DOI 10.52209/1609-1825_2022_1_135 UDC 622.8

Safety Indicators in Coal Mines

[1]***ISSAKOV Bekzhan,** *Mast. of Tech. Sci., Assistant, isbekjan@mail.ru ,*
[1]**AVDEEV Leonid,** *Cand. of Tech. Sci., Associate Professor, avdeev@kstu.kz,*
[1]**ZHOLMAGAMBETOV Nurbek,** *Cand. of Tech. Sci., Acting Professor, Head of Department, nurbekz@mail.ru,*
[1]**KONAKBAYEV Yerassyl,** *Mast. of Tech. Sci., Assistant, e.konakbaev@bk.ru,*
[1]**ZHOLMAGAMBETOV Syrlybek,** *Cand. of Tech. Sci., Acting Associate Professor, syrlybekzh@mail.ru,*
[1]*Karaganda Technical University, Kazakhstan, 100027, Karaganda, N. Nazarbayev Avenue, 56,*
**corresponding author.*

Abstract. *In underground mining operations, accidents with serious consequences occur every year. The largest number of cases of group injury is associated with sudden outbursts of coal and gas, underground fires, transportation of people, rock mass and materials, poisoning with dangerous and harmful gases. An analysis of the causes of industrial injuries over a long period makes it possible to establish trends. The analysis also makes it possible to establish the most dangerous processes and technological operations at the present stage of technical development, to identify the main traumatic foci and, on this basis, to develop a set of measures, the implementation of which can prevent the occurrence of other similar injuries and traumatic situations. Knowing the results of the analysis of the causes of occupational injuries in the industry as a whole or individual enterprises and regions allows managers of enterprises, safety services to take timely measures to prevent similar violations of safety requirements and exclude cases of injury and accidents. Each accident is ultimately the result of non-compliance with the requirements of safety rules, the result of a dangerous development of technological, organizational or natural processes, as well as the wrong actions of workers, especially work managers.*

Keywords: *safety, safety indicators, safety assurance, coal mining, occupational injuries, safety assessment, contingency, emergency, personnel, work shift.*

Introduction. Knowing the results of the analysis of the causes of occupational injuries in the industry as a whole or individual enterprises and regions allows managers of enterprises, safety services to take timely measures to prevent similar violations of safety requirements and exclude cases of injury and accidents. Each accident is ultimately the result of non-compliance with the requirements of safety rules, the result of a dangerous development of technological, organizational or natural processes, as well as the wrong actions of workers, especially work managers.

An accident most often occurs unexpectedly and within a short period of time, however, the accumulation and formation of the causes and conditions for its occurrence occurs in most cases for a long time. Therefore, the safety engineering services of enterprises should pay serious attention to the analysis of the causes of injury and identified violations.

Methodology for quantitative assessment of the level of safety.

The assessment under consideration is based on the main condition for ensuring safety (Figure 1): the absence of an emergency in the process of underground coal mining or a way out of this situation if it occurs [1].

One of the conditions for ensuring the safety of personnel is the absence of an emergency on the interval $(0, T_c)$, where T_c is the duration of the work shift. Quantitatively, this condition can be expressed through the probabilistic characteristic

$$P(t_i < T_c) \leq \varepsilon, \quad (1)$$

where $P(t_i < T_c)$ is the probability that the random time t_i of the occurrence of an emergency from the i-th source will be less than the value T; ε is an infinitesimal quantity.

A necessary (but not sufficient) condition for ensuring the safety of personnel in the event of an emergency is the margin of time to exit from it (Figure 2) [2] i.e.

$$t_p > t_в \text{ или } t_p - t_в > 0, \quad (2)$$

where t_p is the reserve of time in an emergency (the time interval from the moment the emergency is detected until the moment the emergency parameter reaches the limit value); $t_в$ is the time required for a safe exit from this emergency (localization, liquidation of an emergency or rescue of personnel).

Taking into account conditions (1) and (2), the probability of ensuring the safety of personnel during the work shift is estimated by the expression

$$P_{sp} = 1 - \sum_{i=1}^{m} \sum_{j=1}^{t} [P_{ESij}(1 - P_{вij})], \quad (3)$$

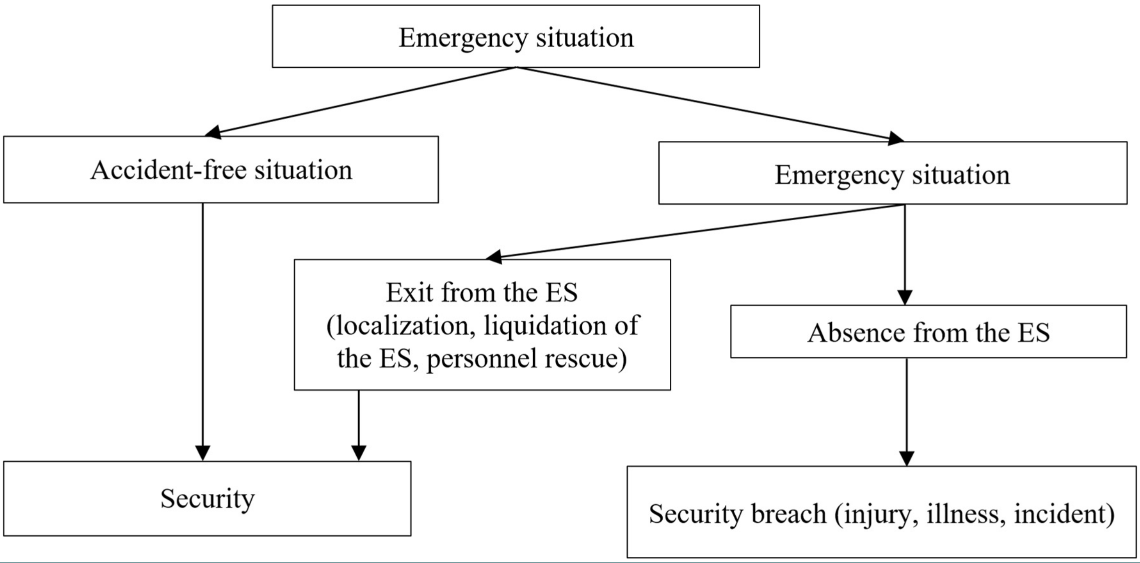

Figure 1 – General safety model (hazards)

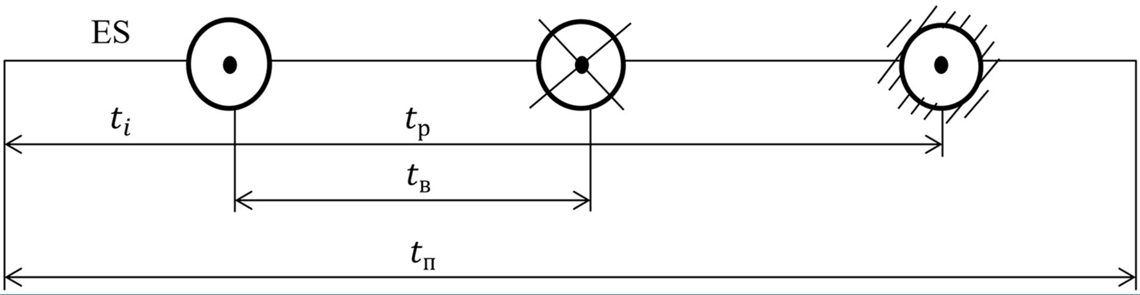

Figure 2 – Time characteristics of an emergency

where P_{ESij} is the probability of emergencies from the i-th source $(i=1,2,\ldots,m)$ at the j-th stage of the work shift $(j=1,2,\ldots,l)$ $P_{вij}$ is the probability of overcoming this emergency.

The quantitative assessment of P_{ACij} is based on the following provisions:

a) the category of emergency situations is one of the components of the flow of emergency situations;

b) the flow of emergency situations obeys Poisson's law;

c) emergency situations in the process of underground work can repeatedly arise and be eliminated, or they can turn into the most dangerous (emergency) states [2].

This circumstance will make it possible to consider the system «employee – equipment – environment» as a queuing system (QS), which, along with the fulfillment of the main task, «serves» the flows of requests for emergency situations of various significance, i.e. exits with a certain probability. In this case, the functioning of the QS to ensure the safety of the work shift personnel can be represented as a multiple stochastic sifting of the initial flow of non-staggering situations [3].

Taking into account that the flow of emergency situations obeys the Poisson law [4], in QS each event of this flow with a probability ϑ_1 is excluded (liquidated) from the flow with a probability $q_1=1-\vartheta_1$ goes into the flow of another, more dangerous criterion of emergency situation. Further, when from the events of the flow of the second category of danger with a probability of ϑ_2 it is excluded from this flow, and with a probability of $q_2=1-\vartheta_2$ it passes into the flow of emergency situation of the third category of danger (the degree of danger of each subsequent category of emergency situation increases). Each event of the j-th hazard category with probability ϑ_k is excluded from this flow, and with probability $q_k=1-\vartheta_k$ it passes into $k+1$ flow of an unshakable situation, etc. The flow of emergency situations of the last M hazard category $(k=1,2,\ldots,M)$ in the scheme under consideration is a flow of emergencies.

Based on the limit theorem for thinning flows obtained as a result of such a ϑ – transformation, the emergency flows (EF) of various hazard categories will also obey the Poisson law with parameters defined as follows:

$\lambda_1=\lambda_{EF}(1-\vartheta_1)$,

$\lambda_2=\lambda_{EF}(1-\vartheta_1)(1-\vartheta_2)$,

……………………………,

$\lambda_k=\lambda_{EF}(1-\vartheta_1)(1-\vartheta_2)\ldots(1-\vartheta_k)$,

…………………………………………,

$\lambda_M=\lambda_{EF}(1-\vartheta_1)(1-\vartheta_2)\ldots(1-\vartheta_k)\ldots(1-\vartheta_M)$,

where λ_{EF} is the parameter (intensity) of the flow of emergency situations that occur in the work process.

Since the emergency flow undergoes ϑ – transformation before the occurrence of an emergency, the flow parameter λ_M corresponds to the emergency flow parameter λ_{ES}.

The general functional diagram of the «worker – equipment – environment» system as a queuing system is shown in Figure 3.

The probability of occurrence of an emergency during time t is determined from the expression

$$P_{ES} = 1 - e^{-\lambda_{EF} t \prod_{k=1}^{M}(1-\vartheta_k)},$$

$$\text{or } P_{ES} = 1 - e^{-\lambda_{ES} t},$$

where M is the number of different states through which the system «worker – equipment – environment» will pass before the occurrence of an emergency;

λ_{ES} – the intensity of the flow of emergency situations.

Probability of occurrence of an emergency situation in time t

$$P_{EF} = 1 - e^{-\lambda_{EF} t},$$

$$\text{or } P_{EF} = 1 - e^{\frac{-N_{EF} t}{t_2}},$$

where N_{EF} – the total number of emergency situations that occur in technological operations on the same type of control objects;

t_2 is the total time during which N_{EF} emergency situations occurred.

The probability of occurrence of any other emergency situation [5], which differs in the degree of danger (for example, a dangerous or catastrophic situation $P_{\text{кат}}$), is determined similarly

$$P_{\text{оп}} = 1 - e^{-\lambda_{\text{оп}} t},$$

$$P_{\text{кат}} = 1 - e^{-\lambda_{\text{кат}} t},$$

where $\lambda_{\text{оп}}$ and $\lambda_{\text{кат}}$ are the parameters (intensities) of the flows of dangerous and catastrophic situations, respectively.

Knowing the probability of occurrence of an emergency P_{ES} in one period (work shift), we estimate the probability $Q_{N,n}$, i.e. the probability that n emergencies will occur in N_{shift}, where $n = \overline{0, N}$ (here we assume that no more than one emergency occurs in one shift). Assuming that all shifts are the same in terms of the safety of their performance, i.e. $P_{ES_1} = P_{ES_2} = \ldots = P_{ES_N} = P_{ES}$, the probability $Q_{N,n}$ will be determined by the binomial distribution

$$Q_{N,n} = C_N^n P_{ES}^n (1 - P_{ES})^{N-n},$$

$$\text{where } C_N^n = \frac{N!}{n!\,(N-n)!}.$$

To calculate the probabilities of occurrence of a certain number of emergencies, when the probabilities of their occurrence are not the same in different shifts, it is necessary to use the general theorem of probability theory on the repetition of experiments.

Considering that $P_{ES} << 1$ and assuming that N will be large enough (shifts of short duration are assumed, but with a high frequency of execution), the probability $Q_{N,n}$ will be determined

$$Q_{N,n} = \frac{(N\overline{P_{ES}})^n}{n!} e^{-N\overline{P_{ES}}} = \frac{(m_{\hat{n}})^n}{n!} e^{-m_{\hat{n}}},$$

where $m_{\hat{n}} = N\overline{P_{ES}}$ – mathematical expectation of the number of emergency situations for the analyzed number of shifts; $\overline{P_{ES}}$ – average value of P_{ES} – for N shifts.

The probability that at least one emergency situation will occur in N work shifts will be determined by the relation

$$Q_{N,n} = 1 - e^{-N\overline{P_{ES}}}.$$

The probability $Q_{N,n}$, expressed through the intensity of emergency situations λ_{ES}, has the form

$$Q_{N,n} = \frac{(\lambda_{ES} T_n N)^n}{n!} e^{-\lambda_{ES} T_n N}. \quad (4)$$

The average time of appearance per emergency situation for the simplest flow will be equal to

$$\overline{t_{ES}} = \lambda_{ES} \int_0^{\infty} t e^{-\lambda_{ES} t} dt = \frac{1}{\lambda_{ES}}. \quad (5)$$

Taking into account this expression, the probability $Q_{N,n}$ will be written

$$Q_{N,n} = \frac{\left(\frac{t_2}{t_{ES}}\right)^n}{n!} e^{-\frac{t_\Sigma}{t_{ES}}},$$

where $t_\Sigma = NT_n$ – the total time for which N shifts are implemented.

In practice, the flow of emergencies is not the simplest, however, the probability distribution $Q_{N,n}$ remains Poisson, similar to distribution (4). So

$$Q_{N,n} = \frac{a^n}{n!} e^{-a},$$

where $a = \int_{t_0}^{t_0 + t_\Sigma} \lambda_{ES}(t)\, dt = m_{\hat{\imath}}$ – mathematical expectation of the number of emergencies in the operating time interval from t_0 to $t_0 + t_\Sigma$.

For a non-stationary Poisson flow, the connection between $\lambda_{ES}(t)$ and $\overline{t_{ES}}(t)$ will no longer be determined by a dependence of the type (5). However, in principle, considering as a whole the flow of an emergency on the entire numerical axis of time as non-stationary, it is possible to consider it practically stationary on separate segments $\Delta t_j (j = \overline{1, r})$ of this axis.

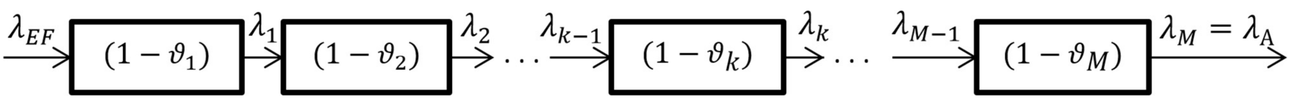

Figure 3 – General scheme ϑ of the transformation of the emergency flow

Then

$$Q_{N,n} = \frac{\left(\sum_{j=1}^{r} \propto_j\right)^n}{n!} e^{-\sum_{j=1}^{r} \propto_j},$$

where

$$\propto_j = \int_{t_0 + \sum_{j=1}^{j-1} \Delta t}^{t_0 + \sum_{j=1}^{j} \Delta t_j} \lambda_{ES}(t)\,dt = \lambda_{ESj}^{av} \Delta t_j; \sum_{j=1}^{r} \Delta t_j = t_\Sigma,$$

where λ_{ES}^{av} – average value of the flow intensity of the emergency situation on the segment Δt_j.

Probabilistic safety indicators.

1. The probability of a safe work shift of an object is the most general (integral) quantitative indicator that characterizes the probability of finishing a work shift without consequences hazardous to the health of team members [6].

2. Mathematical expectation of the number of incidents m_N for the period of a work shift is a quantitative indicator that characterizes the average number of expected incidents for the period of a work shift of a technological object of this type – $m_N = NP_K$, where P_K – is the probability of an incident (accident, catastrophe) during one work shift, N – the number of work shifts for the billing period.

3. The probability of an accident-free work shift is a quantitative indicator that characterizes the probability of the absence of emergencies during a work shift

$$P_a = \prod_{i=1}^{m} (1 - P_{ES_i}),$$

where P_{ES_i} – probability of an emergency from the i-th source $(i = 1, 2, \ldots, m)$.

4. The probability of an emergency [7] during a work shift is a quantitative indicator that characterizes the probability P_{ES} of at least one emergency during one work shift

$$P_{ES} = 1 - e^{-\lambda_{AC} \tau_n}.$$

5. The probability of exit from emergencies in a work shift is a quantitative indicator that characterizes the probability of a successful exit from an emergency due to the elimination, localization of an emergency or rescuing members of the brigade

$$P_e = P_{lq} + (1 - P_{lc}) P_{lc} + (1 - P_{lq})(1 - P_{lc}) P_r,$$

where P_{lq} – probability of liquidation of an emergency; P_{lc} – probability of localization of an emergency; P_r – probability of rescue of members of the brigade.

6. Probability of elimination of emergencies during the work shift – a quantitative indicator that characterizes the probability P_{lc} of a successful exit in the elimination of emergencies during the work shift $P_{lq} = P_d P_3 \text{x} P_4$, where P_d – the probability of detecting an emergency; P_3 – conditional probability of recognition (identification) of an emergency; P_4 is the conditional probability of neutralizing the emergency factor and eliminating the immediate cause of the emergency.

7. The probability of localization of emergencies during the work shift is a quantitative indicator characterizing the probability of a successful outcome in the localization of emergencies during the work shift – $P_{lc} = P_r P$, where P is the conditional probability of termination (localization) of the development of emergency situations.

8. The probability of rescue of the brigade is a quantitative indicator characterizing the probability of a successful outcome of the rescue operation during the work shift $P_s = P_{br} + (1 - P_{br}) P_{br}$, where P_{br} is the probability of brigade rescue with the help of emergency rescue services (VASS «Komir»).

9. Risks of team members – a quantitative indicator characterizing the probability of violating the requirements of safety standards.

Statistical indicators of safety. Various types (groups) of statistical indicators are used to quantify the safety level of the brigade based on the results of technological operations performed. They are expressed in physical quantities or the ratio of these quantities obtained as a result of processing statistical data on the performance of production tasks.

Statistical indicators can be divided into general and particular, absolute and relative [8]. General indicators characterize the level of safety of the brigade at the facility as a whole, take into account the integral influence of all factors on it, and private indicators – only individual factors or groups of factors.

Absolute statistical indicators include: the total number of incidents, accidents and catastrophes, the total number of emergencies, the use of personal protective equipment, the inclusion of an accident response plan, calling the VASS Komir, etc. However, due to their limited practical application (due to their dependence on the total number of mines, facilities, brigades, etc.), the most widely used are relative indicators that can be attributed to a certain period of work of the brigade, the number of homogeneous technological objects, the number of work shifts, the number of occurrences of any events, etc. [9].

Relative statistical indicators can be divided into the following types (groups) of indicators [10]: general; causation of the occurrence of emergency (emergency) situations; distribution of emergency situations by hazard factor; distribution of emergency (emergency) situations by technological operations; temporary indicators of emergency (emergency) situations; indicators of personnel adaptability to exit from emergency (emergency) situations; the effectiveness of the brigade's actions to get out of emergency (abnormal) situations; erroneous actions of personnel; additional indicators.

Conclusions. The main tasks of the analysis of industrial injuries: identification of traumatic factors, technical and organizational reasons that led to injury; identification of faces, areas, technological operations in which there is an increased danger, as well as emergency situations that arise in the production process; establishing the nature and degree of influence of equipment, technology, level of organization and other factors on the safety of work; development of measures to prevent injuries and their causes.

The proportion of incidents by their traumatic factors and causes is determined, as a rule, by a statistical method and makes it possible to fairly effectively assess the state of safety at enterprises and the most dangerous technological processes and sections.

REFERENCES

1. Law of the Republic of Kazakhstan «On Civil Protection» dated April 11, 2014, no. 188-V 3PK.
2. Rules for ensuring industrial safety for hazardous production facilities. February 12, 2015, no. 10244.
3. Law of the Republic of Kazakhstan «On the safety of machinery and equipment» dated July 21, 2007, no. 305.
4. Karnachev I., Nikanov A., Tereshchenko V. Poisson's law. Journal «Tekhnadzor», no. 11 (96). – 2014. – pp. 51-53.
5. T.M. Sheveleva, A.F. Pihlap. Using the fault tree to calculate the probabilities of emergency situations. Collection of scientific articles «Mathematics and its applications in modern science and practice». 2017. – pp. 238-242.
6. V.S. Vaganov. Safety rules in coal mines – development of multifunctional safety systems. Journal «Mining», no. 2 (132). – 2017. – p. 77.
7. R.A. Zhuzhuev, N.N. Dorfman. Determining the probability of occurrence of emergencies. Problems of ensuring safety in liquidation of consequences of emergency situations. Volume 1, 2017. – pp. 1030-1035.
8. P.I. Karnachev, N.A. Vinnichenko, and I.P. Karnachev. «Statistical indicators of industrial injuries used in domestic and international practice for assessing the level of labor safety». Safety and labor protection, no. 2. – 2015. – p. 37.
9. I.P. Karnachev, E.B. Koklyanov. Analysis of statistical indicators of safety and labor protection used in the study of the dynamics of industrial injuries. Bulletin of MSTU, volume 14, no. 4. – 2011. – pp. 751-757.
10. Avdeev L.A., Breido I.V. Comparative analysis of various decision-making methods in automated gas protection systems. RAS Siberian Branch Physical and technical problems of mining. Journal of Mining Science. USA: 2017. – No. 1.

Көмір шахталарындағы қауіпсіздік көрсеткіштері

[1]***ИСАКОВ Бекжан Ерболатович,** т.ғ.м., ассистент, isbekjan@mail.ru ,*

[1]***АВДЕЕВ Леонид Анатольевич,** т.ғ.к., доцент, avdeev@kstu.kz,*

[1]***ЖОЛМАГАМБЕТОВ Нурбек Рысбекович,** т.ғ.к., профессор м.а., кафедра меңгерушісі, nurbekz@mail.ru,*

[1]***КОНАКБАЕВ Ерасыл Куанышевич,** т.ғ.м., ассистент, e.konakbaev@bk.ru,*

[1]***ЖОЛМАГАМБЕТОВ Сырлыбек Рысбекович,** т.ғ.к., доцент м.а., syrlybekzh@mail.ru,*

[1]*Қарағанды техникалық университеті, Қазақстан, 100027, Қарағанды, Н. Назарбаев даңғылы, 56,*

**автор-корреспондент.*

***Аңдатпа.** Жерасты тау-кен жұмыстарында ауыр зардаптарға әкелетін апаттар жыл сайын орын алады. Топтық жарақаттардың ең көп саны көмір мен газдың кенеттен атқылауымен, жер асты өрттерімен, адамдарды, тау жыныстары мен материалдарды тасымалдаумен, қауіпті және зиянды газдармен уланумен байланысты. Ұзақ кезеңдегі өндірістік жарақаттардың себептерін талдау тенденцияларды анықтауға мүмкіндік береді. Талдау сонымен қатар техникалық дамудың қазіргі кезеңінде аса қауіпті процестер мен технологиялық операцияларды белгілеуге, негізгі жарақат ошақтарын анықтауға және осының негізінде жүзеге асырылуы олардың пайда болуын болдырмайтын шаралар кешенін әзірлеуге мүмкіндік береді. Басқа ұқсас жарақаттар мен травматикалық жағдайлар. Жалпы саладағы немесе жекелеген кәсіпорындар мен аймақтардағы өндірістік жарақаттану себептерін талдау нәтижелерін білу кәсіпорын басшыларына, қауіпсіздік қызметтеріне қауіпсіздік талаптарының ұқсас бұзылуын болдырмау және жарақаттану мен жазатайым оқиғаларды болдырмау үшін дер кезінде шаралар қабылдауға мүмкіндік береді. Әрбір жазатайым оқиға, сайып келгенде, қауіпсіздік ережелерінің талаптарын сақтамаудың нәтижесі, технологиялық, ұйымдастырушылық немесе табиғи процестердің қауіпті дамуының нәтижесі, сонымен қатар жұмысшылардың, әсіресе жұмыс басшыларының қате әрекеттерінің нәтижесі болып табылады.*

***Кілт сөздер:** қауіпсіздік техникасы, қауіпсіздік көрсеткіштері, қауіпсіздікті қамтамасыз ету, көмір өндіру, өндірістік жарақаттар, қауіпсіздікті бағалау, күтпеген жағдай, төтенше жағдай, персонал, жұмыс ауысымы.*

Показатели безопасности в угольных шахтах

[1]***ИСАКОВ Бекжан Ерболатович,** м.т.н., ассистент, isbekjan@mail.ru ,*

[1]***АВДЕЕВ Леонид Анатольевич,** к.т.н., доцент, avdeev@kstu.kz,*

[1]***ЖОЛМАГАМБЕТОВ Нурбек Рысбекович,** к.т.н., и.о. профессора, зав. кафедрой, nurbekz@mail.ru,*

[1]***КОНАКБАЕВ Ерасыл Куанышевич,** м.т.н., ассистент, e.konakbaev@bk.ru,*

[1]***ЖОЛМАГАМБЕТОВ Сырлыбек Рысбекович,** к.т.н., и.о. доцента, syrlybekzh@mail.ru,*

[1]*Карагандинский технический университет, Казахстан, 100027, Караганда, пр. Н. Назарбаева, 56,*

**автор-корреспондент.*

Аннотация. *При ведении подземных горных работ ежегодно происходят аварии с тяжелыми последствиями. Наибольшее число случаев группового травмирования связано с внезапными выбросами угля и газа, подземными пожарами, транспортировкой людей, горной массы и материалов, отравлением опасными и вредными газами. Анализ причин производственного травматизма за длительный период дает возможность установить тенденции. Анализ также дает установить наиболее опасные процессы и технологические операции на современном этапе технического развития, выявить основные травмоопасные очаги и на этой основе разработать комплекс мероприятий, осуществление которых может предотвратить возникновение других аналогичных травм и травмоопасных ситуаций. Знание результатов анализа причин производственного травматизма в целом по отрасли или отдельных предприятий и регионам позволяет руководителям предприятий, службам техники безопасности своевременно принять меры по недопущению аналогичных нарушений требований безопасности и исключить случаи травмирования и аварий. Каждый несчастный случай является в конечном счете результатом невыполнения требований правил безопасности, результатом опасного развития технологических, организационных или природных процессов, а также неправильных действий работающих, особенно руководителей работ.*

Ключевые слова: *безопасность, показатели безопасности, обеспечение безопасности, добыча угля, производственный травматизм, оценка безопасности, нештатная ситуация, аварийная ситуация, персонал, рабочая смена.*

REFERENCES

1. Law of the Republic of Kazakhstan «On Civil Protection» dated April 11, 2014, no. 188-V 3PK.
2. Rules for ensuring industrial safety for hazardous production facilities. February 12, 2015, no. 10244.
3. Law of the Republic of Kazakhstan «On the safety of machinery and equipment» dated July 21, 2007, no. 305.
4. Karnachev I., Nikanov A., Tereshchenko V. Poisson's law. Journal «Tekhnadzor», no. 11 (96). – 2014. – pp. 51-53.
5. T.M. Sheveleva, A.F. Pihlap. Using the fault tree to calculate the probabilities of emergency situations. Collection of scientific articles «Mathematics and its applications in modern science and practice». 2017. – pp. 238-242.
6. V.S. Vaganov. Safety rules in coal mines – development of multifunctional safety systems. Journal «Mining», no. 2 (132). – 2017. – p. 77.
7. R.A. Zhuzhuev, N.N. Dorfman. Determining the probability of occurrence of emergencies. Problems of ensuring safety in liquidation of consequences of emergency situations. Volume 1, 2017. – pp. 1030-1035.
8. P.I. Karnachev, N.A. Vinnichenko, and I.P. Karnachev. «Statistical indicators of industrial injuries used in domestic and international practice for assessing the level of labor safety». Safety and labor protection, no. 2. – 2015. – p. 37.
9. I.P. Karnachev, E.B. Koklyanov. Analysis of statistical indicators of safety and labor protection used in the study of the dynamics of industrial injuries. Bulletin of MSTU, volume 14, no. 4. – 2011. – pp. 751-757.
10. Avdeev L.A., Breido I.V. Comparative analysis of various decision-making methods in automated gas protection systems. RAS Siberian Branch Physical and technical problems of mining. Journal of Mining Science. USA: 2017. – No. 1.