Assessment of an occupational risk using injury safety indicators

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Abstract An analytical data mining approach to the assessment of an occupational risks is proposed and based on the use of an injury safety indicator, which allows to determine the degree of safety (hazard) of the workplace, to carry out statistical processing of the results collected with its help, which will help with further planning of labour protection measures. The results of an occupational risk assessment with the use of an injury safety indicator make it possible to predict the levels of occupational risks at various workplaces, which makes it possible to develop the optimal management decisions for the preservation of the life and health of workers in enterprises. The prospect of using data mining methods in the tasks of labour protection management at an enterprise opens up the possibility of creating decision-making mechanisms that take into account the dynamic state of the working environment and make it possible to increase the validity of the choice of priority labour protection measures.

Keywords: safety, risk, occupational risk, indicators, safety indicators.

1 Introduction

Currently, a large and laborious work is being carried out in the country to develop a unified methodology for assessment occupational risks in the framework of creating a management system of labor protection in the organization. While there is no approved methodology, every company can use almost any recommended one that will reflect its specificity [1,14].

Our article discusses the application of the methodology for assessment occupational risks, based on the notion of injury safety. This procedure was canceled with the certification of workplaces, however, the gap that was formed as a result of the cancellation of the injury safety indicators used in the complex of assessments of working conditions has not yet been filled [13].

Why are injury safety indicators chosen as the base of occupational risks assessment methodology?

Injury safety is the property of workplaces to comply with occupational safety requirements, excluding the injury of workers under the conditions established by regulatory legal acts [2,11].

Injury safety of workplaces is ensured by fulfilling the requirements that exclude damage to human body parts, which can be obtained as a result of:

- mechanical effects of moving objects, mechanisms or machines, as well as their fixed elements in the workplace. This items, for example, are: toothed, chain, V-belt drives, crank mechanisms, moving tables, rotating parts, controls, etc.;
- exposure to electric current. The source of damage can be unprotected and uninsulated electric wires, damaged electric motors, open switches, non-grounded equipment, etc.;
exposure to elevated or lowered temperatures. Thermal effect of heated (cooled) elements of equipment, processed raw materials and other coolants;

- exposure to aggressive and toxic chemicals. For example, chemical burns with strong acids, caustic alkalis, and toxic chemicals (chlorine, ammonia, etc.) when they come into contact with the skin or lungs when inhaled;

- damage caused by falls. Falls are divided into two types: falling on a person of various objects and falling of a person as a result of slipping, stumbling, falling from a height or a sudden deterioration in health [3].

The objects of assessment on the injury safety factor at the workplace are:

- production equipment;
- fixtures and tools;
- availability of means of training and instruction.

Therefore, the use of an injury safety indicator in the development and implementation of an occupational risk assessment methodology allows, in addition to its direct purpose - to determine the degree of safety (danger) of the workplace, to display practical value — statistical processing of the results collected with its help, which will help with further planning of labor protection measures [12]. For example, using such an assessment of occupational risks, it can predict the level of industrial injuries.

2 Method

The solution of the task - the assessment of occupational risk using methods of injury safety indicator should:

- to identify the effects of individual production factors that are or may be dangerous and harmful;

- determine the presence and level of safety or the nature and degree of danger and harmfulness of the evaluated types of production equipment and production processes, as well as workplaces, sites, shops and entire enterprises;

- to compare the safety indicators of similar types of production processes.

These tasks can be implemented by assessment the fulfillment of safety requirements for production equipment, devices, tools, means of training and instruction, special requirements should be taken into account that are given in the rules on labor protection (LP) and other regulatory legal acts (RLA) for workplaces of specific types of production processes: requirements for the territory, for the elements of buildings and structures.

The main methodological principle of assessment an occupational risk using an injury safety indicator is comparing the actual state of the assessment objects (production equipment, devices and tools, as well as providing training and instructional facilities) with safety requirements, regulatory legal acts, operational and technological documents.

Safety requirements evaluated include:

- compliance with the maximum permissible levels of hazardous and harmful production factors characteristic for the estimated object;

- the absence of hazardous areas on the estimated object which the documents do not provide for collective protection and (or) use of working personal protective equipment;

- the provision of protective equipment provided in the documents to prevent exposure to working hazardous and harmful factors appearing on the evaluated object.

The comparison is carried out in the following ways:

- visual (an external examination is carried out, as a result it is necessary to ensure the availability of protective equipment, the presence and compliance of signal colors and safety signs, fences, etc.);

- expert (for carrying out assessments related to measuring the parameters of protective equipment, for example, determining the safety of gaps in fences, correctness, tonality or
location of sound or light signaling devices, also to obtain an assessment of individual objects attract experts in a certain area of equipment safety);

- experimental (for evaluation, where calculations and tests of safety devices are necessary, trial starts and equipment stops are carried out, in compliance with labor protection requirements;

- on technical documentation (verification of the availability of acts of acceptance, permits for use of assessment objects, certificates; availability and structure of passports and operating instructions for equipment, devices and tools; availability, content and structure of training and instructional facilities (content must be compared with the requirements of inter-sectoral and sectoral regulations on occupational safety and health, typical industry instructions;

- by interviewing people working in workplaces where the assessment of working conditions is carried out on the basis of the injury safety factor, or from relevant specialists (carried out as an additional subjective assessment in cases of complex work organization, with a large number of objects, with a large spread in space), it turns out: in the workplace, where, according to the respondents, there is a danger of injury, poor floor conditions, the absence of railings on stairs, etc.

The main stages of the assessment are:

- verification of the necessary technical documentation on the objects of assessment in terms of occupational safety;

- verification of the overall performance of the equipment in accordance with the regulated modes, as well as the reliability of the process;

- checking the stability of the design of the machine as a whole and its individual components, identifying unacceptable oscillations of the core or increased vibration of individual parts;

- for each item of the requirements of the RLA that is applicable and subject to assessment of the assessment objects, the availability of appropriate protective equipment (fencing, alarm systems, braking devices, interlocks, etc.), controls, including emergency stop and specially provided automation and mechanization tools, is checked;

- if the workplace due to reasonable technical unattainability does not exclude the impact of hazardous factors on the staff (for example, moving objects), then the implementation of other safety measures is evaluated: the presence of alarms, personal protective equipment, the description in the labor protection manual of safe working methods.

The mathematical model of this method can be represented as follows. The fulfillment or non-fulfillment of each individual safety requirement is called a single evaluation indicator. The result of combining assessments for a group of individual indicators is called a group complex indicator, and the results of combining evaluations for a group of single indicators are called a generalized complex safety indicator of the object being assessed.

The only indicators of the first category are the parameters characterizing hazardous and harmful production factors and are normalized in hygienic and ergonomic documents. Such parameters can be, for example, temperature, humidity and air movement of the working area, the content of various harmful substances in it, the amount of muscular effort performed by workers when moving goods manually, etc.

The values of parameters on the evaluated object are compared with their maximum permissible levels.

The only indicators of the second category are information about the means of protection that prevent the dangerous and harmful effects of each individual production factor, and for factors acting locally, in addition, separately for each danger zone. In conducting the assessment, the availability of protective equipment and their compliance with specified functions are taken into account, and, after being put into production, the operability of the protective equipment used and compliance with the rules for their operation are also taken into account. Evaluate the provision of all the means of protection provided for in the documents, and, if it necessary, also as additional means of protection used in the decisions of the company's management. At the same time take into account remedies:
- included in the design of the equipment - protective fences, screens, protective blocking systems, built-in exhaust ventilation devices (local suction units), etc.;
- general for production premises or for a number of objects in it - ventilation devices, fire and explosion protection facilities, etc.;
- personal protective equipment - helmets, respirators, overalls, etc.

For a general characteristic of the object being evaluated, it is necessary both to evaluate all the individual indicators taken into account, as well as various methods of comparing them in complex indicators. For the most part, the use of both differential and complex methods, that is, a mixed assessment method, is most appropriate. With such an approach, it becomes possible both to formulate individual particular tasks of ensuring security and to give a general characteristic of the object being evaluated.

Differential assessment of all indicators taken into account on a binary scale (there is safety or no safety) is a mandatory prerequisite for further more detailed assessment of use in the management of labor protection. In some cases, for example, if necessary to take into account information on the results of the assessment, among other data on the object being evaluated (on its technical, economic characteristics, etc.), it may be necessary to express the results of a binary assessment in the form of a generalized complex indicator. The value of each single indicator is taken if the safety requirements are equal to one, and if they do not, they are equal to zero. The generalized workplace safety indicator is calculated as follows.

After assessing the compliance of the workplace with the safety requirements, the points “yes” and “no” are counted. For a quantitative assessment of occupational risk, we use the Elmeri index (the so-called IBRM safety index), the percentage ratio, the value of which can be from 0 to 100: In this case, the workplace safety index is:

$$I_{brm} = \frac{N_{sr\text{(real)}}}{N_{all}} \times 100\%$$

(1)

Where - $N_{sr\text{(real)}}$ number of security requirements implemented;
$N_{(all)}$ - total number of requirements.

If for any reason it is not possible to estimate this indicator or it cannot be determined by the observation method, then in the corresponding column of the observation map the mark “absent” or “0” is indicated.

**Figure 1.** Algorithm of work of an occupational risk assessment methodology using safety measures of injury
For risk ranking, the following proportion can be used: according to the averaged data of domestic and foreign researchers, for every 10,000 violations of labor safety requirements (incomplete machines with collective protection equipment, lack of personnel training, non-use of equipment or personal protective equipment, and much more), there are 100 injuries disability, 10 injuries with a disability and one fatal injury.

However, since the consequences of violations (or non-compliance) of labor protection requirements do not have the same consequences the scale includes the category of identified non-conformance indicators, which is reflected in the comments column (Table 1).

### Table 1. Occupational Risk Ranking Rating Scale

| №  | Type of risk            | Comments                                                                 |
|----|-------------------------|--------------------------------------------------------------------------|
| 1  | Low risk (IBRM =100%)   | All safety requirements are met, additional, above-standard measures are carried out. There are no repair works and works of increased danger in the scope of work. |
| 2  | Acceptable risk (IBRM =100%) | All safety requirements are met, additional, above-standard measures are carried out. There are no repair works and works of increased danger in the scope of work. |
| 3  | Average risk (100%>IBRM>80%) | There are unfulfilled requirements included in the set of safety requirements for this workplace. Probable consequences of their non-fulfillment are: micro-injuries and injuries with the transfer of an employee to light labor. |
| 4  | High risk (80%>IBRM>50%) | There are unfulfilled requirements included in the set of security requirements for this workplace. Probable consequences of their non-compliance are: severe injuries with a severity of over 60 days of disability |
| 5  | Very high risk (50%>IBRM>30%) | There are unfulfilled requirements included in the set of security requirements for this workplace. Probable consequences of their non-compliance are: injuries with a disability outcome, permanent disability (disability); loss of professional working ability of 20% and above, etc. |
| 6  | Unacceptable risk (IBRM <30%) | There are unfulfilled requirements included in the set of security requirements for this workplace. Probable consequences of their non-compliance are: fatal injuries. |

The classification of injury safety is based on the principle of increasing the severity of the expected consequences of injuries, similar to the increase in the severity of the impact of hygienic factors.

Occupational risk assessment using an injury safety indicator is carried out at three levels depending on the number of violations detected and the category to which they fall.

### 3 Results

An occupational risk assessment of the employee - reel stacker has conducted on the basis of the above methodology. The workplace has equipment that is used in fiberglass production, called creel.

As a result of the preliminary work on the study of working conditions in the workplace, the following initial data were used:
- scheme and plan of equipment placement;
- technical documentation on the equipment, including the design of the equipment, the technological process.

In addition, the production manager and the workers themselves - the reel shakers were interviewed.
Thus, the obtained initial data formed the basis for the occupational risk assessment using the safety measures of the equipment we chose.

4 Discussion

The creel is a metal frame on which bobbin holders thread guides, frames with tensioning devices, signaling devices and contact hooks of the machine's automatic stop mechanism when the thread breaks are placed.

The creel - consists of two floors - 3.5 thousand places for reels on each floor (in the amount of 7 thousand reels), is attached to the foundation with anchor bolts. Racks creel made of cast iron pipes, rigidly connected by ties.

In the design, combs with porcelain "flags" are used, which ensures reliability in passing the threads and prevents them from sagging.

The general scheme of the workplace of the reel stacker whose professional risk was assessed using the method described above is shown in Figure 2.

![Figure 2. The overall scheme of the workplace stacker reel](image)

The analysis of the initial data allowed to determine the list of regulatory legal acts, in which the requirements for the workplace of the stacker of reels are indicated.

Evaluation of the described equipment was carried out according to the method by comparing (comparing) the actual state with the requirements of regulatory legal acts, operational and technological documents. The basis for the assessment are the requirements of documents for the creel equipment, for the means of training and instruction. For example, according to the creel's design, the condition of the equipment was considered safe if:

- no visible damage, is in a stable position;
- there are no sharp edges and corners that can lead to injuries;
- there are no unprotected moving parts;
- there is information about the timely conduct of the test;
- signal colors are applied to the equipment, there are clear and clearly visible safety signs, etc. for other requirements.

As a result of the occupational risk assessment of the supplier of reels, according to the described method, the following discrepancies were found to meet the requirements of regulatory legal acts, operational and technological documents:
1. The design of the workplace does not provide a comfortable working posture and performance of labor operations within the reach of the motor field (installation of reels on the cobbling holder is carried out at a distance of 800 mm from the edge of the working surface [5].

2. The direct and free position of the body of the worker or its inclination in front of not more than 15 degrees from the vertical is not ensured [6], [7].

3. The size of the passage between the sections constituting 576 mm will be impeded by the presence of the worker installing the reels [6].

4. Installation of bobbins on the upper bobbin holders is planned to be carried out from a ladder of 1.4 m in height, climbing this ladder with a bobbin in hand increases the load on the musculoskeletal system and the risk of injury due to falling from the ladder.

5. With a mass of one reel from 6-7 kg and 19-20 kg and the total number of reel moved (movement frequency per shift) from 1000 to 1070 pcs. during the work of 2 drivers, the arising load exceeds the permissible norms [8, 9].

6. The movement of workers up and down the stairs leads to an increase in physical activity and creates the risk of injury due to possible slipping on the steps.

7. Means of training and instruction are made in violation of the requirements of the Methodological Recommendations for the development of state regulatory requirements for labor protection.

According to the data obtained when evaluating equipment creel \((N_{\text{tripmax}}=5, \ N_{\text{calc}}=15)\) the workplace safety index takes the following value:

\[
I_{\text{opm}} = \frac{5}{15} \times 100\% = 33.3\% \tag{2}
\]

That according to the rating scale corresponds to a very high risk and requires the immediate development of appropriate measures.

5 Conclusion
This method of occupational risk assessment allows to plan labor protection measures with a specific goal - to eliminate the identified non-compliances. Formation of the organization’s modern views on the planning of activities in the field of labor protection is one of the most important conditions for the implementation of a modern system of labor protection management in an organization.

However, the technique requires refinement in identifying and identifying hazards in the workplace so that in practice the occupational risk assessment does not translate into a statement of the presence or absence of violations of labor protection requirements.

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