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Possibility of using the results of non-destructive testing for assessing occupational risks in the labor protection management system

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Introduction. The paper discusses the methods for occupational risks assessment of workers within the framework of the labor protection management system. To date, there is no legally approved methodology for occupational risks assessment. Numerous well-known methods of ORS are advisory in nature. Their main weak point is the influence of the human factor and, consequently, the relative subjectivity of the final conclusions.
Problem Statement. The main objective of this work is to study the possibility of occupational risks assessment of workers by the "Bow tie" method in the occupational safety management system.
Theoretical Part. The method of risk assessment "Bow tie" was adopted as a basis. The main components of this method are considered. Approbation has been carried out. It is proposed to introduce an additional barrier into the "Bow tie" risk assessment method, which is called "Non-destructive control".
Conclusions. As a result, a technique for occupational risks assessment was proposed, taking into account the results of non-destructive testing. The positive aspects of the proposed approach are also identified.

Keywords**:** occupational risk, labor protection management system, bow tie method, risk factor, initiating event, non-destructive testing, barrier.

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Introduction. Occupational risk assessment plays an important role in the occupational health management system. To date, there is no generally accepted and approved by the federal executive authority approach to the assessment of occupational risk in the Russian Federation. The key objective of risk assessment is to collect objective information necessary for risk analysis and improvement of working conditions.

In the wording of the Labor Code of the Russian Federation, occupational risk is the probability of harm to the health of an employee when exposed to harmful and (or) hazardous production factors [1]. Among many approaches to occupational risks assessment (ORA), we note the use of special matrix, Fine— Kinney methods, expert assessments and SWOT[1].

Matrix method is based on the direct dependence of the probability of an event, severity and risk. The Fine-Kinney method also takes into account the frequency of the event. The method of expert analysis involves the opinion of specialists — the employees of the enterprise. SWOT analysis is a more detailed assessment of the external and internal situation in the company (four factors are taken into account: strengths, weaknesses, opportunities and threats). All these methods are quite simple in terms of application and understanding of the results. However, such a risk assessment is subjective, as it depends on a person's opinion.

The choice of the ORA method is influenced by:

— time resources,

[1] Eng. SWOT: S — strengths, W — weaknesses, O — opportunities, T — treats.

— method complexity,

— quantitative and qualitative data,

— conditions for collecting information,

— risk reduction goals,

— required availability of the results.

Problem Statement. The main objective of this work is to study the possibility of applying the results of non-destructive testing to assess the occupational risk of employees of oil and gas industry enterprises within the framework of the occupational health management system. The methodology should be simple and convenient for conducting and evaluating the results.

The "bow tie" method of risk assessment is considered. This approach is used in many areas.

Theoretical Part. "Bow tie" is a schematic way of describing and analyzing a dangerous event from causes to consequences [2, 3]. The causes (risk factors) are investigated using the fault tree (malfunctions), the consequences (dangerous events) — using the event tree. The use of the "bow tie" method involves focusing on conditional barriers between dangerous events, their causes and consequences.

In occupational safety, the risk factor is the reason for the realization of the danger and the onset of the initiating event [4]. Identification of risk factors allows you to identify barriers and prevent triggering events. By influencing the risk factor through the development and implementation of management measures, it is possible to reduce the probability of an initiating event [5].

Events that are fraught with undesirable consequences for a person, assets, the environment or reputation are called initiating. Dangerous events occur due to initiators.

In the "bow tie" diagram, the initiating event is in the center, separating the fault tree (left part) and the event tree (right). Each initiating event has a limited list of corresponding dangerous events [6]. In the "bow tie" diagram, a dangerous event is located at the end of each branch of the event tree.

The result of the ORA analysis is an understandable scheme, which presents the main ways of implementing risk and barriers. The latter serve as a barrier to adverse consequences, or reduce their likelihood, or help to realize the desired consequences.

Let us consider a situation in which an incident is the initiating event. In this case, risk factors may be:

— human factor,

— working conditions,

— production environment.

Dangerous events will be an injury or death of an employee.

One more factor should be taken into account — the barrier. This is a technical and (or) organizational measure aimed at ensuring occupational safety [7]. It reduces the likelihood of an initiating event (a warning barrier) or reduces the harm of a dangerous event (a reacting barrier).

When planning and implementing management measures, it is important to take into account that the barrier system is built for operations in the existing conditions [8]. It is necessary to identify and evaluate the technical, organizational and financial possibilities of eliminating or reducing the danger.

So, for each risk factor, there is a barrier that reduces the likelihood of an initiating event. To prevent it from leading to dangerous events, additional barriers are provided[2].

But this approach does not provide the holistic picture necessary for a full assessment of occupational risk. In this regard, it is proposed to supplement the "bow tie" method with another component (barrier). We are talking about the results of non-destructive testing, which shows the condition of equipment, devices, tools, identifies defects and irregularities in the design of devices and structures. This approach makes it possible to control the reliability of the main components or parameters of the object without its dismantling or decommissioning [9]. The result of non-destructive testing is the assessment of the conformity of the object with the established and required technical

[2] Federal Law No. 116-FZ of 21.07.1997 On Industrial safety of hazardous production facilities. State Duma. ConsultantPlus. Available from: http://www.consultant.ru/document/cons_doc_LAW_15234 (accessed: 04.10.2021) (In Russ.).

standards (i.e., the comparison of real operational data about the object of control with the requirements of regulatory and technical documentation).

One of the examples of non-destructive testing is the determination of harmful and hazardous production factors of an enterprise that contribute to the emergence of risks for employees. This is the beginning of the occupational risk assessment procedure. Then it is necessary to use the information obtained during non-destructive testing, to assess the probability of a dangerous situation and damage from the consequences, to calculate the reliability of the controlled object [10]. Obviously, this process will also reveal unreliable information about the condition of the equipment. Using the obtained set of data on the probability of an emergency situation, it is possible to:

— assess the consequences of an accident,
— identify its scale,
— find out the dangerous factors affecting workers,
— determine the level of this impact

Based on this information, it is possible to compare the risks with the technical condition of the equipment. Thus, technological processes that are dangerous for employees are identified.

In other words, decision makers will be provided with the systematized information obtained as a result of a special assessment of working conditions and non-destructive testing. This is how a holistic view of the existing and probable threats is formed [11, 12], without taking into account the data of long-term statistics (Fig. 1) .

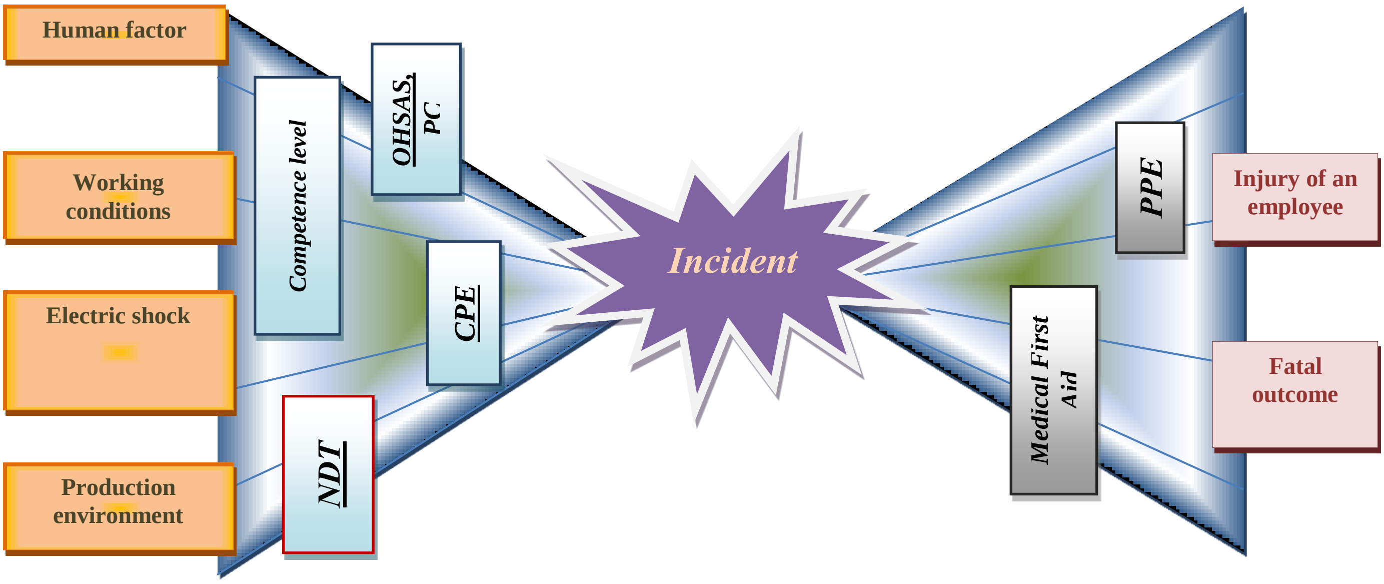

Fig. 1. Scheme of the "bow tie" method for the initiating event "incident" with the "non-destructive testing" barrier: OHSAS — occupational health management system; PC — production control; NDT — non-destructive testing; CPE, PPE — means of collective and individual protection; MFA — medical first aid

Non-destructive testing is only indirectly affected by human influence; therefore it occupies a leading place in the risk assessment system. Flaw detection in this case is not a separate additional procedure. It complements the system with technical diagnostics data.

Conclusions. The article presents a new approach to occupational risk assessment taking into account the methods of non-destructive testing.

Some positive aspects of this method are worth noting:

— increased safety for the facility and employees,
— possibility of timely risks prevention.
— economic feasibility.

This method of ORA can be used at any enterprise, regardless of the field of activity. However, when choosing a non-destructive testing method, it is necessary to take into account the peculiarities of the production process.

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N. Kh. Abdrakhmanov — formulation of the structure of the article, critical analysis, editing; A. V. Fedosov — scientific supervision, formulation of the main goal of the study, development of research methods, processing of the initial observations, text editing; A.S. Guseva — development of the basic research concept, statement of the problem, participation in the study; R. R. Ahmetyanov — collection and analysis of literature data.

LABOR PROTECTION

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Development of a methodology for assessing professional risks in construction

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Introduction. Construction is one of the most injury-causing industries. It is connected with a large amount of operating production factors, that are constant or present potentially, which aggravate the high level of professional risks. The need to develop a methodology on the organization and performance of work in the field of labor protection in case of installation and construction works on building sites is proved in the article and by practical organizational activities of the construction entities.

Problem Statement. The objective of this study is to develop a methodology for assessing occupational risks for construction companies.

Theoretical Part. The paper analyzes dangerous and harmful production factors that affect workers of construction organizations. The emphasis is placed on practical provision of labor protection in construction. At the same time, special attention is paid to the identification of occupational risks, their assessment and management. It is proposed to take into account statistical data on injuries in construction, the content of the construction organization project, work production projects and technological maps for the work carried out in the general assessment of occupational risk in the workplace.

Conclusions. The authors propose an effective methodology for assessing occupational risks, taking into account the specifics of construction production.

Keywords: labor protection, professional risk assessment, construction, construction organization project, project of work production, flow chart.

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Introduction. Since 2011, the concepts of "occupational risk" and "occupational risk management" have appeared in the Labor Code of the Russian Federation. The Approximate Regulation on the Occupational Safety Management System, approved by Order of the Ministry of Labor of the Russian Federation No. 776n of October 27, 2021 (Regulation on OHSAS No. 776n), states that the responsibilities for the organization of the occupational risk management procedure are assigned to the employer, which, based on the specifics of its activities, independently establishes the procedure for identifying hazards, assessing and reducing the level of occupational risks [1, 2].

With the correct assessment of occupational risks, it becomes possible to take into account all hazardous events, document the results of their assessment, analyze the state of the production environment and occupational safety (OS) at the facilities of the country's economy, including checking the effectiveness of the safety measures taken and systematically monitoring occupational safety measures, their control and planning [3, 4].

In the Russian Federation, many enterprises and organizations have started work on the calculation of occupational risks as part of the occupational risk management procedure. However, in construction, risk assessment is not always carried out at the required high level, it is often reduced to blind copying of the recommendations from Regulation on OHSAS No. 776n, and the results of risk assessment are not used in practice [2, 5].

Despite the entry into force on March 01, 2022 of Order of the Ministry of Labor of the Russian Federation No. 796 "On approval of recommendations on the choice of methods for assessing the levels of occupational risks and for reducing the levels of such risks", there is no unified methodology for assessing occupational risks in the Russian

Federation, which introduces additional difficulties in the implementation of the procedure [6]. For the construction industry, which is one of the most traumatic activities, this situation is unacceptable. We need a simple and understandable, and most importantly, useful and effective method for determining occupational risks, the use of which will make it possible to provide analysis and calculation for each specific construction object and at each individual stage of construction with the involvement of line managers and construction participants (line engineers, foremen, etc.) in labor protection issues.

Problem Statement. Indicators of occupational injuries and occupational morbidity in construction are still at a high level. According to statistics, in the world every 6th fatal accident at work occurs during construction work. More than 40% of workers in the construction industry are engaged in work with harmful and (or) hazardous working conditions (assigned to Class 3 and 4), which is one of the main reasons for the high level of occupational injuries and occupational morbidity of construction workers [7, 8].

Effective occupational health and safety management is impossible without occupational risks assessment. However, construction production and the activities of construction organizations have certain specifics associated with a variety of construction projects, technologies for the construction of buildings and structures, the presence of several cycles (stages) of construction, simultaneous participation in the work of several construction organizations on one construction site, etc. This should be taken into account when developing a labor protection management system [5].

The objective of this study is to develop an effective methodology for occupational risks assessment, suitable for practical application in the system of occupational risk management of construction production.

Theoretical Part

The level of occupational injuries in the Russian Federation, even taking into account the official downward trend, remains high. Construction accounts for an average of 17.5% of injuries from total industrial injuries in the country. The causes of injuries and accidents are diverse and come from the specifics of production (Fig. 1) [9].

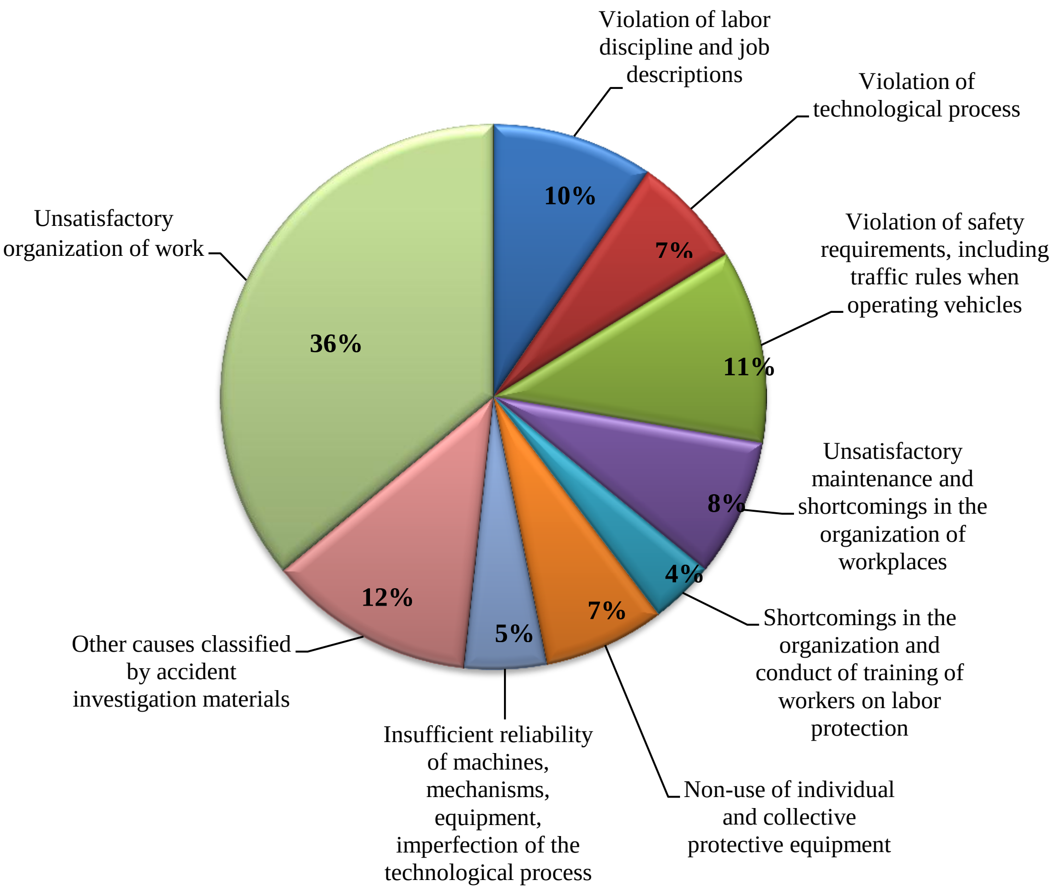

Fig. 1. The percentage of causes of injuries and accidents in construction (compiled according to statistical data for 2010-2020)

Currently, in order to protect the life and health of employees in the course of their work, a transition to a new model of occupational safety management based on occupational risks assessment is being implemented.

In the Russian Federation, employers, including the construction industry, are invited to conduct an assessment of occupational risks using recommendation documents [6, 10-13].

It is important to emphasize that the methods proposed in the listed documents are quite complex and are intended for use in permanent, established production facilities, technological sites with an established organization of work, control and prevention of violations. At the same time, in most cases, enterprises and organizations use the services of specialized labor protection centers to determine occupational risks, which, using various methods, provide the customer with the documentation compiled in such a way that it is understandable only to a narrow circle of experts and labor protection specialists. Therefore, the possibility of its practical use directly at production sites is small. In relation to construction projects, these generalized calculations, as a rule, remain in the offices of occupational safety specialists and are presented only to officials of the State Labor Inspectorate during inspections and during the investigation of serious and fatal accidents. At the same time, the direct managers of the construction industry practically do not know the issues of occupational risk management. Thus, the effectiveness of this crucial procedure remains very low.

In general, the algorithm for assessing technogenic risk is presented in Fig. 2.

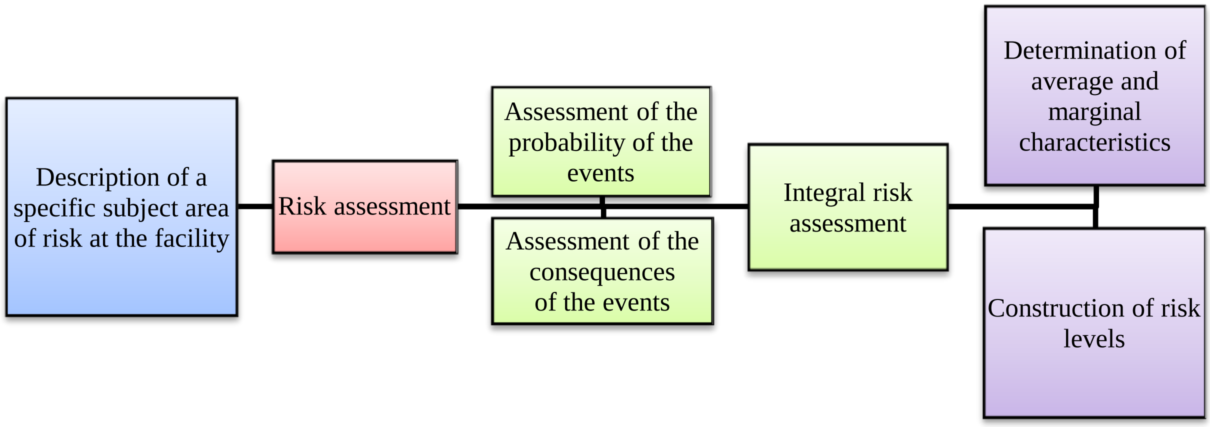

Fig. 2. General scheme of risk assessment

Risk assessment methods are usually divided into two groups: indirect and direct methods.

Direct methods use statistical information on selected risk indicators or corresponding indicators of damage and the likelihood of their occurrence, including the number of accidents when falling from a height, electric shock, etc. However, in most cases, enterprises and organizations do not have sufficiently extensive statistical data, and the statistics within one enterprise are not always objective and acceptable.

When assessing risks using indirect methods, the characteristics of possible fluctuations in indicative parameters that have a causal relationship with risks (the results of practical work, inspections and audits) are introduced.

The risk factors for accidents at work include: the presence of hazardous and harmful production factors in the work area, the physical presence of an employee in the danger zone, the absence or unsatisfactory condition of individual and collective protective equipment, and others. For construction companies, this list of factors can be specified and significantly expanded to include the following items: the quality of organizational and technological documentation, the performance of earthworks (depth, technical equipment), the construction of buildings and structures (number of floors, work production technologies), means of scaffolding, lifting equipment, etc. [14-16]

The choice of a direct or indirect method depends on the available amount of statistical information and the specifics of the tasks being solved. For a relatively small construction company, indirect methods of hazard identification and risk assessment are preferable.

The methodology proposed by the authors is based on the calculation of professional risks in a construction organization when analyzing construction organization projects (COP), method statement (MS) and technological chart (TC), which are developed for each specific object of construction of a building or structure. This choice is determined by the fact that for a purposeful and effective assessment of occupational risks at the workplaces of builders, it is necessary to know by what technology and by what methods construction and installation work will be carried out at this facility, which lifting cranes, fixtures and structures will be used, the sequence of installation and execution of special works, etc., information about which is fully presented in the technological documentation of COP, MS and TC.

Practice shows that most construction organizations do not have specialized groups (departments) on a full-time basis for the development of COP, MS and TC. This work is carried out under contracts by specialized design organizations that have certified specialists, permits of a self-regulatory organization for the right to carry out a certain type of activity in the field of construction and licenses of Rostechnadzor. Therefore, with a qualitative analysis of COP, MS and TC, it is possible to identify the main hazards to the life and health of workers, make a list of them for each construction operations cycle, as well as for almost all technological operations provided for in the technological documentation.

Risk calculation in general can be carried out according to the formula:

$$R = V \times S,$$

where R — the calculated risk; V — the probability of a hazardous event; S — the significance of a dangerous event (severity of health damage, amount of damage, etc.) [4, 13].

When calculating the risk, you can introduce a 10-point scale for the probability of occurrence of a hazardous event V (the range of changes is 0.01–1.00), the significance of a hazardous event S can be expressed in points from 1 to 10 (Tables 1, 2).

Table 1

Characteristics of hazardous events by probability

Semantic expression of probability	**Characteristic of hazardous events occurring with a given degree of probability**	**Probability of occurrence of a hazardous event**
Impossible	A hazardous event can happen only theoretically	0.01–0.19
Unlikely	A hazardous event may occur in exceptional cases with a combination of circumstances	0.20–0.39
Possible	A hazardous event does not occur under normal conditions, but with deviations in operation	0.40–0.59
Reliable	A hazardous event can occur even with minor deviations in operation	0.60–0.89
Inevitable	A hazardous event can occur even in the absence of deviations in operation	0.90–1.00

Table 2

Characteristics of hazardous events by significance

Consequences (semantic characteristic of significance)	**Examples of consequences (by types of hazardous events)**		**Significance of a hazardous event, point**
	Injuries	**Diseases**	
No consequences	Slight bruise, scratch	Sense of discomfort	0.0–1.9
Minor consequences	Microtrauma, bruise, abrasion. There is no disability	Irritation of the mucous membranes of the eyes, nose, larynx. General discomfort	2.0–3.9
Tangible consequences	Injury with the sick-leave (accounting)	Exacerbation of chronic diseases	4.0–5.9
Significant consequences	Fatal accident, severe and group accidents	Occupational disease	6.0–8.9
Catastrophic consequences	Group fatal accident	Acute group disease	9.0–10.0

To determine the level of occupational risk, an expert assessment method can be applied based on the existing work experience and analysis of hazardous events that occurred at this enterprise or in other organizations with a similar profile of industrial activity.

Table 3 shows the values of the risk level depending on the class of working conditions according to the degree of harmfulness and hazard.

Table 3

The value of the risk level depending on the class of working conditions

Working conditions class	**1**	**2**	**2.1**	**3.1**	**3.2**	**3.3**	**3.4**	**4.0**	**4.0**
Risk value, point	1	2	3	4	5	6	7	9	10
Risk level	*R1*	*R2*	*R2*	*R3*	*R3*	*R4*	*R4*	*R5*	*R5*

The risk is considered acceptable if its value falls in the range from 0 to 5.9 points (*R1-R3*). With values from 6 points and above (*R4, R5*), the risk passes into the category of unacceptable, requiring management decisions.

Thus, the algorithm for assessing occupational risk according to the proposed methodology is reduced to the following sequence of actions:

1. Development and analysis of COP, MS and TC of the object, including all stages (cycles) of construction — from the preparation of the construction site to finishing works.

2. Drawing up a register of the main hazards most likely to occur during the production of specific works and for each workplace, for each cycle of construction and installation work at the facility, presented in COP, MS and TC.

3. Risk assessment of the identified hazardous events.

4. Drawing up a risk assessment chart for each stage (cycle) of construction.

As an example of the application of the proposed methodology, we will consider the occupational risks assessment in installation and concrete work on the construction of a residential building using the technology of monolithic housing construction with retractable metal formwork.

In this case, the technological crew consisting of steelfixers, concrete workers, installers, electric welders, slingers. All members of the crew can perform various types of work provided for by this technology, have been trained and instructed on OH&S for all types of work performed.

At the first stage, using COP, MS and TC of the facility, a register of hazards is compiled for the employees of the integrated crew, depending on the types of work in this construction cycle.

List of the main types of work:

1. Erection, installation of roll-out standard scaffold and prefabricated metal formwork using a tower crane.
2. Installation and welding of rebar and reinforcement grids.
3. Concrete works (acceptance of concrete in containers, pouring concrete, vibration compaction).
4. Decoupling of the mounting formwork and tooling, removal of the roll-out scaffolding.
5. Cleaning of workplaces, moving through the floors of a building under construction.

The register of hazards most likely to occur when performing the main types of work:

1. Work at height in the absence of fences (falling from a height).
2. Impact of moving structures, metal formwork, removable lifting devices, containers, etc.
3. Danger of falling weights, objects.
4. Effect of electric current during the operation of electric welding and manual power tools.
5. Danger of using tools and mounting devices.
6. Absence of fencing openings and staircases, platforms.
7. Unsatisfactory weather conditions (snow, rain, wind gusts, low and elevated temperatures, etc.).
8. Presence of untidy and foreign objects in workplaces, playgrounds and aisles.
9. Danger associated with the non-use of collective protection and personal protective equipment.

Other types of hazards listed in Annex 1 to the Regulation on the Management System No. 776n are not taken into account, as they are close to improbability. For example, when performing the listed installation works, is it worth considering the dangers of exposure to liquid under pressure during ejection or weakening of the geomagnetic field, etc. [2].

Further, using the compiled register of hazards and data from Tables 1-3, risk levels are determined and a risk assessment map is drawn up (Table 4).

Table 4

Assessment sheet (risk assessment map)

Workplace: rebarer, concreter, installer, slinger, electric welder *

No.	**Hazards register**	**Characteristics of events occurring with a given degree of probability**		**Characteristics of hazardous events by significance (severity) of consequences**		**Risk level value**		
		Characteristics	**Probability**	**Injuries and consequences**	**Significance of a dangerous event, point**	**Working conditions class**	**Risk value, point**	**Risk level**
1	Work at height without fences	Significant, danger may occur	0.8	Significant consequences: fatal accident or long-term treatment	8.0	3.4	6.4	*R4*
2	Impact of moving structures, formwork, fixtures	Significant, danger may occur	0.7	Significant consequences: fatal accident or long-term treatment	8.0	3.3	5.6	*R4*
3	Danger of falling of weight, objects	Possible, with deviations in operation	0.5	Tangible consequences, injury	5.0	3.1	2.5	*R3*
4	Exposure to	Unlikely, the	0.3	Tangible	5.0	2.0	1.5	*R2*

No.	Hazards register	Characteristics of events occurring with a given degree of probability		Characteristics of hazardous events by significance (severity) of consequences		Risk level value			
		Characteristics	Probability	Injuries and consequences	Significance of a dangerous event, point	Working conditions class	Risk value, point	Risk level	
	electric current	event may occur in the presence of several factors		consequences, injury					
5	Use of tools and devices	Unlikely, the event may occur under the circumstances	0.3	Tangible consequences, injury	4.0	2	1.2	*R2*	
6	Absence of fences of openings and staircases	Unlikely, the event may occur under the circumstances	0.3	Tangible consequences, injury	4.0	2	1.2	*R2*	
7	Danger associated with the non-use of personal protective equipment (safety harness)	Significant, danger may occur	0.8	Significant consequences: fatal accident, long-term treatment	8.0	3.3	6.4	*R4*	
8	Adverse weather conditions	Unlikely, the event may occur under the circumstances	0.25	Minor consequences	2.0	1.0	0.5	*R1*	
9	Mess in the workplace	Unlikely, the event may occur under the circumstances	0.25	Minor consequences (bruise, impact injuries, abrasions)	2.0	1.0	0.5	*R1*	

*) Integrated crew: all members of the team perform the work provided by COP, MS and TC. Instruction and training on OH&S are conducted for all types of jobs and professions.

Similarly to the given example, the occupational risks assessment for other cycles of construction production is carried out: preparatory work, zero cycle work, earthwork, pile-cutting, etc.

The proposed methodology can be applied to assess occupational risks by OH&S specialists together with the heads of production sites and foremen without involving other experts and specialized organizations in this work.

Conclusions. A methodology for occupational risks assessment has been developed, the use of which makes it possible to take into account the specifics of construction work and accurately determine the probability and consequences of hazardous events that cannot be eliminated completely or in the near future.

In the occupational risk management procedure, direct managers of work (foremen, site managers) can be actively involved at the stages of compiling the register of the main hazards during construction and installation work and risk assessment of the identified hazardous events performed according to the developed methodology. This will increase the effectiveness of monitoring compliance with the occupational safety requirements at all stages of the production cycle and provide an opportunity to optimize preventive measures to reduce injuries in the construction industry.

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Assessment of industrial injuries on the example of operating Russian Nuclear Power Plants

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Introduction. The article considers the industrial injuries of personnel working in the Rosenergoatom (energy division of the Rosatom State Corporation) and employees of contracting organizations working on the NPP's territory using the statistical method in the period from 2013 to 2020. Based on the data obtained, the recommendations are proposed to reduce the level of industrial injuries for the personnel of contracting organizations.
Problem Statement. The purpose of this study is to research the industrial injuries and to develop recommendations for reducing injuries with personnel who work on the NPP's territory.
Theoretical Part. Annual reports of Rosenergoatom are used as basic information.
Conclusions. The results of the analysis indicate a significant level of industrial injuries among the employees of contracting organizations. This fact requires the implementation of a set of measures aimed at improving the safety level on the NPP's territory to prevent occupational injuries.

Keywords: nuclear power engineering, contracting organizations, industrial injuries, accident analysis.

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Introduction. Due to the widespread use of nuclear power and the increasing number of commissioned nuclear power plants in the world, the problem of improving working conditions and reducing occupational injuries at nuclear power plants (NPP) is becoming more and more important every year.

In the territory of the Russian Federation over the past eight years, the number of commissioned power units has increased by nine, which implies an increase in the number of NPP personnel and contractor employees servicing them. In addition, the construction of new power units continues, which makes the problem even more urgent.

At the forum-dialogue "Day of Safety of Nuclear Energy and Industry", held in May 2019 in the Russian Federation, the head of Rosatom State Corporation noted that in the Russian nuclear industry there are fewer cases of injuries and deviations in the operation of equipment and the main guarantee of safety remains strict observance of discipline and strict adherence to the norms and rules of occupational health and safety at work. At the same time, for example, in 2018, several dozen cases of injuries, including fatal ones, were recorded in the industry.

The situation with industrial injuries is complicated by the constant presence on the territory of the NPP of employees of contractors who perform construction, installation and commissioning work associated with increased risks.

Injuries among employees of contracting organizations is one of the new problems that arose relatively recently, about 10 years ago, in large companies, especially mining and processing companies, after they began to launch public offerings of securities on well-known exchanges (for example, Initial Public Offering, or IPO) and in this regard had to optimize the number of employees, since a large staff prevents the establishment of a high market valuation of the company. It was the staff of auxiliary maintenance and repair services that fell under the reduction.

According to some reports, previously the share of this staff had been about 20% of the total number of employees of companies, after the reorganization they did not remain at all.

In addition, currently large companies, especially with a share of foreign capital, do not use the frequency coefficient as the main indicator of injuries, as was previously accepted, but the indicator, which is often used in world practice — LTIFR (Lost Time Injury Frequency Rate), which takes into account the actual time worked in the organization for the reporting year. This makes it possible for enterprises and organizations to improve their performance in the field of occupational safety, since LTIFR takes into account injuries only with its own personnel, while auxiliary maintenance and repair services are outsourced, outstaffed, on the commercial basis of contractual relations or in affiliated dependent companies.

The analysis of scientific papers on the issue under study allowed us to find several works devoted to similar topics in related industries, in particular in the fuel and energy complex and electric power industry [1-6], and almost the only article in which the authors proposed a methodology for predicting the number of cases of injuries and occupational diseases in nuclear power workers [7]. This situation confirms the relevance of the study and indicates the need for closer attention to the accounting and analysis of occupational injuries for this industry.

Problem Statement. The objective of this study is to analyze the cases of occupational injuries of personnel working on the territory of the NPP, and to develop recommendations for reducing their number.

Since the Federal State Statistics Service (Rosstat) reflects the number of occupational injuries cases in the nuclear power industry only directly from employees of nuclear power plants, the data on injuries of employees of contracting organizations are not reflected in official reports, which significantly distort the idea of the true number of accidents occurring at nuclear power plants [8]. This, in turn, reduces the quality of measures taken to prevent such cases at nuclear power facilities. In order to eliminate this shortcoming, this article analyzes cases of occupational injuries with NPP employees and the employees of contractors at nuclear power facilities in the period from 2013 to 2020, the Corporation provides such statistics in its annual reports [9].

Theoretical Part. ROSATOM State Corporation is a state-owned joint-stock company that unites more than 400 enterprises of the Russian nuclear industry: nuclear weapons complex, nuclear icebreaking fleet, scientific complex, nuclear medicine, handling of uranium throughout its life cycle and much more. The authors have taken for consideration the energy division of the Rosatom State Corporation, namely Rosenergoatom Concern — the only operator of nuclear power plants in Russia.

Table 1 presents data on the absolute number of accidents involving NPP employees and contractors at the corporation's nuclear power plants for 2013-2020 [10–17].

During the study period, 83 accidents occurred at NPP enterprises, among which 15 cases (18%) occurred with NPP employees and 68 cases (82%) — with the employees of contracting organizations.

Table 1

Number of accidents at Russian nuclear power plants in 2013-2020

NPP name	**Years**							
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Balakovo		3 (1 c)			2			1c
Beloyarsk	5 (1 c)	3 (1 c)	1	1				
Bilibino								
Kalinin	1	2		3 (1 c)		1 c		
Kola				1	3	1		2
Kursk	2	1 c	1	1 c	1	2	2 (1 c)	1 c
Leningrad	6 (1 c)	1c			3 (2 c)		4 (1 c)	
Novovoronezh	2 (1 c)	3 (2 c)	2 c		1 c	1		
Rostov	2	1 c	3 (1 c)	3 (1 c)		3		
Smolensk	2			1		2 (1 c)		
Floating nuclear NPP							2	

Note: "c" – fatal accident, 5 (1 c) means 5 accidents, among which 1 accident is fatal

It is worth noting that out of 83 recorded cases, 25 cases of industrial injuries were followed by death, and among them only two cases occurred with employees of nuclear power plants, and 23 cases — with the employees of contracting organizations (8 and 92%, respectively).

During the period under study, a slight positive trend in the reduction of occupational injuries at nuclear power facilities is noticeable; the number of accidents with a fatal outcome also decreases slightly, but for the period from 2018 to 2020 it remains unchanged (two cases per year). This fact requires the analysis of traumatic factors and causes of accidents for more thorough work to eliminate the root causes of accidents (Fig. 1).

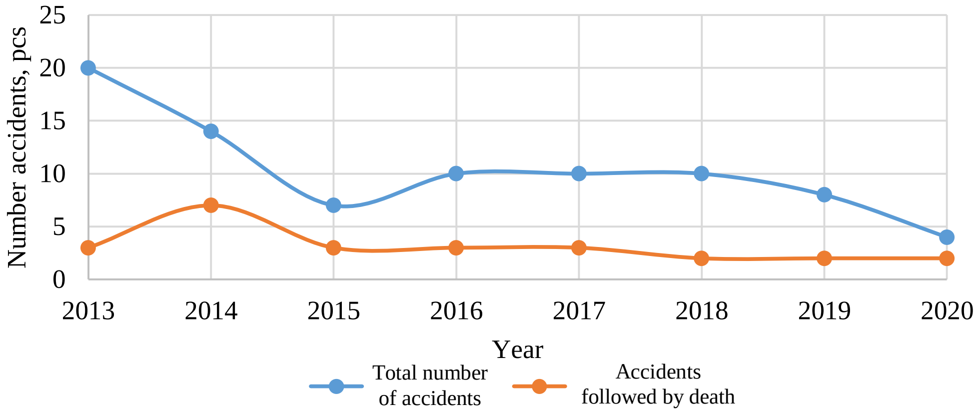

Fig. 1. Dynamics of the decrease in the number of accidents at nuclear power plants for the period from 2013 to 2020

For a more objective analysis of the level of injuries at Russian nuclear power plants, the relative indicator LTIFR was used. The data in Table 2 reflect changes in the LTIFR indicator in the Rosenergoatom concern for the period from 2013 to 2020.

Table 2

The frequency coefficient of injuries with temporary disability (LTIFR)

Years	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
LTIFR Indicator	0,025	0,02	0,02	0,065	0,03	0,08	0,04	0,03

According to this indicator, there is also no particular dynamics of improvement in the situation, in general, it is stable, with the exception of 2016 and 2018. For Rosatom Corporation, the established limit of the LTIFR indicator is 0.15, so we can assume that in general the indicators are small.

The analysis of accidents on traumatic factors shows that the vast majority of accidents occur due to the fall from a height (34%), the collapse of objects and materials (16%), the impact of rotating, moving and flying objects (14%), as a result of road accidents (11%) (Fig. 2).

Moreover, among these traumatic factors, the share of accidents with the participation of employees of contractor organizations is 93% — when falling from a height, 92% — when objects and materials collapse and because of the impact of rotating, moving and flying objects, and 67% — in an accident.

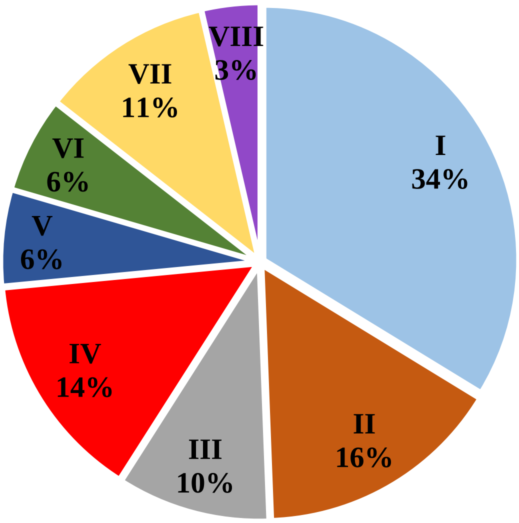

Fig. 2. Distribution of accidents by traumatic factors for the period from 2013 to 2020:
I – fall from a height, II – collapses of objects, materials, III – falling from a man's height, IV – impact of moving, flying, rotating objects, V – thermal burn, VI – electric shock, VII – accident, VIII – other

The analysis of the causes of accidents at nuclear power plants shows that out of 83 cases, the most common causes of occupational injuries for the period from 2013 to 2020 were organizational ones (80%, among them 89% occurred with employees of contracting organizations). Most often, the organizational reasons for occupational injuries are unsatisfactory organization of work, weak control over personnel, shortcomings in the organization of safe work and violation of labor discipline. In addition, personal negligence of victims is often found among the causes of accidents (28%, of which 78% occurred with the employees of contracting organizations).

The analysis of the professions of victims of accidents at nuclear power plants shows that the most susceptible to injuries professions are:

— installers (25% of the total number of accidents, all the victims are employees of contractors), and 57% of the total number of injuries with installers are fatal injuries;

— locksmiths (15%), 83% of them are the employees of contracting organizations;

— drivers, machinists (10%), 75% of them are the employees of contracting organizations;

— rebar workers (8%), all employees of contractors (Fig. 3).

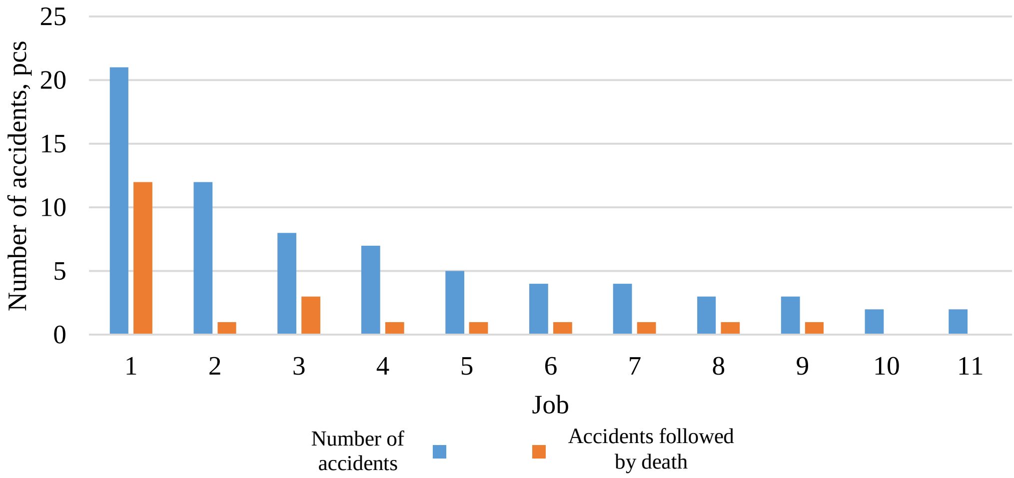

Fig. 3. Distribution of victims by profession for the period from 2013 to 2020:
1 – installers, 2 – locksmiths, 3 – drivers, machinists, 4 – rebarers, 5 – welders, 6 – electricians, 7 – specialists, engineers, 8 – insulators, 9 – concrete workers, 10 – painters-plasterers, 11 – auxiliary workers, cleaners

The most traumatic months at Russian nuclear power plants are March and June (13 accidents each), January and August (9 accidents each), which is due to an increase in repair work in the period from March to September due to scheduled preventive maintenance, major repairs and medium repairs of NPP power units (Fig. 4).

The most traumatic month in terms of fatal accidents is June (30% of all fatal accidents).

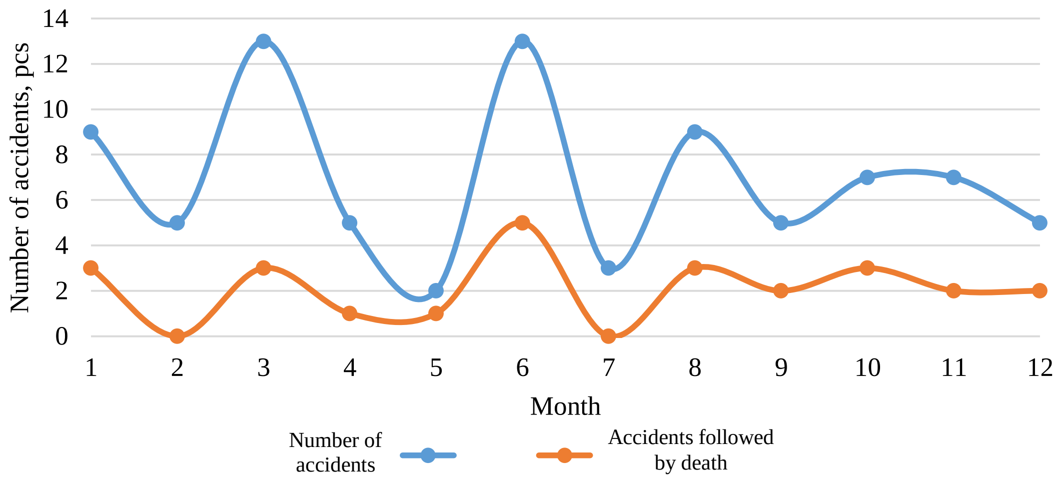

Fig. 4. Distribution of accidents at nuclear power plants for the period from 2013 to 2020 by months

The distribution of accidents by days of the week shows that the largest number of accidents at nuclear power plants occurs at the beginning of the week (Monday and Tuesday) and decreases by the end of the calendar week (Fig. 5).

At the same time, the greatest number of fatal injuries was noted on Thursdays and Fridays, which is probably due to a decrease in concentration due to fatigue accumulated by the end of the working week.

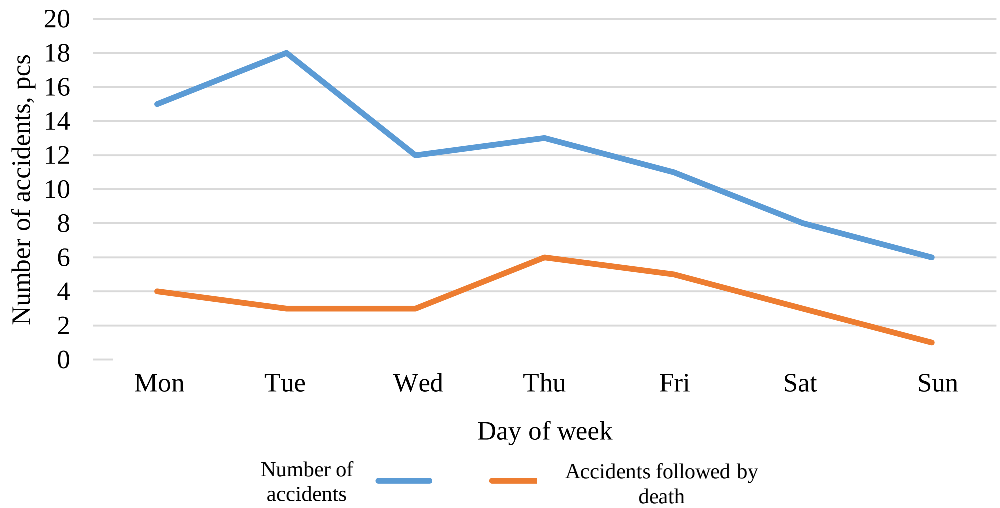

Fig. 5. Distribution of accidents at nuclear power plants for the period from 2013 to 2020 by days of the week

Conclusions. The article analyzes statistical data on cases of occupational injuries in the energy division of the Rosatom State Corporation for eight years, on the basis of which absolute and relative injury rates are calculated, the causes of accidents, the main traumatic factors, the most traumatic professions and periods of injury are determined.

In addition, it was revealed that injuries among employees of contracting organizations are significantly higher than among NPP personnel. This means that it is necessary to find out ways to reduce injuries at nuclear power plants by focusing on working with the employees of contracting organizations.

To do this, the authors have developed the following recommendations:

1. Preliminary qualification selection of contractor organizations with familiarization with the available statistics of occupational injuries cases, possibly with the compilation of a black list of contractors and individual specialists, determination of the rating of desirable contractors.

2. Interaction with contractors in digital format, creation of a "Contractor's Personal Account" to simplify work and reduce the time for processing information.

3. Consideration of the possibility of conducting unscheduled safety briefings with employees of contracting organizations in the most traumatic periods with the involvement of the employees of labor protection department [18].

4. Due to the increase in the level of injuries by the end of the working week, organization of a strict monitoring of compliance with the labor regime, without overwork and with mandatory regulated breaks.

5. For professions that are most susceptible to occupational injuries, apply special requirements to the quality of training of employees, knowledge checks, allow personnel of contractors who have passed a psychophysiological examination to work at nuclear power plants, introduce surprise inspections for drug and alcohol intoxication [19].

6. To develop schemes for motivating employees of third-party organizations to comply with the labor protection requirements, in particular, to introduce a system of incentives based on the results of work without injury for the year /half of the year [20].

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LABOR PROTECTION

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Some aspects of occupational safety at mining enterprises

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Introduction. The article discusses the issues of labor protection at mining enterprises. Timely analysis and elaboration of measures to prevent them can reduce the risks of major accidents with a large number of victims.

Problem Statement. It is necessary to choose the most effective measures to improve the level of industrial safety at mining enterprises based on a ready-made conceptual model of hazardous phenomena and accidents.

Theoretical Part. To solve this problem, the article considers a ready-made conceptual model of hazardous phenomena and accidents that may occur in mines as a result of non-compliance with the requirements of occupational safety and industrial safety of enterprises proposed by A. I. Babenko. The analysis of accidents, risk factors, potential dangerous and harmful production factors at the mining enterprise is carried out. Based on the analysis, the most effective measures to improve the level of industrial safety at mining enterprises are proposed.

Conclusions. The article considers the issues regulating labor protection at mining enterprises, as well as it identifies industrial risks and options for their elimination through the organization of measures to ensure industrial safety. Based on the results obtained, the most effective means to reduce the risks of hazardous production situations is the use of multifunctional systems to ensure occupational safety and industrial safety of mining enterprises.

Keywords: mining industry, labor protection, industrial safety, risks.

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Introduction. Occupational safety and industrial safety issues at mining enterprises are regulated by the Order of the Federal Service for Environmental, Technological and Nuclear Supervision "On approval of Federal Rules and Regulations in the field of industrial safety "Safety Rules for mining and processing of Solid Minerals" [1]. The order defines general requirements for the organization of work related to the production, storage, transportation and use of hazardous substances, the procedure for conducting an expert examination of industrial safety, measures to prevent exogenous and endogenous fire hazards and other issues related to ensuring safe work of people at these facilities.

Other sectoral and supervisory documents regulating occupational safety at mining enterprises have also been developed. One of them is Rostechnadzor Order No. 331 of 03.09.2020 "On approval of Federal Rules and Regulations in the field of occupational safety "Safety rules for explosion- and fire-hazardous production facilities for the storage and processing of plant raw materials" [2].

According to these documents, occupational safety of mining enterprises is defined as "the state of protection of vital interests of the individual and society from accidents at hazardous production facilities and the consequences of these accidents." This definition actually includes the full potential of sources of danger, while safety is determined not by the property, but by the state of the formed occupational safety system at the enterprise.

Problem Statement. The task of the authors of this article is to choose the most effective measures to improve the level of occupational safety at mining enterprises based on the existing conceptual model of hazardous phenomena and accidents.

Theoretical Part. Many experts pay special attention to the study of formal signs of possible accidents. Thus, A. I. Babenko developed a conceptual model of hazardous phenomena and accidents that can occur at mines as a result of non-compliance with the requirements of occupational safety and industrial safety of enterprises [3]. Fig. 1 shows the proposed model

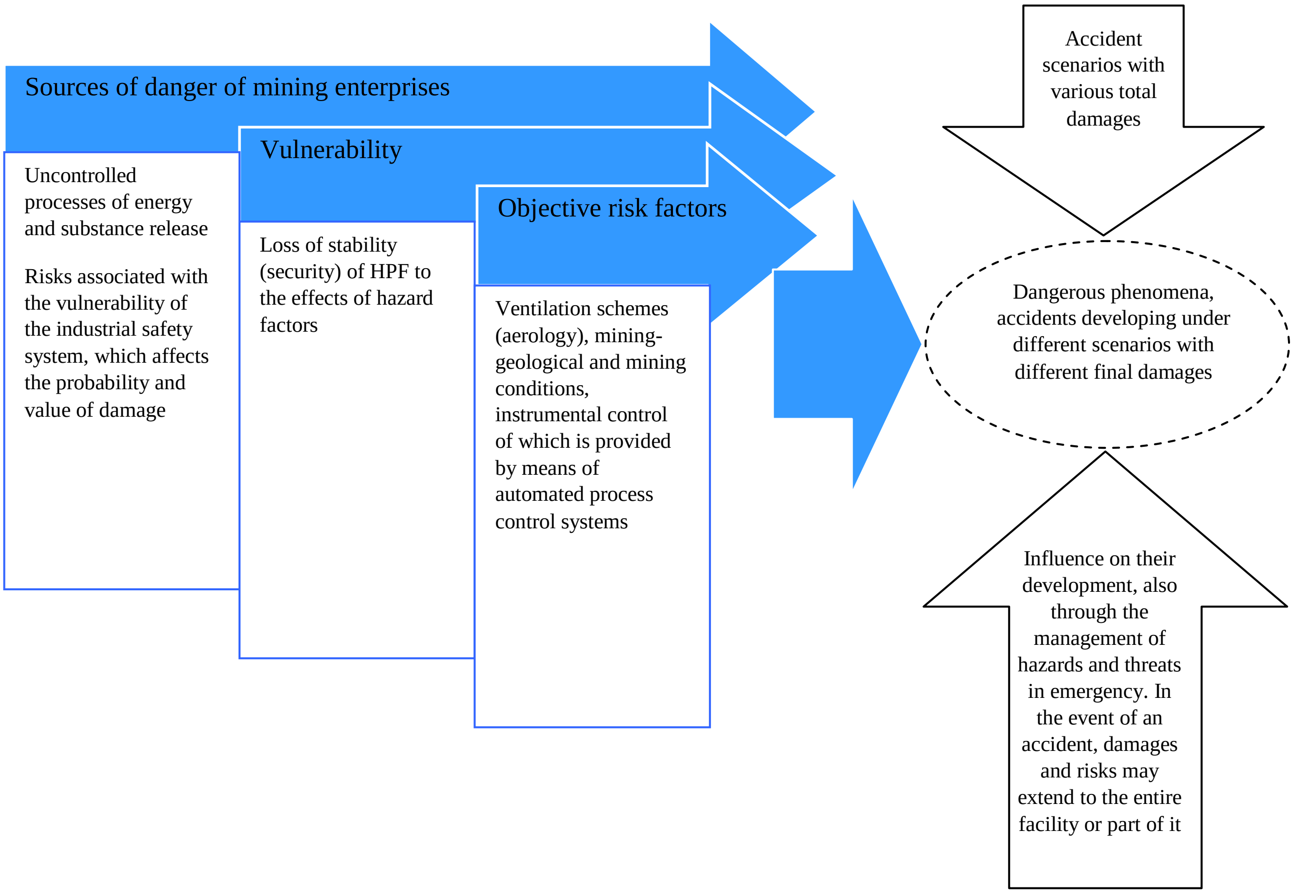

Fig. 1. Model of hazardous phenomena and accidents that may occur in mines as a result of non-compliance with occupational safety and industrial safety requirements. *Compiled by the authors according to [3]*

According to the above model, the analysis of accidents should be accompanied by the elaboration of measures to prevent them. At the same time, these actions should take into account the behavior of accidents, design and beyond-design accidents, hazardous situations and phenomena.

A. I. Babenko considers hazardous situations arising at the mining facilities to be beyond-design risks. Among the project risks, there are regime and hypothetical phenomena that may occur during the service life of the mining field.

Fig. 2 shows the most significant risk factors in the occupational safety of mining enterprises.

1. Aerology (ventilation schemes)

2. Mining and geological conditions of the field development

3. Mining conditions

4. Personnel actions (careless performance of routine maintenance and violation of safety requirements, design and operational documentation)

Fig. 2. Risk factors in the occupational safety of mining enterprises. *Compiled by the authors according to [4]*

In addition to possible accidents, there are many factors in the work of mining enterprises that pose threats to the health and life of personnel, as a result of which there is a need for a comprehensive review of working conditions in order to identify potentially hazardous and harmful production factors and develop effective protection measures. The analysis of potentially hazardous and harmful production factors is given in Table 1.

As it can be seen in the table, all potentially hazardous and harmful factors of production are present in mines to one degree or another; therefore it is advisable to develop measures to protect humans and the environment from them. Protection measures against potentially hazardous or harmful factors are presented in Table 2.

Table 1

Analysis of potentially hazardous and harmful production factors at a mining enterprise

Potentially hazardous or harmful factor	**Source**	**Effect on human**
Unprotected mobile elements of production equipment	Hand punchers, drilling machines and scraper winches	Mechanical injuries of different severity
Polluted air environment: — high concentrations of toxic components of dust and gas aerosols	Self-propelled drilling and loading and delivery equipment with diesel engines	Causes suffocation due to insufficient oxygen saturation of the blood
Vibration	Hand punchers, scraper winches	Reflex syndromes of the cervical and lumbar levels, sensorineural hearing loss, chronic radiculopathy of the cervical-brachial and lumbosacral levels, vibration disease
Acoustic effects: — mechanical noise — aerodynamic noise	Moving parts of machines, vibration Fans	Irritation, hearing fatigue (hearing loss and deafness), damage to the central nervous system
Unsatisfactory parameters of the microclimate of the room		Discomfort, decreased performance

Source: compiled by the authors according to [5]

Table 2

Measures of protection against potentially hazardous or harmful factors in the mining industry

Potentially hazardous or harmful factor	**Source**	**Protective device or action to eliminate harmful factors**
Unprotected mobile elements of production equipment	Hand punchers, drilling machines and scraper winches	Partial stationary devices in the form of casings and nets, enclosing drives and other dangerous areas of moving mechanisms; prohibiting signs
Polluted air environment: — high concentrations of toxic components of dust and gas aerosols	Self-propelled drilling and loading and delivery equipment with diesel engines	Innovative exhaust ventilation systems, an automatic gas analyzer of the MN type and means of light and sound notification in case of detection of low oxygen content in the air
Dangerous voltage level	VDU-1201 rectifiers, inductors and oscillators	Equipment: protective grounding, connection to the neutral wire (connection of metal current-carrying parts with a zero protective conductor); protective disconnection Additionally, the workers use dielectric gloves, galoshes, boots, mats. R<4 ohms
Vibration	Hand punchers, scraper winches	Organizational protection measures: "time protection" Technical measures: passive vibration isolation (installation of units on a vibration-insulated foundation), vibration isolation (use of spring and rubber gaskets)
Acoustic effects: — mechanical noise — aerodynamic noise	Moving parts of machines, vibration Fans	An employee performing a harmful technological operation uses a similar means of protection against vibration, as well as from noise (headphones)

Source: compiled by the authors according to [5]

The list of general organizational measures of protection against potentially hazardous and harmful production factors includes:

— regular safety training of personnel;

— providing the staff with the necessary workwear;

— compliance with the rules of equipment operation (including timely inspection and repair of equipment and testing of protective devices);

— regular mandatory medical examination of personnel in order to identify and prevent the development of occupational diseases and pathologies [6].

Multifunctional safety systems, which are being actively implemented in the mines of foreign countries, have shown the greatest effectiveness.

Fig. 3 shows the composition of such multifunctional systems.

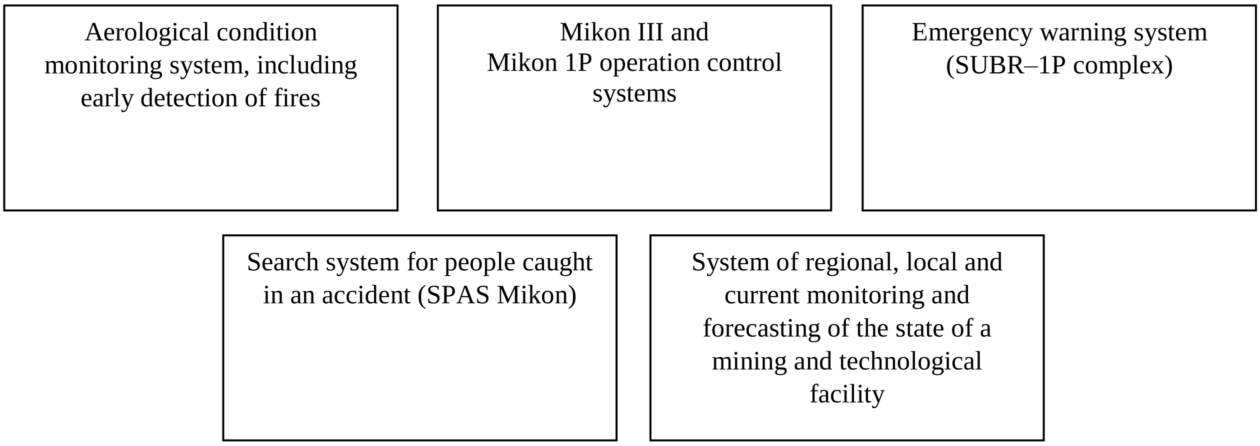

Fig. 3. Composition of multifunctional systems to ensure occupational safety and industrial safety of mining enterprises

Source: compiled by the authors according to [7]

Conclusions. The introduction of multifunctional systems to ensure occupational safety and industrial safety will prevent accidents at mines, increase the level of discipline and prevent mass deaths. At the same time, it is the use of these systems that ensures the compliance with the requirements of standards for occupational safety of workers at mines and allows for a high degree of safe work of personnel.

The most important function of such systems at mines is to notify employees and supervisory authorities about dangerous events at the mine through SMS and E-mail [7].

Multifunctional systems are based on complex programming languages using artificial intelligence and provide prompt response to the slightest violations occurring at the mine. They are the drivers of the growth of safety in the mining industry in the world and in the Russian Federation. Currently, these solutions are being tested in various departments of the mining industry of the country. An important stage is the elaboration of solutions for the conditions and specifics of the detail of each particular mine, which will prevent global and large-scale violations that entail serious consequences.

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A. A. Cheltybashev — formulation of the main concept, goals and objectives of the study, preparation of the text, formulation of the conclusions; S. N. Sudak — processing of theoretical material, development of recommendations, correction of the text, revision of the conclusions; I. P. Karnachev — scientific supervision, analysis of the the research results, revision of the text, correction of the conclusions.

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Occupational morbidity and occupational injury in the food industry

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Introduction. The article considers the problems of occupational morbidity and occupational injuries in the food industry, including factors and causes that form working conditions that contribute to the occurrence of morbidity and accidents.

Problem Statement. The aim of the study is to analyze occupational morbidity and occupational injuries and their causes, as well as to propose corrective or preventive measures aimed at eliminating the causes of accidents, injuries, and the development of occupational diseases.

Theoretical Part. As initial information, the statistical reporting data of the Federal State Statistics Service and the materials of domestic and foreign literary sources are given.

Conclusions. The results of the work indicate the presence of occupational morbidity and occupational injuries among food workers and the need to introduce and implement a number of measures aimed at improving working conditions and improving safety.

Keywords: occupational morbidity, occupational injuries, food industry, hazardous and harmful factors, labor protection.

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Introduction. The tasks of labor protection and organization of safety of workers at enterprises of various fields of activity form the basis of the socio-economic well-being of the country, and are also the most important condition for the formation of the health of the nation. One of the leading branches of the national economy of the Russian Federation is the food industry, which employs about 1.5 million people.

Problem Statement. The objective of the study is to analyze occupational morbidity and occupational injuries and their causes, as well as to propose corrective or preventive measures aimed at eliminating the causes of accidents, injuries, and the development of occupational diseases.

Theoretical Part. Figure 1 shows data from the Federal State Statistics Service on the number of people employed in production with harmful and (or) dangerous working conditions in food production organizations from the beginning of 2018 to the end of 2020 [1].

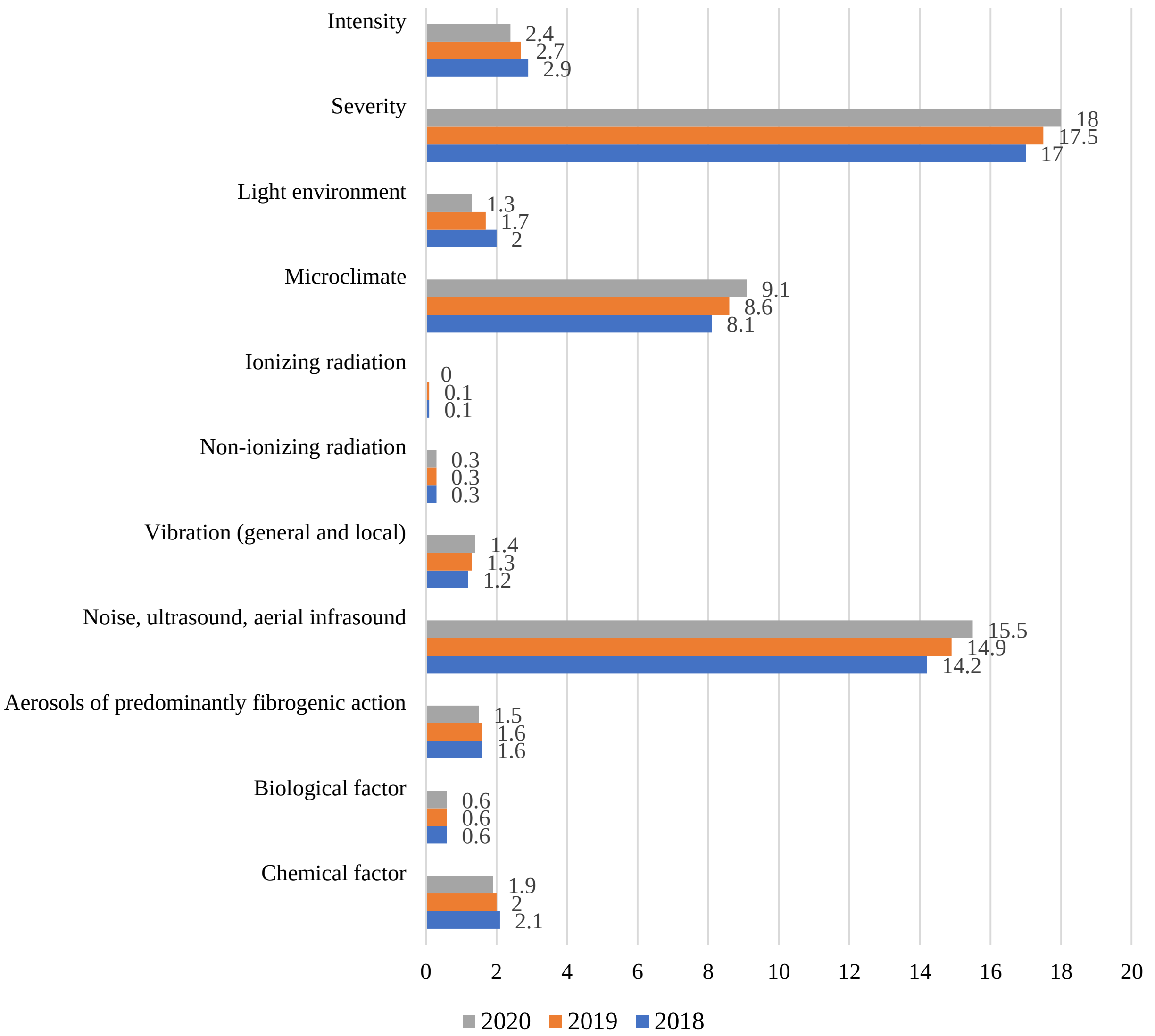

Fig. 1. The number of employees working in harmful and (or) dangerous working conditions at food industry enterprises, in % of the total number

The share of those employed in jobs with harmful and (or) dangerous working conditions is on average 35% per year of the total number of employees in the food industry, while each employee is counted once, regardless of the number of hazardous and harmful production factors affecting him. Thus, more than 1/3 of food industry workers perform their functions under the predominant influence of the heavy labor process, noise, and microclimate. At the same time, it should be noted that during the period under review, there was no decrease in the number of people working in such conditions.

Modern technologies in the food industry, the technical condition of enterprises, working conditions and organization of workplaces do not ensure compliance with sanitary and hygienic standards for a number of indicators: acoustic, microclimate, light environment, air of the working area, severity and intensity of work, etc. These factors contribute to the development of occupational and work-related diseases. Under the influence of the above factors and/or their combinations, a critical mass of toxic (harmful) substances accumulates in the human body and changes the physiological functions of organs and systems, leading to pathological conditions [2]. These include diseases caused by chemical and biological substances, diseases of the musculoskeletal system, peripheral vessels and heart, central nervous system, upper respiratory tract, etc.

According to the European statistics on occupational diseases, diseases of the musculoskeletal system (MSS) account for about 38% of all occupational diseases. In the food and beverage industry, there are many risk factors for the development of MSS diseases: work is characterized by long hours of static loads leaning forward (uncomfortable forced posture), repetitive and rapid movements of hands and wrists (stereotypical movements), prolonged and strong tension of hands and wrists, as well as carrying and lifting heavy objects [3-4].

The prevalence of MSS diseases among food industry workers reaches 67.5%, according to localization they are distributed as follows: 63% — in the lower limbs, 56-65.8% — in the lower back, 49% — in the neck and upper back, 62.3% — in the shoulder [5, 6].

In-depth nosological analysis indicates a significantly increased risk of carpal tunnel syndrome / median/ ulnar nervous disorders, myelopathy, spondylosis, displacement of the thoracic or lumbar intervertebral disc, peripheral enthesopathy, disorders of the synovial region, tendon and bursa, diseases of the extra-articular soft tissues of the back and extremities, as well as trigger finger and radial styloid tendovaginitis [7].

Soft tissue diseases, spondylosis and related disorders occupy a leading place in the ranking of MSS diseases in this group of workers, which is associated with the excessive use of muscles, rapid and repetitive movements, as well as prolonged static loads and uncomfortable forced posture [8, 9].

There is an increased risk of peripheral vascular diseases, including varicose veins of the lower limbs due to prolonged static load during the working day. The results of systematic observations indicate that those who work standing up for more than 3-4 hours a day have an increased risk of varicose veins development (2.5 times) compared to those who do not have such a load. At the same time, the prevalence of this disease or even the risk of acquiring it is higher in women than in men [10, 11].

The risk of developing vibration disease in food industry workers, which may be associated with exposure to local or general vibration, is not excluded. Manifestations: polyneuropathy of the upper limbs, including sensory and vegetative-trophic disorders, peripheral angiodistonic syndrome of the upper limbs (including Raynaud's syndrome), carpal tunnel syndrome (compression neuropathy of the median nerve), myofibrosis of the forearms and shoulder girdle, arthrosis and periarthrosis of the wrist and elbow joints, polyneuropathy of the extremities in combination with radiculopathy of the lumbosacral level, cerebral angiodistonic syndrome [12, 13].

One of the risk factors for food industry workers is exposure to dangerous sound levels. A number of studies have shown that the average sound level in the food industry can vary from 58 to 98 dBA, this affects the development of specific aural effects, manifested both in the form of slowly progressive hearing loss by the type of auditory nerve neuritis (cochlear neuritis), and with some extraaural effects, including headaches, high blood pressure, sleep loss, increased heart rate, pain in the heart, increased blood pressure, gastrointestinal dysfunction, decreased immunological reactivity, stress metabolic reaction [14, 15].

Infrasound sources in the food industry can be compressors, air conditioners, turbines, industrial fans and hoods, large-sized refrigeration equipment [16]. The biological action of infrasound (IS) is characterized mainly by extraaural effects. The mechanism of action of IS is associated with the effect on the mechano- and proprioceptors of the body, with resonant effects, direct propagation of elastic waves through organs and tissues. The critical organs are the vestibular analyzer, the central nervous and cardiovascular systems, and the respiratory organs. The clinical picture is dominated by asthenovegetative and vascular disorders that contribute to the formation of asthenic syndrome, hypertension, encephalopathy of the discirculatory type, etc. [17, 18].

Figure 2 shows the data reflecting the number of employees engaged in the production of food products with the established occupational disease.

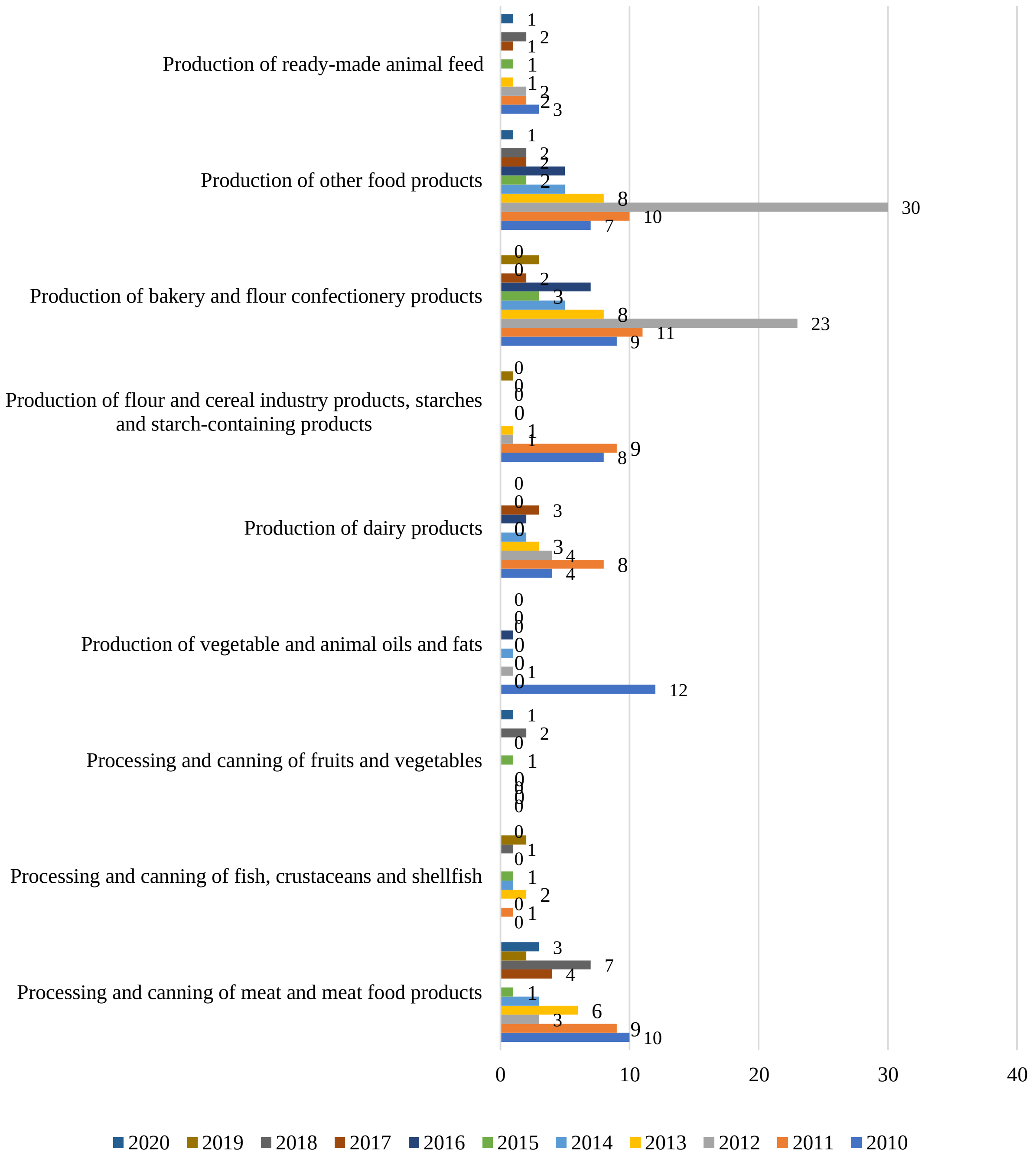

Fig. 2. The number of people employed in the production of food products with occupational diseases established in 2010-2020

The analysis of statistical data indicates the stabilization of the number of occupational diseases in the industry as a whole. However, these data generally reflect the officially confirmed cases, the actual rates are not taken into account, they occur due to late detection or no detection of occupational diseases during periods of medical examinations, but also because of the concealment of the occurrence of occupational diseases, etc.

In addition to occupational diseases, there are risks of traumatic situations and accidents, including fatal outcomes [19].

Tables 1, 2 contain data on occupational injuries in the food industry.

Table 1

Statistical data on victims in the food industry from 2010 to 2020

Type of activity	**The number of victims with disability for 1 working day or more and with a fatal outcome**										
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Processing and canning of meat and meat food products	684/11	567/8	505/15	450/9	360/5	303/4	309/8	363/13	308/8	327/8	273/8
Processing and canning of fish, crustaceans and shellfish	112/6	82/2	75/5	67/3	40/-	39/2	55/5	67/3	63/2	87/2	57/3
Processing and canning of fruits and vegetables	54/2	35/-	35/-	25/1	24/-	25/-	21/-	21/1	11/1	10/1	13/1
Production of vegetable and animal oils and fats	72/5	65/2	81/5	63/5	62/3	61/5	50/3	40/-	56/3	54/2	49/-
Production of dairy products	537/12	474/8	420/10	400/10	300/4	321/5	272/6	216/5	220/8	179/4	167/6
Production of flour and cereal industry products, starch and starch-containing products	220/6	187/1	168/11	112/4	96/6	82/4	61/4	63/1	61/5	67/-	46/2
Production of bakery and flour confectionery products	898/12	796/13	786/16	647/16	595/16	490/10	457/9	454/7	363/6	396/4	319/3
Production of other food products	528/8	468/9	461/9	380/10	349/10	228/6	269/6	268/5	216/8	239/8	210/9
Production of ready-made animal feed	103/2	66/2	64/2	55/3	52/1	47/2	38/7	44/1	34/-	31/-	23/2
TOTAL	3502/70	2994/49	2595/73	2199/61	1878/45	1656/38	1532/48	1536/36	1331/41	1390/29	1157/34

Table 2

Statistical data on the total number of employees and the number of victims in the food industry from 2010 to 2020

Indicator	Period										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Average number of employees, people	1053666	1034207	876126	848335	832456	821365	825123	832900	805487	830396	802799
Number of victims, people	3502	2994	2595	2199	1878	1656	1532	1536	1331	1390	1157
Expenses for labor protection measures, thousand rubles	4530588,4	4783211,2	5033211,2	5546878,4	5881758,8	6932264,8	7064749,3	8071147,8	8195880,5	9273797,3	11368203,4

The data provided on injuries and the number of established occupational diseases indicate a downward trend in recent years. However, at the same time, there is a clear correlation between the reduction in the number of victims in the industry with a decrease in the average number of employees and an increase in the costs of labor protection measures. So, from 2010 to 2020, the number of employees decreased from 1,053,666 to 802,799 people, expenses aimed at improving working conditions increased from 4,530,588.4 thousand rubles to 11,368,203.4 thousand rubles. For example, the number of accidents fell from 3502 to 1,157, and the number of people with the established occupational diseases decreased from 53 to 6.

It should be noted that the violation of the procedure for providing statistical data, their untimely provision or the provision of unreliable data by enterprises occurs for a number of reasons. Firstly, the size of the insurance tariff for the enterprise, as well as the return of funds from the social insurance fund provided for the prevention of injuries at work, directly depend on the number of injuries and deaths. Secondly, the employers are afraid of penalties from the supervisory authorities, namely the State Labor Inspectorate. In case of a serious or fatal accident at an enterprise, an inspector of the State Labor Inspectorate is included in the investigation commission, who has the right to fine for violations detected or issue instructions for their elimination, and these actions are costly for owners. Thirdly, officials are afraid of fall under the criminal liability under Article 143 of the Criminal Code of the Russian Federation "Violation of labor protection requirements". Fourthly, the investigation of accidents requires time and financial costs, as well as the collection of a significant number of documents.

Statistical data, as well as the research by a number of authors, indicate that accidents occur at enterprises due to unsatisfactory organization of production and technological violations, weak control by management or those responsible for production and labor discipline, regular deviation from the rules and instructions of safety by employees, employers' evasion from the introduction of a labor protection management system and inclusion in the structure of labor protection and/or industrial safety services, and in the staffing table — specialists in labor protection, operation of obsolete morally and physically technological equipment or its use in a faulty condition, poor equipment of workplaces and their maintenance in improper order, absence or malfunction of blocking devices, fences of rotating and moving parts of equipment, absence or non-use of personal and collective protective equipment, erroneous actions of employees, their presence in a state of alcoholic, narcotic and other types of intoxication, etc. [16, 20-21].

All of the above reasons are common to the businesses in question. However, there are also specific causes of injuries at food industry enterprises related to the peculiarities of the technological process, the equipment used, etc. For example, at enterprises for processing and canning meat and meat food products, where the greatest number of accidents are found, the facts of injuries are caused by malfunction and wear of machines and mechanisms (such as saws, meat grinders, cutters, lifts, tops, etc. d.), close contact of workers with dangerous production equipment or tools (for example, when working with knives), imperfection of technological equipment (for example, there are no devices on the machine for processing intestines that ensure the safety of loading and unloading, pressure monitoring and control devices are not installed on vacuum boilers, there are no locking systems on power grinders and crushers, fences are not installed at electric dehumidifiers, etc., there are no emergency switches on the line of primary processing of poultry, etc. non-compliance of the placement of technological equipment with the requirements of safety and ergonomics (for example, the distance between the work places of boners and meat trimmers is not observed, there are no devices for storing hand knives during the work of the operator of the machine for removing the skin from the fat, etc.), non-compliance with labor protection rules when working with technological equipment. The main types of injuries in the above cases are limb injuries, fractures, dislocations, burns, electric shocks [21].

In order to reduce the number of accidents, injuries and occupational diseases, as well as to bring working conditions in line with sanitary and hygienic standards, it is necessary to solve the following tasks on labor protection at food industry enterprises:

— to increase the effectiveness of occupational safety training and promotion of labor protection;

— to normalize sanitary and hygienic working conditions;

— to ensure the safety of production equipment, technological processes, buildings, structures, premises, and the territory of the enterprise;

— to carry out professional selection of employees from the point of view of suitability for work safety;

— to provide workers with individual and collective protection means;

— to carry out constant monitoring and introduce control over the compliance with the occupational health and safety regulations;

— to motivate employees to observe their own safety, etc.

To develop corrective or preventive measures and eliminate the causes of accidents, injuries, the development of occupational and work-related diseases, it is possible to use modern approaches to protecting the health of workers. These include:

— implementation of national standards of the "Risk Management" system;

— use of a causal relationship diagram of occupational injuries and occupational diseases Ishikawa;

— development of programs for accounting and analysis of working conditions at the whole enterprise and separately by workshops, sites, divisions;

— use of visual management methods based on the principles of lean manufacturing and workplace safety, methods of standardization of work and visualization, protection against unintentional errors, the method of universal maintenance of equipment;

— use of modern digital tools in the field of occupational safety, especially virtual and augmented reality technologies, serious games and gamified methods aimed at training employees in the field of occupational safety by immersion in the production environment, including with the increased danger conditions, emergency situations;

— creation and implementation of tracking devices that allow you to track and analyze the work of personnel and prevent emergencies (at the same time, both standard mobile gadgets and specially designed devices can be used as such devices);

— introduction of positioning devices related to the movement of machines, mechanisms, production equipment (for example, to prevent the number of accidents associated with the runover on staff, collision);

— development of organizational measures by introducing critically important rules, in case of non-compliance with which the violators are dismissed from work, etc.

Conclusions. The results of the analysis of statistical data on occupational morbidity and occupational injuries from 2010 to 2020 indicate a downward trend in the total number of cases of occupational morbidity and occupational injuries among food industry workers, which is primarily due to the decrease in the average number of employees in the industry and the increase in the cost of occupational safety measures, rather than a general improvement in working conditions and the introduction of measures to improve safety. Thus, there is a need to introduce and implement a number of corrective or preventive measures at enterprises aimed at eliminating the causes of accidents, injuries, and the development of occupational diseases.

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V. Y. Kontareva — formulation of the basic concept, goals and objectives of the study, preparation of the text, formulation of the conclusions; S. N. Belik — analysis of the research results, revision of the text, correction of the conclusions.

FIRE AND INDUSTRIAL SAFETY

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Questions of safety of load-lifting cranes structural connections

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Introduction. The article presents an analysis of accidents of lifting cranes, the causes of which are the destruction of load-bearing structural connections during the designated service life, caused by structural and technological deficiencies, with operational loads not exceeding the passport specifications.

Problem Statement. The objective of the study is to analyze the causes of accidents of different types of lifting cranes and the features that connect these accidents.

Theoretical Part. A review of statistical data on accidents on lifting cranes has shown that the destruction of load-bearing structures occurs not only due to fatigue strength during long-term operation, but also due to insufficient bearing capacity of the hinge joints, violations of technological processes of structural elements welding in conditions not exceeding the passport specifications during the service life.

Conclusions. It is established that the destruction occurs in the design elements of metal structures associated with the crane mounting at a relatively high level of operating stresses and insignificant loading cycles, which indicates errors in the design and violations of welding processes during their manufacture.

Key words: lifting crane, structural element of a lifting crane, safety, accident.

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Introduction. According to the data of the Federal Service for Environmental, Technological and Nuclear Supervision, more than 200 thousand lifting cranes are currently registered in the territory of the Russian Federation, of which more than 64% have served the standard service life [1].

It is known that the operation of lifting cranes that have served the standard service life is more associated with accidents due to fatigue failures of load-bearing structures. More dangerous cases of accidents occur at facilities during the specified lifetime at loads not exceeding the passport specification, due to insufficient bearing capacity of hinge joint structures or insufficient strength of welded joints of structural elements.

Problem Statement. The analysis of the operation of lifting cranes shows that there are cases of accidents at the facilities that have not worked out even half of the standard service life specified by the manufacturer [2, 3]. Let us analyze the causes of accidents of different types of lifting cranes and determine the features that unite these accidents.

Theoretical Part. Let us consider the examples of accidents related to the destruction of design elements of lifting cranes.

Example No. 1. An accident on a bridge crane with a lifting capacity of 10/10 tons. The specified service life of the crane when operating in passport mode is 10 years, the warranty period of operation is 24 months, the operating time of the crane at the time of the accident is no more than A4 with a passport value of A7.

After a year of operation of the bridge crane, during the movement of the crane, when performing technological operations with an empty grab, the welded joints of the walls of the free wheel module with a vertical sheet of metal structure of the end beam were destroyed from the side of the feeding trolleys (Fig. 1). Repair and restoration was carried out. The operation was continued.

Fig. 1. Destruction of welds along the metal boundary of the fusion of the connection of the free wheel module with the vertical sheet of the end beam

A year later, there was a complete destruction of the two nodes during crane movement when performing technological operations:

— welded joints of the module walls of the free wheel with a vertical sheet of metal structure of the end beam from the control cab side, while the wheel module fell into the aisle (Fig. 2);

— welded joints of the elements of end beams (belts and walls) with a vertical sheet of the free wheel module from the feeding trolleys side, the module wheels stay on the track (Fig. 3).

Fig. 2. Complete destruction of welded joints along the metal boundary of the fusion of the walls of the free wheel module with the vertical sheet of the end beam from the side of the crane operator's cabin

Fig. 3. Complete destruction of welded joints along the metal boundary of the fusion of the walls of the free wheel module with the vertical sheet of the end beam from the side of the trolleys

All the above-mentioned destruction of welds occurred along the metal boundary of the fusion of the elements "module elements — vertical sheet" and "end beam elements — vertical sheet". The destruction of welds on the weld metal has not been recorded.

The establishment of the circumstances of the accidents showed that the operating mode and operating conditions of the crane did not exceed the passport values, and the condition of the crane tracks met the requirements of the FRR [4].

By checking the strength of the end beam of the crane using the integrated structural analysis system "STRUCTURE CAD", it was confirmed (Fig. 4) that the applied materials and metal thicknesses of the end beams correspond to its load capacity and operating loads [5].

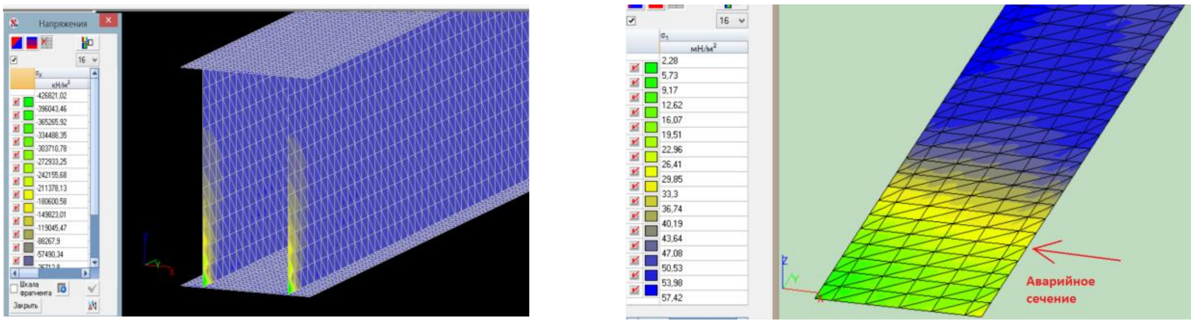

Fig. 4 Calculation model of the crane end beam

The investigation of the crane accident showed that the destruction of the end beams occurred due to insufficient structural strength (bearing capacity) of the welded joints of elements of the free wheels modules and elements of end beams with vertical sheet, namely:

— welded joints was performed without edge preparation, seam T1 GOST 14 771-76 [6], which does not match the type of the weld specified in the passport of the crane (T6 GOST 14771-76 with edge preparation);

— the actual leg, height and cross-sectional area of the destroyed welded joints made with a T1 type seam did not provide the necessary strength of the joints;

— the actual absence of a gap (less than 0.2 mm) between the welded elements of the joints (at an acceptable value of 1.5-2 mm) prevented high-quality penetration of the welded joint;

— the geometric parameters of the destroyed welding joints of the end beam elements did not meet the requirements of the design standards according to GOST 14 771-76 and RD 36-62-00 [7].

The cause of the accident should be considered a violation of welding technologies in the manufacture of the metal structure of the end beam of the bridge crane.

Example No. 2. The accident of a portal crane with a lifting capacity of 20 tons. The service life specified by the manufacturer when working in passport mode is 20 years or 50,000 hours.

During the operation of the portal crane, fatigue destruction of the two axes of the balance trolley attachment occurred.

At the time of the accident, the crane had the following operational parameters:

— the operating time of the crane of the service life — 25,000 hours;

— the mass of the overloaded material is 2.2 million tons;

— the number of work cycles is 220,000.

The analysis of the circumstances of the accidents showed that the working surfaces of all 16-running wheels have a characteristic wear of the rolling surface (Fig. 5) in the form of a "roll" with a height of 3-4 mm. The wheel flanges came into contact with the inside of the rail head due to the movement of the crane along curved sections of the track.

Fig. 5 Wear of the working surfaces of the running wheels

According to the results of the planned high-altitude alignment of the section of the rail track on which the accident occurred, a narrowing of the track above the permissible value was established.

The axles of wheeled trolleys are made of forged steel 40XFA GOST 4 543-71 [8]. 40XFA grade steel [9, 10] is alloyed, heat-treatable, has low weldability due to high crack sensitivity.

The destruction of the axles of wheeled trolleys occurred in the transition zone of the axis diameters from ∅ 150 mm to ∅ 230 mm. This section of the axis is characterized by an increased effective stress concentration coefficient at cyclic variable loads not lower than $K_\sigma = 2.5$ [11, 12]

Traces of corrosion were found on the surface of the axis fracture, which indicates the presence of an old crack with an area of about 50% of the area of the axis of the balancer. The fracture surfaces (Fig. 6, 7) have characteristic zones indicating fatigue failure of the metal resulting from the influence of alternating cyclic stresses (Fig.. 8) [12, 13]:

— 1 – zone of origin of the fatigue crack is located on the lateral surface of the axis in its most loaded part;

— 2 – fatigue crack development zone, has a smooth (lapped) surface;

— 3 – rupture area, has a coarse-grained fibrous structure of the surface, indicating the direction of destruction (Fig. 9).

Fig. 6. Fracture surfaces of axis No. 1

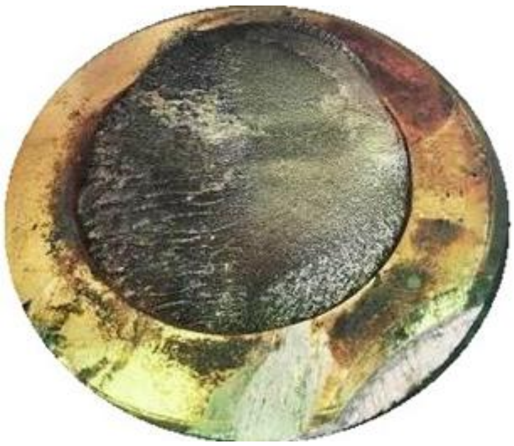

Fig. 7. Fracture surface of axis No. 2

Fig. 8. Fatigue failure with characteristic zones

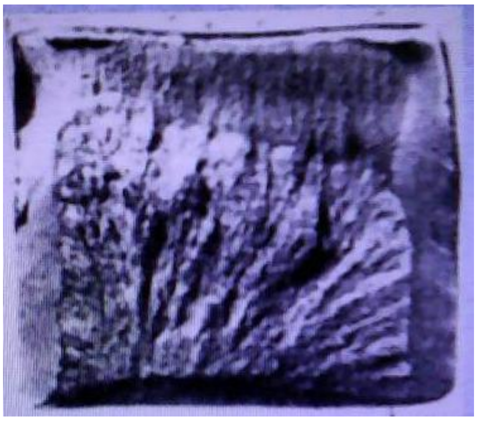

Fig. 9. Fibrous structure of the rupture area

The calculations performed using the integrated structural analysis system "STRUCTURE CAD" (Fig. 10) has showed that the combination of loads during crane operation on a curved section of the track is damaging and the condition of long-term strength is not met.

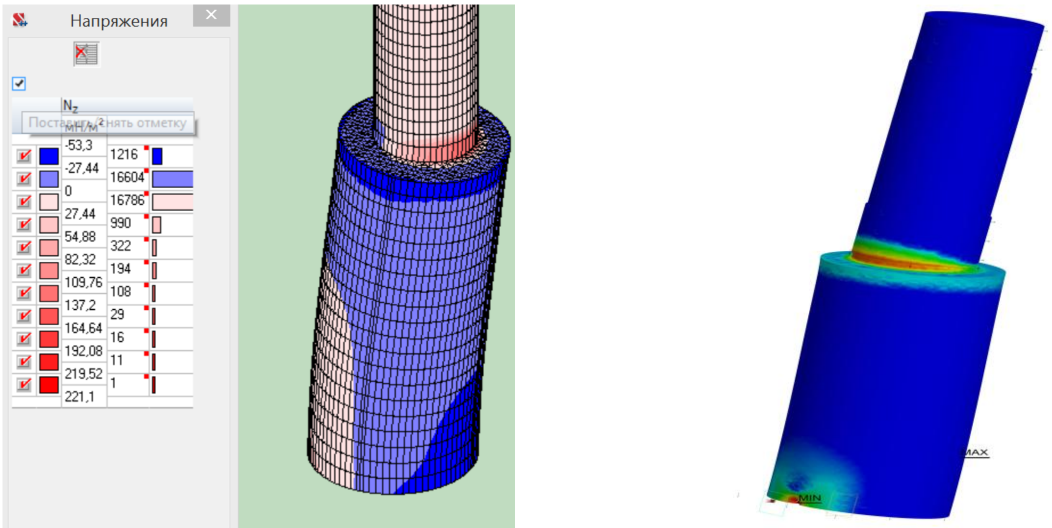

Fig. 10 Deformations and stresses in the axle of a wheeled trolley

The calculations performed on the static and fatigue strength of the axis of the balancing trolley has showed that:

1. Static loading, taking into account the weight of the grab with the load at the maximum reach in the section of the sharp transition of the diameter of the axle of the trolley, is not damaging, because the design voltage is significantly lower than the permissible one.

2. When operating the crane on a curved section of the rail track, the horizontal component of the force from the rotary part of the crane and the reaction from the interaction of the running wheel with the rail are transmitted to the crane gantry. The above combination of loads is damaging, which leads to the beginning and subsequent development of fatigue cracks in the dangerous section of the axes.

The cause of the accident and premature destruction of the axis of the balancing trolley is an error in the design of a complex-shaped product having a transition section with a high effective stress concentrator.

Conclusions. The accidents described above of lifting cranes that have not worked out even a half of the standard service life are united by the following features:

— the cranes belong to the classification group (mode) according to ISO 4301/1 – A7;

— destructions occur in the design elements of metal structures associated with the crane mounting that receive loads from the crane's own weight, moving loads and reactions from the crane rail;

— the stressed state is characterized by a relatively high level of operating stresses and the number of cycles less than $N = 10^5$.

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ENVIRONMENTAL SAFETY AND ENVIRONMENTAL PROTECTION

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Dynamics of anthropogenic pollution of the Glubokaya River in the Rostov Region

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Introduction. The article deals with the problems of deterioration of water quality in rivers in the Rostov region, their shallowing and drying out. The degradation of reservoirs is associated with various aspects of economic and industrial anthropogenic activities. The degree of influence depends on the intensity of the negative impact, and can be reduced if environmental measures are implemented.

Problem Statement. The objective of this study is to monitor the water quality of the Glubokaya River in the Rostov region on different sections of the river and to assess the degree of anthropogenic impact.

Theoretical Part. Water quality studies were carried out in three channels of the Glubokaya River on the territory of the cities of Millerovo and Kamensk-Shakhtinsk, as well as near them. The content of ammonia, phosphorus was determined by spectrophotometric analysis methods and petroleum products by IR photometric analysis method. The results of the study of water quality in the reservoir are compared with the normative values for three years with a certain periodicity.

Conclusions. The results of the studies on changes in the chemical composition of water at various sites in dynamics, taking into account the degree of anthropogenic load, are analyzed.

Keywords: chemical composition, pollution of water bodies, anthropogenic impact.

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Introduction. The Rostov region belongs to the industrially developed regions. Many local large enterprises are engaged in aviation and mechanical engineering, housing-and-municipal services and agriculture, produce chemical products and construction materials. The activities of such companies have a negative impact on the environmental situation. We are talking about air and water pollution, outdated approaches to the disposal of production and consumption waste, degradation of soil cover, frequent cases of dangerous burning of dry vegetation. The improvement of the state of the environment (including reservoirs recovery) is possible only with an integrated approach to solving environmental problems.

Almost all reservoirs of the Rostov region are exposed to anthropogenic impact of varying degrees of intensity. The results of long-term monitoring of river pollution indicate that wastewater discharges from enterprises, as well as surface runoff, including agricultural land and livestock complexes, are particularly harmful[1]. In recent years, there has been a constant deterioration of water quality in the rivers of the Rostov region, their shallowing and drying up. Possible causes are climate change [1] and an increase in anthropogenic load.

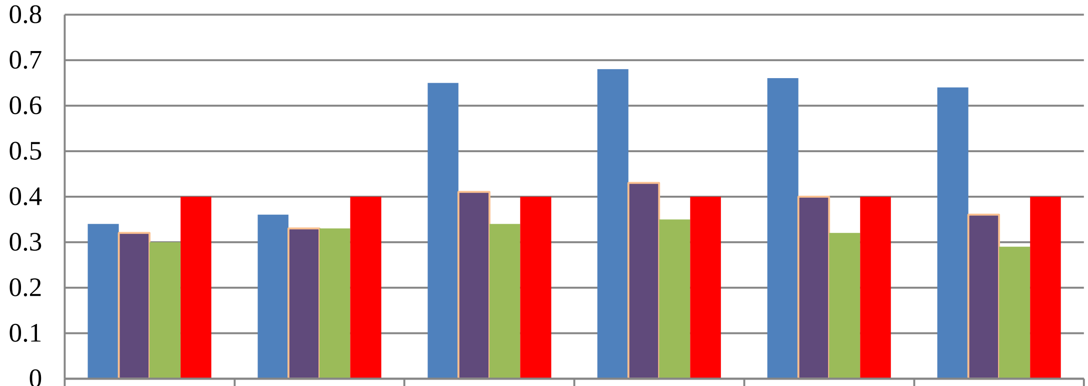
Problem Statement. Within the framework of the presented work, the state of the Glubokaya River on the territory of the cities of the Rostov region Millerovo and Kamensk-Shakhtinsky, as well as in their vicinity, was studied. The dynamics of changes in water quality for three years has been recorded. The main sources of negative impact on the

[1] Water Cadastre of the Russian Federation. Surface and groundwater resources, their use in quality. Federal Service for Hydrometeorology and Environmental Monitoring. Saint Petersburg, 2016. p. 163. (In Russ.).

reservoir are listed, taking into account the quantitative and qualitative characteristics of pollutants in different sections of the river.

Theoretical Part. The object of the study is the water quality of the Glubokaya River in the Rostov region. The samples were taken in 2019-2021 according to GOST 31861-2012[2] to determine hydrochemical parameters and chemical composition of water. Observation of changes in the quantitative and qualitative characteristics of pollutants entering the reservoir was compared with possible causes of anthropogenic impact.

For three years, during warm periods, water quality monitoring was carried out on three sections of the river. The content of ammonia and phosphorus was determined by spectrophotometric analysis methods, petroleum products — using infrared (IR) photometry using special techniques [3, 4, 5]. As part of the research, expeditionary water sampling was carried out six times a year. Information has been collected on all factors affecting water quality. The content of pollutants was determined experimentally [2] (Fig. 1-8). Here and further, the unit of measurement of concentration and maximum permissible concentration (MPC) is milligrams per cubic decimeter.



	April	May	June	August	September	October
2019	0.34	0.36	0.65	0.68	0.66	0.64
2020	0.32	0.33	0.41	0.43	0.40	0.36
2021	0.30	0.33	0.34	0.35	0.32	0.29
MPC	0.4	0.4	0.4	0.4	0.4	0.4

Fig. 1. NH_4 concentration in the Glubokaya River above Millerovo

The studies have shown that the main pollutants of the Glubokaya River are nitrate nitrogen, phosphorus and petroleum products. Figure 1 shows the annual concentration of ammonium compounds in the Glubokaya River above Millerovo.

From June to October, there was a significant excess of ammonium nitrogen. This can be explained by:

— the influence of agricultural activity (the effluence of dissolved mineral fertilizers from storm drains)

— the decrease in the volume of water in the driest periods.

In April 2019, 43 mm of precipitation fell, which was 108 % of the norm, in May — 77 mm (164 % of the norm)[6, 7, 8]. Table 1 shows the average temperatures.

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[2] GOST 31861-2012. Water. General requirements for sampling. Federal Agency for Technical Regulation and Metrology. Moscow, 2019. p. 2–14. (In Russ.).

[3] RD 52.24.383-2018. Mass concentration of ammonium nitrogen in the waters. Photometric measurement method in the form of indophenol blue. Federal Service for Hydrometeorology and Environmental Monitoring. Rostov-on-Don, 2018. p. 18–25. (In Russ.).

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[7] idem. 2020 year.

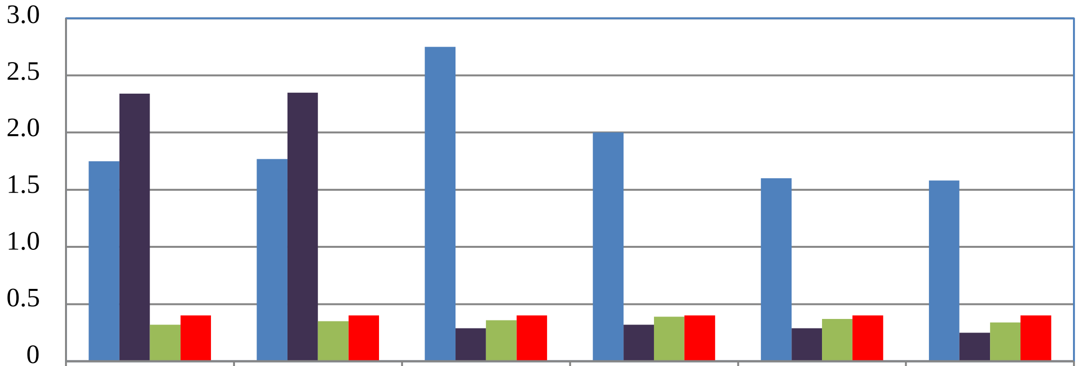
[8] idem. 2021 year.

Table 1

Average temperatures in 2019-2021, °C

Month	0.5 km above Millerovo	0.5 km below Millerovo	Within the boundaries of Kamensk-Shakhtinsky
2019			
April	10.6	14.1	13.0
May	22.3	24.6	22.5
June	24.2	18.9	24.6
August	23.8	25.0	24.9
September	19.5	20.2	20.0
October	12.9	13.1	13.4
2020			
April	16.2	13.3	16.9
May	26.4	25.5	26.2
June	27.8	28.2	27.4
August	26.5	20.0	25.6
September	19.5	18.2	19.1
October	12.7	10.7	15.2
2021			
April	8.6	7.7	7.9
May	21.0	24.1	21.8
June	21.6	17.6	20.1
August	24.6	23.5	25.8
September	16.4	16.7	17.8
October	5.2	5.9	6.8

Fig. 2. shows data on the content of ammonium compounds in the water downstream

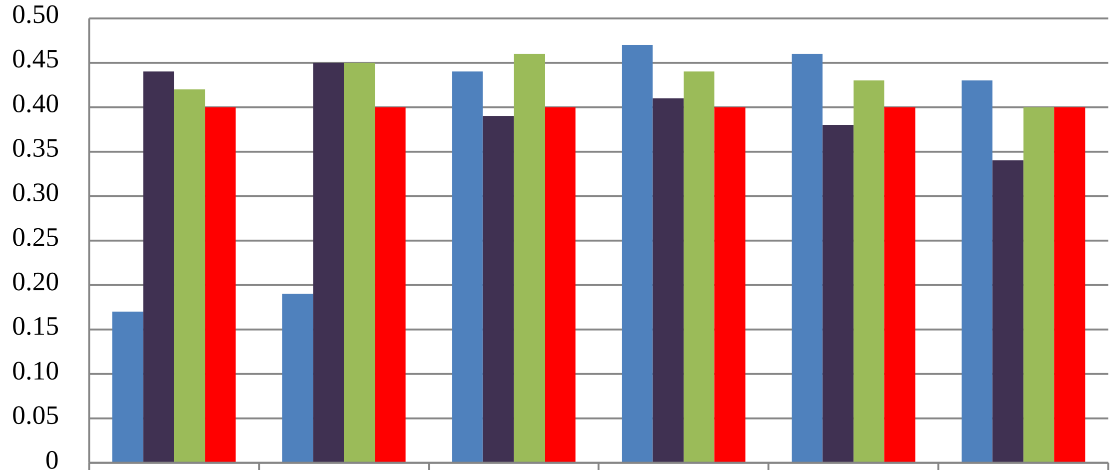


	April	May	June	August	September	October
2019	1.75	1.77	2.75	2.0	1.6	1.58
2020	2.34	2.35	0.29	0.32	0.29	0.25
2021	0.32	0.35	0.36	0.39	0.37	0.34
MPC	0.4	0.4	0.4	0.4	0.4	0.4

Fig. 2. NH_4 concentration in the Glubokaya River below Millerovo

In this case, a multiple increase in the content of ammonium compounds is obvious. Abnormal concentrations were recorded in 2019. This is due to the production activity of local companies. The largest objects affecting the environment are the Millerovo glucose-maltose plant and the Vodokanal (water services company). In 2020 and 2021, the intensity of the negative impact on the river decreased due to the shutdown of the enterprises.

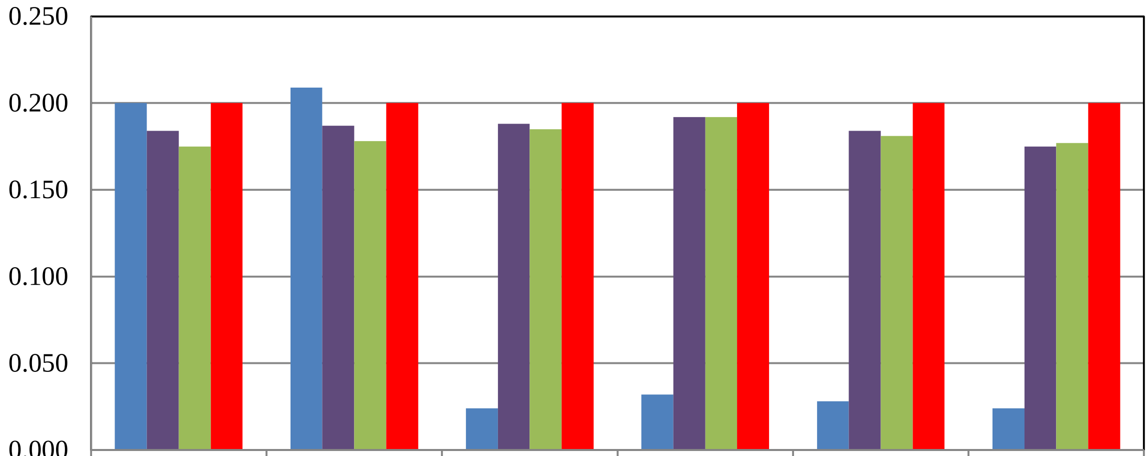
Fig. 3 shows the monitoring data of the Glubokaya River in the area of Kamensk-Shakhtinsky, located 90 km downstream. There was a slight decrease in the concentration of ammonium compounds due to the mechanism of self-purification of the reservoir.



	April	May	June	August	September	October
2019	0.17	0.19	0.44	0.47	0.46	0.43
2020	0.44	0.45	0.39	0.41	0.38	0.34
2021	0.42	0.45	0.46	0.44	0.43	0.40
MPC	0.4	0.4	0.4	0.4	0.4	0.4

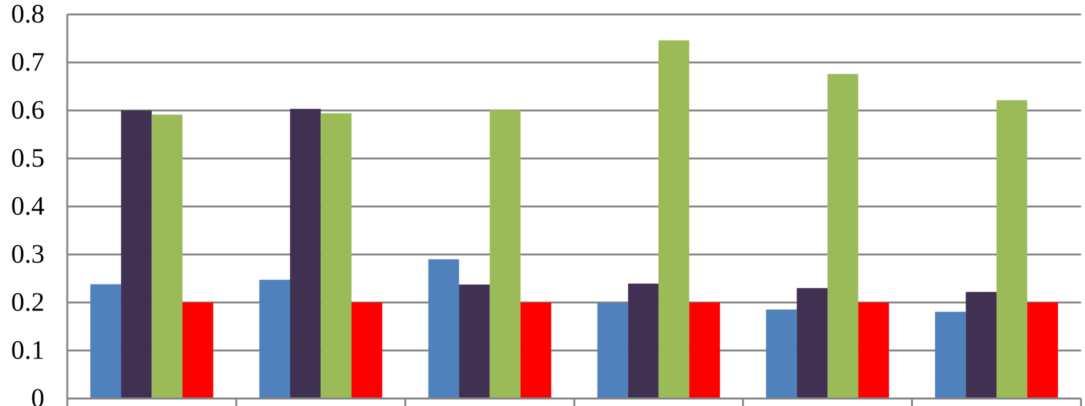
Fig. 3. NH_4 concentration in the Glubokaya River near Kamensk-Shakhtinsky

Figures 4-6 show the dynamics of phosphate concentration in the Glubokaya River during the year.



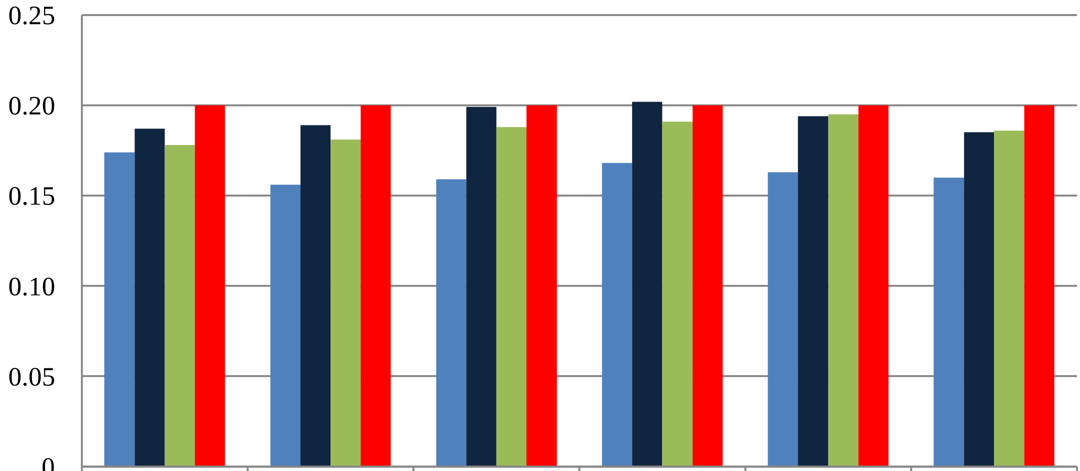
	April	May	June	August	September	October
2019	0.200	0.209	0.024	0.032	0.028	0.024
2020	0.184	0.187	0.188	0.192	0.184	0.175
2021	0.175	0.178	0.185	0.192	0.181	0.177
MPC	0.2	0.2	0.2	0.2	0.2	0.2

Fig. 4. PO_4 concentration in the Glubokaya River above Millerovo



	April	May	June	August	September	October
2019	0.238	0.247	0.29	0.199	0.185	0.181
2020	0.600	0.603	0.237	0.239	0.230	0.222
2021	0.591	0.594	0.601	0.746	0.676	0.621
MPC	0.2	0.2	0.2	0.2	0.2	0.2

Fig. 5. PO_4 concentration in the Glubokaya River below Millerovo

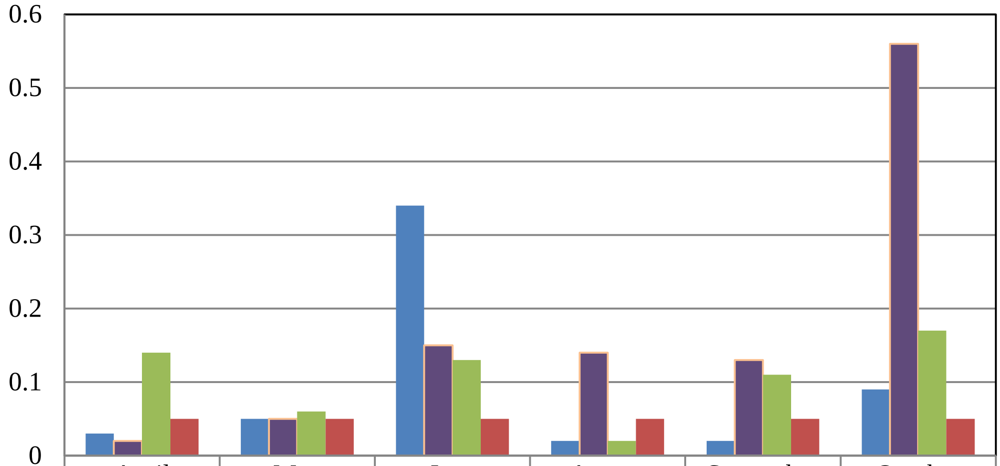


	April	May	June	August	September	October
2019	0.174	0.156	0.159	0.168	0.163	0.16
2020	0.187	0.189	0.199	0.202	0.194	0.185
2021	0.178	0.181	0.188	0.191	0.195	0.186
MPC	0.2	0.2	0.2	0.2	0.2	0.2

Fig. 6. PO_4 concentration in the Glubokaya River near Kamensk-Shakhtinsky

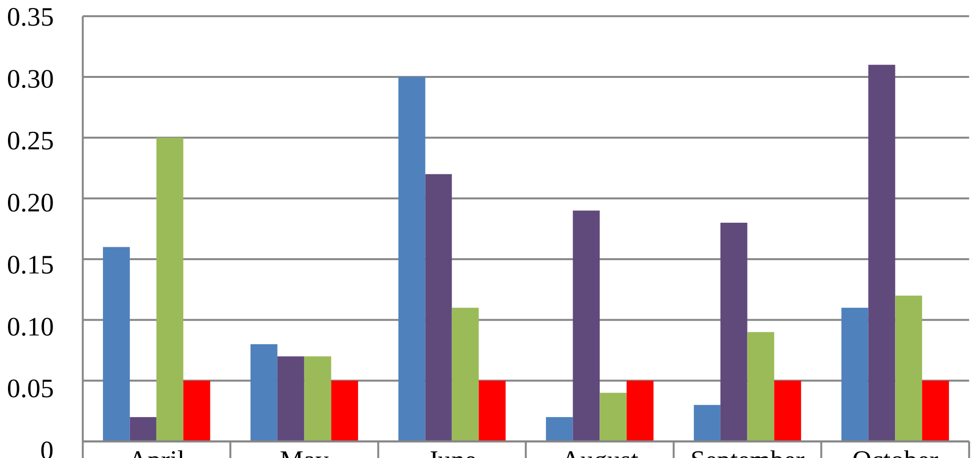
Monitoring data allow us to conclude about the adverse impact on the river of enterprises and the urban ecosystem of Millerovo. The greatest excess of phosphate concentration was recorded in 2021 in the water downstream of the city.

Figures 7-9 show the results of determining the dynamics of the content of petroleum products.



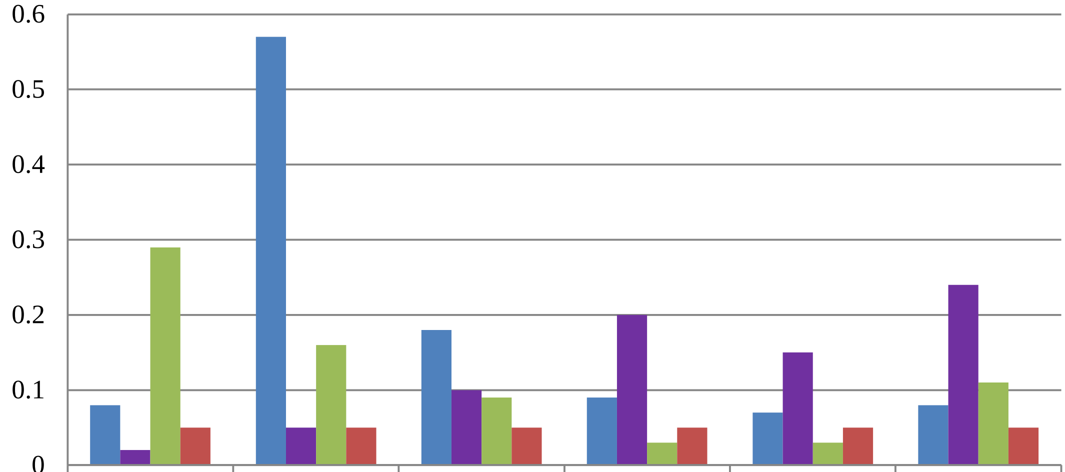
	April	May	June	August	September	October
2019	0.03	0.05	0.34	0.02	0.02	0.09
2020	0.02	0.05	0.15	0.14	0.13	0.56
2021	0.14	0.06	0.13	0.02	0.11	0.17
MPC	0.05	0.05	0.05	0.05	0.05	0.05

Fig. 7. Concentration of petroleum products in the Glubokaya River above Millerovo



	April	May	June	August	September	October
2019	0.16	0.08	0.30	0.02	0.03	0.11
2020	0.02	0.07	0.22	0.19	0.18	0.31
2021	0.25	0.07	0.11	0.04	0.09	0.12
MPC	0.05	0.05	0.05	0.05	0.05	0.05

Fig. 8. Concentration of petroleum products in the Glubokaya River below Millerovo



	April	May	June	August	September	October
2019	0.08	0.57	0.18	0.09	0.07	0.08
2020	0.02	0.05	0.10	0.20	0.15	0.24
2021	0.29	0.16	0.09	0.03	0.03	0.11
MPC	0.05	0.05	0.05	0.05	0.05	0.05

Fig. 9. Concentration of petroleum products of the Glubokaya River in Kamensk-Shakhtinsky

Oil pollution occurs at any time on all sections of the river. This allows us to talk about unauthorized discharges, for which both legal entities and individuals are responsible. According to statistics, petroleum products are the most common environmental pollutants. This is due to the wide range of compositions with petroleum products used in industry and in everyday life. The level of pollution decreased during the lockdown periods.

Table 2 summarizes the monitoring results, which make it possible to track the dynamics of the average annual indicators of river pollution in Millerovo.

Table 2

Dynamics of pollution indicators of the Glubokaya River in Millerovo (2019-2021), mg/dm^3

Indicator	**Year**			**MPC**
	2019	**2020**	**2021**	
O_2	7.43	7.16	7.81	4.0
ultimate BOD	3.37	3.27	3.30	2.0
NH_4	1.9	0.97	0.35	0.5 (0.4N)
NO_3	0.37	0.38	0.50	40 (9.0N)
NO_2	0.05	0.06	0.08	0.08 (0.02N)
Petroleum products	0.12	0.16	0.11	0.05
$Fe_{общ}$	0.52	0.61	0.65	0.1
PO_4	0.22	0.36	0.63	0.2
Ca^{2+}	201.2	321.6	301.9	180
Mg^{2+}	121.6	193.8	182.2	40.0
Na+K	480.8	163.8	222.4	120
SO_4	610.5	769.5	757.2	100
Cl	642.2	524.8	549.4	300
Mineralization	2572	2483	2511	1000

To assess the quality of the Glubokaya River on the territory of the Millerovsky and Kamensky districts, the specific combinatorial index of water pollution (SCIWP) was calculated and compared with the MPC.

Quantitative chemical analysis recorded an excess of MPC of sulfates, total iron, BOD_5, three forms of nitrogen, phosphates and petroleum products.

On average, SCIWP is within the 4th class of categories "A" and "B" with a rating of "dirty". The level of water pollution ranges from "dirty" to "very dirty".

According to the results of the study, it can be concluded that in 2019-2021 all indicators exceeded the maximum permissible values. This indicates a violation of clause 6 of Article 56 of the Water Code of the Russian Federation.[9].

The influence of industrial and municipal water intakes on river runoff is especially significant in the area of large cities [3]. The most serious sources of pollution of the Glubokaya River are municipal and industrial wastewater. The water quality is negatively affected by the glucose-maltose plant, the Vodokanal and other Millerovo enterprises.

According to the quality criteria, the condition of water bodies is determined, as well as the suitability of water for the habitat and development of commercial fish and organisms [4]. In the Rostov region, active silting of small riverbeds, the spread of woody and shrubby vegetation in them, the presence of numerous non-engineering structures were noted. All this leads to degradation of water resources and prevents their use as sources of water supply. The water-bearing capacity and fishery importance of reservoirs are decreasing. In addition, in most cases, silting and overgrowing of riverbeds prevents the trouble free passage of flood waters, which is fraught with flooding of the territories of 179 settlements of the Rostov region.

Conclusions. The analysis of the state of reservoirs of the Rostov region on the example of the Glubokaya River has confirmed the shortage of high-quality water resources. The discrepancy between the state of surface waters and the current standards has been revealed. This situation hinders the sustainable supply of drinking and industrial water to the territories.

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O. V. Dymnikova — scientific supervision, analysis of the research results, revision of the text, conclusions formulation; A. E. Borman — formulation of the main concept, goals and objectives of the study, calculations, text preparation.