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Analyzing and Developing Measures to Reduce Industrial Injuries in the Abayskaya Mine

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Abstract. *The purpose of the study is to analyze and develop measures to reduce industrial injuries at the Abayskaya mine. The results of a statistical analysis of mine accidents over six years were considered. It was determined that the main cause of industrial injuries at the mine is organizational reasons, the share of which is 80% of the total number of injuries. It was determined that cases of injuries due to psychophysiological reasons occupy the second place in the total number of victims. Technical and hygienic causes of occupational injuries account for 7.4 per cent and 1.7 per cent of injuries, respectively. The article shows the distribution of cases of industrial injuries by types of work and by types of incidents. An analysis of types of industrial injuries was also carried out on the basis of initial data on injuries recorded at the Abayskaya mine.*

Keywords: *industrial injuries, mine, accident, technological process, simulators, virtual reality.*

Introduction

One of the most important sectors in the economy of the Republic of Kazakhstan is the coal industry. Our country has large geological reserves of coal, the volume of which exceeds 283 billion tons [1].

The technological process of coal mining is accompanied by hazardous production factors, such as moving machines and mechanisms, moving elements of production equipment, electric current, enclosed space, the rock massif collapse. As a result of these factors, a high level of industrial injuries is observed in coal mines, which is one of the main problems in the field of occupational safety at mining enterprises.

Research results

This article presents the results of a statistical analysis of accidents that occurred in the Abayskaya mine from 2010 to 2016, on the basis of which measures were developed to reduce the level of industrial injuries.

Within the period under review from 2010 to 2016, in the Abayskaya mine there occurred 119 cases of industrial injuries. Based on the initial data of the incidents collected in the Abayskaya mine, a statistical analysis of industrial injuries was carried out according to the following criteria: causes, the type of incident, the type of mining operations, the type of industrial injuries and their severity.

The causes of industrial injuries are conventionally divided into 4 types: organizational, technical, sanitary-hygienic and psycho-physiological [2]. Table 1 shows the distribution of the number of victims for these types of causes.

Table 1 shows that the main causes of industrial injuries in the mine are organizational causes, which account for 80% of the total number of injuries. Organizational causes include violation of safety rules during mining, driving workings, non-observance of the rules of operating mining equipment, violation of the rules of transportation, loading, unloading the materials, violation of safety rules when mounting powered support and its parts and violation of the passport of supporting mine workings.

Cases of injuries conditioned by psycho-physiological causes take the second place among the total number of victims. These causes include fatigues caused by large physical (static and dynamic) overloads, overstrain of analyzers (visual, auditory, tactile), monotony of work, stressful situations, a painful state.

The share of technical and sanitary-hygienic causes of industrial injuries accounts for 7.4% and 1.7% of injuries of the total number, respectively. The technical causes of industrial injuries in the mine arose as a result of design flaws, malfunctions of machines, mechanisms, insufficient mechanization and automation of heavy and harmful work. The sanitary-hygienic causes of industrial injuries are associated with violation of the requirements of sanitary standards for lighting extraction areas.

The results of the analysis of industrial injuries that occurred in the Abayskaya mine by the type of incident are presented in Table 2.

Table 1 – Causes of industrial injuries

Causes of industrial injuries	Number of victims	
	prs	%
Organizational	96	80
Technical	8	7.4
Sanitary-hygienic	2	1.7
Psycho-physiological	13	10.9
Total	119	100

Table 2 – Types of incidents

No	Types of incidents	Number of victims	
		prs	%
1	The rock massif collapse	52	43.7
2	Heavy object fall	22	18.5
3	Man fall	16	13.4
4	Clamping limbs in equipment	10	8.4
5	Impact of body parts on equipment	8	6.7
6	Methane poisoning	7	5.9
7	Traffic accident	4	3.4
Total		119	100

Based on the data in Table 2, it can be stated that the main type of incident in the mine is the rock massif collapse on the workers. This type of incident accounts for almost 44% of the total number of injuries.

Falling heavy objects on workers and falling people are also frequent accidents, 18.5% and 13.4%, respectively, of the total number of victims.

It should be noted that a small number of road accidents took place in the mine, which include accidents involving underground mine transport.

To carry out a statistical analysis of industrial injuries by type of mining operations, a set of basic and auxiliary operations was determined, during which mine workers received industrial injuries. The main operations included tunneling and stoping operations, as well as auxiliary transport and repair operations. Based on these data, the distribution of industrial injuries by type of operations was made, which is presented in Table 3.

The distribution of industrial injuries by type of operations in Table 3 shows that most injuries occurred during sinking (35.3%) and stoping (26.9%) operations. During sinking operations, the largest number of injured workers was recorded when supporting mine workings (15.9%) and when extracting rocks (11.7%). During stoping operations, the largest number of victims of coal mining accounted for 21% of all injuries. Such a high level of industrial injuries in breakage and drifting faces is explained by the fact that these places are the concentration of the main production processes, during which workers are exposed to hazardous and harmful factors such as moving and rotating parts and mechanisms of mining equipment, increased dustiness of the air in the extraction area, an increased level of noise and vibration, the likelihood of the rock massif collapse on a worker, etc.

Thus, the number of injured people accounted for in the breakage and drifting workings is 62% of all cases of injuries, in transport and repair work 22.7% and 15.1%, respectively.

Based on the initial data of injuries registered in the Abayskaya mine, an analysis of the types of industrial injuries was carried out. Table 4 and Figure 1 show the results of the analysis.

According to Table 4, when driving underground mining, miners most often get bruises, dislocations of the limbs (arms, legs): 33.6% and fractures of the limbs: 25.2%.

Figure shows the ratio of the severity of injuries that occurred during stoping and sinking operations in the mine.

In Figure, minor injuries are at the same level during stoping and sinking operations. Severe injuries are more prevalent in sinking operations than in stoping ones. Fatal injuries occurred only during sinking operations; this degree of severity is absent in stoping operations.

Thus, the statistical analysis of industrial injuries that occurred in the Abayskaya mine shows that the most frequent causes of accidents are violation

Table 3 – Distribution of industrial injuries by the type of operations

No	Operation type	Operation subtype	Number of victims			
			prs	%	prs	%
1	Sinking operations	Supporting mine workings	19	15.9	42	35.3
		Extracting the rock mass	14	11.7		
		Assembly/dismantling equipment	4	3.4		
		Repairing a support	2	1.7		
		Drilling holes	3	2.5		
2	Stoping operations	Mining coal	25	21	32	26.9
		Assembly/dismantling powered support	7	5.9		
3	Transport operations	Transporting materials	14	11.8	27	22.7
		Transporting people	7	5.9		
		Loading/unloading materials	6	5.04		
4	Repair operations	Repair of equipment	9	7.5	18	15.1
		Assembly/dismantling equipment	5	5.04		
		Repair of supports	4	4.2		

Table 4 – Types of industrial injuries

No	Types of industrial injuries	Number of victims	
		prs	%
1	Contusions, dislocations of limbs (arms, legs)	40	33.6
2	Fractures of limbs (arms, legs)	30	25.2
3	Head contusion	10	8.4
4	Contusions of the supporting apparatus (neck, back)	9	7.7
5	Traumatic brain injury	8	6.7
6	Gas poisoning	5	4.2
7	Fractured ribs	5	4.2
8	Injuries incompatible with life	4	3.4
9	Contusion of joints	3	2.5
10	Fractures of the supporting apparatus (neck, back)	3	2.5
11	Broken nose	1	0.8
12	Injury to eyes	1	0.8
Total		119	100

of safety rules of mining and sinking operations, violation of the passport of supporting mine workings; the main types of accidents are the rock massif collapse and heavy objects fall; industrial injuries were most often received by miners who worked in breakage faces during coal mining and in development mine workings when extracting rocks and supporting mine workings.

Conclusion

Taking into account the results of the carried out statistical analysis, the following measures are recommended to eliminate the main causes of industrial injuries:

- to prevent violations of safety rules and regulations during mining operations, it is recommended to introduce interactive training simulators in virtual reality for mine workers;

- to increase the safety of the process of the mine working roof cleaning.

Virtual reality is one of the highly developed forms of computer modeling that realizes the illusion of a person's entry and stay in the artificial world in real time. Technologies of this kind make it possible to act directly in the virtual world using sensory devices that associate movements with the accompaniment of audiovisual effects [3, 4, 5].

The main purpose of simulators in virtual reality is to track the sequence and correctness of performing

The severity of injuries that occurred when performing stoping and sinking operations

all kinds of technological operations that meet the safe requirements for performing work. In virtual reality simulators, you can reproduce the areas of stoping operations and assembly chambers and the working that take place in these areas and train workers safe conducting of mining operations without violating the rules and safety measures with the definition of hazardous working areas, and what situations can arise if workers do not adheres to safety rules.

The use of simulators in virtual reality allows:

- organizing the training in the most realistic conditions of virtual mining, without assuming the risk to the trainee and expensive equipment;
- using the visual and muscle/motor memory of the trainee;
- making trainees interested in the learning process: new technologies will replace «boring» learning;
- evaluating the behavior of employees in various situations: the employee gets lost, gets confused in actions, panics or acts according to requirements (in contrast to traditional training, where the teacher, to whom the trainee has learned and told the instructions, cannot be sure how the trainee will behave in a real workplace);
- promoting the image of the mine to the modern one, attracting the attention of the media, thereby creating a positive image;
- provoking interest in young people, attracting new promising personnel.

Virtual reality simulators immerse miners in a simulated underground environment where miners can be trained in real life scenarios and test their response to hazards in a safe environment.

To improve the safety of the process of the mine working roof cleaning, it is necessary to take the following recommendations [6]:

- to pay the main attention to the fact that the lag of the permanent support does not exceed the passport value;
- the loading of the rock mass, breaking up oversized pieces of the rock mass, preparation of holes for support props, erection of permanent support frames and other work in the face before mounting permanent support frames should be carried out only under the protection of a temporary support;
- before starting any work in the face, it is necessary to clean carefully and to knock off the roof, the bottom of the face and the walls of the working with a 2.5-3 m long undercut from under the supported space, which will increase the distance between the dangerous zone of the roof and the rafter, thereby providing his security;
- to pay special attention to the quality of the roof cleaning, to the fore-head and sides of the face before mounting a temporary support and the permanent support elements;
- in case of signs of increased rock pressure in the face, take measures to reduce the length of the unsecured part of the face.

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«Абайская» шахтасында өндірістік жарақаттануды төмендету бойынша шараларды дамыту және талдау

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Аңдатпа. *Зерттеу мақсаты – «Абайская» шахтасында өндірістік жарақаттануды төмендету бойынша іс-шараларды әзірлеу және талдау. Алты жыл ішінде шахтадағы жазатайым оқиғаларды статистикалық талдау нәтижелері қарастырылды. Шахтадағы өндірістік жарақаттанудың негізгі себебі ұйымдастырушылық себептер болып табылады, олардың үлесі жалпы жарақаттану жағдайларының 80%-ын құрайды. Психофизиологиялық себептерге байланысты болған жарақат жағдайлары зардап шеккендердің жалпы санынан екінші орын алатындығы анықталды. Өндірістік жарақаттанудың техникалық және санитариялық-гигиеналық себептерінің үлесіне зардап шеккендердің жалпы санының тиісінше 7,4% және 1,7%-ы тиесілі. Мақалада өндірістік жарақаттану жағдайларын жұмыс түрлері және оқиғалар түрлері бойынша бөлу келтірілген. Сондай-ақ «Абайская» шахтасында тіркелген жарақаттану туралы бастапқы деректер негізінде өндірістік жарақаттардың түрлеріне талдау жүргізілді.*

Кілт сөздер: *өндірістік жарақаттану, шахта, жазатайым оқиға, технологиялық процесс, тренажерлар, виртуалды нақтылық.*

Анализ и разработка мероприятий по снижению производственного травматизма на шахте «Абайская»

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Аннотация. *Цель исследования – анализ и разработка мероприятий по снижению производственного травматизма на шахте «Абайская». Рассматривались результаты статистического анализа несчастных случаев на шахте за шесть лет. Определено, что основной причиной производственного травматизма на шахте являются организационные причины, доля которых составляет 80% случаев травматизма от общего числа. Определено, что случаи травматизма, происшедшие из-за психофизиологических причин, занимают второе место от общего числа пострадавших. На долю технических и санитарно-гигиенических причин производственного травматизма приходится 7,4% и 1,7% случаев травматизма от общего числа пострадавших соответственно. В статье приведено распределение случаев производственного травматизма по видам работ и по видам происшествий. Также проведен анализ видов производственных травм на основании исходных данных о травматизме, зарегистрированных на шахте «Абайская».*

Ключевые слова: *производственный травматизм, шахта, несчастный случай, технологический процесс, тренажеры, виртуальная реальность.*

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