UDC 331.45 https://doi.org/10.23947/2541-9129-2020-4-17-23

Calculation of collective risk of foundry professional groups based on the analysis of individual risk of each employee

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Introduction. The article presents the technique of the definition of integral risk in the organization, on the basis of which the collective risk of several professional groups involved at the foundry is calculated.
Problem Statement. The purpose of this study is to calculate the collective risk in the foundry.
Theoretical Part. The initial data are the values of individual occupational risk of employees depending on their age, work experience, gender and disability, as well as the quality of working conditions, injury risk and susceptibility to the development of occupational diseases.
Conclusion. The results of the calculation indicate a high collective risk of professional groups of the foundry, which requires the development of corrective engineering or organizational measures.

Keywords: foundry, working conditions, professional groups, individual and collective risk.

For citation: Maslenskiy V. V., Lyubetskaya N. A. Calculation of collective risk of foundry professional groups based on the analysis of individual risk of each employee: Safety of Technogenic and Natural Systems. 2020;4;17−23. https://doi.org/10.23947/2541-9129-2020-4-17-23

Introduction. The tasks to reduce harmful and (or) dangerous effects of industrial environment factors that cause injuries and the development of occupational diseases of employees are considered as one of the highest priorities in our country. In this regard, the vast majority of enterprises must ensure the effective functioning of the Occupational Health and Safety Assessment System (OHSAS), aimed at predictive assessments of working conditions and safety. To do this, there are currently a huge number of different methods for predicting risks, which the employer has the right to choose independently.

Relevance of the Research Topic. Unfortunately, the experience of studying this issue shows that mostly the least advanced methods are used, which are not able to take into account absolutely all the factors that affect the risk. For example, at one of the machine-building enterprises of the Rostov region (OOO "PK "NEVZ", Novocherkassk) the matrix method of risk assessment is used by which the occupational health service of OOO "PK "NEVZ" managed to build a risk map (Fig. 1), which shows the units of the enterprise that are most exposed to risk-contributing factors.

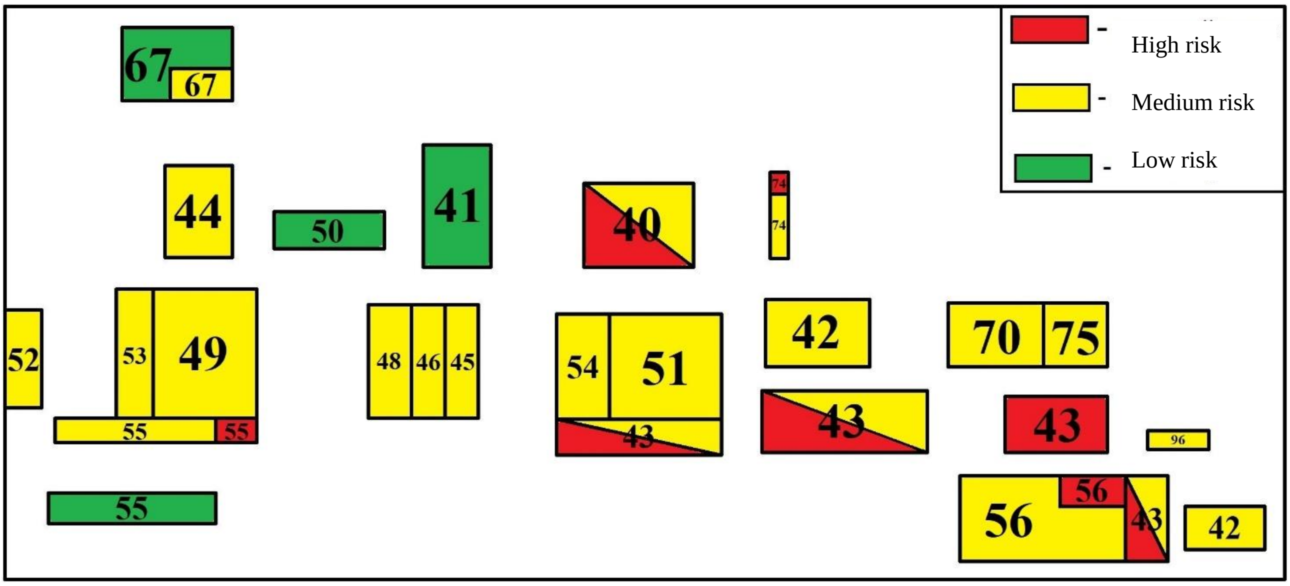

Fig. 1. Risk map of the OOO "PK "NEVZ"

However, there was revealed a number of shortcomings during the analysis of the application of this method in the foundry No. 40:

— only hazards are considered as input data for the assessment, while the amount of harmful factors, significantly contributing to occupational risk, remain unaccounted for;

— there is no risk assessment for occupational diseases;

— the role of the degree of protection of employees with personal protective equipment that reduces the negative impact of environmental factors is not clear;

— health status of employees is not taken into account, the deterioration of which may aggravate the impact of harmful and (or) dangerous factors;

— employees' personal data (gender, age, work experience), which may indicate the reasons for violations of labor protection requirements and may help identify them in the future, are not taken into account.

The method of assessment of collective exposure of workers compensate for all of the above disadvantages, which is a statistical value obtained by analyzing records of individual occupational risk (IOR) of employees, classified by professions or by business units.

Problem Statement. In addition to the methodology for IOR determination, which is the basis for collective risk calculation, there are other numerical methods for assessing risk for an employee, but their application directly affects the reliability of the result. For example, in [1], the previously mentioned matrix method is presented, which consists in expert determination of the probability levels of an adverse event and the severity of its consequences. The result of risk assessment using the matrix method is the construction of a matrix in which the classification of risks is made depending on their magnitude (table 1). There are acceptable risks (< 20), medium risks (from 20 to 39), strong risks (from 40 to 99) and unacceptable risks (> 100).

Table 1

Risk matrix

Severity (coefficient) / Probability of impact (coefficient)	Non-life-threatening injuries (2)	LIGHT (6)	MEDIUM (10)	HIGH (20)
Seldom (2)	4	12	20	40
Often (6)	12	36	60	120
Very often (10)	20	60	100	200

The advantages of this method are its simplicity and low requirements for expert qualification.

The logical-probability method [2] is much more accurate than the matrix method. Its advantage is associated with the assessment of the possibility measure of adverse events implementation, including actual values of the impact parameter s and susceptibility parameter value r defined on the basis of hygienic standards. As a result, based on the data obtained, we can construct a possible form of the function for the implementation of any adverse event (Fig. 2).

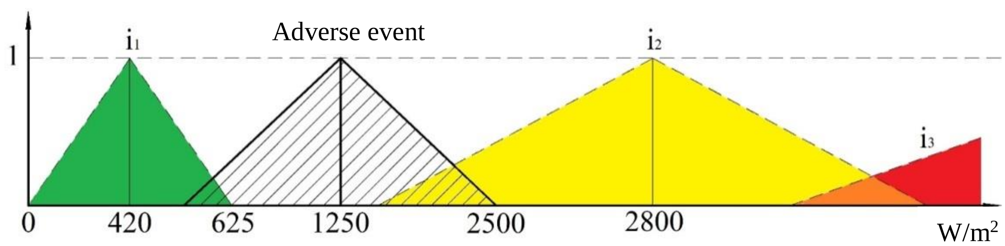

Fig. 2. The possible form of the function of implementation of an adverse event when exposed to thermal radiation: i_1 — easy outcome; i_2 — difficult outcome; i_3 – fatal outcome

The purpose of this study was to determine the collective risk of employees of the most numerous and exposed to workplace hazards professional groups of the foundry, based on the values of their individual risk of injury and the development of occupational diseases.

The objects of the study, i.e. professional groups, were represented by employees of the professions "Molder", "Hand-formed rod maker" and "Metal and alloy smelter". The number of employees is shown in table 2.

Table 2

Number of employees of some professional groups of the foundry of the OOO "PK "NEVZ"

	Number of employees in the profession		
	"Molder"	"Hand-formed rod maker"	"Metal and alloy smelter"
at all similar workplaces	10	24	4
among them:			
women	9	17	0
persons under the age of 18	0	0	0
disabled persons allowed to perform work at this workplace	0	4	0

The initial data for the calculation of collective risk were the values of employees' IOR depending on their age, work experience, gender and disability (table 3) [3-5].

Table 3

IOR values of employees of some professional groups of the foundry of the OOO "PK "NEVZ"

Gender	Age	Experience	Disability	IOR values of employees in the profession		
				"Molder"	"Hand–formed rod maker"	"Metal and alloy smelter"
men	18–27	0–10	–	–	0.23	–
	28–37	11–20	–	–	0.30	0.34
	38–47	21–30	+	0.48	0.43 (0.86)*	0.46
	48–57	31–40	+	–	0.45 (0.59)	–
	58–67	41–50	–	–	–	–
women	18–27	0–10	–	0.25	0.20	–
	28–37	11–20	–	0.37	0.35	–
	38–47	21–30	–	0.44	0.36	–
	48–57	31–40	+	0.51	0.41 (0.62)	–
	58–67	41–50	+	–	0.56 (0.83)	–
* the values of IOR for employees with disabilities are shown in parentheses						

Theoretical Part. For the calculation basis for collective risk finding, the method of determining the integral indicator of the level of occupational risk in organizations [6] is taken, which includes the following sequence:

1. Summation of the values of IOR of each employee's individual professional group (IOR_i):

$$КР = \sum_{i=1}^{m} IOR_i, \quad (1)$$

where m — the number of employees in the professional group.

$$КР_з = 0,48 + 0,25 \cdot 3 + 0,37 \cdot 3 + 0,44 \cdot 2 + 0,51 = 3,73;$$

$$КР_с = 0,23 \cdot 2 + 0,30 + 0,43 + 0,86 + 0,45 + 0,59 + 0,20 \cdot 7 + 0,35 \cdot 5 + 0,36 + 0,41 + 0,62 + 0,56 + 0,83 = 9,02;$$

$$КР_п = 0,34 \cdot 2 + 0,46 \cdot 2 = 1,60.$$

2. Calculation of the average value of the collective risk of a separate professional group:

$$КС = КР/m. \quad (2)$$

$$КС_з = 3,73/10 = 0,37;$$

$$КС_с = 9,02/24 = 0,38;$$

$$КС_п = 1,60/4 = 0,40.$$

3. Summation of squared deviations of IOR values of every employee of each individual professional group from the mean collective risk value of individual professional group:

$$КК = \sum_{i=1}^{m}(IOR_i - КС)^2. \quad (3)$$

$$КК_з = (0{,}48 - 0{,}37)^2 + (0{,}25 - 0{,}37)^2 \cdot 3 + (0{,}37 - 0{,}37)^2 \cdot 3 + (0{,}44 - 0{,}37)^2 \cdot 2 + (0{,}51 - 0{,}37)^2 = 0{,}0847;$$

$$КК_с = (0{,}23 - 0{,}38)^2 \cdot 2 + (0{,}30 - 0{,}38)^2 + (0{,}43 - 0{,}38)^2 + (0{,}86 - 0{,}38)^2 + (0{,}45 - 0{,}38)^2 + (0{,}59 - 0{,}38)^2 + (0{,}20 - 0{,}38)^2 \cdot 7 + (0{,}35 - 0{,}38)^2 \cdot 5 + (0{,}36 - 0{,}38)^2 + (0{,}41 - 0{,}38)^2 + (0{,}62 - 0{,}38)^2 + (0{,}56 - 0{,}38)^2 + (0{,}83 - 0{,}38)^2 = 0{,}8584;$$

$$КК_з = (0{,}34 - 0{,}40)^2 \cdot 2 + (0{,}46 - 0{,}40)^2 \cdot 2 = 0{,}0104.$$

4. Determination of the collective risk value of a particular professional group:

$$КВ = (m - 1)/КК. \quad (4)$$

$$КВ_з = (10 - 1)/0{,}0847 = 106{,}26;$$

$$КВ_с = (24 - 1)/0{,}8584 = 26{,}79;$$

$$КВ_п = (4 - 1)/0{,}0104 = 288{,}46.$$

5. Calculation of the weighted average value of the collective risk of a separate professional group:

$$К = КВ \cdot КС. \quad (5)$$

$$К_з = 106{,}26 \cdot 0{,}37 = 39{,}32;$$

$$К_с = 26{,}79 \cdot 0{,}38 = 10{,}18;$$

$$К_п = 288{,}46 \cdot 0{,}40 = 115{,}38.$$

6. Summation of weighted average values of collective risks of the analyzed professional groups:

$$СК = \sum_{j=1}^{n}(К_j), \quad (6)$$

where j — the number of analyzed professional groups.

$$СК = 39{,}32 + 10{,}18 + 115{,}38 = 164{,}88.$$

7. Summation of the weights of collective risk values of the analyzed professional groups:

$$СКВ = \sum_{j=1}^{n}(КВ_j). \quad (7)$$

$$СКВ = 106{,}26 + 26{,}79 + 288{,}46 = 421{,}51.$$

8. Determination of total collective risk of the analyzed professional groups:

$$КР_\Sigma = СК/СКВ. \quad (8)$$

$$КР_\Sigma = 164{,}88/421{,}51 = 0{,}39.$$

Table 4 summarizes the values of indicators of collective risk of the studied professional groups calculated according to the described method.

Table 4

Results of collective risk calculation of professional groups of the foundry of the OOO "PK "NEVZ"

No.	Indicator	The values of the collective risk indicators of professional group		
		"Molder"	"Hand-formed rod maker"	"Metal and alloy smelter"
1	КР	3.73	9.02	1.60
2	КС	0.37	0.38	0.40
3	КК	0.0847	0.8584	0.0104
4	КВ	106.26	26.79	288.46
5	К	39.32	10.18	115.38
6	СК	164.88		
7	СКВ	421.51		
8	$КР_\Sigma$	0.39		

The value $КР_\Sigma = 0.39$ indicates a high collective risk of professional groups. Moreover, the main contribution to the collective risk is made by "Hand-formed rod maker" (Fig. 3). This fact is the reason for the development of risk control actions, which are implemented in the following priority:

— elimination of the danger, if possible;

— replacement of equipment, modification of the technological process if possible, use of safer materials and substances;

— engineering and technical solutions, construction of fences, application of security equipment, alarm devices, etc. ;

— application of warning marks, inscriptions, security signs, administrative control methods, documented operational procedures, instructions, training, control over the execution of the procedures;

— use of personal protective equipment (PPE), ensuring control over their proper use and care.

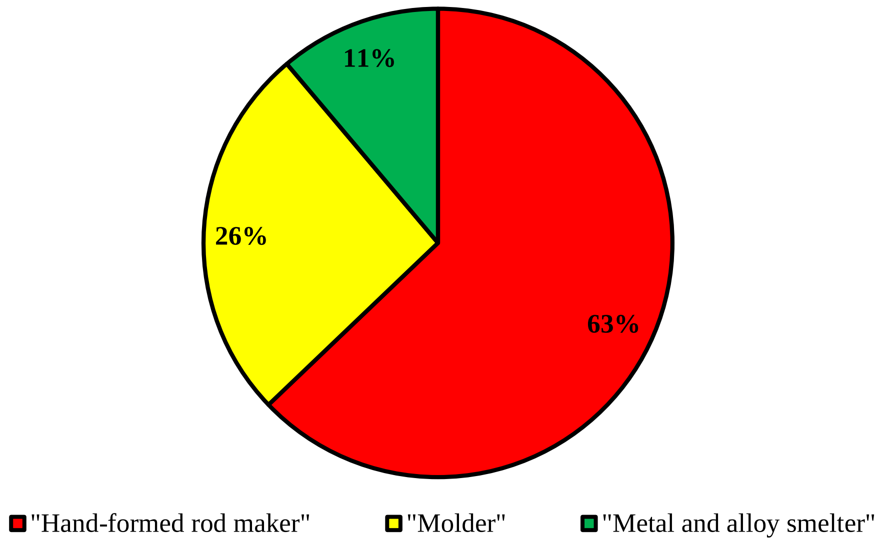

Fig. 3. Contribution of the analyzed professional groups to the total collective risk

As a possible option to reduce the professional risk of a "Hand-formed rod maker" and, accordingly, the collective risk in the foundry of OOO "PK "NEVZ", we can offer automation of the technological process of manufacturing casting rods, which involves the commissioning of molding machines, and, in addition, the introduction of cold-hardening mixtures. The advantages of cold-hardening mixtures are:

— absence of toxic emissions;

— reduction of dust emission when knocking out forms;

— hardening without exposure to high temperatures [7].

Thus, this approach will almost completely eliminate the harmful effects of the number of factors, such as chemical factors, dust, microclimate parameters and the severity of the labor process.

Conclusion. Assessment of occupational risks of employees of hazardous industries is undoubtedly one of the key elements of the enterprise's OHSAS. The correctness of this assessment allows you to identify jobs with unfavorable working conditions in time, preventing the occurrence of accidents among employees. In this study, using the results of the risk assessment of specific jobs, the collective risk of an entire division of the enterprise is determined, on the basis of which the most at-risk profession is identified. Corrective engineering measures aimed at protection from occupational risks are proposed for employees of this profession.

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Submitted 10.09.2020

Scheduled in the issue 13.10.2020

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Contribution of the authors:

V. V. Maslenskiy — formulation of the main concept, goals and objectives of the research, analysis of the research results, revision of the text, correction of conclusions; N. A. Lyubetskaya — calculations, preparation of the text, formulation of conclusions.