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Introduction

Underground mines will be hazardous production facilities (HPF) at all times for: first, the working environment is formed by natural and geological conditions to a great extent; second, mining technologies include complex processes to be run mostly underground; and, third, highlyengineered mining machinery contains elements that could be injurious given unsafe practices. HPFs of the highest hazard are coal mines. Russia is now producing coal in 50 mines. The vast majority of these mines are hazardous in terms of coal, gas and rock outbursts, coal ignitability and other factors.

Occupational health and safety (OHS) in coal mines is a great concern of both the state represented by control and supervision agencies, and the owners and managers comprehending responsibility of business for safe and comfortable working conditions of employees [1–3].

Health and safety management in coal mines

Over the recent 5–8 years, there is a general trend of increase in the economic efficiency of mines, decrease in the total rate of injuries and improvement of OHS (**Table**) [4].

As seen from the Table, the number of injuries in coal mines was more than 10.1 times higher than in open pit coal mines in 2010 and reduced later on. The number of casualties after accidents in coal mines decreased from 122 people in 2010 to 12 people in 2018. Such result was promoted by appropriate activities, including the Federal Law on Special Evaluation Study of Working Conditions effective as of January 1, 2014. The Law stimulates the employers to change from indemnification to precaution and prevention of hazards.

The specific fatal traumatism was 0.14 people/Mt in all kind mines in 2017 and reduced to 0.04 people/Mt in 2018. Despite the essential decrease, the level of fatal traumatism remains to be higher than in the other coal-producing countries such as South Africa (0.035), Australia (0.03) and the United States (0.011). This index is higher in China (0.25) and in Ukraine (1.194).

Amidst the causes of accidents and fatalities, the top place belongs to the human factor, including low culture, infringement of various regulations and technologies, poor management and relaxed control over adherence to

OCCUPATIONAL HEALTH AND SAFETY DIGITALIZATION IN THE COAL INDUSTRY

The article discusses problems of occupational health and safety in coal mines. These problems draw great concern both of the government represented by control and supervision agencies and the owners and management of coal mining companies which realize responsibility of business for safety and comfort of miners at work. Any accident inflicts a heavy economic loss to a mine or a business; moreover, it causes irreparable social damage connected with injuries, hurt to health or mortality. The authors believe the hazardous impact of industrial factors on production performance is much higher in mining than in the other industries for the reason that a mineral deposit is concurrently an object of economic activity and a factor of risk. Therefore, mines are assumed as the hazardous production facilities with high probability of emergency. The occupational health and safety control is specific for its functioning indirectly governs efficiency in a number of business activities of a company: production, commerce, economy, social sphere and ecology. The article reviews operation of one of the leading coal mining companies proposing and introducing advanced digital solutions in occupational health and safety. Mining industry raises high safety standards and, thus, uses many innovations, for example, mobile positioning and control of employees in case of emergency, introduction of the United Automated Control Center information and analysis system, etc. Currently, it is undertaken to change ERP system from SAP NANA Platform to SAP Cloud Platform, which will expand the performance range of the system in all structures of the company.

Key words: digitalization, coal industry, labor protection, occupational health and safety, injuries.

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the health and safety standards by employees [5–7]. For instance, SUEK Company reduces production risks by developing and implementing yearly an integrated OHS action plan. In 2017 the implementation expenses of SUEK totaled USD 56 millions. The lost time injury frequency rate (LTIFR) is permanently low in SUEK's mines—at the level of 1.0. In 2017 LTIFR decreased by 15% (as compared with 2016) and made 6593 h. In that very year, in mines of SUEK, 65 injury cases were recorded, which was equal to the index of 2016. The mine management pay insufficient attention to such important OHS actions as organization and motivation towards health and safety behavior, and limit to only engineering controls. This fact is proved by the analysis of distribution structure of OHS money resources at SUEK in 2017.

As seen in the figure, the institutional arrangements took merely 8% of total OHS assets. And this happens despite the organizational framework and human factor are at the top on the list of causes of accidents and injuries. The analysis of the accident investigation documents (NS-1 form) and reports on injuries and accidents (TB-2-Ugol) disclosed an even more impressive picture: the cause of 67% of accidents and injuries was the human factor, including organizational framework. In 2018 SUEK raised the OHS expenses up to 3,5 billion rubles.

Year	Coal production, Mt		Accidents		Fatalities, people		Specific fatal traumatism, people/Mt	
	UM	OPM	UM	OPM	UM	OPM	UM	OPM
2010	102.7	220.5	17	1	122	12	1.19	0.05
2011	101.0	234.4	9	1	33	10	0.33	0.04
2012	12.9	42.3	11	2	28	5	0.25	0.02
2013	101.0	251.0	11	0	57	4	0.56	0.02
2014	105.3	252.9	7	1	18	5	0.17	0.02
2015	103.7	269.7	6	2	11	7	0.1	0.02
2016	104.6	281.1	7	0	53	2	0.5	0.01
2017	104.5	304.4	3	0	12	5	0.1	0.02
2018 9 months	80.5	238.7	2	0	9	4	0.1	0.01
Comment: UM—underground mining; OPM—open pit mining.								

Rate of accidents, fatalities and specific fatal traumatism versus open pit and underground coal mining methods in 2010–2018

The analysis of injury rates in the mining industry shows a drawdown in the number of injuries and accidents in recent years. Naturally, attenuation of influence exerted by the human factor is one of the critical missions of OHS control. At the same time, the human factor is the least controllable and unforeseen event, especially, under extreme conditions. It is exceptionally difficult to foresee actions of a team of workers operating in such a challenging working environment as a coal mine.

A vital part belongs to prevention of accidents and emergences at hazardous production facilities based on minimization of industrial risk [8–10].

The occupational health and safety control is provided and supported by:

 recognition of goals and objectives in the field of production safety;

 planning, development and implementation of measures towards reduction of risk of accidents at hazardous production objects;

identification, analysis and prediction of risks and hazards;

- process inspection of adhesion to OHS standards;

prompt adjustment of risk reduction measures at hazardous production objects;

 participation of personnel in the risk reduction activities;

- accident and injury risk reduction coordination.

Mining companies in foreign countries, which have minimized industrial risks and improved OHS performance, cut down expenses connected with insurance, casualty loss indemnification, legal proceedings as well as shorten downtimes [11–14].

It is necessary to change from recovery from injuries and accidents to their prevention. One of the criteria can be the number of safety violations, including repeated violations. To combat the hookup of natural disasters and human factor, it is proposed to use the systems of equipment named *Digital Mine* [15–17].

Such systems already exist, including transfer of huge arrays of data—readings of instruments, location and



Distribution of money resources for occupational health and safety at SUEK in 2017

actions of each miner, air, heat and condition of machines. In this case, an operator on ground surface makes decisions in time, without delay and based on objective indices of instruments rather than on dissonant evidences of eye witnesses. Moreover, the use of such systems will solve the problem of search, rescue and homing both people and machines.

Digital Mine in practice: Case study

A unique achievement of the production safety management and control digitalization and informatization is engineering and introduction of the United Automated Control Center information and analysis system at SUEK-Kuzbass. In 2013–2015 two control and analysis centers were arranged at the headquarters of SUEK (Moscow) and in Kuzbass.

The center in Moscow controls the industrial safety system in real time mode and coordinates actions of all specialists in off-normal situations. The center in Kuzbass accumulates information on all processes and key indices in OHS sphere—from gas content of air to positioning of employees and machines, and displays abnormities automatically.

Mines of SUEK operate a set of intelligent systems, e.g. underground wi-fi, which ensures coordination and highlevel safety of personnel activities in the course of production, and methane sensors incorporated in lamps on headpieces, and functional 3D models of all mines, and various simulators for personnel training. The coal mining industry specifies high safety standards, which explains application of numerous innovations, for instance, mobile positioning or management of personnel in cases of emergency. At the present time, the modern platform solutions connected with SAP products are utilized. LTIFR has reduced by 18%, from 1.50 to 1.23 in 2013–2015, made 1% in 2016 and remained unaltered in 2017. Transition of ERP system from SAP NANA Platform to SAP Cloud Platform will push the limits of of the system performance in all structures of SUEK.

Conclusion

Thus, efficient OHS control requires interlinking issues of resources, management and social services subject to allowable risk at the desired performance. Specific place in safety management belongs to control of the human factor and, in particular, stimulation to adhere to occupational health and safety standards. These problems will be solved in the coal mining industry upon transition to OHS control digitalization.

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