

MINING RISKS AT EXPLOITATION IN ROȘIA POIENI OPEN PIT MINE, ROMANIA

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Abstract: *The mining sector is a particularly important field that has the ability to support the economic development of a country by supplying various mineral products that are used as raw materials in other sectors of activity. When the depth at which a deposit is located and the geological conditions allow, the exploitation of useful mineral substances is realized through open-pit mine. The aim of this paper is to analyze the malfunctions that could occur and cause susceptible incidents and that could have consequences on staff safety and the environment. These malfunctions can have different causes: either an internal origin of the mining unit, or in natural phenomena. In this paper are identified and analyzed the potential mining risks that may occur in the Roșia Poieni open pit mine. The guidelines underlying the identification of these risks took into account three main principles: reducing risks for people, ensuring their security and at the same time limiting the risks on the property, respectively the financial risk for the mining unit. Acknowledge these risks, allows the delimitation of areas that are directly or indirectly exposed to potential risks and the establishment of specific measures for prevention, protection and security regarding the realized activities. Depending on the potential mining risks identified, we have made a hazard map that can be used to develop a risk prevention plan, taking into account the presence of several types of risks that may overlap in the same work area of the quarry.*

Keywords: *open pit mine exploitation, risk, severity, probability level, event, risks matrix, security*

1. Introduction

The quarry exploitation of useful mineral substances deposits is realized by different methods. The correct choice of exploitation method is determined by geographical position, topography and environmental factors. Whatever the method of exploitation, it involves the preliminary removal of the waste rocks that cover the deposit. If open-pit mine exploitation is generally less dangerous compared to underground mining exploitation, it still presents sufficient specific risks that are important to know. Using heavy machinery or equipment not only involves the risk of accidents, but can expose workers to exhaust fumes, noise and products such as fuels, lubricants and solvents [1], [2], [3], [4], [5]. Also, weather conditions can cause problems, especially in case of abundant rainfall or snow, ice or frost, low visibility and extreme temperatures. If the extraction of the deposit requires the use of explosives, special precautions must be taken regarding their handling, storage and use. Sterile rocks and other waste occupy significant volumes, which requires appropriate measures to prevent the risks of potential landslides and to ensure the protection of workers and the environment.

The dangers study has a dual purpose, namely: to present the dangers due to exploitation in case of accident describing the possible consequences and to explain the measures taken to reduce the probability of occurrence and the effects of a potential accident [5], [6], [7], [8], [10]. Open pit exploitation is an industrial activity that requires the presence of a large number of materials, equipments and installations, but also explosive materials. The dangers that may arise are related to the exploitation works, blasting works and the

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use of explosives, fires and explosions, the manifestation of the phenomenon of general instability of emplacement and/or instability of the exploitation benches and possible rockfalls in the work fronts, even due to the movement of equipment.

2. General presentation of activity in Roșia Poieni's open pit mine

Geographically, the poor copper ore deposit from Roșia Poieni, is located in the area of the Apuseni Mountains in the southern extremity of the Metaliferi Mountains, 90 km north-west of Alba Iulia and approximative 7 km from the Arieș River. The upper elevations in the deposit area (Vârși - Curmătura - Ruginiș hills) have values between 1,150 m and 1,250 m and correspond to the maximum elevations of the interested area where the main mine yards of the mining objective were located. The open-pit mine exploitation started in 1978, in the Abrud - Mușca - Bucium area, the copper production starting in 1983. The exploitation perimeter in which the activity takes place has an area of 21.9 km² and is located on the territory of Lupșa, Bucium, Bistra, Roșia Montană communes in the north-eastern area of the Metaliferi Mountains. The morphology of the area is characterized by a rugged relief, with deep valleys and suspended platforms imposed by the existence of facies formations that highlight specific forms of volcanic regimes. The slopes of the valleys have many dislevelments, with some negative forms and sloughy areas, both on platforms and in meadows or terraces of valleys. The lands are frequently affected by erosions, due to the high value of the relief energy, manifested especially between the elevations of 900 m and 400 m, as well as the poor consistency of the clays and Senonian marls that mostly cover the surrounding area of deposit [11].

The activity carried out in the process of capitalization of copper ore has two important phases, namely: copper ore exploitation in the open-pit mine and preparation of extracted ore from the quarry in the preparation plant. In addition to these main activities, there are also a series of secondary activities within the objective of waste tailings resulting from open pit mine discovery works, hydrotransport of flotation tailings to tailings ponds and transport activities of raw materials (ore), the sterile and finished product (concentrate). For the development of the complex activity of ore extraction and preparation, Roșia Poieni has a quarry, a preparation plant with tailings ponds and a number of mines yards to which are added the auxiliary facilities for transport, handling, and ore and concentrate storage [11].

The surrounding area of the deposit is mountainous, with elevations between 600 m and 1250 m and is furrowed by deep valleys, which are generally oriented as it follows: from the deposit to the north in the Arieș Valley; from the deposit to the south, stopping in the Abrud Valley. The mineralization of the deposit is located within Fundoia andesitic body and only on restricted areas in the Poieni andesite and surrounding sedimentary rocks. All the waters that cross the surfaces of the dumps and ponds flow gravitationally, so that the waters from Valea Șesei area reach gravitationally in TMF Valea Șesei, and those from the Valea Ștefancei area, reach gravitationally Valea Ștefancei ponds. The only waters that reach the Bucium brook and then the Abrudel brook are those that drain from the Obârșia Muntari dump, but whose flow is very small ($2 \div 6$ l/s) and discontinuous.

The set of objectives (figure 1) is located in a perimeter between Valea Șesei (where are Cariera Romaneasa and Valea Șesei tailings pond) as eastern limit, Culmea Muntari (where is Muntari dump), as southern limit and Valea Ștefancei (with Valea Ștefancei dump) as a western limit. To the north, the perimeter is limited by inhabited areas that extend along the Arieș Valley (Bistra, Lazuri-Mușca, Hădărău and Lupșa localities). For the ponds, all hydrotechnical works related to their safe functioning were provided. Incidents or damage during exploitation are also part of the site's history [11].

The main activities that take place at the level of Roșia Poieni exploitation, consist of:

- Extraction of mining mass from open-pit mine (ore and quarry sterile) by drilling, blasting, loading, and transport;
- Storage the quarry sterile in Geamăna, Cuibaru and (possibly at the extension of the exploitation activities) Obârșia Muntari tailings dumps;
- Classical preparation of copper ore by: crushing, grinding, flotation, and filtration (obtaining copper concentrate);
- Thickening, gravitational transport and sterile hydromass storage in Valea Șesei and Valea Ștefancei tailings ponds;
- The tailings dumps for which the assessment of environmental balance sheet is made are: tailings dumps where the quarry sterile obtained from extraction activity of mining mass are stored; tailings ponds where the flotation tailings from the preparation plant are stored.

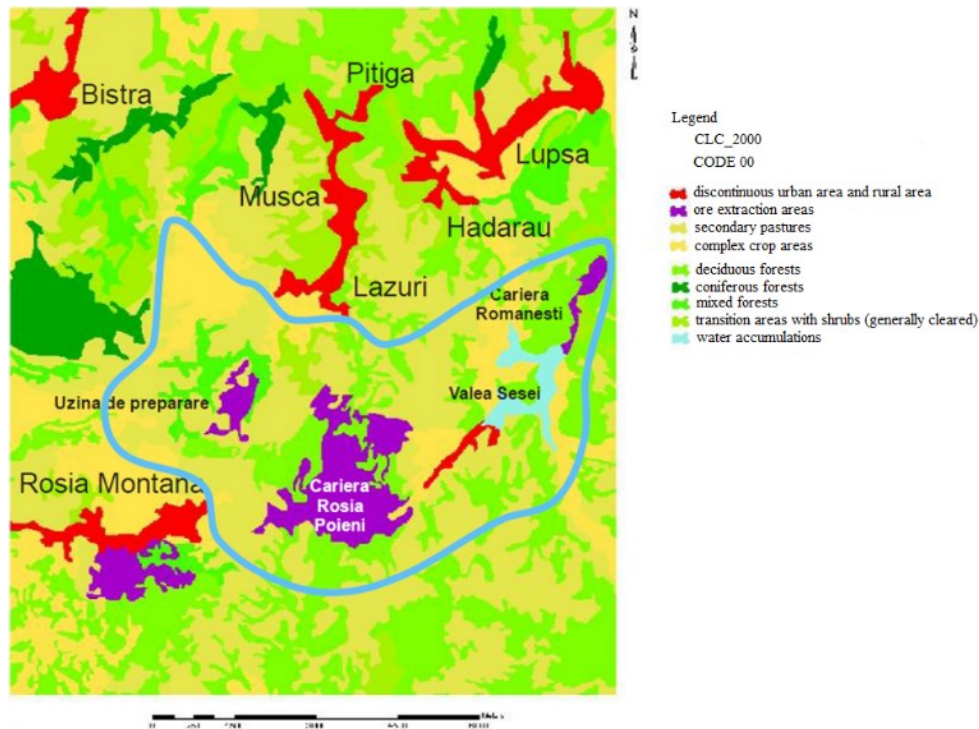


Figure 1. The perimeter of Roșia Poieni mining project (blue line)
(source: National Agency for Environmental Protection)

The main objective of the company is the development of the complex activity of ore extraction and preparation, by expanding the mining perimeter (Roșia Poieni open-pit mine). For the exploitation and capitalization of the other useful mineral substances from the Roșia Poieni perimeter, four quarries were opened. The stone quarry from Valea Ștefancei provided the rocks necessary for the construction of Valea Ștefancei I and Valea Ștefancei II tailings dams. From Vârșii Mici quarry, the stone sorts necessary for the construction of access roads to the mining objective were extracted, the operation of this quarry being stopped for several years.

Dealul Jgheabului quarry is the main source for the production of industrial andesite in various particle sizes, achievable with the existing crushing - grinding and grading installation, the resulted products being crushed stone and crushed aggregates on different classes (0 - 4 mm, 4 - 8 mm, 8 - 16 mm, 16 - 25 mm, 25 - 65 mm); most of the quarry production is used for construction and maintenance of technological roads within the Roșia Poieni exploitation perimeter, but the quarry products are also intended for marketing to external beneficiaries depending on requests.

From the Piatra Tichileu quarry, the same type of andesite (Poieni andesite) is exploited as the one from Dealul Jgheabului quarry, their productions being complementary, and its processing is made by crushing installation located in areas. In addition to the industrial andesite resources, S.C. Cupru Min S.A. also exploits the Pârâul Româneasa limestone quarry, from which the rocks necessary for the construction and successive elevations of the Valea Șesei tailings dam were extracted [11].

The main phases of copper ore exploitation involve: open pit mine exploitation in order to extract the ores rich in metals; obtaining copper concentrate and storing tailings. In conditions of economic profitability, the ore with exploitable content is transported to the crushing, grinding and flotation units.

At the level of Roșia Poieni mining emplacement, the extraction process of useful mineral substance involves only mechanical and physical processes (flotation), excluding any metallurgical, chemical or electrolytic processes. The crushing of extracted ore from the open-pit mine from the size of 0-1200 mm to 0-300 mm is performed in a rotary crusher type KKD 1500/180 located at elevation +900 m. After the first crushing phase that takes place in the rotary crusher, where the rock blocks are dimensionally reduced, to sizes below 300 mm, the primary crushed ore is transported on conveyor belts with a width of 1,400 mm, extending over a length of 2,432 m. Grinding takes place in the semi-autogenous mill (8,500 ÷ 3,800 mm) and then in the ball mill (5,200 × 8,000 mm), the ground material being sizing in hydrocyclone batteries of D = 500 mm. After grinding and flotation, a concentrate with a minimum concentration of 16.5 % Cu is obtained. The thickening process of tailings takes place in installations called thickeners (D = 80 m). As a result of these mechanical and physical processes, the tailings are separated and transported by gravity up to TMF tailings

Valea Șesei. In case of damage, or during maintenance works, the sterile hydromass is diverted to the TMF Valea Ștefancei 2. At the level of the tailings ponds there is a mechanical separation (decantation of ground rocks followed by clarification of water), and the water is discharged into the emissary [11].

3. Identifying potential mining risks in Roșia Poieni open pit mine

Risks related to the blasting operation and working with explosives. Explosives are chemicals or mixtures substances that under the influence of an external action undergo fast chemical transformations accompanied by the fast release of heat, forming of a large volume of gases at high pressures and temperatures, which by expansion are able to perform a mechanical work of dislocation. The transferred energy to the outside to perform the mechanical work of dislocation determines that chemical phenomenon of fast decomposition of the explosive, called explosion. Detonation and/or deflagration may occur due to initiating events, the latter being grouped into several categories [2], [3], [4], [5], [7], [9], [12]: explosions due to shock waves; explosions due to mechanical energy; explosions due to thermal energy; explosions due to chemical energy; explosions due to electromagnetic radiation. In the Roșia Poieni open-pit mine, the rock dislocation is carried out using explosives. On-site there are special warehouses for storing explosive materials; these are included in the category of consumer warehouses, from which fireworks take over the needed amount of explosive materials in the face to carry out a blasting operation. In this case, the major accidents that can occur on site are represented by explosions, fires and emissions of toxic substances. The consequences of these accidents can be serious, sometimes even catastrophic, resulting in loss of life and damage to the environment. Under the conditions established by law, the joint transport and storage of explosive materials used in the Roșia Poieni quarry are accepted (dynamite, explosives based on ammonium nitrate, boosters, Detinel, electrical primers).

Even if the risk is low, it can also appear after the rock dislocation, namely after the blasting operation. The risks associated with the blasting operation are as it follows: throwing pieces of rock at distances greater than the permitted limits; vibrations; noise (air overpressure); the instability of benches and the explosion itself. The risks of rock-throwing and instability can also occur due to the structure of the rock mass or due to human error. The last ones are unlikely, because the blasting operation is performed only by authorized personnel; however, their probability is not excluded.

Air overpressure is a very short noise due to the detonation of the explosive charge, but which is greatly attenuated by increasing the distance from the place where the explosion takes place. That is why a minimum distance of 200 m is needed to ensure that there will be no consequences for the people working in the quarry. Before starting the boreholes loading operation with explosive, the persons responsible for the blasting operation shall ensure that within a radius of at least 200 m around the blasting face there are no persons. An unexpected explosion is a risk that can occur mainly in the event of a blown-out shot or during a storm. In case of blown-out shot (unexploded charges and/or detonators) the open-pit mine exploitation will be stopped immediately and the perimeter will be secured. If the weather is cloudy, the blasting operation must be interrupted.

The risks of explosion in Roșia Poieni open pit mine may have as origin: the use of explosives for rock dislocation operation; use of compressed gases for welding operations; the existence of hydrocarbon tanks at the level of which filling operations may generate a low risk of explosion; due to the presence of explosives used in blasting operation. The effects of explosions are related to their main manifestations: maximum overpressure generated by explosion or detonation, the detonation pressure being much higher and causing greater damage; the blast whistle in the immediate proximity of explosion; flames that can occupy a volume of 10 times higher than that of the explosive atmosphere; throwing pieces of rocks or other materials; initiating a fire with all its consequences. We can mention the fact that regarding the blasting operations carried out in Roșia Poieni open-pit mine, so far no incident related to this type of operation has been registered. Due to the emplacement configuration and location of different susceptible sectors that could become the site of an uncontrolled explosion in an abnormal situation, the problems (with moderate intensity) could only occur in areas where blasting operations are being carried out.

The risks due to the instability of emplacement take into account the tectonics of the massif in which the deposit is located, as well as the presence of geological discontinuities. The deposit is located in a ruptural tectonic node resulting from the intersection of two main fault systems specific to the entire chain of Metaliferi Mountains: the North-West - South-East system and the one oriented in the North-East - South-West direction. The rupture dislocations constituting areas of minimum resistance used as access ways of Neogene magmatites, and their dominant direction controlled the spatial distribution of the volcanic apparatuses. Successive eruptions of magmas have given to the perimeter long-term tectonic mobility, affecting both the already

consolidated igneous rocks and sedimentary formations. The area mobility continued even after the installation of the eruptive rocks, a fact highlighted by the fractures with a high slope that affected this magmatic structure. By repeated fracturing and at different intervals, a series of compartments shifted vertically were formed, with minor detachments horizontally. The existence of major fractures is also confirmed by geophysical measurements (aeromagnetic and partially gravimetric) that highlight the fractures Mușca – Vârful Curmătura – Vârful Bucium Muntari și Dealul Tili – Roșia Montană – Curmătura – Geamăna, which intersects in the south-western part of Fundoaia sub-volcano. In addition to the major tectonic movements that compartmentalized the area, a lot of cracks and support fractures (exokinetic) of the main systems produced either simultaneously or after the replacement of Neogene magmatites, were also highlighted. Cracking measurements highlighted the main directions of the crack planes to the North West – South East, North East – South West and less frequently East-West. The systems of cracks and cooling fractures (endokinetic) formed in the rock mass intersecting the major tectonic fractures, favored the movement of mineralizations, generally constituting the determining factors in the control of sulfur mineralization. The presence of these cracks in the rock mass leads to their division into separate blocks, thus reducing the strength and slopes stability within the quarry. In the case of dips in accordance with the angles of the slope, planes of minimum slip resistance are created. At the same time, the frequency of these cracks leads to the secondary alteration of eruptive rocks by the cumulative action of atmospheric agents in the presence of water, a phenomenon that will continuously affect the quarry edge slopes.

The rocks that appear in the contour of the open-pit mine have been affected by alteration processes related to the hydrothermal manifestations of magmatic eruptions, developed over large areas, including both eruptive and sedimentary rocks. Hypogenic transformation products have a zonal development around the Fundoaia type andesitic body and are characterized by certain mineral associations of neoformation. The chemical alteration processes with variable degrees and different mineral associations, give to the andesites from the area an anisotropy of mechanical properties, which determines different behaviors of the rocks from the open-pit mine perimeter.

The risks related to exploitation can be said to be limited in time depending on the work schedule and working day. This risk can occur during the drilling of wells, the operation of equipment, the circulation of dump trucks, the loading of dislocated rocks and the manifestation of the phenomenon of benches exploitation instability. Following the technological phases of the ore preparation process extracted from Roșia Poieni quarry, the resulting tailings are settled and stored in TMF Valea Șesei or in case of damage the role is taken over by TMF Valea Ștefancei 2. The nature and origin of the waste that is deposited is: flotation tailings resulting from the preparation of copper ore and waste from the physical and chemical processing of metalliferous ores. From the stability studies carried out over time, it was concluded that the slopes of the pond are stable, being made of very resistant limestone rocks that do not endanger the stability [11].

The risks of exposure to dust and noise of personnel present on the quarry emplacement have a special character in the case of open-pit mine exploitations [6], [13], [14], [15]. In Roșia Poieni open-pit mine, the main activity is the extraction of the copper deposit and as secondary activities the production of quarry aggregates (industrial and construction andesite and limestone) used in various fields in constructions. These materials are non-toxic. On the other hand, the operations that make up the technological flow in the quarry and at the preparation plant can suspend particles with very low particle size, potentially dangerous by their action on the pulmonary system of workers.

Dust emissions occur as a result of rock blasting from work fronts, loading - transport - deposition in tailings dumps, transfer to the belt conveyor system, crushing, sorting the aggregates by particle-size distribution class and storage of materials; however, dust also occurs during the movement of machinery in quarry perimeter. The installations and equipment that function in quarry are generally noisy. Noise sources may originate from: drilling – blasting operation, loading and transporting equipment, aggregates crushing and sorting plants. With regard to the blasting operation, the personnel present at the working face fall back during the explosive loading and detonation at a distance of least 200 m; this operation is punctual and takes only a few seconds. Excavators, loading and transport equipment of dislocated material are mobile sound sources and produce noises that have a floating and intermittent character; the geographical distribution of these sources is variable and very extensive. Crushers, as fixed sources, produce noises with a stable, sometimes fluctuating character.

Risk of fire. A fire can be defined as combustion that generally develops quite disorderly and without the possibility of being controlled. The risk of fire could arise from electrical installations or even from the working of machinery and equipment in the quarry or from improvised installations, uninsulated conductors and overload; the fire may also occur if flammable materials are stored near areas where open flameworking or in

welding workshops [2], [3], [5], [7], [9], [16]. As possibilities of occurrence of fire in open pit mine, we can have storage of flammable products such as machine fuels, hydraulic oils and engine oils. Regarding the risk of fire that may arise from the machinery in the open pit mine, it will be limited to that machine only; the risks of propagation would be reduced due to the nature of extracted rock from Roşia Poieni mining perimeter. During the almost 45 years of exploitation in this open-pit mine, no fire was registered.

Environmental risks: The current mining industry is under increasing pressure especially due to the multitude and severity of environmental problems generated in particular by the storage and management of waste resulting from technological extraction and preparation processes.

Mining waste management at the level of Cupru Min society represents a set of activities that converge towards the same final purpose, namely the reduction of environmental pollution, generated by mining waste deposits. The company keeps under control the action of acidic waters from rocks that solubilize heavy metals from tailings dumps and reduces their impact on the quality of surface waters by treating them with lime milk solution 3 – 10 %. The deposit from Roşia Poieni being of porphyry copper type is mainly characterized by the fact that pyrite and copper minerals are finely disseminated throughout the body of the deposit. With the passage of time in contact with air and moisture present, the ore and the quarry sterile have an acidophilic character. The waters that flow through the tailings dumps become acidic and strongly mineralized; thus mine waters are formed as a result of the natural process of oxidative biochemical solubilization [11].

In the Valea Şesei tailings pond, located downstream of the tailings dumps, they reach in addition to the sterile pulp coming from the preparation plant, which has a high basic pH (between 10 - 12), neutral waters from the area and acid waters from tailings dumps with acid pH (about 1.5 - 2.8) and high heavy metal contents. In order to solve these environmental problems, the former reverse well evacuation gallery was additionally closed for better safety in the operation of TMF Valea Şesei, by mortar injection works with setting accelerators similar to those used in filling the gaps behind the support of hydrotechnical galleries. The risk of seepage through dams with an impact on groundwater or surface water downstream and ultimately any source of groundwater downstream has a low probability of occurrence, but cannot be excluded. Risk of breakage of the tailings transport pipeline, with a moderate to high probability of appearance, but this phenomenon can be considered to have fewer consequences compared to the risk of failure, breaking of the dam body. The risk of breakage of tailings dam due to an extreme seismic phenomenon could cause a sterile flow downstream, in which case another risk occurs, namely accidental pollution; however, the probability of breaking the dam body is very low, given the materials in dam foundation. At the same time, the emplacement is located in the low seismic risk area.

In case of exploitation in Roşia Poieni open-pit mine, potential risks of accidental pollution may occur in the following situations:

- On the path of the thickening sterile transport pipelines to Valea Ştefancei and Valea Şesei tailings ponds (available until the G3 gallery, downstream of this the leaks are collected in this pond), due to: wear pipes and their breaking or pipes breaking due to landslides pipes break due to landslides;
- At the reverse wells for the evacuation of the clarified waters and of the connecting pipes between them and the coastal overflow channel of Valea Şesei tailings pond, having as causes: failure of the reverse well or connecting pipes due to landslides or due to corrosion of reverse wells over time;
- The crest of Valea Şesei pond, the possible cause being the deterioration of the tailings distribution system on the crest;
- On the path of lime milk transport pipeline in the back end of Valea Şesei pond (available until the G3 gallery), the possible causes being: wear and breakage of pipelines; breakage of pipes due to landslides or impact them;
- At Gârde dam, the cause being the large number of suspensions deposited inside the dam, due to the alluvium brought by Arieş river from Arieş river basin, upstream of the dam;
- At the tailings dumps and deposit of poor ore prepared for bacterial leaching, due to the sulphides content, by exposure to atmospheric oxygen a series of bio-geo-chemical processes can be triggered which can lead to the production of acid rock drainage (increasing the acidity of waters that wash these dumps leading to an increase in the content of copper, iron, zinc, manganese ions);
- Stone quarry, as a result of fault conditions of drilling, loading and transport equipment; engine and hydraulic oils can cause accidental soil pollution with petroleum products.

Risks related to electric discharges may occur given that the altitude at which the quarry is located is over 1,200 m. Lightning is a high-intensity current that propagates with extremely varied fronts like value, between two masses of clouds or between a mass of clouds and ground. The manifestation of these phenomena can have harmful consequences on the structure of buildings when they are hit directly; may severely damage

electrical, electronic and computer equipment that is close to the point of lightning action; it also generates a high electromagnetic field, which generates parasitic currents on cables. Under such conditions, it is forbidden to carry out blasting operations, because the presence of random currents in the atmosphere could initiate an uncontrolled explosion with very serious consequences. In Roşia Poieni open pit mine, AM1 is used as a basic explosive, an explosive composed of ammonium nitrate and diesel fuel. 450 gram boosters, dynamite and encapsulated explosive gels are used as initiating explosives. The loading of AM1 explosive in the boreholes is realized mechanically with Kenworth T800 special equipment. It uses a blast schema with delay of boreholes loads placed on the same row of 25 ms, respectively 42 - 84 ms between rows of holes, thereby obtaining a corresponding effect of grinding and dispersion of dislocated mining mass.

In case of Roşia Poieni open pit mine, the risks of technical equipment being affected by an atmospheric discharge relate in particular to explosives during blasting operations and to the places of storage of hydrocarbons, quarry equipments and their tank. The appearance of fire is then theoretically possible, but unlikely. It should be recalled, however, that occupational safety and health measures when carrying out operations with explosive materials, must ensure the interdiction of working during storms, electrical discharges, rain, fog, night, and in all cases where natural visibility is insufficient.

Other risks, which can be human nature (movement of equipments and even personnel in unauthorized places, acts of malice etc.) or extreme natural (extreme weather conditions, floods, earthquakes etc.). The risks of accidental penetration into the perimeter of the quarry, collision with a machine on-site or discovery of an explosive device are very low and are limited to the emplacement of the quarry. However, we cannot exclude the possibility of a risk related to an act of malice, even if the perimeter is provided with security at all important points in the quarry, including places where there may be access to the exploitable area.

From a seismic point of view, the national territory is divided into different areas of increasing seismicity, depending on the probability of occurrence of earthquakes. Romania's seismic zoning is based on the seismic map, which divides the territory into five areas of increasing seismicity: very low seismicity, low seismicity, moderate seismicity, medium seismicity and high seismicity. According to the norm P100 / 2013, for the area of Roşia Poieni open-pit mine perimeter, including the tailings ponds, the maximum acceleration of earth (horizontal) for the earthquake with a recurrence period of 225 years is 0.10g and the corner period T_c is equal to 0.7s. There is no risk of flooding, the quarry being located in an unflooded area. The tailings pond is dimensioned for taking over special hydrological events (floods), likewise, Valea Ştefancei pond (as an emergency pond) has the capacity to take over the waters resulting from special meteorological phenomena, being able to be stored in the pond with a level rise of approximately 2.5 m. Risks of natural origin (fire, landslides or movements, extreme weather conditions, earthquakes, etc.) refer only to the open pit mine exploitation perimeter. These are very small, because the location of quarry is not placed in a predisposed area to natural disasters.

The synthesis of potential mining risks from Roşia Poieni open pit mine is presented in table 1. All these potential risks can only manifest themselves when there are favorable circumstances, which means that their occurrence depends on the human factor together with the corresponding associated risk factors (for example, intrinsic technical nature risk factors).

Table 1. Synthesis of potential mining risks in Roşia Poieni open pit mine

Type of potential mining risk	Main consequences	Protective or preventive measures
Risks related to the blasting operation and working with explosives (explosion risks)	Misconduct during blasting operation Uncontrolled explosion Material destructions and/or loss of human lives	Technical and technological measures Specific working procedures Organizational measures
Risks due to emplacement instability	Movement of excavated material Intensification of major fractures and the phenomenon of rock weathering Landslides; creating plans for minimum slip resistance	Monitoring and ensuring the slopes stability and the general stability of emplacement Protection against falling rock blocks
Risks related to exploitation	Accidents during the circulation of dump trucks due to unrespecting with the route Instability of tailings dumps Instability of exploitation benches	Development of framework exploitation methods covering all elements necessary for safe exploitation Technical and technological measures Specific working procedures Organizational measures

Risk of fire	Ignition of flammable and / or combustible liquids Risk of dust explosion, fire at belt conveyors	Avoiding sources of initiation, Avoiding the presence of combustible materials Avoiding contacts between initiation sources and combustible materials Preventive measures (combustible products away from ignition sources; reduced storage to reduce the risk of fire propagation; adapted operating instructions and periodic inspections of electrical equipment) Necessary measures for providing first aid, fire extinguishers and evacuating workers, adapted to the nature of the activities
Environmental risks	Accidental contamination of surface water and groundwater	Environmental impact studies
Risks related to electric discharges (low probability)	Uncontrolled explosion by unwanted detonation of explosive charge used in blasting operations	Technical measures
Other risks (human or extreme natural) (very low probability; the area is not predisposed to natural disasters)	Material damages	Measures according to established emergency plans

4. Analysis and mapping of potential mining risks from Roşia Poieni open pit mine

Risk analysis consists of identifying the sources of hazards and associated dangerous situations that may occur in quarry and quantifying them using two main criteria: the severity and occurrence probability to define the level of risk [2], [4], [6], [16], [17]. In the previous section we identified the potential mining risks that could occur during the exploitation in Roşia Poieni quarry. The severity scale and occurrence probability presented in Table 1 allow the quantification of the level of risk associated with each identified hazardous situation and have been developed taking into account the occurrence probability, kinetics, the intensity of effects and consequences severity of potential accidents. These are inspired by the probabilistic data regarding possible human errors, equipment failure or the occurrence of an event and validated by the occupational safety and health department from CupruMin Company [11].

The severity levels and occurrence probability are determined considering the protection and prevention measures taken or planned by CupruMin. Preventive measures reduce the probability of events occurring, and protective measures reduce or limit the impact. The risk assessment for each hazardous situation identified is estimated by the risk matrix that defines the three levels of risk: acceptable, critical and unacceptable. The analysis of potential mining risks began with an analysis of consequences - limits of extension couple that defines the severity and its level (table 2) and with the definition of estimated probability levels, given the occurrence probability, kinetics, the intensity of effects and severity of consequences of potential accidents (table 3 and figure 2).

Table 2. Consequences - limits of extension couple to define the estimated severity classes

Severity class	Consequences and severity upon personnel	Goods	Environment
1 Low	Negligible, small consequences; work incapacity up to 3 calendar days	No significant effects on the equipment on site	Limited overtaking and transition to an evacuation state without a declaration requirement
2 Medium	Medium, reversible consequences, with great work incapacity	Damage to equipment on site without accident synergy	Exceeding an evacuation rule requiring a declaration to authorities, but without consequences on the environment
3 High	Serious, irreversible consequences, with a partial decrease of work capacity	Damage to hazardous equipment on site without accident synergy or to non-critical safety equipment	Moderate to limited pollution of open pit mine perimeter

4 Very high	Very serious, irreversible consequences, with total loss of work capacity	Damage to hazardous equipment or critical safety equipment on site without general aggravating of consequences	Significant pollution outside of open pit mine
5 Catastrophic	Maximum consequences, death	Damage to goods and equipment on site leading to general aggravating of the consequences	High pollution with important consequences outside of open pit mine

Table 3. Defining estimated probability levels in relation to occurrence probability, kinetics and severity of potential accidents consequences

Occurrence probability	Probability class	Probability level
Very frequently	A	At least monthly
Frequently	B	Between 1 month and 1 year
Rare	C	Between 1 and 5 years
Extremely rare	D	Between 5 and 10 years
Improbable	E	Once to 10 years

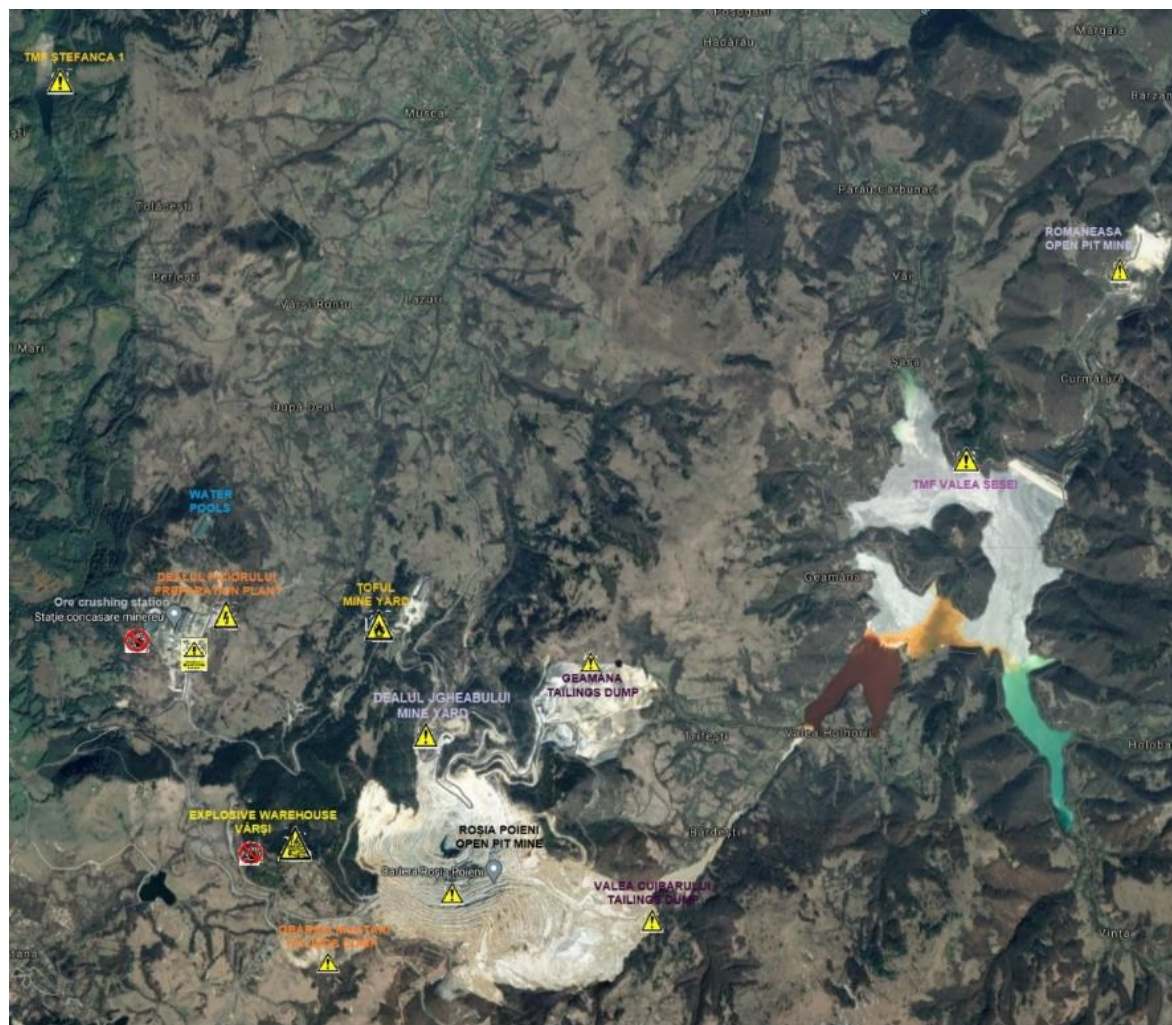


Fig.2. Hazards map from Roșia Poieni open pit mine

The assessment of potential mining risks associated with major accidents was performed in accordance with the methodology based on consequences, which assesses the consequences of risks, without explicit quantification of occurrence probability of these risks [1], [4], [6], [10], [13], [16], [17]. Table 4 presents the matrix of potential mining risks, and in table 5 the plan of measures depending on the level of considered risk. In the matrix of potential mining risks, the two considered variables, namely probability and severity are classified qualitatively.

Table 4. Matrix of potential mining risks

			SEVERITY				
			Negligible	Medium	Grave	Very grave	Catastrophic
			1	2	3	4	5
PROBABILITY	Very frequently	1	1	2	3	4	5
	Frequently	2	2	4	6	8	10
	Rare	3	3	6	9	12	15
	Extremely rare	4	4	8	12	16	20
	Improbable	5	5	10	15	20	25

Table 5. Risk level

Risk level	General measures plan
Very low risk (1 – 3)	Observance of procedures and work processes
Low risk (4 – 6)	
Medium risk (7 – 13)	Identifying and implementing the necessary technical or organizational measures to reduce the risk
High risk (14 – 18)	Identifying and implementing the necessary technical and organizational measures to reduce the risk
Very high risk (19 – 25)	Immediate implementation of the necessary technical measures with the use of all available resources

Existing measures or those that will need to be implemented in order to have an appropriate level of safety are determined according to frequencies and consequences.

In order to assess the potential mining risks associated with the activity carried out in Roşia Poieni open pit mine, numerical values were assigned for each probability level of potential mining risk manifestation and for each level of severity.

The thick black line in the potential mining risk matrix is the extent to which the probability of these identified risks should be maintained; in these situations, procedures and work processes must be followed, which means that no additional risk reduction measures would be needed.

In the yellow zone the risks could be reduced to the lowest level considered tolerable, but this reduction involves identifying and implementing necessary technical or organizational measures.

For all risks with frequencies in the red zone, immediate implementation of technical measures is required, using all available resources to reduce the level of risk (s).

5. Conclusions

Health Risks in underground mining and open-pit mine exploitation can be classified into two categories: risks related to aerosols and dust, and physical risks. In the first category several types can be included: natural gas in the atmosphere of the mine, exhaust gases from engines and certain chemical vapors. Regarding physical risks, these include: noise, vibration, heat, variations in barometric pressure and ionizing radiation. All these risks are present in different degrees, depending on ore nature and surrounding rocks, depth at which it is exploited (the depth of mine) and the methods of exploitation. In addition, miners working together in isolated areas may be exposed to the risks of transmitting certain infectious diseases. The degree of exposure of miners to these risks varies depending on the task they perform or job they each hold, proximity of the risk and effectiveness of implemented prevention or repression measures.

Most risks have a certain dynamic; therefore, it is important to monitor their progress in order to decide whether improvements are needed to the level of personnel training, methods and equipment level. It may be necessary to change the order of risk priorities or the ability to intervene. Risk management allows the approach in a complete and systematic way the knowledge of the own dangers of mining exploitations and implementation of plans and effective means of intervention in case of emergency.

The severity of the potential predictable consequences of an accident or of people's results from a combination of the effects of a dangerous phenomenon and the vulnerability of people potentially exposed to such effects at a certain place within open-pit mine perimeter, taking into account constructive measures concerning personnel safety.

In conclusion, in any open-pit mine exploitation, it will be possible to obtain a level of risk as low as possible if we take into account the level of knowledge, practices and vulnerability of entire mining perimeter.

Just a simple quantitative risk assessment does not eliminate the risk of events caused by activities involving explosives, and tools are needed to ensure the application of a management system as efficient as possible; through these, it is necessary both to assess the level of risk in the performed activities, but also the measures to be taken to eliminate or minimize the risks and consequences of possible events.

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