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Determination of the injury probability among coal mine workers

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Abstract

Purpose. Establishing regularities of change in the injury probability and development of a methodology for determining the injury probability of coal mine workers to improve the occupational health and safety (OSH) management system efficiency.

Methods. Methods of mathematical statistics and mathematical analysis were used in the data processing of coal mine workers' injuries; probability theory and risk theory were applied for setting equations to determine the injury probability; correlation and regression analysis were used to determine the density and nature of the dependences reflecting changes in the injury probability.

Findings. A calculator has been developed to compute the injury probability of an employee. This instrument distributes the probability into three "zones": high probability – "red zone", medium probability – "yellow zone", and low probability – "green zone". The injury probability for all employees of the mine administration was calculated. It was found that the closest relationship between the number of injuries and the calculated probability is observed for mining sites (medium probability) and for tunneling sites (high probability). For employees with a calculated high injury probability, in most cases, the causes of injury were objective and less dependent on employees themselves. For employees with a medium probability, the causes independent of and dependent on employees were approximately equally correlated. In the case of employees with a low probability, the main reasons were subjective – dependent on the employees themselves. For employees in the main operational sites (mining and tunneling), the cause of injury is directly related to the specifics of the production operations performed: the presence of loose space.

Originality. For the first time, relationships were determined between the injury probability and the profession. We also established relationships between experience at the enterprise, age, marital status of an employee and the injury causes, as well as between the actual number of injuries and the calculated injury probability.

Practical implications. A method for determining the injury probability of coal mine workers has been developed and implemented. The ways of improving the methods for calculating the injury probability are determined.

Keywords: *injury probability, coal mine, position, age, experience, marital status, injury causes, relationships*

1. Introduction

One of the main measures to improve safety is the introduction of occupational health and safety (OSH) management systems based on risk management, which is regulated by a number of international standards [1]-[3].

As a part of the OSH management system functioning at the enterprises of the Coal Business Company DTEK ENERGO LLC, a number of procedures and techniques have been developed and implemented with a view to improving OSH: the procedure for identifying hazards and assessing risks in the field of labor protection; procedure for classification, analysis and response to hazardous activities; methodology for assessing managers of a coal mine in the field of labor protection [4]-[6].

At the same time, injuries and accidents at enterprises are still at a fairly high level. This explains the necessity to search for new approaches to determining the probability of injury among mine workers. The issues of identifying risk, its probability, and risk management in mines are discussed in the works of scientists from China, Mexico, Turkey, Poland, Ukraine, and other countries.

In [7], the authors present the data on the level of production and injuries at Polish coal mines. The definition of the injury risk concept is substantiated, and a method for its interpretation is presented. A new relationship – "injury risk hysteresis" – has been established.

Methodology for quantifying the risk of injury is described in [8]. It was shown that the frequency of injury occurrence

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and the degree of severe harm inflicted to health are not independent – they obey the exponential distribution law.

Personal and impersonal factors, such as personality, job profile, maturity, job satisfaction, involvement in work, stress at work, risky behavior and safety indicators, were considered as predictors of miners' injuries in a cause-effect relationship [9]. A model of the structural equation was developed to identify significant cause-effect relationships between factors.

Methodology based on fuzzy logic was proposed for assessing risks associated with human health, for managing control measures and supporting decision-making [10]. A model is proposed for identification of potential dangers and assistance in taking appropriate measures to minimize or eliminate risks before accidents in mines occur.

The influence of miners' working conditions while mining thin coal seams on the nature and pace of their aging were established by determining their biological age and assessing the risk of occupational diseases [11].

It was shown in [12] that the unsafe behavior of miners is the main cause of accidents in coal mines, and intervention in behavior plays a significant role in increasing the safety level of miners. A process was developed to determine the location of the intervention target, and, based on the analysis of 331 coal accidents in China, three types of intervention targets were discovered. When preventing accidents in coal mines, the nodes of the targeted intervention have a significant positive influence on the intervention effect.

The Decision Matrix Risk Assessment Methodology (DMRA) was applied for improving working conditions, in which accidents are classified according to their severity and probability in order to perform a risk assessment [13]. Corrective actions that can help avoid accidents are suggested.

The works [14]-[20] are devoted to various aspects of risk management during mineral mining and increasing the safety of underground mining. To date, the effect of such indicators as the employee's age, experience, marital status, and the relationship between the causes and the probability of the injury has not been holistically determined.

Thus, the development of a technique for determining the probability of injuries in coal mines to increase the efficiency of the OSH management system is an important scientific and applied task, which is vital for the coal industry.

To achieve this goal, the following tasks were solved: analysis of employees who obtained industrial injuries according to the following indicators – profession, experience at the enterprise, gender and age, marital status, place of residence, unit; development of a methodology for calculating the injury probability of an employee; determination of the relationship between the injury probability and the position, experience, age, marital status of the employee and the causes of injury, as well as between the actual number of injuries and the calculated injury probability; recommendations for improving calculation of the injury probability.

2. Methodology

The occupational safety and health department of the PU "MA Pavlohradske" conducted an analysis of workers who got work-related injuries from 2006 to 2015 (inclusive) by the following indicators: profession, experience, gender and age, marital status, place of residence, work site.

Based on the results of the analysis, a calculator was developed for calculating the probability of employee injuries, which distributes the probability into three "zones": high probability – "red zone", average probability – "yellow zone", and low probability – "green zone". The calculation is performed in MS Excel (Fig. 1).

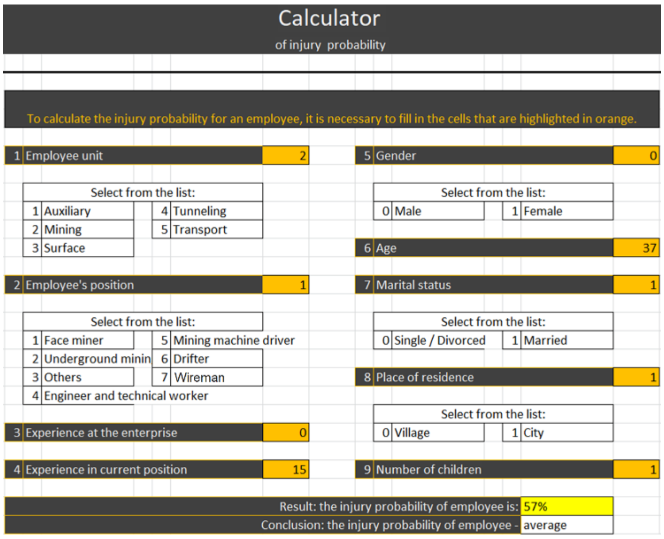

Figure 1. The window of injury probability calculator

The probability P is determined on the basis of the following conditions:

$(S = 1 \wedge S = 3 \wedge S = 5) \vee E_{tot} \leq 22 \vee A \leq 28 \Rightarrow P = 0.4;$

$(S = 1 \wedge S = 3 \wedge S = 5) \vee E_{tot} \leq 16 \vee (28 < B \leq 37) \Rightarrow P = 0.192;$

$(S = 1 \wedge S = 3 \wedge S = 5) \vee E_{tot} \leq 16 \vee A > 37 \Rightarrow P = 0.028;$

$(S = 1 \wedge S = 3 \vee S = 5) \vee E_{tot} > 16 \vee (28 < A \leq 40) \Rightarrow P = 0.583;$

$(S = 1 \wedge S = 3 \wedge S = 5) \vee (16 < E_{tot} \leq 22) \vee A > 40 \Rightarrow P = 0.15;$

$(S = 1 \wedge S = 3 \wedge S = 5) \vee (22 < E_{tot} \leq 28) \Rightarrow P = 0.491;$

$(S = 1 \wedge S = 3 \wedge S = 5) \vee E_{tot} > 28 \Rightarrow P = 0.769;$

$(S = 2 \wedge S = 4) \vee E_{tot} \leq 16 \vee A \leq 40 \vee (Pos = 3 \wedge Pos = 5 \wedge Pos = 6 \wedge Pos = 7) \vee (NC = 0 \wedge NC = 2 \wedge NC = 3) \Rightarrow P = 0.341;$

$(S = 2 \wedge S = 4) \vee E_{tot} \leq 16 \vee A \leq 40 \vee (Pos = 3 \wedge Pos = 5 \wedge Pos = 6 \wedge Pos = 7) \vee (NC = 1 \wedge NC \geq 4) \Rightarrow P = 0.627;$

$(S = 2 \wedge S = 4) \vee E_{tot} \leq 16 \vee A \leq 28 \vee (Pos = 1 \wedge Pos = 2 \wedge Pos = 4) \Rightarrow P = 0.757;$

$(S = 2 \wedge S = 4) \vee E_{tot} \leq 16 \vee (28 < A \leq 40) \vee (Pos = 1 \wedge Pos = 2 \wedge Pos = 4) \Rightarrow P = 0.567;$

$(S = 2 \wedge S = 4) \vee E_{tot} \leq 16 \vee A > 40 \Rightarrow P = 0.111;$

$(S = 2 \wedge S = 4) \vee (16 < E_{tot} \leq 25) \vee A \leq 43 \Rightarrow P = 0.843;$

$(S = 2 \wedge S = 4) \vee (16 < E_{tot} \leq 25) \vee A > 43 \Rightarrow P = 0.556;$

$(S = 2 \wedge S = 4) \vee E_{tot} > 25 \Rightarrow P = 1,$

where:

S – subdivision (1 – auxiliary; 2 – mining; 3 – surface; 4 – tunneling; 5 – transport);

Pos – position (1 – face miner; 2 – underground mining worker; 3 – others; 4 – engineer and technical worker; 5 – mining machine driver; 6 – drifter; 7 – wireman);

E_{tot} – total work experience at the enterprise, years;

A – age, years;

NC – number of children.

At $P \leq 0.4$ – the probability is taken low, at $0.4 < P \leq 0.6$ – medium, at $P > 0.6$ – high.

3. Results and discussion

According to the calculator, in June 2017, the probability of workers' injury at the tunneling No. 2 site was calculated. The calculation shows that the composition of employees, as distributed in the "zones" of probability, looks the following way:

– high – 72 employees (37%);
– average – 37 employees (19%);
– low – 84 employees (44%).

The composition of the tunneling No. 2 site workers from the "red zone" was distributed by professions as follows: drifters – 51%, underground mining workers – 15%, wiremen – 15%, mining machine drivers – 10%, engineers and technical workers – 7%, others – 2%.

All workers who fell into the "red zone" were balanced by teams, according to the principle of reducing the number of workers in the "red zone". The largest number of workers was assigned to first shifts, where the control and supervision of the engineering department of the site and the mine is highest. A total of 12 people were displaced (Table 1).

Table 1. The heat map of the teams at the tunneling No. 2 site

Team	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
before redistribution																
•	16	3	2	2	4	17	2	3	2	3	15	4	3	3	3	2
•	7	0	1	1	0	8	1	1	1	2	9	1	2	1	0	2
•	13	3	3	3	2	13	3	2	3	2	16	1	2	2	3	1
after redistribution																
•	14	3	3	3	4	16	3	3	3	3	15	3	3	3	3	2
•	6	1	1	1	0	7	1	1	1	2	9	1	2	1	1	2
•	16	2	2	2	2	15	2	2	2	2	16	2	2	2	2	1

Mine data show that injuries at the tunneling No. 2 site were distributed as follows. In 2016, no injuries were registered. In 2017, 2 cases of injuries were registered before balancing workers by teams, and after balancing workers by teams – 1 case of injury.

In the same way, the probability of injury was calculated for all employees of the mine administration numbering 3378 people, as a result of which the employees were divided into "zones" as follows:

– high – 670 employees (20%);
– average – 689 employees (21%);
– low – 2024 employees (59%).

The composition of the mine administration employees by profession in the "zones" of probability was distributed as follows (Table 2). The composition of the mine administration workers located in the "red zone" distributed by profession was as follows: face miners – 143 (21%), drifters – 131 (20%), wiremen – 109 (16%), others – 84 (13%), underground mining workers – 76 (11%), mining machine drivers – 74 (11%), engineers and technical workers – 53 (8%).

From the analysis it follows that basically high probability of injury (the "red zone") corresponds to workers of the principal professions – face miners, drifters and wiremen working in mining and tunneling sites. In January 2018, analysis of 2017 injuries was carried out, depending on the "injury hazard according to the calculator" of employees who were injured. The probability of injuries was distributed as follows:

– high – 11 (25%);
– average – 12 (27%);
– low – 21 (48%).

Table 2. Composition of mine administration employees by profession in the "zones" of probability

Probability	Profession						
	face miner	drifter	mining machine driver	wireman	underground mining worker	engineer and technical worker	others
High	143	131	74	109	76	53	84
Average	236	28	13	75	59	130	148
Low	42	172	81	462	220	126	921
Total	422	331	168	646	355	309	1153

The number of injuries in the sites, depending on the composition of workers in the "zones" of probability, is shown in Figure 2.

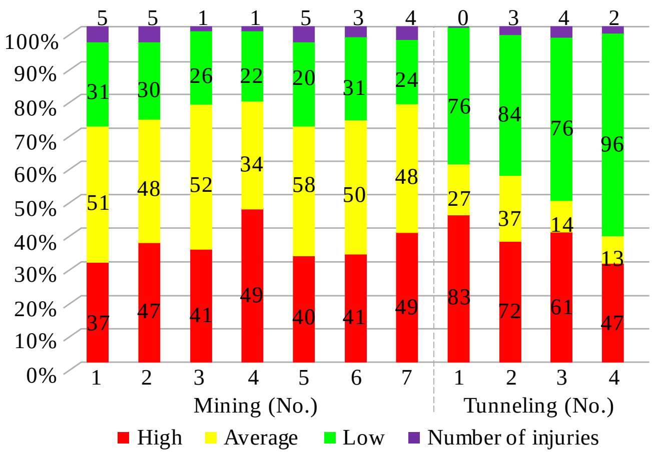

Figure 2. The number of injuries in the sites, depending on the composition of workers in the "zones" of probability

Analysis of the data indicates that a high probability of injury ("red zone") was observed for 37% of workers of mining sites, average ("yellow zone") for 41% and low ("green zone") for 22%. For tunneling sites, high probability of injury was observed in 38% of cases, average in 13%, and low in 49%. It can be noted that for both mining and tunneling areas, the proportion of workers with a high probability of injury is approximately the same. The difference lies in the fact that for workers in mining sites, the prevalence of average probability of injury is predominant, while for drifters it is low. Moreover, this trend is observed for ¾ workers in mining and tunneling sites.

The correlation analysis of the obtained data indicates the following. The greatest correlation between the number of injuries and the calculated probability is observed for mining sites with medium probability (correlation coefficient 0.55), and for tunneling sites with high probability (correlation coefficient -0.47). For other ranges of probability changes, the correlation with the number of injuries is not high.

Table 3 shows the data on employees' injuries at the PU "MA Pavlohradske" in 2017.

Table 3. The results of determining the injury probability of workers

No.	Profession	Site	Severity of injury (mild/severe)	The probability of employee injury according to the calculator
1	standardizer	department of labor and wages	mild	76%
2	face miner	mining No. 2	mild	84%
3	loading engineer	mining No. 2	mild	34%
4	wireman	automation, communication and information technology	mild	40%
5	drifter	tunneling No. 2	mild	55%
6	face miner	mining No. 7	mild	19%
7	face miner	downhole equipment repair	mild	19%
8	mining master	mining No. 3	mild	56%
9	deputy mechanic	mining No. 7	mild	56%
10	miner	ventilation and safety No. 1	mild	15%
11	shift supervisor	production service No. 1	mild	15%
12	mining master	mining No. 2	mild	55%
13	wireman	mining No. 6	mild	62%
14	drifter	tunneling No. 2	mild	62%
15	face miner	mining No. 5	mild	55%
16	face miner	mining No. 2	mild	56%
17	mining and quarrying machine driver	mining No. 6	mild	62%
18	drifter	tunneling No. 3	mild	34%
19	site surveyor	surveying service	mild	76%
20	face miner	mining No. 5	severe	55%
21	face miner	mining No. 6	mild	55%
22	face miner	mining No. 1	severe	56%
23	face miner	mining No. 7	mild	56%
24	underground mining worker	tunneling No. 4	mild	19%
25	drifter	tunneling No. 4	mild	62%
26	mining master	repair works	mild	40%
27	mining and quarrying machine driver	tunneling No. 3	mild	34%
28	electric locomotive driver	mine transport mining No. 2	severe	19%
29	face miner	mining No. 2	mild	84%
30	face miner	mining No. 4	mild	57%
31	shift supervisor	production service	mild	19%
32	wireman	tunneling No. 3	mild	34%
33	underground mining worker	repair works	mild	40%
34	deputy the head of the site	mining No. 5	mild	56%
35	mining master	ventilation and safety No. 1	mild	19%
36	surface wireman	technological complex of the surface No. 1	mild	19%
37	underground wireman	maintenance service No. 2	mild	28%
38	face miner	mining No. 1	mild	56%
39	mining and quarrying machine driver	mining No. 1	mild	84%
40	drifter	tunneling No. 3	mild	34%
41	drifter	tunneling No. 2	mild	11%
42	underground wireman	mining No. 1	severe	84%

Analysis of the data shows that high probability of injury computed by the calculator corresponded to 22% of those injured, average probability of injury – to 33%, and low – to 45%. Mild injury severity was in 90% of cases, while in 10% – the injury was severe. Only in one case did an employee receive a serious injury, having a high calculated probability of injury.

Speaking about the causes of injuries, it should be noted that for workers with high probability of injuries in most (67%) cases, the cause of the injury was a fall or careless handling of the tool, in 33% of cases the cause was collapse of the rock mass. For workers with an average probability of injury in 50% of cases, the cause of the injury was the collapse of the rock mass, in 14% – a fall and in 35% – other reasons. For workers with a low probability, in the vast majority of cases (63%) the cause of injuries was a fall or careless handling of the tool, only 15% – collapse of the rock mass.

Thus, we can conclude that for workers with a calculated high probability of injury, in most cases the causes of injury were objective and less dependent on the workers themselves. For workers with an average probability, reasons independent of and dependent on workers were roughly equal. In the case of workers with low probability, the main reasons were subjective – depending on the workers themselves. In the last case, the so-called human factor played a dominant role.

It should also be noted that among the face miners, only in 16% of cases the cause of injury was a fall, in 50% – the collapse of the rock mass and in 33% – other reasons. For drifters in 83% of cases, the cause was a fall or improper handling of the tool. For workers of the main work sites (mining and preparatory faces), the cause of the injury is directly related to the specifics of the operations performed: the presence of loose space for face miners in lavas and junctions, as well as the need to move over the workings to considerable distances – fordrifters.

Improving the methodology for calculating the probability of injuries should be aimed at taking into account the human factor by assessing the individual characteristics of miners based on the results of psychophysiological testing.

An example of determining the probability of injuries for a typical employee (a man, marital status – married, place of residence – city) by main professions is given in Table 4. In the Table, the main influencing parameters are highlighted in yellow; probability zones: low – green, medium – yellow, high – red.

Table 4. An example of determining the probability of injury inflicted to a typical worker

Sub-division	Position	Experience		Age	No. of children	Zone
		at the enterprise	in current position			
mining	face miner	2	1	22	1	76%
mining	face miner	6	5	26	1	76%
mining	face miner	8	7	28	1	76%
mining	face miner	9	8	29	1	57%
mining	face miner	12	11	32	1	57%
mining	face miner	16	15	36	1	57%
mining	face miner	17	16	37	1	84%
mining	face miner	19	18	39	1	84%
mining	face miner	21	20	41	1	84%
mining	face miner	1	1	41	1	11%
mining	face miner	11	11	51	1	11%
mining	face miner	16	16	56	1	11%
tunneling	wireman	2	1	22	1	63%
tunneling	wireman	6	5	26	1	63%
tunneling	wireman	9	8	29	1	63%
tunneling	wireman	12	11	32	1	63%
tunneling	wireman	16	15	36	1	84%
tunneling	wireman	17	16	37	1	84%
tunneling	wireman	19	18	39	1	84%
tunneling	wireman	21	20	41	1	84%
tunneling	wireman	2	1	22	0 or 2	34%
tunneling	wireman	6	5	26	0 or 2	34%
tunneling	wireman	9	8	29	0 or 2	34%
tunneling	wireman	12	11	32	0 or 2	34%
tunneling	wireman	16	15	36	0 or 2	34%
tunneling	wireman	17	16	37	0 or 2	84%
tunneling	drifter	2	1	22	1	63%
tunneling	drifter	6	5	26	1	63%
tunneling	drifter	9	8	29	1	63%
tunneling	drifter	12	11	32	1	63%
tunneling	drifter	16	15	36	1	84%
tunneling	drifter	17	16	37	1	84%
tunneling	drifter	19	18	39	1	84%
tunneling	drifter	21	20	41	1	84%
tunneling	drifter	2	1	22	0 or 2	34%
tunneling	drifter	6	5	26	0 or 2	34%
tunneling	drifter	9	8	29	0 or 2	34%
tunneling	drifter	12	11	32	0 or 2	34%
tunneling	drifter	16	15	36	0 or 2	34%
tunneling	drifter	17	16	37	0 or 2	84%

From the above Table, it can be seen that when changing the data of face miner experience and age, they never fall into the "green zone". Face miner will fall into the "green zone", if their age is over 40 years, with low experience at the enterprise and in their current position.

When changing the wireman experience and age, they will never fall into the "green zone". They will fall into the "green zone", if they have 2 children or no children.

When changing the drifter experience and age, he will never fall into the "green zone". The drifter will fall into the "green zone", if he has 2 children or no children. Moreover, upon reaching 37 years, he again falls into the "red zone".

The main problems in calculating the probability of injury are as follows:

– teams and brigades of mining and tunneling sites consist of the primary professions, which, due to their specificity, fall into the "red zone" according to the main criteria. It is not possible to exclude workers with high risk probability from the teams;

– since the main criteria affecting the calculation of the probability of injury are the experience at the enterprise and in the current position, it is mainly workers with significant work experience who fall into the "red zone". Replacing them in the mining teams with less qualified workers is not advisable;

– the composition of workers by probability zone will change every year, because the criteria for calculating the probability of injury are the age and experience at the enterprise and in the current position, which are constantly changing;

– direct dependence of the accident probability in the team on the number of employees with a high probability of injury is not observed;

– injury at the site does not directly depend on the number of workers with a high probability of injury;

– the causes and conditions of the accident occurrence, as well as the fact that the accident could have occurred as a result of the actions (or inaction) of other employees, do not affect the calculation of the injury probability.

4. Conclusions

1. Despite the continuous improvement of the OSH management system, injuries and accidents at coal mining enterprises are still at a fairly high level. The occupational safety and health service of the PU "MA Pavlohradske" analyzed the workers who received work-related injuries by the following indicators: profession, experience at the enterprise, gender and age, marital status, place of residence, site. Based on the results of the analysis, a calculator was developed for calculating the probability of employee injuries, which distributes the probability into three "zones": high probability – "red zone", average probability – "yellow zone", and low probability – "green zone".

2. The calculation of injury probability was done for workers of tunneling sections. According to the calculation results, the composition of workers was distributed in the "zones" of probability as follows: high – 37%; average – 19%; low – 44%. All workers who fell into the "red zone" were balanced in teams, on the principle of reducing the number of the "red zone" workers in a team. The largest number of workers was assigned to first shifts, where the control and supervision of the engineering department of the site and the mine is highest. Before balancing workers by

teams, 2 cases of injuries were registered, after balancing workers by teams 1 case of injuries was registered.

3. The probability of injury for all mine workers was calculated, subsequently the employees were divided into "zones" as follows: high – 20%; average – 21%; low – 59%. The analysis of injuries was done, depending on the "injury hazard on the calculator" of workers who have been injured. The probability of injuring the victims was as follows: high – 25%; average – 27%; low – 48%.

4. For mining and tunnel sites, the proportion of workers with a high probability of injury is approximately the same. The difference lies in the fact that for the workers of mining sites the prevalence of the average probability of injury is characteristic, and for drifters – low. Moreover, this trend is observed for workers in ¾ of mining and tunneling sites. A correlation analysis of the data indicates that the closest relationship between the number of injuries and the calculated probability is observed for mining sites – for medium probability, for tunneling sites – for high probability. For other ranges of probability changes, the correlation with the number of injuries is low.

5. For workers with a calculated high probability of injury, in most cases the causes of injury were objective and to a lesser extent depended on the workers themselves. For workers with an average probability, causes independent of and dependent on workers were roughly equal. In the case of workers with low probability, the main reasons were subjective – depending on the workers themselves. For workers in the main areas of work (mining and preparatory faces), the cause of the injury is directly related to the specifics of the production operations performed: the presence of loose space for face miners in lavas and at junctions, as well as the need to move along the workings over significant distances – for drifters.

6. The main way to improve the calculation of the injury probability is that it is not possible to exclude workers from the teams at mining and tunneling sites; the composition of workers by probability zone will change every year, since the criteria for calculating the probability of injury are the age and experience at the enterprise and by profession, which are constantly changing. Improving the methodology for calculating the injury probability should be aimed at considering the human factor by assessing the individual characteristics of miners based on the results of psychophysiological testing and taking into account the influence of causes and conditions of the accident occurrence, as well as the fact that the accident could have occurred as a result of actions (or inaction) of other workers.

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Визначення ймовірності травматизму працівників вугільних шахт

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Мета. Встановлення закономірностей зміни ймовірності травматизму і розробка методики визначення ймовірності травматизму працівників вугільних шахт для підвищення ефективності функціонування системи управління охороною праці.

Методика. Використано методи математичної статистики і математичного аналізу при обробці даних травматизму працівників вугільних шахт, теорії ймовірностей, теорії ризиків при завданні рівнянь для визначення ймовірності травматизму, кореляційного та регресійного аналізу при визначенні тісноти й характеру залежностей зміни ймовірності травматизму.

Результати. Розроблено калькулятор розрахунку ймовірності травматизму працівника, який розподіляє ймовірність за трьома "зонами": висока ймовірність – "червона зона", середня ймовірність – "жовта зона", низька ймовірність – "зелена зона". Виконано розрахунок ймовірності травматизму всіх працівників шахтоуправління. Встановлено, що найбільша тисніть зв'язку між кількістю травм і розрахованою ймовірністю спостерігається для добувних ділянок – для середньої ймовірності, для прохідницьких ділянок – для високої ймовірності. Для працівників з розрахованою високою ймовірністю травматизму в більшості випадків причини травми були об'єктивними і в меншій мірі залежали від самих працівників. Для працівників із середньою ймовірністю причини, які не залежать і залежні від працівників, співвідносилися приблизно порівну. У разі працівників з низькою ймовірністю основними причинами були суб'єктивні, тобто залежали від самих працівників. Для працівників центральних місць робіт (видобувні та підготовчі вибої) причини травм безпосередньо пов'язані зі специфікою виконуваних виробничих операцій: наявність незакріпленого простору для ГРОВ у лавах і на сполученнях, а також необхідність переміщення по виробках на значні відстані – для прохідників.

Наукова новизна. Вперше визначено залежності між ймовірністю отримання травми та посадою, стажем, віком, сімейним станом працівника і причинами травми, а також між фактичною кількістю травм і розрахованою ймовірністю травматизму.

Практична значимість. Розроблено та впроваджено методику визначення ймовірності травматизму працівників вугільних шахт. Визначено шляхи вдосконалення методики розрахунку ймовірності травматизму.

Ключові слова: *ймовірність травматизму, вугільна шахта, посада, вік, стаж, сімейний стан, причини травми, залежності*

Определение вероятности травматизма работников угольных шахт

Д. Носаль, С. Коновалов, В. Шевченко

Цель. Установление закономерностей изменения вероятности травматизма и разработка методики определения вероятности травматизма работников угольных шахт для повышения эффективности функционирования системы управления охраной труда.

Методика. Использованы методы математической статистики и математического анализа при обработке данных травматизма работников угольных шахт, теории вероятностей, теории рисков при задании уравнений для определения вероятности травматизма, корреляционного и регрессионного анализа при определении тесноты и характера зависимостей изменения вероятности травматизма.

Результаты. Разработан калькулятор расчета вероятности травматизма работника, который распределяет вероятность по трем "зонам": высокая вероятность – "красная зона", средняя вероятность – "желтая зона", низкая вероятность – "зеленая зона". Произведен расчет вероятности травматизма всех работников шахтоуправления. Установлено, что наибольшая теснота связи между количеством травм и рассчитанной вероятностью наблюдается для добычных участков – для средней вероятности, для проходческих участков – для высокой вероятности. Для работников с рассчитанной высокой вероятностью травматизма в большинстве случаев причины травмы были объективными и в меньшей степени зависели от самих работников. Для работников со средней вероятностью причины, не зависящие и зависящие от работников, соотносились примерно поровну. В случае работников с низкой вероятностью основными причинами были субъективные – зависящие от самих работников. Для работников основных участков работ (добычные и подготовительные забои) причины травм напрямую связаны со спецификой выполняемых производственных операций: наличие незакрепленного пространства для ГРОЗ в лавах и на сопряжениях, а также необходимость перемещения по выработкам на значительные расстояния – для проходчиков.

Научная новизна. Впервые определены зависимости между вероятностью получения травмы и должностью, стажем, возрастом, семейным положением работника и причинами травмы, а также между фактическим количеством травм и рассчитанной вероятностью травматизма.

Практическая значимость. Разработана и внедрена методика определения вероятности травматизма работников угольных шахт. Определены пути совершенствования методики расчета вероятности травматизма.

Ключевые слова: *вероятность травматизма, угольная шахта, должность, возраст, стаж, семейное положение, причины травмы, зависимости*