Risk assessment of Herja mine closure by building a retention dam

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Abstract: The first documentary of mining works of Herja mine dating from 1579. Up to 2007, based on estimation calculus more than 17.500.000 t of ore has been excavated so that the total cave volume reach 7.000.000 m^3. In 2007 the mine was closed but the mine closure and rehabilitation works are hard to achieve because of the high intake of capital required and the fact that it can quickly eliminate sources of pollution, contaminated soil and mine water, potential sources of damaging environmental factors. The polymetallic ore of the Herja mine, in Maramures County, Romania is in the form of nests and the predominant sulphide bands: galena, blende, chalcopyrite, pyrite, gold and silver and related fracture system formed either during volcanic activity or after its completion can be observed also. Between Herja Mine and the preparation plat an underground tunnel (5,560 m) was excavated. The paper will present the closure and rehabilitation works, including the risk assessment after the building works of a retention dam in the tunnel.

Key-Words: mine closure, retention dam, risk assessment, environmental factors, underground tunnel

1. Introduction

It is well know, that unfortunately, the purpose of mining to extract the useful minerals, creating an imbalance in the environment, both at the point where they are extracted and processed minerals substances and the places where they are stored as mine waste [1, 2]. In Romania, the year of 2007 was the decisive time for mining industry, when the mining sector restructuring begun, aimed at separating viable to nonviable mines and privatize profitable mining companies. The Maramures County (Fig. 1) is strongly affected by the closure of mining activity in the economic, social and environmental way.

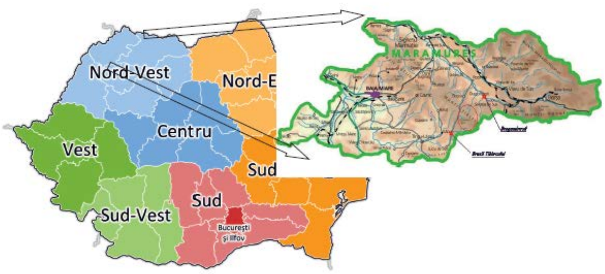

Fig. 1: Maramures County

The Herja Mine is located in Maramures County, in the north of Baia Mare, on the southern slope of the Ignis Mountains, about 9 km from the city of Baia Mare (Fig. 2).

Fig. 2: Location of Herja Mine and the Central Mineral Processing Plant

The specific activity of Herja Mine was the underground extraction and processing of polymetallic ores. The Polymetallic ores results by underground exploatation have been mainly transported by an underground tunnel (5,560 m) to the processing plant for processing by the Central Mineral Processing Plant to extract Pb and Zn, and the amounts of Cu, Au and Ag [9].

The Main chamber is at elevation +380 m, here is a link to the main underground adits through Joachim adit (Fig. 3), considered the basic level ± 0.

Fig. 3: The Joachim Adit

The underground Tunnel Herja - Central Mineral Processing plant is a work which served to transport ore from the mine Herja (level -IX) by means of a conveyor belt to Central plant.

The tunnel has a length of 5.6 km and variable sections between 12.5 to 26 sqm.

The Polymetallic ore is in the form of nests and the predominant sulphide bands: galena, blende, chalcopyrite, pyrite, gold and silver [3].

2. Problem Formulation

Mine closure and cleaning jobs are hard to achieve because of the high intake of capital required and the fact that it cannot quickly eliminate sources of pollution, contaminated soil and mine water, potential sources of damaging environmental factors.

Starting with the Romania's entry in the EU in 2007, with the HG no. 644/2007 the closure of the Mine Herja Perimeters has been done in seven stages:

Stage I - Planning, development and analysis of the cease

Stage II - Ending of mine activities by mine operator

Stage III - Contracting works by auction organized by Ministry of Economy

Stage IV - Implementation of the contract by selecting a company to Ministry of Economy to modernization works that will leave the site of the works to be performed, bye the performer after the winner auction

Stage V – Delivery of the land to Ministry of Economy

Stage VI – Post-closure monitoring

The main idea of the mine closure activities was to close all the access in the mine, including the underground tunnel, to stop the water pumping and so the mine will be flooded.

In the follow we will present the summary of the underground spaces estimation based on excavated ore volume as follow:

To estimate the underground spaces were used Herja mine production data, as the average annual production of 350,000 t / year with a length of service with that average annual quantity of ore was 50 years. The total production of ore was cca. 17,500,000 t. Divided with the density of ore of 2.5 t/m³ will result a space volume of 7 Mio. m³. Adding the volume of the underground tunnel of 59,280 m^3 will result a total space volume of 7,059,280 m³.

To retain the underground water it was plant a retain dam to be constructed in the tunnel. The tunnel construction is straight, has a slope of 2° on the length of approx. 5 km from the mine to the processing plant and the last 500 m has a slope of 13°.

Environmental risks arising from the construction of retention dam is primarily due to mine water. Mine ores exploited in Herja mine consisting of sulfides and the operating method meant partial backfilling, subsidence in the undergrowth, discharging the pillars, which led to a large amount of residual mineralization left in underground. This leads to the formation of significant amount of sulfuric acid resulting in very acidic waters laden with heavy metals.

Before construction of retention dam, mine water discharge is achieved by pumping underground stations located at horizons -IX-IV respectively to horizontal 0. From here the water flows by gravity to the surface Joachim adit, where he was led through the sewage pipe Herja.

After [4] the resulting sizes of the retaining dam was a 2.3 m thick dam with a cylindrical shape with a width of 7.1 m and height of 6.3 m (Fig. 4)

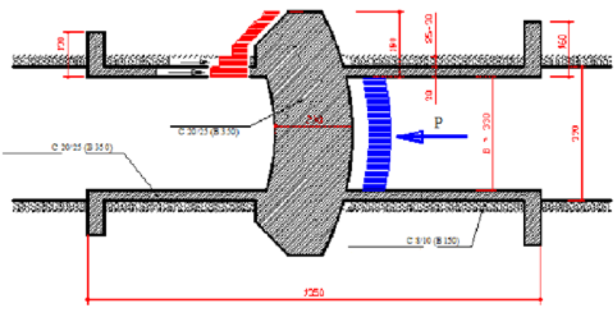
Fig. 4: Retaining dam in the tunel

The difference level of 215 m will give a water pressure of 2,257 kPa. The high pressures on this point could cause a number of adverse effects due to existing fracture of rocks fractures arising from mining or drilling and blasting method.

3. Environmental risk evaluation

Risk identification is the first and most important phase of risk management; it consists in identifying hazards in the present case. This activity is done to detect, if possible, all existing risk factors due to retention dam construction in the tunnel Herja - Central Processing Plant.

To identify these hazards in this case, will go the route Dam retention - Horizon IX of Herja Mine - Adit Joachim and should be identified as vulnerable areas or existing critical points on this route. The following areas have been identified, the corresponding critical points and dangers.

3.1 Retention dam - Breaking the dam due to the mechanical action of hydrostatic pressure

If the underground water will reach the horizon 0, the retention dam shall be subjected to hydrostatic pressure values over 2,257 kPa (22.3 atmospheres) [10].

Due to the high pressures and some factors such as: concrete casting defects, failure resulting bye size calculations, breach of the quantity required for the construction of the dam, foundation soil behavior, and so on, the dam may fail causing a number of serious adverse effects. Thus, a large volume of acid mine water laden with heavy metals would be discharged in a short time, causing pollution of soil, groundwater and the surface effects of pollution is aggravated by the fact that close to the flotation central residential areas are located.

3.2 Retention dam - Breaking the dam due to chemical and biological degradation

When the containment dam is coming in contact with the acid mine water, it will act on a number of agents for the degradation due to the load and to the mine water in the underground environment. The corrosive mine water is well known and is done due to sulfate ions (SO_4^{2-}), hydrogen ions (H^+) and magnesium salts ($MgSO_4$). Also, depending on the conditions of the ground, on the concrete could act as a number of bacteria which play a role in its degradation.

All these agents can act simultaneously on the concrete containment dam, the degradation was enhanced, especially the fact that bye the preparation of the concrete was used a Portland cement, which has not resistance to aggressive compounds.

The resistance dam will decrease significantly over time and can cause hydrostatic pressure action at a time, breaking the dam, causing a number of serious adverse effects, such as those mentioned above.

3.3 Infiltration of mine water besides retention dam

This danger is made possible by high hydrostatic pressures exerted on the rock in which the dam is built.

Also, the surrounding rock breakwater and erosion can act chemically bye laden mine water with SO_4^{2-}ions, H^+ ions and magnesium salts, possibly creating spaces infiltration besides retention dam.

This would create a major pollution of surface water and groundwater over large areas, and pollution of soils in the Central Processing Plant [9].

If the infiltration rate near dam would be small, the polluted waters could be driven by underground waters, thereby causing groundwater pollution.

3.4 Rise of mine water and it's infiltration into groundwater

Due to the high pressures of the retention dam, the acid mine water laden with heavy metals may follow an upward direction thereby polluting the groundwater. And because many of these homes over the mine area are not connected to the public water supply, but still use groundwater (wells, boreholes, springs) these will use for consumption polluted water. The toxic effect of heavy metals in organisms is well-known.

3.5 Vulnerable areas along the tunnel - Changes in the morphology of the land

The ground surface deformation may occur due to destruction of supporting concrete and rock roof collapse. It is unlikely that the tunnel collapsed to the ground surface deformation will occur immediate due to capacity loosening, but after a settling time these can produce such changes in morphology and land. The effects of these changes can be felt on the premises located above the tunnel, thus causing damage.

3.6 Vulnerable areas along the tunnel - Rise of mine water and infiltration into groundwater

By destroying the roof support, the mine water will get in direct contact with the surrounding rock,

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favoring the ascent of water pollution due to low mechanical strength of these rocks at hydrostatic pressure action.

3.7 Vulnerable areas along the tunnel – Rise of mine water on faults

Throughout its length, the tunnel Herja - Central Processing Plant, intersecting numerous faults which in this case, may favor the occurrence of adverse effects.

When the mine water will fill the tunnel and mining voids, the hydrostatic pressure in the faults will be very high. Hydrostatic pressure value increases as we move away from the dam at level IX.

3.8 Mining area - Mine water infiltrating the fissures and cracks

If the water column will rise up on the horizon 0, the groundwater within the mine voids will develop hydrostatic pressure.

The highest values are recorded in the horizon IX (36.3 atm) but also in the upper horizons will develop high pressures, for example, VII horizon we have 2,992 kPa (29.6 atm) [10].

Due to the method of operation in the Herja Mine (drilling - blasting) the surrounding rocks have a high degree of cracking [10].

Thus, due to the fragmentation, the mine water can infiltrate cracks and cracks under the action of high hydrostatic pressure, can pollute the groundwater, but there is the possibility that these waters to flow on up to the surface, polluting both groundwater and surface waters, including soils, as in the case of Ţibleş – Tomnatec [1].

3.9 Mining area - Pollution of surface water due downtime of treatment plant Herja

It is possible that the mine water will reach the horizon 0, as envisaged in the project [4], but no study was done on time filling of underground voids.

A large flow of mine water can come anytime in the adit Joachim, even faster than is appreciated or estimated, but Herja treatment plant is not ready for such a stream of water.

Summarizing, we can say that the main risk of retention dam in to the tunnel Herja - Central Processing Plant refers to pollution over large areas of groundwater, surface water and soils with acid mine water laden with heavy metals.

4. Analysis of alternatives

Here we will highlight two of the best solutions for closing or redevelopment that could be possible on Herja mining area, given that flooding the underground voids and the retention dam proves to be a solution that involves risk, major on environmental and human health.

4.1 Conservation of Herja mine for tourism and research areas

One of the best solutions applicable to mine conservation Herja were once mine closure stage and its arrangement has been done, to introduce it on the tourist circuit, including setting research areas in the fields of geology, mining technology, ventilation, etc.

An example of this is the mine Reiche Zeche of the City Freiberg in Germany [5, 6]. Planning for tourism of Herja mine would have been possible by including a wide range of interests.

- Planning construction area for accommodation;
- Land and various buildings surrounding areas for entertainment, sports, recreation, and so on;
- Arrangement of mountain trails;
- Setting upper horizons for tourism, etc;
- Lower horizons could be arranged as research areas.

Achieving these objectives mentioned above, would have required the underground water pumping and treatment by Herja treatment plant, the possibility of recovering metals from sludge.

The costs of pumping and treatment of mine water were covered completely or partially by proceeds resort and scientifically arranged in the mining area Herja.

In conclusion, this solution for mining area Herja arrangement would be one that would not have required major environmental hazards and in addition would bring benefits to both the academic and scientific environment and local community, contributing to the development and diversification of the tourist heritage.

4.2 Flooding the lower underground voids and conservation the upper horizons

Alternatively to closing / preservation could be applied to mine the preservation horizons Herja of the higher works and acid drainage control in tunnel Herja - Central Processing Plant.

Construction of the surface and the top of mine had the opportunity to be exploited for the purposes mentioned above, tourism or scientific aim.

5. Conclusions

This two solution would have meant stopping the pumping mine water to the treatment plant including its cessation.

The mine water would be accumulated in the lower horizons and was eliminated the costs of pumping and treatment of groundwater. This situation would allow the naturally drainage acid in the tunnel [7, 8].

Regarding the tunnel, there could be possible to arrange it in different lengths through the construction of filters mineral in form of granular materials such as limestone and zeolite filters.

Thus, the water which comes out of the tunnel, it would have an adjusted pH, the more heavy metals or other suspensions such as sediment being treated. In this way we would have solved the problem of water, would have eliminated the cost of pumping and a reduced costs and Environmental Risks compared to closing the retention dam.

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