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Improvement of methods for analyzing and forecasting industrial injuries in the electric workshop of the Don Mining and Processing Plant of the Republic of Kazakhstan

Abstract. *The article deals with the issues of injury research at the enterprises of the electric power industry of the CIS countries and Kazakhstan. The study of the causes of injuries and ways to solve them at enterprises and industries of the mining, oil-gas and construction sectors has attracted a lot of attention of researchers in recent years and the study of this issue is also relevant in the western regions of Kazakhstan.*
The methodological basis of the study was the modern provisions of the theory and practice on occupational safety and health, injuries at enterprises and industries of the mining, oil and gas and construction sectors, as well as at enterprises of the electric power industry of Kazakhstan.
According to the results of the study, it was also determined that the most common cause of accidents is a violation of safety and labor protection rules, unsatisfactory organization of work production. The study of the circumstances of accidents and the identification of their causes makes it possible to develop preventive measures that prevent the recurrence of emergencies. The obtained results of the study can be used at the enterprises of the electric power industry of the CIS countries and Kazakhstan.
Keywords: *electric power industry, danger, risk, accident, injury, electrical shop, statistical method.*

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1. Introduction

Due to the rapid growth of the development of mining and processing, oil and gas and construction industries in the CIS countries and including the regions of Kazakhstan, it requires a very responsible approach to occupational health and safety in enterprises.

The study of the causes of injuries and the ways to solve them at the enterprises of the mining, oil and gas and construction sector has attracted much attention of scientists from CIS countries and abroad in recent years, as well as the study of this issue is relevant in the facilities of the power grid economy of Kazakhstan.

In recent years, much attention of scientists has been attracted by research on accidents at power plants with an installed capacity of 25 MW or more and at the facilities of the electric grid of grid companies and large consumers of electricity, which has a great impact on the work of metallurgical, mining and processing and petrochemical enterprises [1-25].

Various statistical data on accidents in the electric power industry as a whole are contained in the works of [2-21] and other authors.

Data on accidents at power plants and at power grid facilities of grid companies and large consumers of electricity were analyzed using the example of the Russian power system (Fig. 1).

It should be noted that the number of accidents at electric power facilities tends to decrease. However, the number of accidents in most joint-stock companies of generating companies is in the hundreds, and in joint-stock companies of the electric grid economy is in the thousands. Statistical data on accidents in the electric power industry were taken from the works [3-20].

Among the injury indicators that were widely used back in the USSR, there was an indicator of the number of fatal accidents per ton of coal mined. If we consider the electric power industry, then a similar indicator could be the ratio of the number of fatal accidents associated with the production and transmission of electric energy per 1 TW (1TWT = 1012W) of energy consumed.

Data on occupational injuries were taken from sources and works [8-12]. For 2014-2019, i.e. for 6 years, electricity consumption in Russia has hardly changed, the total number of accidents during the production and transmission of electric energy has changed significantly, but the number of fatal accidents, most of which occur in electric grid enterprises and are associated with the impact of electric current, has hardly changed.

Thus, this indicator can be used as an indicator indicating the need to use innovative technical means to ensure the safety of employees at a qualitatively higher level.

The greatest number of injuries occurs in electrical networks. A significant number of them, 20% or more, occurs due to the impact of an electric current and (or) an electric arc on the victim (Fig. 1).

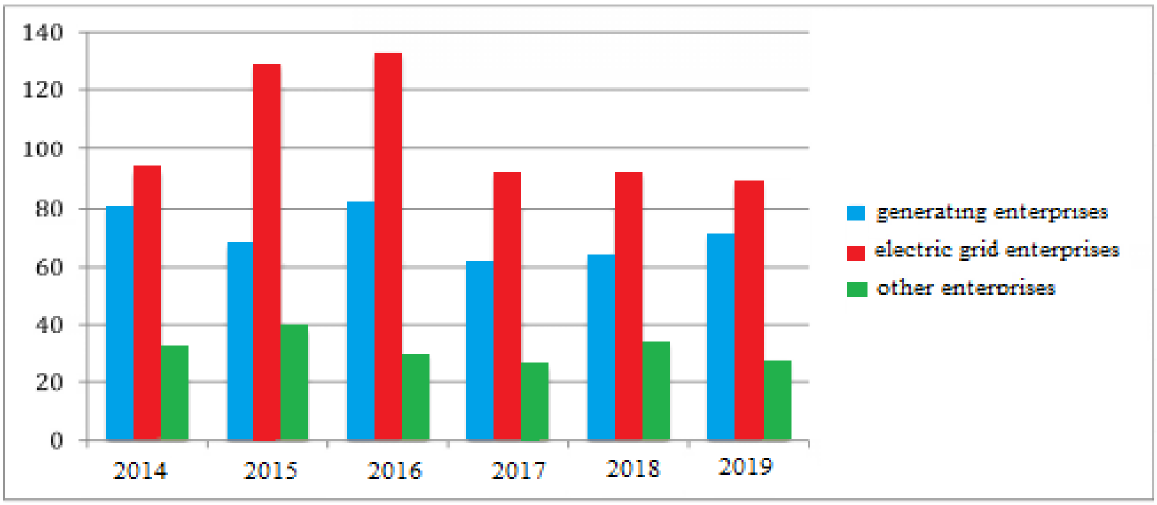

Figure 1. Dynamics of injuries in the Russian electric power industry

The largest number of victims are men and women aged 50 to 59 years, who have more than 10 years of professional experience and are workers in the main professions of electric grid enterprises (Fig. 2, 3).

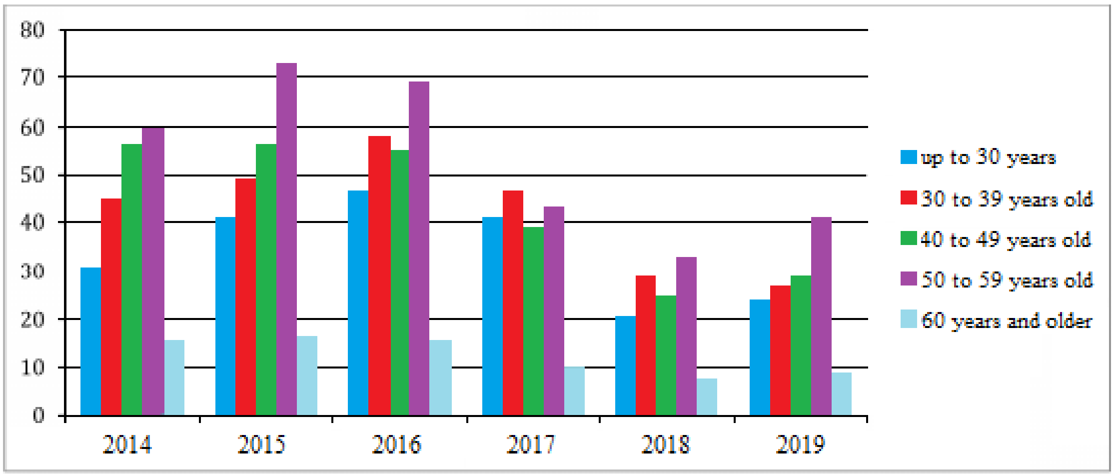

Figure 2. Dynamics of injuries by age in the Russian electric power industry

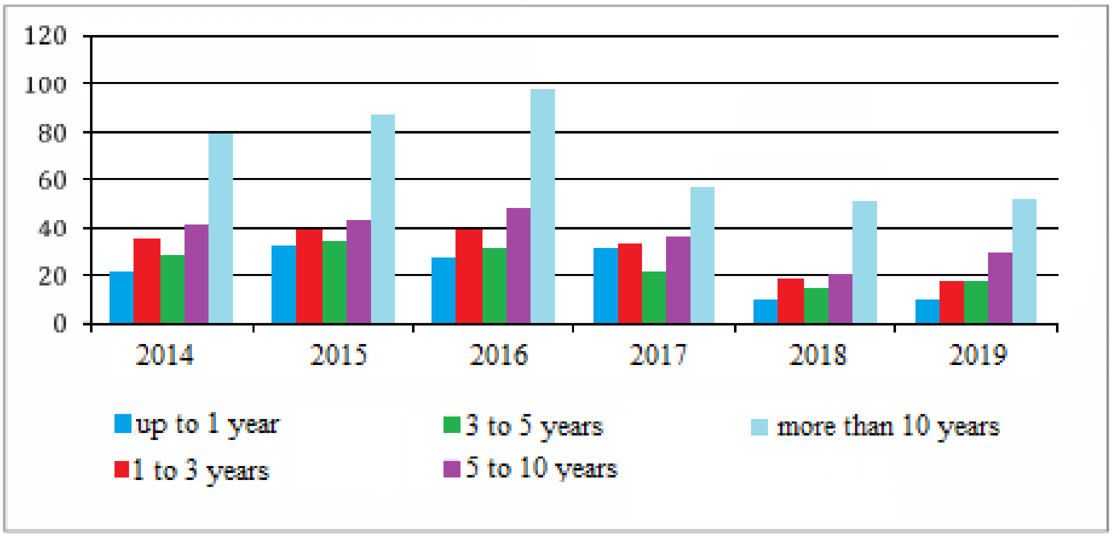

Figure 3. Dynamics of injuries depending on the length of work by profession of victims in the Russian electric power industry

This category of workers was injured during repair work or operational maintenance. All employees passed introductory, repeated and targeted briefings, most of the victims of electric current had the 3rd or higher electrical safety group.

This state of affairs leads to the idea of the need to introduce innovative technical means to minimize personnel errors and thereby significantly reduce the number of possible accidents. It is possible to reduce the number of accidents due to special training of employees of electric power enterprises. The program of such training should be developed for each specific joint-stock company, taking into account the frequency of accidents due to improper actions of personnel.

It should be noted that for decades most of the group, severe and fatal accidents occurred in electrical installations due to an insufficient level of organizational and operational characteristics [10-14].

These reasons indicate the presence of serious shortcomings in the work of managers at all levels of management of a number of subjects of the electric power industry responsible for the fulfillment by workers of the requirements of norms and rules of labor protection.

Therefore, we have proposed a new method for calculating the occupational risk reduction program, providing an optimal set of preventive measures and optimal timing of their implementation, using the data of workplace certification according to working conditions as well as the results of the analysis and assessment of occupational risk for employees of the mining industry. Using the proposed recommendations for optimal planning of control actions to reduce occupational risk in organizations and enterprises of the mining industry, which are based on an integrated approach that takes into account both harmful and hazardous production factors, provides the possibility of more effective planning of all types of activities aimed at reducing occupational risk.

2. Methods and Materials

In this paper, the object of the study is the persons affected by industrial injuries in the electric workshop of the Don Mining and Processing Plant of the Aktobe region of Kazakhstan for the period from 2014 to 2019 inclusive. In all cases, the monitoring unit was the workers of the Don Mining and Processing Plant who were injured during the calendar year. The research, analysis and processing of the results were carried out on the basis of the educational institution "Kazakh-Russian International University".

The total volume of the studied material for clarity and the results of statistical data on industrial injuries in the electric workshop of the Don Mining and Processing Plant are shown in Table 1.

Table 1. Indicators of industrial injuries in the electric workshop of the Don Mining and Processing Plant in the period from 2014 to 2019

Item No.	Indicator name	years					
		2014	2015	2016	2017	2018	2019
1	The average number of employees in the electrical shop during the study period	137	138	140	141	142	143
2	The number of victims of accidents at work with disability for one day or more, people.			1	1		1
3	The number of accidents	1		1	1		1
	in total including:						
	with a mild outcome			1	1		1
	with a fatal outcome	1					

The Don Mining and Processing Plant has developed and operates a "General Classifier by types of identified hazards", according to which an identified number is assigned to each type of hazard. The types of hazards that may be the causes of accidents are included. The classifier is presented in Table 2.

Table 2. General classifier by types of identified hazards

Danger code	Name of the hazard
01	Traffic (automobile, railway)
02	Height
03	Falling, collapse, collapses of objects, materials, rock mass, etc.
04	Moving, flying, rotating objects and parts
05	Extreme temperatures
06	Electric current
07	Harmful substances (dust, gas, chemicals)
08	Ionizing radiation
09	Physical overload
10	Neuropsychic stress
11	Contact with animals and insects
12	Drowning
13	Unintentional murder
14	Natural disasters
15	Falling (uneven and slippery surfaces)
16	Unauthorized explosions of explosives during blasting operations
17	Formation of explosive mixtures
18	Vibration and noise
19	Fires
20	Accidents of a natural nature
21	Man-made accidents
22	Hazards, other than those listed, characteristic of the mining industry
23	Other

To study mortality from non-occupational injuries, the section of the electronic card on injury outcomes was selectively filled in. During the study period, 3 cases of disability at work, 4 accidents and 1 fatal case were registered.

The following research methods are used in the work: statistical, comparative analysis, content analysis of regulatory documentation, modeling.

To study mortality from non-occupational injuries, the section of the electronic card on injury outcomes was selectively filled in. To determine the most injury-prone areas, we used a statistical method, and a quantitative assessment of the risk of danger was determined using the Kinney method. To quantify the risks in the electric workshop of the Don Mining and Processing Plant, the Kinney method described in [21] was used. According to which we calculated a potentially dangerous situation, indicated by the risk according index **R to i** classifier, according to the following formula:

$$\mathbf{R_i = P_i \cdot E_i \cdot G_i},$$

where, $\mathbf{P_i}$ is an indicator of the probability of a dangerous event; $\mathbf{E_i}$ is an indicator of the frequency of risk exposure; G_i is an indicator of the severity of damage caused by the consequences of a dangerous event.

The assessment of risk indicators R_i for various analyzed hazardous situations is carried out by assigning a score to each of the above parameters, and the corresponding numerical values determined in Tables 3, 4, 5 below.

According to the methodology, according to Tables 1 and 3, we will determine the number of accidents (DNA_i) for the main of the identified hazards, for this we will analyze statistical data on 4 accidents among the staff of electrical shop workers for the period from 2011 to 2016

Table 3 provides data from which the following dangerous events can be distinguished: - No. 6 (exposure to electric current) - 4 cases (1 fatal).

Having analyzed the data on accidents in the electrical shop for the period from 2014 to 2019, we can say that the main danger for the manifestation of injuries at work is a dangerous event No. 6 from the classifier - electric shock. There are 4 cases of this danger.

Table 3. Information on the types of injuries that occurred in the electrical shop in the period from 2014 to 2019

Item No.	Date	Profession	Type of incident
1	11.10.16	Conveyor operator	6
2	22.04.17	Electrician on duty and equipment repair	6
3	19.07.18	Electrician on duty and equipment repair	6
4	16.08.19	Electrician on duty and equipment repair	6

The calculation will be carried out on dangerous event No. 6. The total number of accidents according to hazard No. 6 will be ANA = 4.

The average number of accidents (ANA) per year,

$$\mathrm{ANA} = \frac{\mathrm{NAA}}{4},$$

where, T is the reporting study period of 6 years.

$$\mathrm{ANA} = \frac{\mathrm{NAA}}{4} = \frac{4}{6} = 0{,}67$$

The expected frequency of occurrence of the event (FOE) is determined by the formula:

$$\mathrm{FOE} = \frac{\mathrm{ANA}}{n},$$

where, ***n*** is the average number of employees in the electrical shop for the study period

$$\mathrm{FOE} = \frac{\mathrm{ANA}}{n} = \frac{0{,}67}{140} = 0{,}005$$

P – the indicator of the probability of a possible dangerous event occurring is determined according to Table 4.

Table 4. Indicator of the probability of a possible dangerous event P

ANA	Name	Scores
> 1 $year^{-1}$	High degree of probability	10
1 – 1 • 10^{-2} $year^{-1}$	Average degree of probability	6
1 • 10^{-2} - 1 • 10^{-4} $year^{-1}$	Not always, but maybe	3
1 • 10^{-4} - 1 • 10^{-5} $year^{-1}$	Low probability	1
1 • 10^{-5} - 1 • 10^{-6} $year^{-1}$	Incredibly, but it is impossible to completely exclude the possibility	0,5
1 • 10^{-5} - 1 • 10^{-7} $year^{-1}$	Almost impossible	0,2
1 • 10^{-7} - 1 • 10^{-8} $year^{-1}$	Virtually impossible	0,1

E is an indicator of the frequency of risk exposure, determined in points from Table 5.

Table 5. Indicators of the frequency of exposure to risk E

Name	Scores
Constantly (at least once an hour)	10
Often (at least once a day)	6
Sometimes (at least once a week)	3
Not constantly (at least once a month)	2
Rarely (several times a year)	1
Very rarely (less than once a year)	0,5

G – the severity of the damage caused by the consequences of a dangerous event is determined in points from Table 6.

Table 6. Damage severity index G

Name	Scores
Tragic consequences (death of several people)	100
Very serious consequences (death of one person)	40
Severe consequences (permanent disability)	15
Significant consequences (temporary disability)	7
Mild consequences (ambulance call)	3
Microtrauma (without disability)	1

According to Table 3, the value of **P** at PTS = 0.005 corresponds to the value of P = 3 points (not always, but possible).

3. Results and Discussion

Based on the actual statistical data of the number of accidents for this dangerous event, we will determine E. During the study period, 4 cases were identified for event No. 6, which is 0.67 cases per year. This value corresponds to the column in Table 4 - Very rarely (less than once a year), then the value of E = 0.5 points.

According to Table 5, we determine the severity of the consequences of dangerous event No. 6, then G = 7 points, which corresponds to the column - Significant consequences (temporary disability). If the risk index calculated according to this formula does not exceed 50, then the risk is considered acceptable. Based on the data obtained , we calculate:

R = 3 x 0.5 x 7 = 10.5 < 50. Thus, the risk level is acceptable.

According to the Kinney method, a quantitative assessment of the risk of danger was established. We have established that the most traumatic profession is an electrician on duty and equipment repair.

According to the analysis of injuries, we also found that the distribution of accidents due to the causes of occurrence in the Donskoy GOK electrical workshop for the period 2014-2019 shows that most accidents occur due to violations of safety and labor protection rules.

The occurrence of an emergency in an electrical shop, including with human casualties, is an extremely rare event, the level of risk in an electrical shop can be considered acceptable.

As additional measures to reduce the potential risks of industrial injuries, we recommend the subjects of the electric power industry:

- to improve the quality of staff briefings regarding the use of personal and collective protective equipment by employees, as well as the quality of training in safe methods and skills of performing work;

- ensure the proper quality of labor protection instructions and other production documentation;
- strengthen control over the organization of work by managers at all levels of management and supervision of workers during the execution of work;
- optimize the number and types of work, reducing as much as possible the number of jobs that are not the main ones for employees. At the same time, in case of an urgent need for such work, it is necessary to ensure the safety of employees and continuous monitoring by designated responsible persons.

4. Conclusion

Injuries at the enterprise are directly related to the level of labor organization, compliance with the norms and rules of work in electrical installations. Traumatism depends on the personality of the worker, his mental and physical condition, his reaction to emergency situations, a tendency to unsafe methods of work. It is necessary not only to prevent risks, but also to pay attention to the composition of the staff, take into account the specifics of the work at the planning stage, introduce innovative devices that help the employee in difficult situations and ensure control over the correctness of the actions performed by him. The obtained results of the study can be used at the enterprises of the electric power industry of the CIS countries and Kazakhstan.

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Талдау әдістерін жетілдіру және Қазақстан Республикасы Дөң тау – кен байыту комбинатының электр цехындағы өндірістік жарақаттануды болжау

Аңдатпа. Мақалада Қазақстан және ТМД елдерінің электр энергетикасы кәсіпорындарындағы жарақаттануды зерттеу мәселелері қарастырылады. Соңғы жылдары тау-кен, мұнай-газ және құрылыс салаларының кәсіпорындары салаларында жарақаттанудың себептері мен оларды шешу жолдарын зерделеу зерттеушілердің үлкен назарын аударды және бұл мәселені зерделеу Қазақстанның батыс өңірлерінде де өзекті.

Зерттеудің әдіснамалық негізі тау-кен, мұнай-газ және құрылыс секторларының кәсіпорындары мен өндірістерінде, сондай-ақ Қазақстанның электр энергетикасы кәсіпорындарында еңбекті қорғау, жарақаттану жөніндегі теория мен практиканың қазіргі заманғы ережелері болды.

Зерттеу нәтижелері бойынша жазатайым оқиғалардың ең көп тараған себебі еңбек қауіпсіздігі және еңбекті қорғау ережелерін бұзу, жұмыс өндірісін қанағаттанарлықсыз ұйымдастыру болып табылатыны анықталды. Апаттардың мән-жайларын зерттеу және олардың себептерін анықтау төтенше жағдайлардың қайталануын болдырмайтын алдын алу шараларын әзірлеуге мүмкіндік береді. Зерттеу нәтижелері Қазақстан және ТМД елдерінің электр энергетикасы кәсіпорындарында пайдаланылуы мүмкін.

Түйін сөздер: электр энергетикасы, қауіп, апат, жазатайым оқиға, жарақат, электр цехы, статистикалық әдіс.

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Совешенствования методов анализа и прогнозирования производственного травматизма в электроцехе Донского горно – обогатительного комбината Республики Казахстан

Аннотация. В статье рассматриваются вопросы исследования травматизма на предприятиях электроэнергетики стран СНГ и Казахстана. Изучение причин травматизма и путей их решения на предприятиях и отраслях горнодобывающей, нефтегазовой и строительной отраслей в последние годы привлекло большое внимание исследователей, и изучение этого вопроса также актуально в западных регионах Казахстана.

Методологической основой исследования послужили современные положения теории и практики по охране труда, травматизму на предприятиях и производствах горнодобывающего, нефтегазового и строительного секторов, а также на предприятиях электроэнергетики Казахстана.

По результатам исследования также было определено, что наиболее частой причиной несчастных случаев является нарушение правил техники безопасности и охраны труда, неудовлетворительная организация производства работ. Изучение обстоятельств аварий и выявление их причин позволяет разработать превентивные меры, предотвращающие повторение чрезвычайных ситуаций. Полученные результаты исследования могут быть использованы на предприятиях электроэнергетики стран СНГ и Казахстана.

Keywords: электроэнергетика, опасность, риск, авария, несчастный случай, травма, электроцех, статистический метод.

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