

Reducing Occupational Risks in Industrial Processes: Analysis and Recommendations for Improving Safety in Production Equipment and Facilities



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ABSTRACT

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This study is centered on devising preventive strategies to enhance safety and diminish occupational risks associated with the operation of novel industrial facilities and production equipment. Utilizing qualitative research methods, this investigation scrutinizes reporting documents, exploiting indicators of occupational injuries and identified causes of such injuries. A combination of monographic and statistical methods was leveraged to process the results. An examination of occupational risks reveals that a substantial proportion is linked to production equipment, flawed technological processes, and substandard conditions of industrial facilities and structures. Informed by the outcomes obtained, recommendations were formulated for establishing and employing feedback mechanisms. This approach facilitated the systematization of causes leading to industrial injuries and the modification of regulatory documentation to curtail occupational risks. The study advocates the development of specific checklists featuring exemplar questions and a unified database for work-related injuries. It also proposes amplifying the legal status of documents that prescribe requirements for production processes. The implementation of these solutions is projected to result in a reduction of occupational risks and work-related injuries.

1. INTRODUCTION

1.1 Problems of industrial safety

The advancement of technology stimulates socio-economic growth, necessitating production, technical, and technological evolution in nearly all sectors [1, 2]. Such progress should align with technical, economic, environmental [3, 4], and industrial safety standards [5]. The commissioning of new industrial facilities, structures, and equipment [6], the innovation of technological processes [3], and the creation of novel materials and jobs are all inherent to production, technical, and technological development. Contemporary safety mandates necessitate employers to devise preventive strategies, aimed at ensuring safe conditions and evaluating the level of professional risks prior to the commissioning of facilities and the creation of new positions [7, 8]. Occupational risks, potential hazards confronted by employees in their work environment, can lead to an array of work-related injuries, illnesses, or even fatalities. Particularly, production processes involving heavy machinery, chemicals, and hazardous materials pose significant occupational threats [9]. To address these challenges, a paramount role is assigned to the organization and management of labor safety, along with the prevention of work-related injuries [10]. Analysis, generalization, and systematization of these risks can facilitate the implementation of preventive measures to rectify identified deficiencies during the design, construction, organization, and commissioning phases [11].

The selection of innovative technological equipment and the creation of new jobs necessitates interventions to lessen occupational risks. Despite a general downward trend in industrial injury indicators, these incidents represent irreparable losses of labor resources (fatalities, accidents with severe outcomes often leading to disability) [12], and diminished working capacity of the economically active population for a certain period [13]. Consequently, the implementation of modern technologies in the system for collecting and processing information on work-related injuries is an imperative issue.

1.2 The main reasons for occupational risks

A comprehensive analysis of occupational risks, utilizing work-related injury data as exemplars, reveals that the main precipitators include the unsatisfactory condition of facilities, structures, and territories [14], flaws in technological processes and violations [15], and inappropriate interactions with production and technological equipment. Instances of this can be observed in injuries across diverse sectors such as railway transportation [16], the construction industry [17], and foundry production [18].

Production equipment, encompassing an assortment of machines and mechanisms exerting direct mechanical, thermal, or chemical impact on the labor object throughout the production process, plays a significant role. General technical purpose technological equipment constitutes lifting equipment, transport equipment, lubricating and filling equipment, anti-

corrosion equipment, and diagnostic equipment [19].

The origins of occupational risks (work-related injuries) linked to industrial facilities and structures, flawed technological processes, and violations can be technically categorized as follows:

- Design flaws and insufficient reliability of machines, mechanisms, and equipment;
- The imperfection and violation of technological processes;
- The unsatisfactory technical state of facilities, structures, territories, etc.

1.3 Gap in occupational injury research

The mitigation of occupational risks and the development of preventive measures to ensure secure conditions during operation and before the commissioning of production equipment and newly established workplaces hinge upon an exhaustive analysis and specification of the causes of work-related injuries. These injuries are often associated with facilities, structures, and equipment, and require a comprehensive identification of the factors contributing to trauma [20]. Presently, this issue remains insufficiently studied, lacking a thorough account and analysis of [21]:

- Design flaws;
- Manifestations of insufficient reliability of industrial facilities, structures, equipment, and mechanisms;
- Operational errors;
- Shortcomings in the location of production facilities;
- Shortcomings in the arrangement of production equipment;
- Shortcomings of technological processes;
- Errors in technological processes, etc.

The matter of providing and utilizing feedback remains inadequately addressed at present. However, based on the systematization of the causes leading to work-related injuries, modifications to regulatory and legal documents containing mandatory state requirements for ensuring the safety of production processes can be made [22]. Articles that encompass safety and injuries [23, 24] merely touch upon safety regulations, with a conspicuous lack of focus on the potential for amending regulatory documents in light of systematized technical causes leading to injuries. A review of scientific literature on reducing occupational risks in production processes [25-27] reveals a similar trend.

The question that thus arises is: How can we obtain and utilize feedback, the essence of which relies on the analysis and systematization of the technical causes of injuries, to improve legal acts regulating safety requirements for industrial facilities, structures, equipment, and technological processes?

1.4 Purpose and objectives of the study

The primary goal of this study encompasses the development of measures to preemptively ensure secure working conditions and minimize occupational risks associated with the operation of newly established industrial facilities and production equipment.

To accomplish this task, the following methodologies were employed:

- The analysis and identification of changes in occupational risks due to the unsatisfactory technical condition of facilities and structures, imperfect technological processes and violations, design flaws in production equipment, and operation of faulty equipment;

- The analysis of the legal regulation of industrial facilities, structures, equipment, technological processes, and their safe operation;

- The development of recommendations and measures to reduce occupational risks of production processes (primarily in the operation of industrial facilities, structures, and equipment).

In this article, an examination of the existing regulatory legal framework governing the safety of production processes is undertaken, along with an analysis of occupational risks associated with the operation of industrial facilities, structures, equipment, imperfect technological processes, and violations. The aim is to develop recommendations that align with modern industrial safety requirements. By systematizing the causes leading to work-related injuries, feedback is utilized to enhance regulatory documents and reduce occupational risks. The findings suggest the need for an in-depth exploration into the development, creation, and use of such feedback. This would allow, through generalization, systematization, and the creation of a unified database of work-related injuries, to consider the reasons contributing to industrial traumatism. Based on the results, proposals were formulated for amending relevant regulatory documents (namely, the Technical Regulations, the system for assessing compliance of technical objects with these regulations, and the Labor Protection Rules), which is anticipated to lead to a reduction in occupational risks.

2. METHODS

2.1 Design of the study

When choosing the design of the study, we proceeded from the fact that production processes are understood as a set of technical elements that ensure the operation of an enterprise (industrial facilities and structures, production equipment, technological processes, and materials).

To select negative events that have already taken place, ended in an occupational accident, and led to industrial injuries, qualitative research methods were used: Reporting documents were studied, in which the indicators of occupational injuries and the identified causes of injuries were used, the monographic method and the statistical method of processing the results were used.

2.2 Analysis of documents and reports

Statistical reports submitted, among other things, by the bodies that oversee labor protection and work-related injuries in the Russian Federation (the Federal Service for Labor and Employment (Rostrud)), open data on occupational risks (work-related injuries), and the current legal acts ensuring the safety of industrial facilities, structures of technological processes and equipment were studied.

While analyzing the reporting documents for the period 2012-2021, we used the indicators of industrial injuries and the identified causes of injuries. This analysis determines the comparative dynamics of injuries by years, industries, organizations, professions, etc. [28-30]. The analysis should establish the total number of accidents that occurred due to technical reasons related to industrial facilities and structures, imperfect technological processes, violations, and production equipment, including technological equipment. The data obtained were used to determine changes in accidents for the

periods of 2012-2021, shortcomings in the collection and presentation of information on work-related injuries, and inconsistencies in regulatory legal requirements.

2.3 Monographic method and statistical analysis

To determine specific circumstances of occupational accidents, a monographic method is used to identify potential workplace hazards [31, 32].

Statistical methods for processing the results were based on Excel capabilities to more accurately track the number of accidents related to technological equipment [33], perform modeling [34] and forecasting [35] of the process, and reveal trends in occupational injuries for two reasons:

- Design flaws, insufficient reliability of machines, mechanisms, and equipment;
- The operation of faulty machines, mechanisms, and equipment.

3. RESULTS

3.1 The analysis of regulatory and legal regulation to ensure the safety of industrial facilities, structures, technological processes, and production equipment

The scientific results obtained show that regulation is ensured by various documents at different stages of the life cycle of these technical elements. In the Russian Federation, two main areas have developed containing requirements for ensuring the safety of production processes. They are enshrined in:

- Federal Law “On Technical Regulation” of December 27, 2002 No. 184-FZ [36];
- Labor Code of the Russian Federation of December 30, 2001 No. 197-FZ [7].

According to the Federal Law “On Technical Regulation” [4], Technical Regulations have been developed to govern relations arising in the development, adoption, application, and implementation of mandatory requirements for products, including facilities and structures, or products and design processes related to production, construction, installation, commissioning, operation, storage, transportation, sale, and disposal requirements. These do not apply to requirements in the field of labor protection, including socio-economic, organizational, sanitary, hygienic, medical, preventive, and rehabilitation measures.

The Labor Code of the Russian Federation contains state regulatory requirements for labor protection, which establish rules, procedures, criteria, and standards aimed at preserving the life and health of workers, i.e., relationships that arise in the course of work. Legal acts containing state regulatory requirements in the field of labor protection include:

- Labor protection rules;
- Uniform standards for providing employees with free personal protective equipment.

A special role is played by the national standardization system. Its standards contain the following requirements:

- Confirm the compliance of products, design processes, production, construction, installation, adjustment, operation, storage, transportation, sale, disposal, works, services, or other objects;

- Ensure the safety of technological processes;
- Promote compliance with labor protection rules (labor safety standards).

Currently, the requirements of these standards are rather advisory, except for cases when they are used for the mandatory certification of products and compliance confirmation.

The safety of technological processes is governed by technological regulations and national standards. Technological regulations relating to hazardous production facilities and approved by the relevant federal supervision services are mandatory.

3.2 The analysis of statistical data on work-related injuries

We considered data on work-related injuries and industrial accidents. The analysis of industrial injuries with severe consequences in the period from 2012 to 2021 (Figure 1) showed the following results:

- There is a general trend of reducing industrial injuries;
- The main technical reason is a violation of the technological process (from 292 to 510 accidents);
- The second reason is the operation of faulty machines, mechanisms, and equipment (from 83 to 284 accidents);
- The third reason (average values for 10 years almost coincide) is the unsatisfactory technical condition of facilities, structures, and territories (from 88 to 212 accidents) and design flaws and insufficient reliability of machines, mechanisms, and equipment (from 92 to 159 accidents);
- The last reason is the imperfection of the technological process.

The data on work-related injuries associated with the unsatisfactory technical condition of buildings, structures, and territories differ by type of economic activity. The largest number of industrial accidents occurs in manufacturing industries, construction, and agriculture. All in all, we analyzed the data on severe injuries in these industries for 2018-2021 (for example, the highest indicator was in the manufacturing industry in 2019 (27 people); the lowest in agriculture, forestry, hunting, fishing, and fish farming in 2020-2021 (8 people)).

For this period, we also compared the data on work-related injuries associated with the imperfection of technological processes for various types of economic activity. The largest number of industrial accidents occurs in the manufacturing industry (for example, 20 people in 2019). Significant indicators were typical of construction and mining (10 people and 4 people, respectively, in 2019).

The data presented in Figures 2 and 3 show a general downward trend in occupational injuries due to design flaws, insufficient reliability of machines, mechanisms, and equipment, and the operation of faulty machines, mechanisms, and equipment in 2012-2021. However, the injuries caused by design flaws and insufficient reliability of machines, mechanisms, and equipment had a clear downward trend in 2012-2013. In the period from 2015 to 2020, there was no clear downward trend. The trend line of injuries caused by the operation of faulty machines, mechanisms, and equipment also demonstrated a clear decrease between 2012 and 2016. In the period from 2016 to 2021, there was no significant decrease. In recent years, there has even been an upward trend.

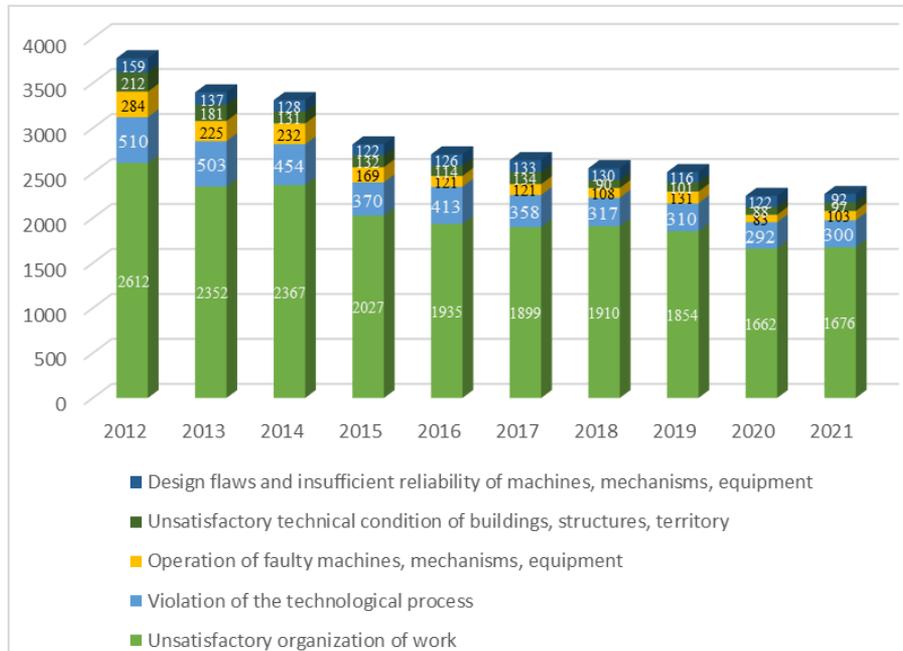


Figure 1. Severe industrial accidents caused by technical causes between 2012 and 2021

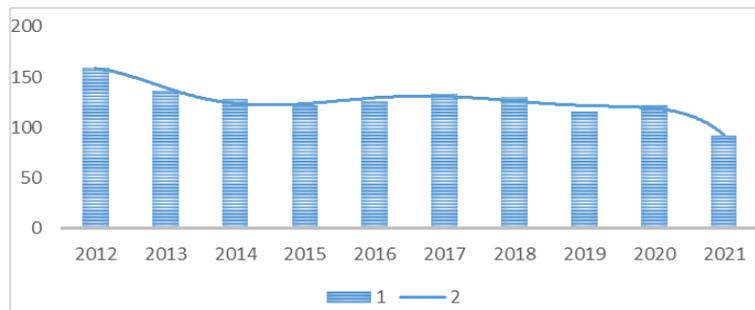


Figure 2. The indicators of work-related injuries with due regard to design flaws and insufficient reliability of machines, mechanisms, and equipment, where: 1 – actual indicators; 2 – trend line

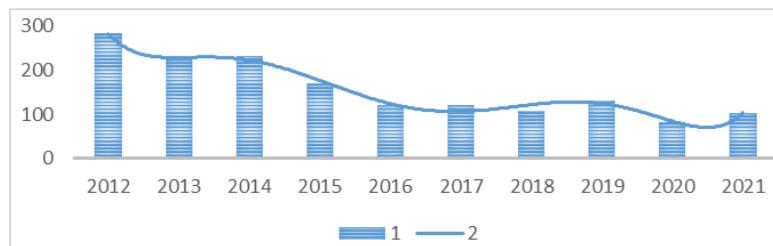


Figure 3. The indicators of work-related injuries with due regard to the operation of faulty machines, mechanisms, and equipment, where: 1 – actual indicators; 2 – trend line

4. DISCUSSION

4.1 The development of uniform recommendations to reduce professional risks

To develop recommendations for reducing occupational risks associated with work-related injuries during the operation of industrial facilities, structures, technological processes, and equipment, as well as recommendations for reducing work-related injuries and improving legal regulatory requirements, it is necessary to highlight the main conclusions.

The above-mentioned results show that there is a system that contains state requirements and regulates procedures

throughout the life cycle of production elements to ensure their safety and the safety of production processes. However, the analysis of statistical data on work-related injuries revealed that despite the decrease in injury rates there are still considerable occupational risks (risks of work-related injuries) associated with industrial facilities, structures, and equipment, imperfect technological processes, and violations. Accordingly, an important reason for the realization of occupational risks is not only the imperfection of technological processes but also a violation in their execution. As the results of our research have shown, the largest number of accidents occurs in manufacturing industries, followed by construction and mining. First of all, this is due to the fact that

a lot of industrial equipment is used in manufacturing, but high qualifications are not required to perform production tasks, such as in the gas or oil industry. However, the use of equipment is traumatic, so it is important to follow the recommendations for improving the safety of production equipment and facilities. Moreover, the number of accidents due to non-compliance with the rules of use of equipment exceeds the indicators due to the imperfection of technological processes.

Preventive measures to reduce occupational risks in production processes include the strict compliance of industrial facilities, structures, and production equipment with the safety requirements laid down in the relevant technical regulations [14]. Mandatory requirements for technological processes are technological regulations related to hazardous production facilities and approved by the relevant federal supervision services of Russia. In our opinion, there is a need for a regulatory act containing mandatory state requirements for all production processes. In addition, employers should take measures, such as training and education [1, 37], the use of personal protective equipment [15, 38], the introduction of technical controls [16], regular risk assessment [7], and workplace culture [5], to reduce these risks.

Based on the results obtained, we should also pay attention to the creation and use of feedback, which allows, based on systematization and generalization of the causes that led to work-related injuries, to develop recommendations for amending regulatory and legal documents that impose safety requirements on industrial facilities and structures, industrial equipment and technological processes [39].

First of all, in our opinion, organizational and production measures are necessary. As for organizational measures, to implement feedback, it is necessary to create a unified system for transmitting information about work-related injuries as an important element in the further digitalization of work. In 2011, the database “Fatal and severe injuries in the agro-industrial complex of the Russian Federation” was registered. The retrospective search of information on fatal injuries and severe injuries embraces 22 years and 13 years, respectively. An accident entered into the database is described using 40 features, each of which has from 2 to 500 gradations [40]. However, a unified database has not been created yet.

In our opinion, the production measures aimed at reducing occupational risks and ensuring safety during operation and before the commissioning of production equipment and new workplaces should be based on two fundamental rules:

- Machines, mechanisms, and other production equipment, including foreign technological production, that are put into operation must comply with state safety requirements and have mandatory compliance in the cases established by the legislation of the Russian Federation on technical regulation;

- Measures to ensure safety during the operation of industrial technological equipment should be based on the strict implementation of the relevant state regulatory requirements. Therefore, when organizing new jobs, the arrangement of equipment, the location of internal transport routes, etc. must comply with labor protection rules.

4.2 The implementation of checklists and additional regulatory documents

When examining accidents in the workplace (work-related injuries), we need additional measures to identify and describe the causes. It is necessary to indicate what shortcomings in

production equipment led to the realization of this type of occupational risk.

We propose to develop additional documents and include them in the existing system for investigating industrial accidents. Checklists are necessary for the timely and clear identification of valid technical reasons. Possible problems with the implementation of checklists may be related to the fact that questions (bullet points) should be clear and simple to obtain a reliable answer, regardless of the level and type of education and knowledge in the field of production processes of persons investigating work-related injuries. Problems may also arise with the unification and automation of checklists at enterprises of different industries, since the risks of injury are highest in industries with difficult working conditions. Moreover, such checklists are required when investigating all incidents related to industrial technological equipment, regardless of the severity of consequences, including minor injuries.

It is also recommended to include several bullet points in checklists to identify causes and analyze the causes of injuries associated with production equipment:

- The lack of safety fencing;
- Link breakage;
- Fatigue failure;
- The wrong location of the emergency stop button;
- Limited visibility of the equipment operator from the workplace;
- Redundant, insufficient, or ambiguous information necessary to control the machine and/or equipment;
- An indication at what stage of the life cycle of equipment an accident occurred, etc.

If necessary, amendments should be made to the relevant standards governing the safety of production equipment. Such amendments will ensure the safety of production equipment and eliminate design flaws.

We also propose to include the following bullet points in checklists for identifying causes and analyzing the causes of injuries associated with industrial facilities and structures (including their constituent networks of engineering and technical support and systems of engineering and technical support):

- Insufficient mechanical resistance that led to destruction;
- Failure to ensure fire safety;
- Instability to natural hazards or man-made impacts;
- Dangerous conditions for human health in facilities and structures (illumination, microclimate, excessive noise, vibration, various types of radiation, etc.);
- Dangerous facilities and structures, etc.

The generalization and systematization of the identified causes (violations that led to work-related injuries) allow amending the relevant articles of the Technical Regulations on the safety of facilities and structures, the Rules for the mandatory assessment of the conformity of facilities and structures, and the operational processes associated with such facilities and structures.

4.3 The development of safety requirements in the field of labor relations between employers and employees

Labor protection acts regulate the mandatory safety requirements that develop in the field of labor relations between employers and employees when working in industrial facilities and structures and utilizing industrial technological equipment.

When examining professional risks associated with equipment, first of all, it is necessary to identify the reasons associated with the organization of workplaces, for which the employer is responsible [5, 7, 16]:

– The lack of proper control over the technical condition of facilities and structures: Employers should conduct regular risk assessments to identify potential hazards in the workplace, including the state of facilities and structures, and take measures to reduce or eliminate these risks;

– Equipment safety training programs: Training workers on how to use machines and hazardous materials can significantly reduce occupational risks. Workers should be trained in safety protocols and procedures, as well as how to respond to emergencies;

– No proper supervision of machines and equipment and the operation of faulty equipment: employers should maintain and inspect machines to ensure that they are in good condition;

– Separation distances between equipment and facility structures: Production processes often involve the use of heavy machinery, chemicals, and other hazardous materials that can pose significant occupational risks to workers and facilities;

– Improving workplace culture: Creating a safety culture in the workplace can significantly reduce occupational risks. Employers should encourage workers to report hazards and incidents and provide incentives for safe behavior.

The identification, systematization, and generalization of such reasons as insufficient separation distances between equipment and building structures, dimensions of installation sites, etc. might be the basis for amending labor protection rules when placing, installing, maintaining, and repairing technical equipment.

Since modern regulatory legal acts in the field of labor protection provide an opportunity to use digital technologies to ensure safety, their use, including video surveillance, allows monitoring technological activities at all stages of the labor process. The analysis of such records will allow one to identify the causes of accidents in the operation of industrial facilities, structures, and production equipment and the execution of technological processes.

5. CONCLUSION

The research question was based on the need to obtain feedback, whose essence is that the analysis and systematization of the technical causes of injuries are used to improve legal acts that regulate safety requirements for industrial facilities, structures, equipment, and technological processes.

The study of work-related injuries showed that there has not been a downward trend in recent years. The study proposes the creation and use of feedback, which allows, based on systematization and generalization of the causes that led to work-related injuries, to develop recommendations for changing regulatory and legal documents. We suggest forming special checklists indicating sample questions and a unified database of work-related injuries. It is also proposed to increase the legal status of documents that impose requirements on production processes. These solutions will reduce occupational risks (work-related injuries).

The conducted studies have shown that there is a well-established system of normative and legal regulation of production safety in the Russian Federation, both through the system of technical regulation and through the implementation

of labor protection rules. The latter allows employers to implement effective preventive measures when creating new jobs, ensuring the safety of production processes and reducing occupational risks. The existing state regulation of production safety and corresponding legal acts have their scope and specific features.

Based on the type of research, we focused on the analysis of occupational risks based on open statistical data on injuries demonstrates that a significant part is associated with production equipment, imperfect technological processes, or unsatisfactory conditions of industrial facilities and structures.

In future studies, it is proposed to conduct an experimental study on the introduction of checklists to receive feedback, which will help reduce occupational risks in production processes.

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