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Selection of Employees for Performing Work Activities in Currently Used Ventilation Systems in Hard Coal Mining

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Abstract: The way in which rescue actions are carried out in a hard coal mine is conditioned by a number of factors, including the type, scale, and location of the hazard; location of employees at the danger and level of their endangerment; and the ventilation system used in the impacted area. In this article, the importance and necessity to take into account a human factor, specifically the propensity for risky behavior, alongside the selection of rescuers for rescue action is pointed out. As an introduction to the key research studies presented in this article, main ventilation systems used in hard coal mines are described and three real cases of natural hazard occurrences in hard coal mines are discussed. An analysis of these events has shown that the degree of difficulty of a rescue action depends, among other aspects, on the ventilation system applied. Next, a study covering a synthetic assessment of 25 mining rescuers taking into account the 'risky behavior' parameter is presented. The results were interpreted considering the—described earlier—cases of hazard occurrence in coal mines and ventilation systems applied there. For the research sample, a selection of rescuers to carry out actions in particular types of ventilation systems, taking as a criterion the mark they obtained in the synthetic assessment, is proposed.

Keywords: mining; ventilation system; risky behavior

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1. Introduction

On the basis of detailed criteria for the assessment of natural hazards included in the provisions of the Regulation [1] (Regulation of the Minister of the Environment, Journal of Laws from 2013 item 230, as amended), rock bursts, methane hazards, risk of gas and rock outbursts, climatic hazards, water hazards, coal dust explosion hazards, and radioactive substance risks can be indicated as natural hazards in underground mining plants extracting hard coal.

All the above-mentioned hazards may lead to an accident that requires a rescue operation. The higher the scale and severity of the threat, the greater the risk.

For each of the hazards, a classification taking into account their characteristics is defined in the Regulation, as follows:

- two stages of rock bursting threats in underground mining plants extracting hard coal (§ 4.1);
- four categories of methane hazards in underground mining plants extracting hard coal (§ 8.1);
- three categories of gas and rock outbursts in underground coal mines (§ 13.1);
- two classes of coal dust explosion hazards in underground mining plants extracting hard coal (§ 18.1);
- three degrees of climatic hazards in underground mining facilities (§ 22.1);
- three levels of water hazards in underground mining plants extracting minerals other than salt (§ 25.1); and

- two classes of radiation hazards in underground mining plants (§ 42.1).

Natural hazards related with methane, fire, and climate are taken into account, alongside a selection of wall ventilation systems in Polish hard coal mining. The other factors are:

- the state of preparatory works and the possession of an appropriate mining front;
- recognition of the deposit, its thickness, the tectonics of seams, and the geological disturbances; and
- the concentration of the extraction.

The following ventilation systems for exploitation walls are used in coal mining:

- ventilation system at U from the boundaries of the field of exploitation, in which the air is led through the head gate gallery along the coal body and after the longwall is ventilated, it is also discharged along the fail gate gallery of the coal body;
- ventilation system at U to the boundaries of the field of exploitation, in which air is supplied to the longwall excavation and discharged from it along the goafs;
- ventilation system for Y, in which air flows to the longwall along the coal body and is discharged along the goafs with simultaneous refreshment of the fail gate gallery;
- ventilation system on Y, in which the air flows to the longwall along the coal body and after its ventilation, is discharged towards the goafs and coal body;
- ventilation system for Y, in which air flows to the longwall along the coal body and after it is vented, it is discharged along the coal body with simultaneous refreshment of the fail gate gallery from the side of the goaf;
- ventilation system on Z from the boundaries of the field of exploitation, in which air is supplied to the longwall along the coal body and after its ventilation is discharged along the ventilation gallery along the goaf; and
- ventilation systems for H, in which air can be brought to the longwall on a coal body and along the goafs, and is discharged from the ventilation gallery in both directions.

The advantages and disadvantages of the ventilation systems used in the conditions of methane and fire hazards are presented in the publication [2].

The use of an appropriate ventilation system should ensure not only the continuity of extraction and obtaining of certain economic results but also safe operation (and safety of the employees involved) [3]. The effectiveness of ventilation system is conditioned by the equipment used [4]. In all systems, there may be events (rock bursts, fires, and gas and rock outbursts) interfering with stabilized ventilation, resulting in a non-breathable atmosphere.

The ventilation system applied at a given area of a hard coal mine is also one of the factors that are taken into account during the withdrawal of crew once a hazard occurs. It affects the possibilities and limitations in this matter, and—consequently—affects the employees' endangerment to risks. This regards both the miner and mine rescuers, i.e., miners with qualifications of a mine rescuer.

How the applied ventilation system can affect employees' endangerment to risk once a hazards occurs is discussed below for a ventilation system for U.

The occurrence of three potential hazards (fire, rock burst, and methane occurrence) in an area of a coal mine where the ventilation system on U is applied is shown in three diagrams below. Characteristic workstations have been marked. For the employees present there, a degree of risk in relation to withdrawing from the endangered area through designated evacuation routes is defined.

In the event of a fire at the inlet to the ventilation area, as shown in Figure 1, situation of employees will be as follows:

- the crew staying in the face of bored walkway no. 1 (point 6) are the most endangered due to the time of withdrawal from the face to the holding ramp and then along walkway 4 to the assembly point on the ditch at the level of 400 m;
- the crew employed in longwall number 1 (point 3) are also at risk and they must retreat along the wall towards wall walkway 3, over the wall, to the haulage ramp as well as further towards the assembly point due to movement in the wall;

- crew at workstations marked with point 1 and point 2 are less endangered, as the employees can quickly retreat through the ventilation dams in the holding ramp and further to the assembly point; and
- employees at workstations marked with point 4 and point 5, with the shortest time of withdrawal to the assembly point, are the least endangered.

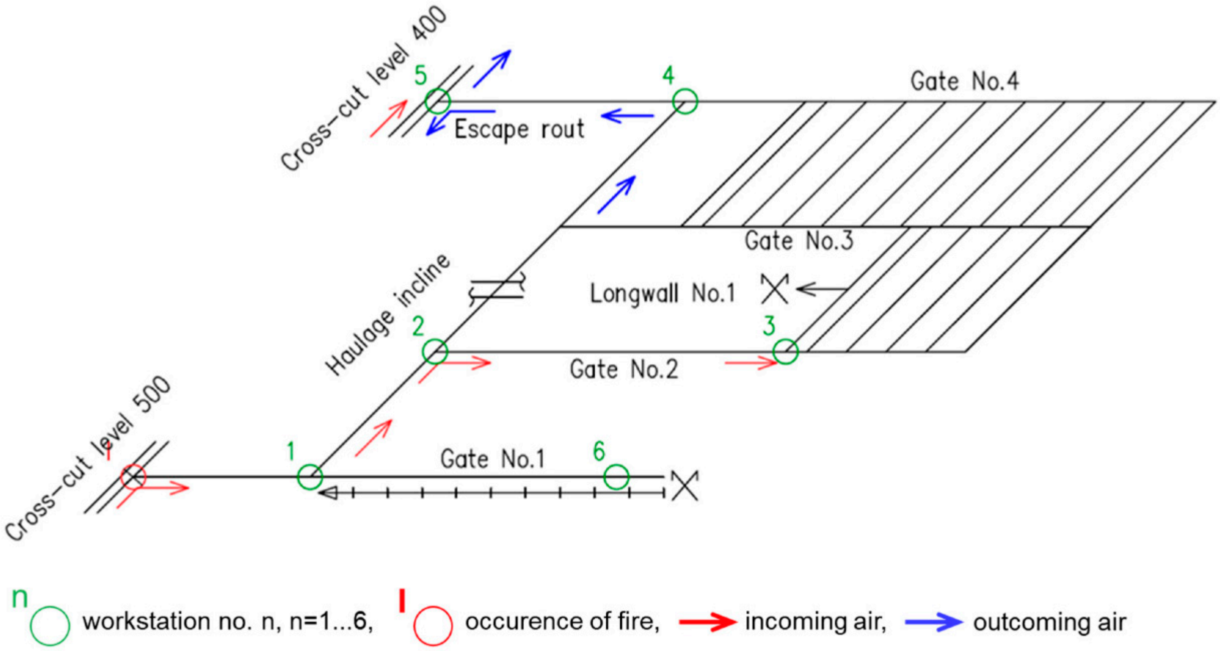

Figure 1. An example of a ventilation system on U with the occurrence of fire.

In the event of a collapse with the effects of a full collapse in pavement 3, as shown in Figure 2, situation of employees will be as follows:

- crew residing in longwall no. 1 (point 3) are the most endangered due to the possible occurrence of an unbreathable atmosphere. The crew must retreat up the wall and down to the holding ramp towards the 500 level;
- crew at workstations marked with point 4 and point 5 are less endangered, as employees' escape routes to level 400 are short and easy to cover; and
- the least threatened are the employees at workplaces marked with point 1 and point 2, as well as the face crew (point 6), as they retreat from the area of workings not affected by the effects of the collapse and in the fresh air current.

In the event of a methane hazard in pavement 2 at the intersection with the wall, as shown in Figure 3, situation of employees will be as follows:

- people employed in longwall no. 1 (point 3) are most at risk, as they retreat along the wall towards the over-gate walkway, to the holding ramp, and further towards the assembly point;
- crew at workplaces marked with points 1, 2, and 6 are less endangered, as the employees may retreat to 500 m in fresh air; and
- employees at workplaces market with points 4 and 5 are the least threatened due to the short time of withdrawal.

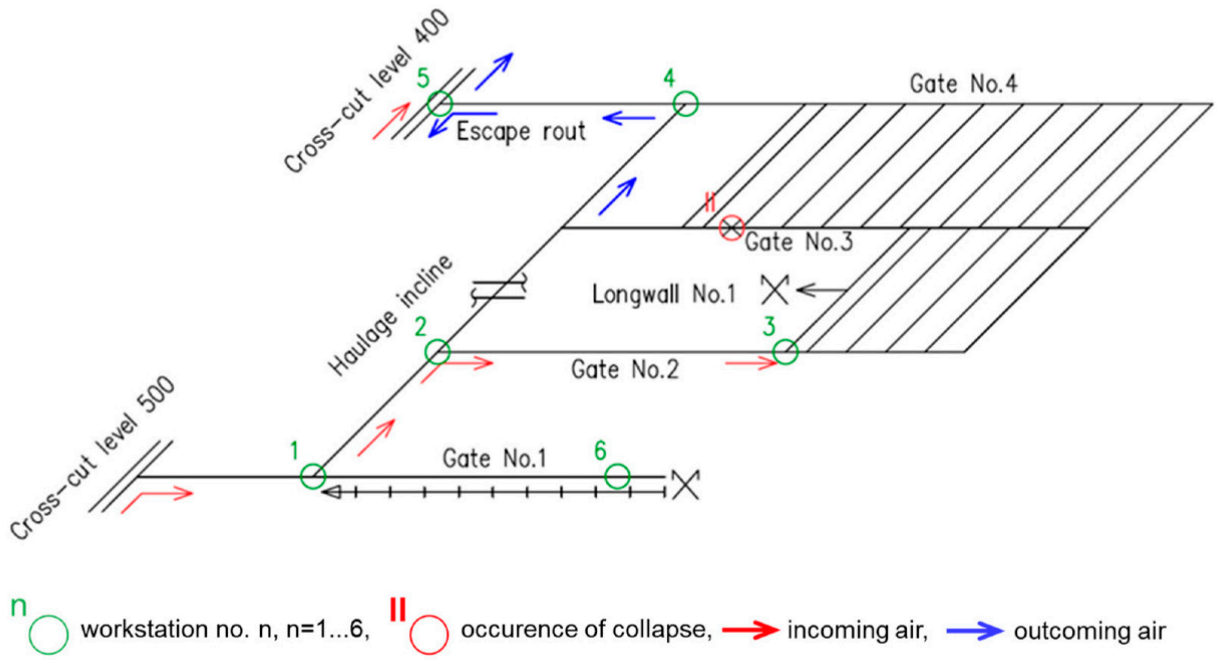

Figure 2. An example of a ventilation system on U with the occurrence of a collapse.

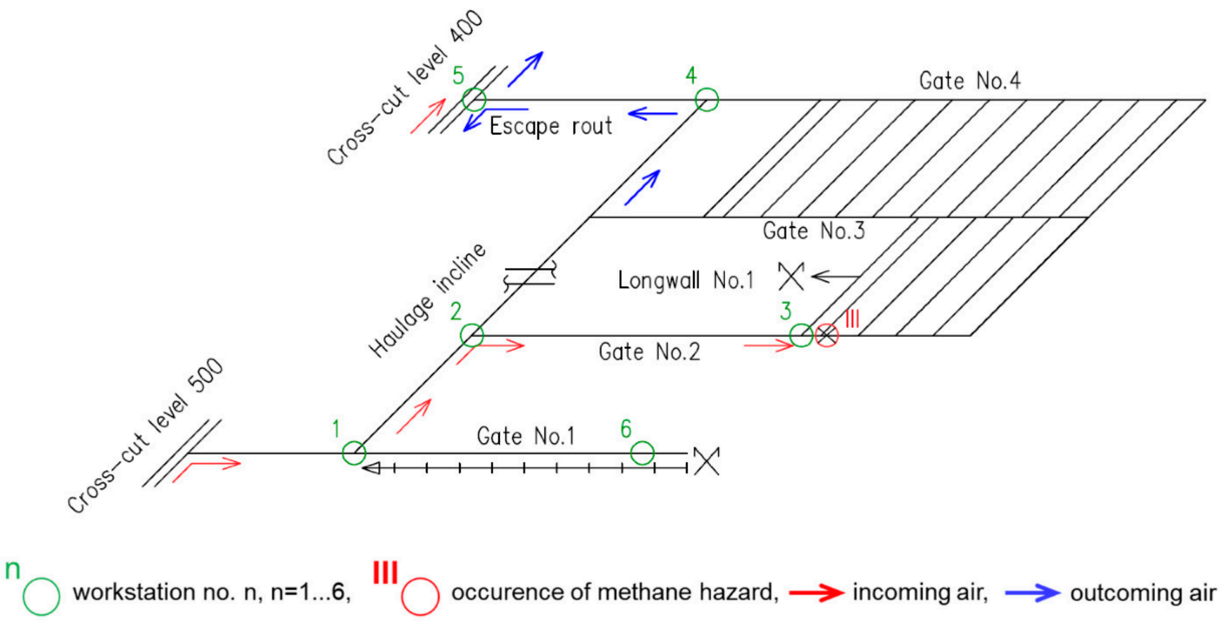

Figure 3. An example of a ventilation system at U with the occurrence of a methane hazard.

Methane hazard means exceeding the permissible methane concentrations with the necessity to withdraw the crew.

As the above descriptions show, once a hazard occurs, employees are exposed to risk at different levels depending on the place they are working at and their location in relation to the location of the hazard, as well as depending on the possibilities and limitations they may encounter upon withdrawal. The selection of ways for leaving the dangerous area and related risks are conditioned by the ventilation system applied. Therefore, it can be stated that it would be appropriate to select low-risk workers for the jobs with the highest risk.

Taking into account employees' risk-taking tendency and a ventilation system applied at the hard coal mine as the basis for the selection of the employees to carry out activities at particular locations is the subject of interest and discussion in the further part of this article.

2. Human Factor, Risks, and Safety—Relations and Shaping

Combating natural hazards is accomplished through appropriate prevention. So far, prevention has not taken into account the human factor, although it has a significant-negative or positive-impact on its effects. Referring to the rescue operations carried out as a result of natural events, it is stated that until now, the human factor was not included as one of the elements of combating natural hazards.

In the US, the mining regulations are well established at the federal and state level in the implementation and organization of mine rescue and crisis management. These federal regulations oblige each underground mining plant in which miners work underground to have two mining rescue teams. The standard practice is that isolated mines can share rescue teams based on agreements made with neighboring mines or states. These basic rescue teams must be available on site as soon as possible after notification [5].

Safety is conditioned by the competencies, experience, and approaches of employees. The greater professional experience they have, the higher their ability to predict the risk they have. The risk of an accident is reduced.

Ford and D'Amelio [6] pointed out that employees may show reluctance to change their behavior. The reason for this resistance may be the interpretation made by the change agents or their own actions. In recent times, safety culture has become one of the priorities to improve safety in the workplace [7]. According to [8], the involvement of managers who manage safety improvement initiatives contribute to the success of any change in culture.

Xia noticed that in everyday life, the aim is to improve safety by cultivating the habits associated with safe behavior. This is achieved by the conscious prevention of threats. Such activities significantly reduce accidents at the workplace. The proposed system should be based on effective employee management, safety training, and the use of security techniques [9].

Every employee who participates in an event leading to injury takes part in effective prevention of injury [10]. After applying all levels of employee intervention in each phase of the safety program, a significant reduction in the number of accidents was observed after a year following implementation [11]. The results of research carried out by Williamson et al. [12] and Heinrich [13] showed that in any case that causes serious injuries, there are 29 accidents that cause minor injuries and 300 accidents that do not cause injury. They stated that in the event of a large number of minor accidents in the plant, fatal accidents are likely to occur in the future. According to Banks and Davey [14], road safety depends on diverse organizational characteristics. These features help to increase the level of security. The authors claim that the conditions that promote dangerous culture in the organization include priorities for complacency with risk.

During rescue operations, among other aspects, there may be a loss of fixed assets such as a longwall shearer, conveyor system, mining supports, etc. The fixed assets lost as a result of mining catastrophes were addressed in the market, property, and income method presented in the publication of [15].

In order to improve the safety of using tourist routes, mine rescuers carry out a trial evacuation of tourists to the surface. This is one of the key elements determining the development of underground tourist routes. This issue is included in the publication on the protection of monuments of underground areas in accordance with natural processes applicable in nature [16]. An example of another approach to ensuring safety was presented by authors of [17] who developed fuzzy comprehensive evaluation model for flight safety.

Risky behaviors are analyzed during the study of safety culture and safety and accident rates. Employee behavior affects not only work efficiency but also safety. In many companies, research on pro-safe behaviors is conducted to improve safety.

In mining rescue, training is designed to establish confidence and predictability of behavior. Employees take risk because they have a high propensity to behave in a risky manner and need a thrill of emotions or they take risk in a situation of saving human life.

A rescue operation is accompanied by a higher risk and all the activities carried out during the operation have to be compliant with the regulations. There is no place for risky behavior that can lead to dangerous events. However, life has shown that in rescue actions, there were risky behaviors that led to the death of rescuers. That is why rescuers during classes and training are taught to master not only stress but also risky behaviors. Risky behavior can be compared to a quick reaction to the existing stimulus. In underground conditions, rescuers receive a lot of stimuli that can affect their behavior. These may be limited visibility; working in difficult thermal conditions and in conditions that arise after the occurrence of dangerous natural events; and the desire to reach the victims as soon as possible. Each candidate for service in mining rescue operations enters voluntarily and is probably dictated by the desire to save both human life and assets (machines, devices, systems, etc.) at the workplace. Before taking risky actions, the risk is assessed by the regulator in a threatening situation.

Psychologists claim that the risk assessment by employees affects their behavior, which may manifest as being cautious, prudent, or encouraging of risky activities by ignoring the threat [18]. During risky activities, if information about the conditions or consequences of actions is transmitted, then we are talking about a situation that is dynamic, opposite of a case of a situation with static character [19].

Situations and behaviors can be risky. Behavior is risky if it is implemented in a situation of uncertainty regarding the achievement of the intended results. Taking risks or caution can be the result of internal stimulation triggered by personality, attitudes, knowledge, and experience, but also by external factors. The willingness to take risk and the characteristics of the situation remain in a mutual relationship and together they have an impact on risk taking or avoiding [20].

In mining rescue operations, there is often a risk situation, which is dynamic, where conditions may change during the action and rescuers will receive information about the consequences of their actions. An employee has the opportunity to choose behavior in a risky situation, which is realized on the basis of perceiving the size of the risk and motivation. Motivation is triggered by the existing situation and the perception of risk is an individual cognitive process for each individual. The unit analyzes the scope of damage with the possibility of experiencing it. Motivation, on the other hand, determines the direction of behavior and satisfaction [21]. Inclination to risk is a subjective feature of a human being who is conditioned by a personality trait through which an individual will assess, accept, or challenge a risk. The choice of behavior is influenced by motivational tendencies, such as the propensity to risk (seeking or taking a risk) and aversion (avoiding risk) [20].

Consideration of the human factor in analyses of mine safety management under the conditions of the hazards present in mines is very rare. The most common efforts are limited to:

- ensuring technical measures which are designed and implemented to take into account the results of the risk analysis and assessment so that all identified hazards are eliminated or the risks associated with them are reduced to an acceptable level, and that the risks are monitored so that the risks do not increase as a result of the preventive measures taken; and
- using safe working methods and ensuring both adequate collective and personal protection measures to achieve and maintain an acceptable level of risk.

3. Hazard Events and Related Rescue Actions in Coal Mines—Case Studies

To illustrate the relation between the ventilation system used and rescue actions carried out, three real cases of the occurrence of natural hazards in underground mining plants are presented, including the events and related rescue actions. The analysis was carried out while taking into account both how ventilation systems affect rescue actions and the role of employees' risk propensity.

3.1. Events Description

Event 1. The rockfall connected with the rapid outflow of methane in Mine "X" that took place in 1996 on the maintenance shift, in the area of the exploited longwall in the C deck, where 23 miners were employed. There was a mining crump of 5×10^7 J which caused a rock burst. Its effects occurred in the under-wall sidewalk on the length of 270 m in front of the wall, with a total destruction of 140 m on the length of 140 m. The clamping of the head gate gallery caused ventilation disturbances in the wall that manifested in the lack of air flow to the longwall and sudden outflow of methane to the mine workings. At the time of the event, a total of 18 employees stayed in the longwall and head gate gallery. In the presented event, the Y-ventilation system was used, in which the air was supplied through the head gate gallery along the longwall and discharged by the fail gate gallery in both directions, i.e., towards the coal body and along the goaf.

Event 2. The discharge of methane and rocks in Mine "Y" occurred in 2005, in a hollowed transport gallery. In this region, 31 employees of the preparatory works and a longwall brigade were employed. In the works related directly to the drilling of the transport gallery, a five-person forward crew was employed. During the rescue operation, a total of 93 employees were withdrawn. A ventilation system was applied to the U from the boundaries of the field of exploitation, bringing in fresh air to the hollowed transport gallery and then to the head gate gallery to the exploited longwall; after its ventilation was discharged, air continued to travel to the ventilation gallery along the coal body to the group air current.

Event 3. The ignition and explosion of methane in Mine "Z" took place in 2003 during the morning shift. The ignition and explosion of methane in the goaf of the longwall caused a violent blast of air, a rise in temperature, and the smoke of the fail gate gallery behind the longwall's front. As a result of this incident, 10 employees were injured (three mortally injured, while others were burned and, to a different degree, poisoned by carbon monoxide). Due to the applied Y-ventilation system with the experience of the fail gate gallery along the coal dust, all the fire gases were directed towards the goobs and further to the outlet current. The use of the ventilation of the fail gate gallery contributed to a quick and efficient rescue operation. Self-rescue of the crew, assistance to the injured, and the entry of rescue teams into the area of the longwall took place in the fresh air current.

3.2. Rescue Actions—Description, Analysis, and Conclusions Drawn

1. In the X mine, the longwall ventilation system (for Y with air extraction in the fail gate gallery in both directions, i.e., along the coal and after the goaf) had no particular impact on the course of the action. The shock in the area of the longwall caused a rock burst and its effects occurred on a considerable length of the fail gate gallery, where the gallery was clamped and caused the air to not flow to the longwall. There was a sudden inflow of methane to the excavation areas. Two rescue teams operating in the area of the longwall provided assistance to the injured without using oxygen work machines. The next two groups directed to penetrate the fail gate gallery—due to the lack of air flow—began to penetrate the excavation area using working machines. The hosts who arrived at the scene had information on the oxygen and methane concentrations, as well as on the victims there. Such information may have had an impact on their decisions.

2. In the Y mine, the ventilation system (on the U from the field boundaries of the exploited longwall) and the drilling transport gallery caused a rapid displacement of the separated methane from the hollow transport gallery towards the longwall and then to the ventilation gallery to the group air current. Prior to the arrival of the first rescue team, the miners initially retreated safely to the circulating air current in the slipway above the head gate gallery. Then, using escape devices, they decided to re-enter the face of the transport gallery, were the injured face crew were located. The first rescue team, arriving at the area of the face transport gallery, knew that a crew rescuing the injured had already arrived there. Having such information can influence their decision making. It is important that rescuers do not take risks in such situations.

3. In the Z mine, the longwall ventilation system on Y contributed significantly to the fast and efficient rescue operation and to the withdrawal of the crew. Rescue assemblies entering the fail gate gallery were subject to less stress due to the lack of smoke and awareness of working in the fresh air current. Despite such working conditions, the risky behavior of employees should not be underestimated. The awareness of staying and providing help of rescuers in such conditions should not affect their risk-taking behavior.

For each of these events, it can be stated that such situations may have had an impact on the behavior of the crew involved in the danger. This is also important in the case of rescue aid (in the first phase of the rescue operation regarding the removal of the crew and first aid by the rescue team).

The presented cases show that when a hazard occurs and rescue action is carried out, there might be situations and circumstances in which decisions and actions taken by employees could be affected by their risk propensity. This regards also mining rescuers whose duty and responsibility is to properly carry out rescue action. Therefore, it seems advisable to identify, in advance, their risk-taking tendencies and, based on it, to assign employees to jobs where the risk propensity will not translate into risky behaviors.

Another conclusion is that the crew should be familiar with the ventilation systems, as these also determine the escape routes in the event of a hazard. After the hazard occurrence, the rescue teams directed to the action may find themselves in various ventilation systems. Lifeguard groups are acquainted with the area they go to—they know the conditions prevailing there and have equipment adequate for the anticipated work.

4. Methods

For the synthetic evaluation of mining rescuers' behavior, taking into account the 'risky behavior' parameter, the method developed by A.Grodzicka (co-author of this article) was applied. In the method development, professional mine rescuers were involved both in the conceptual phase and validation phase. Pilot studies were carried out on a research sample representing directors and deputies of the District Mining Rescue Station as well as miners' shifts and deputy managers of the Central Mining Rescue Station [21–23]. Practical application of the method took place on a research sample of 383 mining rescuers employed in eight coal mines [24].

The final version of the method has been accepted by: (1) the scientific environment, as the monograph [24] in which the method has been discussed obtained positive reviews, (2) professionals in mining rescue, as the method was developed in cooperation (a number of consultations) with the Central Mine Rescue Station in Bytom; and (3) the mining authorities, namely the State Mining Authority.

Below we present an application of the method in another coal mine. Twenty-five mining rescuers employed as miners in the hard coal mine constituted the research sample. In the coal mine, a ventilation system for Y was used. Thus, in the event of hazard, the mining rescuers would be the first to help and control the crew or give first aid to the victims.

A survey sheet consisting of 15 closed questions was used. All respondents were instructed on how to complete the questionnaire as well as were informed about the duration of the survey. In addition, they were informed about their anonymity and regarding the purpose of the research study being carried out.

Following the method of a synthetic assessment of behavior by A. Grodzicka, the following steps were carried out:

1. Conduct a survey of the prepared questionnaire consisting of 15 closed questions (own research; Table 1);
2. Analyze the results according to the procedure while taking into account the nine preferred affirmative answers by estimating the rank and interpretation as proposed in the assessment criteria (own research; Table 2);

3. Analyze the results according to the procedure while taking into account the six preferred negative answers, estimating the rank and interpretation as proposed in the assessment criteria (own research; Table 3);
4. Make a summary assessment based on the sum of the criterion rankings obtained from the tests (own research; Table 4); and
5. Draw conclusions and determine whether respondents received an 'incorrect' interpretation, which should be repeated because these people tend to have risky behaviors.

Table 1. List of questions contained in the questionnaire [24].

No.	Questions Asked in the Questionnaire	Preferred Answer
1.	If you see an unconscious person, will you start providing pre-medical help immediately?	affirmative
2.	Has frequent participation in training in the field of first pre-medical help established your confidence of carrying it?	affirmative
3.	Are you able to give pre-medical help even to a very injured person without any inhibitions?	affirmative
4.	Do you fear for your life and health when you give pre-health help?	negative
5.	Do you think about your family when taking part in a rescue operation, knowing that something may happen to you?	negative
6.	Is anyone involved in the rescue action stressful for you?	negative
7.	Have you become a mining rescuer because you like risk?	negative
8.	Does the risk give you an extra boost of emotions?	negative
9.	Do you feel safe when you participate in the rescue operation, being aware that there are colleagues from the rescue squad beside you?	affirmative
10.	Do you analyze each time you make a decision to enter the danger zone to help other colleagues?	affirmative
11.	Will you make an emergency decision when you see an accident?	affirmative
12.	If you see a threat to the lives of others, will you wait for your superiors to say what to do?	affirmative
13.	Do you analyze the decisions you made after the rescue operation?	affirmative
14.	Do you have to de-stress after the action?	affirmative
15.	Will you give your breathing apparatus to the person you leave in the danger zone?	negative

Table 2. Criteria for the assessment of the parameter "risky behavior": affirmative answers [24].

No.	Number of Affirmative Answers to Questions No. 1–3 and 9–14, Given by a Rescuer	Rank of the Criterion	Interpretation Evaluation (Mark)
1.	8–9	3	distinguishing
2.	6–7	2	satisfactory
3.	4–5	1	correct
4.	0–3	0	incorrect

Table 3. Criteria for the assessment of the parameter "risky behavior": negative answers [24].

No.	Number of Affirmative Answers to Questions No. 4–8 and 15, Given by a Rescuer	Rank of the Criterion	Interpretation Evaluation (Mark)
1.	6	3	distinguishing
2.	4–5	2	satisfactory
3.	2–3	1	correct
4.	0–1	0	incorrect

Table 4. Summary assessment (affirmative and negative answers) according to the parameter "risky behavior" [24].

No.	Rank Sum According to the Parameter "Risky Behavior"	Interpretation of the Summary Assessment According to the Parameter "Risky Behavior"
1.	6	distinguishing mark
2.	4–5	satisfactory mark
3.	2–3	correct mark
4.	0–1	incorrect mark

The obtained answers were summarized in one table (Table 5) and analyzed. Depending on the number consistent with the preferred answers, appropriate rankings were assigned separately for questions with the preferred affirmative answers and for questions with the preferred negative answers in order to interpret the assessment of the tested parameter (Tables 6 and 7). The summed up ranks of both groups of answers gave the basis for a summary assessment of the risky behaviors of individual rescuers according to the analyzed parameter (Table 8).

Table 5. Statement of answers (A—affirmative and N—negative) of the rescuers examined.

No. of the Rescuer	No. of Question														
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15
1.	A	A	A	N	N	A	N	N	A	A	A	A	A	A	N
2.	A	A	A	N	N	N	N	N	A	N	A	A	A	A	N
3.	A	N	A	N	N	N	N	N	A	A	A	A	A	A	N
4.	A	N	A	N	N	N	N	N	A	N	A	N	A	N	N
5.	A	A	A	N	N	N	A	N	A	N	A	N	A	N	N
6.	A	A	A	N	N	N	A	N	A	A	A	N	A	A	N
7.	A	A	A	N	N	N	N	N	A	A	N	A	A	A	N
8.	A	N	A	A	A	N	N	N	A	N	A	A	N	N	N
9.	A	N	A	A	A	A	A	N	A	N	N	N	A	N	N
10.	A	A	A	A	A	N	N	N	A	N	A	N	A	A	A
11.	A	A	A	N	A	N	N	N	A	A	A	A	A	A	N
12.	A	A	A	N	N	N	A	N	A	A	A	A	A	A	N
13.	A	A	A	N	N	N	A	A	A	N	A	N	A	N	A
14.	A	A	A	A	A	A	N	N	A	A	A	A	A	N	N
15.	A	A	A	A	A	A	N	N	A	A	A	N	A	A	N
16.	A	A	A	A	A	N	A	A	A	A	N	A	A	A	A
17.	A	N	A	N	N	A	N	N	A	N	A	A	A	A	N
18.	A	A	A	N	N	N	A	A	A	A	A	A	A	A	A
19.	A	A	A	A	A	A	N	N	A	A	A	N	N	A	N
20.	N	N	A	N	A	A	N	N	A	A	A	N	N	N	N
21.	A	A	A	N	A	N	N	N	A	A	A	A	N	N	N
22.	A	A	A	A	N	A	N	N	A	A	A	A	A	N	A
23.	A	A	A	N	N	N	A	A	A	A	N	N	A	A	N
24.	A	A	A	A	A	N	A	N	A	A	A	A	N	N	N
25.	A	A	A	N	N	N	N	N	A	A	A	N	N	N	N

Table 6. Results of the answers for questions in accordance with the preferred affirmative answers along with the interpretation.

Rescuer	Affirmative Answers to Questions No. 1–3 and 9–14	Rank Criterion	Interpretation Assessment
1.	9	3	distinguishing mark
2.	8	3	distinguishing mark
3.	8	3	distinguishing mark
4.	5	1	correct mark
5.	6	2	satisfactory mark

Table 6. *Cont.*

Rescuer	Affirmative Answers to Questions No. 1–3 and 9–14	Rank Criterion	Interpretation Assessment
6.	8	3	distinguishing mark
7.	8	3	distinguishing mark
8.	5	1	correct mark
9.	4	1	correct mark
10.	7	2	satisfactory mark
11.	9	3	distinguishing mark
12.	9	3	distinguishing mark
13.	6	2	satisfactory mark
14.	8	3	distinguishing mark
15.	8	3	distinguishing mark
16.	8	3	distinguishing mark
17.	7	2	satisfactory mark
18.	9	3	distinguishing mark
19.	7	2	satisfactory mark
20.	4	1	correct mark
21.	7	2	satisfactory mark
22.	8	3	distinguishing mark
23.	7	2	satisfactory mark
24.	7	2	satisfactory mark
25.	6	2	satisfactory mark

Table 7. Results of the answers for questions in accordance with the preferred negative answers along with the interpretation.

Rescuer	Negative Answers to Questions No. 4–8 and 15	Rank Criterion	Interpretation Assessment
1.	5	2	satisfactory mark
2.	6	3	distinguishing mark
3.	6	3	distinguishing mark
4.	6	3	distinguishing mark
5.	5	2	satisfactory mark
6.	5	2	satisfactory mark
7.	6	3	distinguishing mark
8.	4	2	satisfactory mark
9.	2	0	incorrect mark
10.	3	1	correct mark
11.	5	2	satisfactory mark
12.	5	2	satisfactory mark
13.	3	1	correct mark
14.	3	1	correct mark
15.	3	1	correct mark
16.	1	0	incorrect mark
17.	5	2	satisfactory mark
18.	3	1	correct mark
19.	3	2	satisfactory mark
20.	4	2	satisfactory mark
21.	5	2	satisfactory mark
22.	3	1	correct mark
23.	4	2	satisfactory mark
24.	3	1	correct mark
25.	6	3	distinguishing mark

Table 8. Total rank along with the interpretation of the summary assessment according to parameter 'risky behavior'.

Rescuer	Sum of Rank	Interpretation of the Total Rank Summary Assessment
1.	5	satisfactory mark
2.	6	distinguishing mark
3.	6	distinguishing mark
4.	4	satisfactory mark
5.	4	satisfactory mark
6.	5	satisfactory mark
7.	6	distinguishing mark
8.	3	correct mark
9.	1	incorrect mark
10.	3	correct mark
11.	5	satisfactory mark
12.	5	satisfactory mark
13.	3	correct mark
14.	4	satisfactory mark
15.	4	satisfactory mark
16.	3	correct mark
17.	4	satisfactory mark
18.	4	satisfactory mark
19.	4	satisfactory mark
20.	3	correct mark
21.	4	satisfactory mark
22.	4	satisfactory mark
23.	4	satisfactory mark
24.	2	correct mark
25.	5	satisfactory mark

5. Research Results

The results of the research study according to the synthetic method of risky behavior assessment are discussed below.

Table 5 presents the results of the responses obtained during the survey. The questionnaire consisted of 15 closed questions, where six negative answers were preferred.

Regarding the preferred negative answers, nine rescuers declared to be concerned about their lives and health during the provision of pre-health assistance and 11 rescuers declared to think about their family while participating in the rescue operation because they are aware that something may happen to them. For eight rescuers, everyone involved in the rescue operation is stressful for them. Nine respondents declared that they became a mining rescuer because they like the risk but—what is comforting—only four of them admitted that the risk gives them an additional boost of emotion. The answers indicate also that during the rescue of a victim from the danger zone, five rescuers would provide him with his oxygen apparatus. An oxygenator is an individual means of respiratory protection and sharing it with a colleague can have serious consequences for both miners. Therefore, providing such help should not take place in spite of the fact that immediate provision of pre-medical help is a natural activity for mining rescuers.

Respondent #20 was the only one who declared that upon seeing an unconscious person, he would not start providing pre-medical help immediately. Nineteen rescuers declared that frequent participation in the training in first pre-medial help makes them feel confident regarding their ability to give such help and all rescuers surveyed declared that they were able to give pre-medical help even to a very injured person without any inhibitions. Additionally, all rescuers declared that during the participation in a rescue action, they feel safe due to the presence of colleagues from the rescue team. While helping other colleagues, 15 rescuers analyze the decision to enter the danger zone. Twenty-one rescuers declared that they make a decision to save those injured when they see an accident.

However, seeing the threat to the lives of other, 14 rescuers will wait with taking actions for the orders of the superiors. Generally, it is expected that after each completed action, rescuers think about it and return to memories as if they were repeating it again. Nineteen rescuers declared that after the rescue action was completed, they analyzed the decisions they made. In addition, after the action, 14 rescuers have the need to de-stress.

Table 6 contains the results regarding the questions with preferred affirmative answers along with the interpretation consistent with Table 2, i.e., taking into account the criterion 'risky behavior'. For the whole research sample, nine satisfactory marks, four correct marks, and 12 distinguishing marks were obtained.

Table 7 contains the results regarding the questions with preferred negative responses along with their interpretation made based on Table 3, i.e., taking into account the "risky behavior" parameter. From the entire test sample, 11 satisfactory marks, seven correct marks, five distinguishing marks, and two incorrect marks (for rescuers 9 and 16) were obtained.

Table 8 contains the final assessment of each rescuer surveyed while taking into account the 'risky behavior' parameter. The summary interpretation was made based on Table 4. From the entire study sample, three distinguishing marks, 15 satisfactory marks, six correct marks, and one incorrect mark (for rescuer no. 9) were obtained.

6. Discussion of the Survey Results, Taking into Account the "Risky Behavior" Parameter

The study to conduct a synthetic assessment of mining rescuers' behaviors according to the 'risky behavior' parameter covered 25 miners possessing the qualifications of mine rescuers. The method developed by A.Grodzicka [24] was applied. It includes:

- two partial assessments based on answers provided for questions with preferred affirmative answers and based on answers for questions with preferred negative answers; and
- one summing-up assessment based on the two above ones.

In each assessment, respondents could obtain one of the following assessments that characterize a rescuer in terms of risky behaviors in rescue actions: distinguishing mark, satisfactory mark, and correct mark.

Regarding the final summing-up mark, a rescuer with a distinguishing mark is highly capable of properly controlling their risky behaviors in variable and difficult rescue actions. In the survey sample, there were three such persons. A rescuer not demonstrating excessive propensity or risk aversion obtains a satisfactory mark and in the study there were 15 such persons. If a 'correct mark' is obtained by a rescuer, this means that he is characterized by the ability to control risk behaviors during rescue operations. Among the rescuers surveyed, there were six such persons.

Regarding obtaining an 'incorrect mark', an additional training is recommended. To properly tailor such training, the answers provided and marks obtained in the partial assessments should be taken into account. The study revealed that rescuer no. 9 should undergo additional training, followed by a second synthetic assessment of risky behavior because he scored incorrectly. It should be noted that the situation resulted from an 'incorrect mark' obtained based on answers provided to questions with preferred negative answers.

Table 9 presents—in a detailed way—the results of the assessment of risky behaviors of mining rescuers according to the 'risky behavior' parameter (where N—number of responses,%—share of responses, OA—affirmative answer, and ON—negative answer).

Table 9. Evaluation sheet of the risky behaviors of mining rescuers according to the parameter "risky behaviors".

No.	Affirmative Answers		Negative Answers		Total Rating		Interpretation of the Assessment
	N	%	N	%	OA	ON	
1.	9	100	5	83.3	3	2	satisfactory mark
2.	8	88.9	6	100	3	3	distinguishing mark

Table 9. *Cont.*

No.	Affirmative Answers		Negative Answers		Total Rating		Interpretation of the Assessment
	N	%	N	%	OA	ON	
3.	8	88.9	6	100	3	3	distinguishing mark
4.	5	55.6	6	100	1	3	satisfactory mark
5.	6	66.7	5	83.3	2	2	satisfactory mark
6.	8	88.9	5	83.3	3	2	satisfactory mark
7.	8	88.9	6	100	3	3	distinguishing mark
8.	5	55.6	4	66.7	1	2	correct mark
9.	4	44.4	2	33.3	1	0	incorrect mark
10.	7	77.8	3	50	2	1	correct mark
11.	9	100	5	83.3	3	2	satisfactory mark
12.	9	100	5	83.3	3	2	satisfactory mark
13.	6	66.7	3	50	2	1	correct mark
14.	8	88.9	3	50	3	1	satisfactory mark
15.	8	88.9	3	50	3	1	satisfactory mark
16.	8	88.9	1	16.7	3	0	correct mark
17.	7	77.8	5	83.3	2	2	satisfactory mark
18.	9	100	3	50	3	1	satisfactory mark
19.	7	77.8	3	50	2	2	satisfactory mark
20.	4	44.4	4	66.7	1	2	correct mark
21.	7	77.8	5	83.3	2	2	satisfactory mark
22.	8	88.9	3	50	3	1	satisfactory mark
23.	7	77.8	4	66.7	2	2	satisfactory mark
24.	7	77.8	3	50	2	1	correct mark
25.	6	66.7	6	100,	2	3	satisfactory mark

Referring the study results to the description and analysis of events in mines X, Y, and Z, additional conclusions might be drawn.

Respondents who received a distinguishing mark are characterized by the lowest risk propensity, which qualifies them for employment in difficult work positions in the ventilation system on U and in the most endangered positions. In the ventilation system on U, in the case of fire, the crew withdraws from the danger zone. Depending on their location, the withdrawal might take a lot of time and might be carried out in an unbreathable atmosphere. This indicates a possibility of the high endangerment of workers. Such difficult circumstances took place in mine Y. Mining rescuers involved in rescue actions in ventilation systems on U should be more sensible and should not take big risks.

Respondents who have received a satisfactory mark are characterized by an average propensity to risk, which qualifies them to be employed at workstations in the Y ventilation system with air discharging along the goaf and in the direction of the coal body. In this type of ventilation system, the crew can choose an escape route towards the goaf or along the goaf depending on the conditions in these escape directions. An example is the case of mine X, where there was no air flow to the wall due to the clamping of the sidewalk. Rescue teams approached from the side of the over-the-wall sidewalk to penetrate the area.

Respondents with a correct mark are characterized by a high propensity to risk. They are indicated for employment in the Y-ventilation system with refreshing the fail gate gallery along the coal body. In such a ventilation system, the crew retreats in an unbreathable atmosphere but with the possibility of going to the over-the-wall walkway (where refreshing is being carried out). An example is the case of mine Z, where the ventilation system contributed to a quick and efficient rescue operation along with the withdrawal of the crew from the endangered area. The situation gave no reason and no opportunity for risky behaviors.

7. Summary

In coal mines, the occurrence of natural hazards always means a danger for employees who are present at the area covered. The level of endangerment depends on a number of factors including, among others, the type and scale of the hazard, workers' location in relation to the hazard, and ventilation system used. What affects employees' safety (in terms of health and life) in such situations is rescue operations. External rescue teams might be involved as well as employees of a given mine who have qualifications in mining rescue operations. The second situation was the main subject of the research study in this article.

Although propensity for risky behavior affects human decisions and actions, this aspect is not taken into account while considering rescuers for rescue actions. In this article, the use of a synthetic assessment of mining rescuers based on the 'risky behavior' parameter was proposed to properly assign them to carry out work at particular locations of a hard coal mine. The assumption is that in the case of a hazard occurrence, these persons will properly cope with the situation. Similarly, in situations when mining rescuers are sent to particular locations to carry out a rescue action, taking into account the results of the synthetic assessment will contribute to better assignments.

The method used for the synthetic assessment has been developed by A.Grodzicka, who is one of the present article's authors. Its application was shown in the research study covering 25 mining rescuers. Relations between the ventilation system applied in the area of a hard coal mine where a hazard occurred and employees' endangerment was taken into account for the interpretation of the research results. References to the cases of three coal mines, as described in this article, in which hazards occurred and rescue actions were carried out, were made.

The study revealed—for the research sample—that it is possible to propose a selection of workers for performing work activities in currently used ventilation systems, taking into account the employees' propensity for risky behavior as follows:

- for the ventilation system on U, three respondents who received a 'distinguishing' mark should be selected;
- in the Y-ventilation system with airflow in the goaf and towards the coal body, 15 respondents who received a 'satisfactory' mark should carry out activities; and
- for the Y-ventilation system with refreshing the fail gate gallery along the coal body, six respondents who received a 'correct' mark should be chosen.

Synthetic assessment of rescuers based on the 'risky behavior' parameter can be also helpful to shape their propensity for risky behavior. Based on the analysis of the data collected from employees during the study, it is possible to provide them with proper training. Based on the study carried out, it was stated that one of the 25 mine rescuers surveyed should undergo additional training and then be tested once again with the same method because he received an 'incorrect' mark.

The method of a synthetic assessment of the risky behavior of mine rescuers can be used for other applications of analysis of human behavior in the work environment. However, it has to be properly adapted to the given research group regarding their activities, hazards that are present or might occur at the workplace, etc. Currently, questions are addressed to mine rescuers working in hard coal mines, taking into account their work activities and working environment conditions.

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