standards. It was noted that workers who have worked with vibration equipment for many years often suffer from diseases related to the nervous system, blood circulation, joints, and bones.

Table 1

Relationship between vibration level and health problems (based on 100 workers)

Vibration level (m/s2)	Number of workers	Nervous system disorder (%)	Hand tremor (%)	Joint pain (%)
Up to 1.5 (norm)	30.	10%	5%	7%
1.6 - 2.5	40.	28%	15%	22%
2.6 - 3.5 and higher	30.	43%	30%	38%

As can be seen from the table above, as the level of vibration increases, the frequency of health problems also increases. Especially in workers working in highly vibrational environments, complaints related to the nervous system (fast fatigue, insomnia, distractibility) are significantly more common.

In addition, it was found that the indicators of the use of protective equipment are also at a low level. In some workshops, it was observed that 60% of workers do not use protective gloves and special vibration-reducing coatings. This further increases the risk to health.

Table 2

Level of protective equipment use and vibration disorders

Presence of protective equipment	Number of workers	Vibration-related disease conditions
Regularly used	35.	12%
Occasionally used	30.	26%
Unavailable	35.	39%

As can be seen from this table, the risk of diseases is much higher if the level of use of protective equipment is low. Therefore, it is important not only to carry out technical modernization at production enterprises, but also to provide workers with the necessary personal protective equipment.

Similar conclusions have been drawn in foreign literature on the topic under discussion. For example, in laboratory experiments conducted by Griffin (1990), it was proven that if the vibration exceeds 1.5 m/s2, a constant stress state, muscle fatigue, and weakening of bone tissue are observed in the human body. Bovenzi (2005) noted circulatory disorders (Raynaud syndrome) in workers subjected to prolonged hand vibration. Local scientists, including Turaev (2018) and Kholboev (2019), conducted practical observations confirming the negative impact of industrial vibration on the body. In their research, changes in blood pressure, heart rhythm disorders, and diseases of the peripheral nervous system were especially widely studied.

Another important point revealed during the discussions is that men are more exposed to the negative impact of vibration than women, because they are more involved in workshops that work directly with heavy machinery. Also, these effects were more pronounced in workers over 40 years of age, as the body's compensatory mechanisms slowed down.

At the same time, the fact that workers do not pay attention to their health, do not undergo regular medical examinations, and have a low level of health culture contributes to the deepening of the problem. Many workers seek late treatment, perceiving symptoms of vibration sickness as simple fatigue. At foreign enterprises, modern

technologies such as vibration-reducing shoes, gloves, shock absorbers on machine handles, and ergonomic workstations have been widely implemented. This serves to effectively reduce vibrational risks.

4. Conclusion

In this study, the influence of vibration arising at production enterprises on the health of workers was deeply analyzed. Based on observations, laboratory measurements, and medical examinations, it was established that vibration is one of the most dangerous physical factors in the work environment, which has a significant negative impact on the nervous system, circulatory system, musculoskeletal system, and general health.

In the course of the research, it was established that in some workshops of industrial enterprises, the level of vibration exceeds the normative indicators, and workers do not sufficiently use protective equipment. Workers who have been exposed to vibration for a long time often experience fatigue, nervousness, hand tremors, joint pain, and other vibration diseases. This leads to negative consequences not only for human health, but also for production efficiency. Compared with international literature, in particular, with the research of such scientists as Griffin, Bovenzi, Seidel, it was noted that the level of combating this problem at production enterprises in Uzbekistan is low. While abroad vibration hazards are controlled through artificial intelligence-based sensory systems, ergonomic workstations, and modern personal protective equipment, measures in this area are still insufficient in our country.

It has also been established that personal protective equipment plays a significant role in the fight against vibration. Regular use reduces the risk of vibration-related diseases by 2-3 times. This is one of the real and cost-effective solutions for creating a healthy and safe working environment at production enterprises.

Based on the research results, the following practical recommendations were developed:

- Establishment of a permanent monitoring system for the detection and reduction of vibration sources.
- Providing workers with modern personal protective equipment and its mandatory use.
- Organization of regular training sessions on occupational hygiene and safety.

Conducting regular medical examinations of workers exposed to vibration and strengthening control over their health.

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