The specific risks encountered at workplaces in the mines of the Jiu Valley and their correlation with the levels of danger

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Abstract. In order to ensure an appropriate level of security and health in underground mining works, it is necessary to apply some methods of diagnosing the situation of the work system/workplace, from the aspect of work security, which involves:
- knowing the risk factors of occupational injury and illness;
- the ranking of risk factors in relation to the potential seriousness of the consequences on the executor;
- identification and ranking of preventive measures to be applied.
The assessment of the risk level is a systematic examination of all aspects of the work process, undertaken in order to eliminate the sources that could cause bodily harm, which constitute the basis for the substantiation of measures to prevent and combat risks. For this reason, all those involved in the work process must be consulted in the risk assessment process.
Specific risk monitoring aims to carry out a pre-accident type assessment of the risk of occupational injury and illness using assessment criteria that are based on quantitative risk assessment.

1 The risk

Risk is the probability that damage (injury or material damage) will materialize under the conditions of exposure to danger. The risk level of a system / workplace is an indicator inversely proportional to the security level: the higher the risk level, the lower the security level. A risk can be small (acceptable), even if the probability of occurrence of the event is very high, but the severity of the consequences is small, or if the severity of the consequences is high but the probability of occurrence is very small.
The danger of explosion is major in the gritty underground mining works in the Jiu Valley coal basin, due to its catastrophic consequences, both for the personnel in the affected area, as well as for the workplaces and the deposit. Under these conditions, protection against explosive underground atmospheres remains a primary concern for all mining decision-makers. [1]

2 Defining the components of work subsystems

The defined labor system is, in fact, a technical system. The work system can be superimposed in space on the technical system, and the work process can be superimposed on the functional process of the technical system. That is why, in the paper, the two aspects, technical and labor, will be treated together. In other words, the division into work subsystems corresponds to technical areas.
The technical areas of a mechanized slaughterhouse with a long retreating front, over which work subsystems overlap are:

ZONE A - The work subsystem in the area of the intersection of the stope with the head gallery, consisting mainly of:
- elements to support the intersection;
- material winch, monorail with drive motor, coupling, brakes and control device;
- the drive head of the conveyor in the stope, the drive motor, the elastic coupling and the disconnection device in case of failure;
- high pressure pump and control device and lighting objects;
- detection head, alarm and disconnection of electricity from the stope when the maximum allowed concentrations are exceeded; the water pipe;
- the power plant ash introduction pipe in order to prevent/fight/extinguish endogenous fires;

ZONE B - The work subsystem in the slaughterhouse area, consisting mainly of:
- the support sections of the complex, with the control and actuation devices;
- the felling combine with the drive motors, the cutting drums and the control device;
- the armored transporter from the stope; pushers for tearing the conveyor;

ZONE C - The work subsystem in the area of the intersection of the stope with the base gallery, consisting mainly of:
- elements to support the intersection; the drive head of the conveyor in the stope;
- the end frame and the coal reloader; the lump breaker;
- the return head of the conveyor from the pre-stope;
- remote control panels and buttons and emergency controls; lighting objects;

ZONE D - The work subsystem in the area of the base gallery, consisting mainly of the elements of the subsystem in zone C, less of the elements supporting the intersection.

▪ **ZONE A** - the area of the intersection of the stope with the head gallery - where the components of the work subsystem analyzed and the actions carried out in this space are:

- The components of the work system

These components are: performers, technical equipment and the work environment.

  - Executors (E)
  - Technical equipment (ET)
  - Environment (Me)

▪ **ZONE B** - slaughterhouse area - where the components of the work subsystem are:

  - **Executors (E)**

The staff required for:
- combine order; directing the support; pushing transport to the front;
- cleaning the hearth; handling of materials brought to the slaughterhouse
- routing of cables related to electrical installations;
- moving the high-pressure pipes to actuate the support;
- operations to detach some coal blocks from the front; directing the spraying devices;
- auxiliary assembly, adjustment and maintenance operations of transport, combine and support; local ventilation of spaces where methane can accumulate;
- operations to monitor the quality of the atmosphere in the slaughterhouse; etc.

  - **Technical equipment (ET):**

- supporting elements (sections, frames, pillars, beams, etc.);
- the devices for pushing the conveyor out of the stope and stepping on the support;
- the conveyor from the slaughterhouse; combine; lighting objects;
- fans or ejectors for local ventilation; independent combiner devices for local spraying;
- flexible pipes for the special liquid under pressure, for operating the support;
- cables related to power and control electrical installations; water pipes for sprinklers.

- **Medium (Me):**

- the coal front, unsupported or temporarily supported;
- portions of the roof, in the vicinity of the front, unsupported or temporarily supported;
- the cavity artificially supported by mechanical means, with degree of coverage depending on the type of support, on which the mining pressure acts;
- the exploited space, closed or not with a shield, space whose closure is directed by support, depending on the character of the rocks in the bedding and cover, in which dynamic phenomena can occur;
- space in direct connection with the exploited coal front, potential sources of flammable and toxic gas releases.

- **ZONE C** - the area of the intersection of the stope with the base gallery
  - The components of the work system are:
    - **Executors (E)**

The staff required for:
- supporting the intersection and directing the pressure in the intersection;
- moving the end frame and the drive head of the conveyor from the stope, located in the base gallery;
- maneuvering the reloader or manually loading the spilled coal onto the hearth of the base gallery and execution of the niche for the combine (if applicable).

- **Technical equipment (ET):**

- supporting elements of the intersection and directing the pressure;
- the drive and return head of the conveyor from the stope; end frame;
- the recharger; the lighting installation; cables related to electrical installations;
- the return head of the conveyor from the pre-stope;
- high-pressure pipes related to the hydraulic system of the support in the stope;
- communication, signaling and control equipment; water pipes.

- **Environment (Me):**

- the broken front of the basic gallery;
- the L-shaped cavity, mechanically supported with support elements determined by the exploitation method, making the interface between the support from the stope and the support from the base gallery;
- the portion from the base gallery, up to the pre-stope, under the effect of the support from the intersection

- **ZONE D** - the pre-stope area and/or the base gallery
  - System components in this area, where most of the technical equipment serving the slaughterhouse are located, are:
    - **Executors (E)**

Personnel required for:
- reloading the coal on the pre-loading conveyor or on the main conveyor
- supervision of the lump breaker and pressure pumps; the handling of high-pressure;
- water pipes; performing orders, signaling and communications.

- **Technical equipment (ET):**

- the conveyor in advance; the lump breaker;
- pressure pump and actuation of the main conveyor in the head gallery;
- cables of electrical installations; water pipes; lighting installations.

- **Environment (Me):**

- the portion of approx. 10-50 m from the base gallery, where the technical equipment related to the slaughterhouse is located.

3 The technological operations specific to the mining method with frontal stopes with a coal bank undermined behind the front line

The undermining bank mining method consists of extracting horizontal slices of coal, with long cuts in the direction, in descending order, by dividing the layer vertically into subcuts.
Directing the mining pressure at the level of an undermining sub-floor is done behind the line of the working front of the stope by collapsing/overlapping the coal in the undermining bank and the covering rocks.
The preparation of the layer is carried out in continuation of the network of opening mining works, by executing:
- number of transversal galleries (aeration and transport) executed in tailings and coal that cross the coal layer;
- number followers executed between the transverse galleries delimiting the slaughter fields, located in relation to the bed of the layer at distances of 20-40 m;
- risers executed in the roof of the layer, in the barren rocks at distances of 10-20 m;
- directional aeration and transport galleries (pre-cuts) executed in coal, on the bed and under the roof of the layer up to the limits of the cut-down field, from the attacks, respectively, from the transverse number galleries;
- the attack gallery executed between the directional aeration and transport galleries, at the limit of the slaughter field.
The preparatory works are carried out in the coal layer and in its immediate vicinity, being therefore in the area of influence of the exploitation works. The support of the directional abutments on the layer was realized in metal reinforcements arranged in fields of 0.5 - 0.7 m, reinforced by the installation of round wooden yokes and bandaging with round wooden halves / cupboards mounted in the thicket.
The size of the section of the two preparation works of the stope was established according to the gauge of the means of transport and according to the aeration criterion.
Coal extraction is carried out at the level of the base slice of the stope, followed by the descent / free flow of coal from the mined bank behind the front line at the level of the escape windows.
The operation of directing the mining pressure consists in removing the pillars and beams related to the last row located towards the exploited space.
The technology of working in the slaughterhouse involves the following phases:
- cutting the coal in the front at the level of the basic slice;
- raising the beam in the console and bandaging the ceiling;
- the evacuation of the dislocated coal and the support of the beams in the console;
- evacuation of the coal from the undermined bank;
- moving the conveyor from the stope to the new alignment and shortening the conveyor from the base gallery and directing mining pressure.
The ventilation of the stope is carried out under the general depression of the mine.
In addition to the technological operations specific to the classical method of mining with mechanized frontal cuttings in retreat when mining with frontal cuttings with a coal bank undermined behind the front line, they are:
- the execution of the attack gallery of the stope; forming the shoe;
- the extraction of coal from the stope with an undermined bench;
- cutting the coal in front of the base slice;
- raising the beam in the console and bandaging the ceiling;
- the gradual evacuation of the coal from the undermined bank; directing mining pressure;

Extraction of coal from the undercut stope

The extraction of coal from the undercut mine is carried out in compliance with the work technology specific to the mining method with undermining behind the front line – the case of coal evacuation on 3 beams, the following stages being completed:

– cutting coal and tailings at the front of the base slice (phase II);

– raising the beam in the console and bandaging the ceiling (phase III);

– evacuation of coal and tailings dislodged from the front of the base slice, supporting the beams in the console and bandaging the front with mesh (phase IV);

– evacuation/ gradual unloading of the coal from the undermined bank and respectively of the tailings belonging to the bedding area (phase V);

– mounting the conveyor from the stope on the new alignment (the middle aisle of the rows of beams), shortening the conveyor from the stope to the sleeper; supporting intersections (phase VI);

– directing the mining pressure (phase VII), by removing the pillars and the last row of beams.

Cutting the coal in front of the base slice

The cutting of coal and tailings at the front is carried out by perforating-shooting and partially with the felling hammer in the case of coal, starting from the pre-cutting located in the bed towards the one executed under the roof of the layer.

Depending on the strength of the rock intercepted at the working front, schemes are applied for shooting that can include one or two rows of ordinary mine holes in the case of coal and, respectively, up to five rows in the case of intercepting tailings from the bedding area. Also, in case of interception of the tailings area, it will be ensured as much as possible that the evacuation of the resulting material is done on the same coal transport flow, but with its separate storage on the surface, in a similar way to the evacuation of the tailings resulting from the execution of the pre stope from bed. [3]

Raising the beam in the console and bandaging the ceiling

After carrying out the operations of dislocating the coal and tailings by drilling-shooting at the front, respectively cleaning and rectifying the ceiling of the stope, the cantilever beams ("c" beams - phase III) are lifted on the stope sections, sequentially. Simultaneously with the lifting of the beams in the console, the short GS-570 beams are mounted as clamps and the ceiling is bandaged with metal mesh.

Gradual evacuation of coal from the undermined bank

After completing the operations of cutting and supporting the front in front of the stope, the evacuation of the coal from the undermined bank is carried out. The evacuation of the coal from the undermined bench is done starting from the pre-cut from the bed towards the one under the roof of the layer, through the evacuation windows practiced after cutting the metal mesh behind the cut. The realization of the evacuation windows is done at distances equivalent to two fields of the row of beams, for which two distinct stages are completed, namely:

- In a first stage, cutting the net to make the exhaust windows is done in the shape of the letter "H" lying down, at approx. 0.5 m below the ceiling of the stope, at the dimensions of approx. 0.5 x 1.6 m.

Through the exhaust windows thus created, on sections, successively, the coal is unloaded by free fall, along the front line, including the area of the two intersections. In the case of the bedding area of the seam, the coal and tailings are discharged after the artificial discharge slope created by drilling and shooting long mine holes into the tailings rock if applicable.

During the coal unloading operation, an unevacuated coal bed is left behind the felling, which will fulfill the role of damping and protection of the support against possible falls of the blocks in the exploited space. [2]

The coal bed and tailings bed will measure a height of approx. 50 cm higher than the 250 cm height of the stope, they will be partially evacuated, on a thickness of approx. 1.5 m, at the level of the last unloading phase within the first stage of the coal evacuation operation, after previously making contact with the barren rock driven and uprooted from the artificial ceiling of the stope.

– In the second stage, it is envisaged to cut the net in a vertical plane, starting from the hearth of the stope towards the window made previously, with the aim of evacuating the remaining coal at the base of the stope. [2]

The cutting (cutting) of the metal mesh in this way is done after, in advance, the previous/upper windows have been sewn with string along the entire length of the stope, after which the evacuation of the coal (and tailings for the sleeping area) is done at the level of cutting, starting from the pre-cutting in the bed, next to the existing cutting area in the tailings, towards the pre-cutting under the roof. After the end of the evacuation operation, which coincides with the appearance of the tailings from the ceiling on the hearth of the stope, at the level of one cutout, the net will be sewn, the complete evacuation of the coal continuing identically at the level of all the cutouts related to the stope line in its entirety, which corresponds to the thickness on horizontal of the coal seam.

In order to prepare the mining pressure directing operation and resume a new felling cycle with the coal unloading option on 3 beams, the scraper conveyor from the felling is dismantled chute by chute and mounted on the new alignment of the felling, respectively on the middle aisle of the row of beams. Simultaneously with moving the conveyor from the slaughterhouse, the conveyor is shortened with scrapers from the pre-slaughterhouse, after which the support with cross beams from the intersections is mounted.

Before removing the metal reinforcements from the pre-cuts, the additional support of wooden yokes is mounted, with the placement of the poles under the metal reinforcements, this type of support constituting a temporary safety support for the metal reinforcements to be removed. [3]

The mounting of the additional support made of wooden yokes is done on lengths of at least 30 m, starting from the intersections in the direction of the advance of the stope.

Both intersections are bandaged with metal mesh on the ceiling, including in the area of the wall at the level of the pre-stope located in the sterile bedrock.

The working technology at the level of the undermining bench stope provides for the perforation and shooting of long holes, for the formation of the artificial slope for unloading tailings and coal from the bedding area of the layer.

Compared to the presented framework technology, which provides for the reprofiling of the directional preparation galleries and the raising at the level of the intersections of one more beam at the level of a row, on the last 6.25 m measured from the front line to the decommissioning border, it is possible to extend additional intersections, especially in the case of pre-bracing from the sleeper, with the equivalent of 4 more beams at row/column level, resulting in a total of 5 beams/row.

Concomitantly with the advance of the stope, the coal related to the spike is extracted/cleaned from the roof of the layer, the remaining free space being supported and bandaged with wood or netting.

Directing the pressure

Directing the mining pressure consists of the total collapse/surprise of the coal detached from the undermined bank. The routing operation is done starting from the pre-stope from the bed to the one under the roof.

4 The assessment of specific risks and their correlation with the levels of danger

The monitoring of specific risks at the frontal stopes with an undermined coal bank behind the front line, aimed to carry out a pre-accident type assessment of the risk of occupational injury and illness. For this purpose, the following stages have been established:
- working out in principle the program for assessing the level of risk;
- establishing the evaluation structure, formulating decisions regarding the approach;
- the collection of information, regarding the work environment, technical equipment, work load, executor and acquired experience;
- hazard identification;
- identification of workers exposed to risks and of the type of risk exposure;
- risk assessment;
- studying different possibilities for eliminating or reducing risks and formulating protection measures and establishing the modes of action and protection measures

The assessment of the risk level is a systematic examination of all aspects of the work process, undertaken in order to eliminate the sources that could cause bodily harm, which constitute the basis for the substantiation of measures to prevent and combat risks. [4, 5]
When carrying out productive activities at the mines in Jiu Valley, four elements exist and come into relationship: executor, workload, means of production - technical equipment and work environment. [2, 3]
As a result, in order to identify the causes of occupational accidents and illnesses, it is necessary to analyze what was happening inside the work system. Any deficiency at the level of one or more elements, representing a deviation from the predetermined functioning of the system, leads to the increase of entropy, thus to the manifestation of its tendency to self-destruction, including by harming the person. In order for such an effect to occur, it is necessary that the deviations from functioning form a causal chain, the last link of which is the meeting between the victim and the material agent that injures him. For this reason, dysfunctions of the elements of the work system are considered as potential causes of occupational injury and/or illness, respectively risk factors of occupational injury and/or illness. [4]
The structure of occupational injury and disease risk factors, which will be taken into account when establishing the safety and health requirements for the extraction activity, is:

- The executor's own risk factors:

- human errors (omissions in performing some operations, delays in performing some operations, non-synchronization of operations);
- the wrong performance of some operations (commands, maneuvers, positioning, fixings, consolidations, assemblies, adjustments, etc.);
- carrying out operations not foreseen by the work load (starting or interrupting the operation of machines, energy supply, etc.);
- stationing in dangerous areas (unsupported areas, under moving sections);
- wrong communications (through content or method of transmission);
- presence at work in inappropriate psychophysiological conditions;
- sudden annihilation of functional capacity (loss of consciousness).

- Risk factors specific to the work load:
  - the content or structure of the work load inappropriate to the purpose of the work process or potential risk situations:

- wrong operations, rules, procedures;
- absence of operations and improper work methods (wrong sequence of operations).

- under/oversized requirements imposed on the executor in relation to his possibilities (time constraints related to the pace of work, repetitive short-cycle operations, extremely complex operations, etc.)

- The risk factors specific to the means of production:
  - Physical risk factors:
    - Dangerous movements:

- functional movements of machines, mechanisms, fluids, etc.;
- self-triggers or self-controls of machines, mechanisms, etc.;
- movements under the effect of gravity (slipping, rolling, slipping on wheels, overturning, free fall, leakage, spillage, tripping, collapsing, sinking);
- movements under the effect of propulsion (deviations from the normal trajectory, swing, recoil, excessive shocks, projectors of bodies or particles, jet, eruption);
- movements under the effect of propulsion (deviations from the normal trajectory, swing, recoil, excessive shocks, projectors of bodies or particles, jet, eruption).

    - Dangerous prickly, sharp, slippery, abrasive, adhesive surfaces or contours:

- excessive vibrations of tools, installations, buildings;
- explosions.

  - Thermal risk factors:

- objects or surfaces with excessive temperatures (high or low);
- fires, combustion.

  - Electrical risk factors:

- danger of direct and indirect contact;
- step voltage.

  - Chemical risk factors:

- toxic, caustic, flammable, explosive, carcinogenic, mutagenic substances.

  - Biological risk factors:

- cultures or preparations with microorganisms (bacteria, viruses, etc.);
- dangerous plants or animals (poisonous mushrooms, snakes, etc.).

  - Risk factors of psychophysiological under/overload of the performer:

- static - forced working position;
- dynamics: execution speed too low / high, the difficulty of performing the movements.
- mental (eg: difficult decisions in a short time;
- sensory (ex: monotony of work);
- psychomotor (ex: high execution precision).

- Risk factors specific to the work environment:
  - Physical risk factors:

- excessive air temperature (high / low);
- inadequate air humidity (high/low);
- air currents with too high or too low a speed;
- excessive air ionization, pressure; excessive noise; ultrasound;
- inadequate lighting
- electromagnetic radiation: infrared, ultraviolet, microwave, laser, etc.;
- ionizing radiation: alpha, beta, gamma;
- electrostatic potential; atmospheric over voltages;
- natural disasters (floods, wind, landslides, surprises, avalanches, earthquakes).

  - Chemical risk factors:

- gases, vapors, toxic, caustic, suffocating, explosive aerosols and explosive powders in suspension.

  - Biological risk factors:

- Risk factors for psychophysiological overload of the performer:

- overload due to the special nature of the work environment (underground, aquatic, underwater, aerial, etc.);
- psychic overload due to the inadequate social climate created by inadequate primary relationships, skills inadequate to the levels of responsibility, inadequate communication structure, inconsistency between formal and informational relationships.

Work security implies the absence of occupational injury and illness hazards in the work process. The purpose of assessing the level of risk is to know the real situation at each workplace from the point of view of safety and health at work and to take the most appropriate measures in the given situations. [4]

The measures refer to:
- prevention of professional risks and informing and training employees;
- the involvement of bodies and means that allow the implementation of the expected measures.

To be effective, the specific risk assessment must be structured in such a way as to allow:
- identifying the existing dangers and assessing the risks related to them, in order to establish the measures that must be taken to ensure safety and health at work;
- risk assessment in order to purchase and use the best technical equipment, personal protective equipment, dangerous substances, as well as the arrangement and organization of the workplace;
- verification of the proposed and implemented measures;
- prioritization of prevention actions in order of priority;
- demonstrating to management, workers, their representatives, as well as other persons or authorities, that all work-related factors have been taken into account, that all the necessary measures are known and taken into account in order to ensure adequate safety and health conditions in work.

Each field is characterized by a number of influencing factors, such as:
- the state of the preparatory mining works; layer degassing and methane control;
- preventing and combating fires, mine fires and coal dust;
- preventing the ignition of potentially explosive mixtures of methane-air and/or coal dust during firing or from other sources of initiation;
- electrical safety; equipment; specific aspects of the undermined bank method. [5]

5 Conclusions

1. The analysis of the work systems, specific to the mining activity in the coal mines of Jiu Valley was carried out taking into account the following:
• the spatial delimitation of the labor system in the mining activity, as follows:
- stopes and opening and preparation work fronts;
- horizontal and inclined transport system and the vertical transport system.
• in the analyzed subsystem - frontal stopes with a long mechanized front, respectively with a mined coal bank behind the front line - the technical equipment, the working environment and the attribution of workers by activity area were identified;
• the general work load in stopes was considered to be dislodging a quantity of coal from the layer and transporting it to the transport system in the base gallery;
• the underground work environment - a component of the work system in which workers carry out their activity - is characterized by the simultaneous existence of several risk factors: the microclimate of the workplace, releases of gases and vapors of liquid hydrocarbons, silicon dust and coal explosive, etc.

2. The danger of explosion is major in gritty underground mining works, through its catastrophic consequences, both for the personnel in the affected area, as well as for the

workplaces and the deposit. Under these conditions, protection against explosive underground atmospheres remains a primary concern for all mining decision-makers.

3. The work system analyzed - stope with a mechanized long front in retreat, respectively, with a bank of coal undermined behind the front line - specific to the coal mines in Jiu Valley, was broken down into four subsystems delimited by the specifics of the activity carried out in them, that:

- zone A - Work subsystem in the area of the intersection of the stope with the head gallery;
- zone B - Work subsystem in the slaughterhouse area;
- zone C - The work subsystem in the area of the intersection of the stope with the base gallery
- zone D - Work subsystem in the base gallery area.

fact, which allowed the identification of the activities carried out by the executors, the technical means of the workplace, and the work environment in the technological spaces defined by the respective areas.

4. The risk factors that manifest themselves in the work system can be analyzed taking into account:

- risk factors depending on the physical and intellectual skills of the workers;
- risk factors dependent on the constructive-functional characteristics of the technical equipment;
- risk factors dependent on the underground environment and its evolution, as a result of the workers' actions, directly or through technical equipment;
- risk factors depending on the workload.

5. This general approach to risk factors allows the decision-making staff within the mining units to follow:

• identifying deviations committed by workers from their ideal attitude, in order to establish correct criteria for the selection of workers from a workplace, respectively to establish the objectives of the training processes;

• identification of technical equipment, with increased risk from the point of view of safety and health requirements at workplaces or with their incorrect operating regime, their removal or improvement of their protection systems;

• performing a safety and health audit of all underground workplaces, in order to detect dangerous situations and establish the necessary measures to be taken to eliminate imminent or potential dangerous situations;

• implementation of a new system for monitoring risk factors.

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