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Prof. dr Ivica Ristovic

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PLAN FOR WASTE MANAGEMENT IN THE MINE FOR PRODUCTION OF LEAD AND ZINC "ZLETOVO" – PROBISHTIP

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Abstract: *With the sale of the mine for lead and zinc "Zletovo" to the new concessionaire, the Ministry of economy of the Government in R. Macedonia, called for the development of plan for waste management that will be generated from the production and processing of lead - zinc ore for the period from 2016 to 2020.*
In this paper will be presented the production capacity and planned activities for waste management, with special emphasis on measures for waste management and reduction of harmful impacts of mining activities on the environment.

Key words: *Plan, Mine, Waste, Lead and zinc, Hydro tailings*

1. INTRODUCTION

The mine for production of lead and zinc "Zletovo" is located in the northeastern part of Macedonia in space between Kratovo and Zletovo in the western parts of the Osogovo mountain range.
Mine "Zletovo" started with active production back in 1928. After World War II, the mine restarts again with an initial annual production of 50.000 t. Over the years its production steadily grew, so in 1960 reached 260.000 t per year. Maximum output production is achieved in 1989 with 482.146 t ore.
Mine "Zletovo" operated continuously for about 60 years, followed by a period with a break of about 4 years due to a transformation from social to private ownership.
In its chemical composition, the ore in mine "Zletovo" is polymetallic with a high concentration of minerals of lead and zinc together with minerals of copper, silver, cadmium and other minerals and elements that are economically viable for exploitation with existing technology. Flotation plant is build for the process of separation of these metals in form of concentrate and the end product of this processing are lead and zinc concentrates.
In 2006 the mine for lead and zinc "Zletovo" was privatized by the company "Binani industry" and they registered company with name "Indo minerals and metals Probishtip-Zletovo Mine".
The company "Indo minerals and metals Probishtip" from 24.09.2015 ceased the production, and from 19.11.2015 went bankrupt.
Government of Macedonia assign existing concession to company "BULMAK 2016"- Probishtip and was signed concession for exploitation of minerals in the area of Zletovo, Municipality of Probishtip and Municipality of Kratovo.
The company "BULMAK 2016"-Probishtip based on the available raw materials, mining and geological conditions, the available mechanization and techno-economic factors prepare a 5-year plan for production and processing of lead and zinc ore, which is shown in Table 1.
Production of lead and zinc concentrates is accompanied by generating certain types of mining waste like waste rock and flotation waste. Their expected values are shown in Table 1 [3].

Table 1. *Planned production of ores and concentrates for the period 2016-2020*

Year	Ore production	Waste rock		Pb Concentrate	Zn Concentrate	Flotation waste	
(y.)	(t)	(t)	m^3	(t)	(t)	t	m^3
2016	30.167	21.036	12.374	1.696	466	28.025	15.570
2017	179.527	20.917	11.952	10.638	3.501	165.388	91.882
2018	233.522	29.762	15.292	12.129	6.002	215.391	119.662
2019	212.853	16.734	9.562	11.557	5..511	195.785	108.769
2020	248.212	17.212	9.835	13.967	4837	229.408	127.449
TOTAL	**904.281**	**105.661**	**59.015**	**49.987**	**20.317**	**833.997**	**463.332**

2. STRUCTURE OF THE WASTE MANAGEMENT PLAN

The waste management plan should contain sufficient information for the obligations of Mine "Zletovo" for dealing with mining waste according the Directive on Waste Management and the Law on Mineral Resources. According to the low and the Guidelines for Waste Management [7] it has been determined the structure of the waste management plan (Table 2):

Table 2. *Structure of the waste management plan*

1.	Classification of installation	Review the criteria for classification of the installation for waste from mineral resources
2.	Categorization of waste	Geological characteristics of the mine
		Basic (background) information about the mine
		Nature of waste and the way of dealing with it
		Geomechanical characteristics of the waste
		Geochemical characteristics of waste
		Auscultation of the drainage system
3.	Building and managing the installation of mining waste	Description of the facilities within the hydro tailings
4.	Assessment of risks to the environment and human health	Destabilization of hydro tailings
		Pollution of surface and underground water
		Air pollution
		Pollution of land
5.	Measures to prevent environmental risks	Measures for water protection
		Measures for air protection
		Measures to protect the land
		Measures to ensure stability of the hydro tailings
		Measures to protect the environment in case of accidents
		Administrative measures
6.	Control and monitoring of procedures	Monitoring during the construction and exploitation of hydro tailings
		Monitoring during remediation
		Monitoring after closure
7.	Plan in case of emergencies	Purpose of the emergency plan
		Scope of the emergency plan
		Objectives of the emergency plan
		Alert in case of an incident from the installation of waste from mineral resources
		Level of alert and activities at the location of the tailings
8.	Draft plan for closure, after-care and monitoring	Selection of acceptable methods for closure remediation
		Plan for remediation of the installation for waste from mineral resources

3. NATURE OF WASTE (WASTE-ROCK) AND THE WAY OF DEALING WITH IT

For the categorization of waste we should have enough information about the nature of the waste as a result of the activities of exploatation and processing, especially for: origin of waste that occurs as a result of exploitation and processing of mineral resources, amount of waste, description of the system for transportation of waste, description of chemical substances used in the treatment, classification of waste in accordance with Commission Decision 2000/532/E0 taking into account the hazardous characteristics, type of installation for waste handling and the disposal of waste in the installation.
Characteristic of all processes of excavation and processing of metallic mineral resources in order to obtain useful minerals in this case of Mine "Zletovo" it is Pb and Zn concentrate, they produced two types of waste: waste rock and flotation waste [3].
The rocky waste material in itself has no economic content of lead and zinc and is classified as waste material generated in the process of exploitation of the mineral ore body. Excavated rocky waste material in the mine "Zletovo" is hazardous waste, ie 01 01 01 waste, generated from mining of metal rich ore minerals. The amount of generated mine waste material is estimated to annually amount of around 30.000 t/yr.
The tailings dam “Skrdovo" of the mine "Zletovo" is in the locality Skrdovo in the valley of the river Kiselica at a distance of 4.100 m from the flotation plant. For choosing this location is used the favorable topographic nature of the ground to be able to deposit the mining waste for more than 24 years.
Construction of the tailings dam was done in two stages [6]. The first stage includes two barrier embankment dams, first upstream dam and cut section to divert the river Kiselica into river Strmos, and then build the initial (starting) dam with 10 m height, which serves as the basis of the downstream sand dam. In the second stage of construction is carried out upgrading of downstream dam with sand from the mining waste to the projected height which forms the accumulation space. The volume of the accumulation is 600.000 m^3, and the dam length is 280 m.
The main parts of the hydro tailings include the following items: downstream dam with drainage system, drainage collector with overflow outlets and upstream dam. In the additional facilities of the hydro tailings are the following items: system for transport of mining waste, pumping station for recycle technological water, cut section for narrowing the flow of river Kiselica.
The downstream dam as a major barrier dam started construction in the first phase in building the foundation of the dam from clay with height of 10 m, width of 5 m and a downstream slope of 1:1.75 and upstream slope of 1:1.5. Over this initial dam is done the upgrading of the downstream dam with sand from the hydro-cyclones in the second phase of its construction. In the downstream dam are designed and built two main drainages for acceptance of water, and also auxiliary drainage for acceptance of additional water in the area of the sand dam. The measurement of the water level in the dam and the ground affected by the dam, is made with piezometers.
For discharging the clarified water from the sedimentary lake is built drainage collector, in the first phase of construction of the hydro tailings.
The upstream dam is barrier embankment dam for the upstream side of the tailing dam. The purpose of the upstream dam is to divert the flow of river Kiselica and together with the downstream dam to form a large accumulation space for disposal of flotation waste material.
Flotation waste material as mixture of solid and liquid phase with 18-20% solid phase, to the downstream dam is deposed with combined transport system [2]. The transport system consists of gravitational and pressure part. Most of the transportation system of the pulp is gravitationally through reinforced concrete channels, while the pressure part is done with pumping station combined with system of plastic tubing.
The need for water in the flotating plant created the need for repeated reuse of the clarified water from the hydro tailings "Skrdovo." For this purpose is installed a pumping station located on the shores of sedimentary lake at the upstream side of the accumulation. Pump station with its capacity of 35 l/s represent additional method for removing water from sedimentary lake which positively affects the stability of the tailings dam and reduce the quantities of discharged water in the river basins, and also in terms of preserving the environment.
The cut section of diverting the river Kiselica, is in form of open channel with depth of 20 m, which represent new river bed for the river.

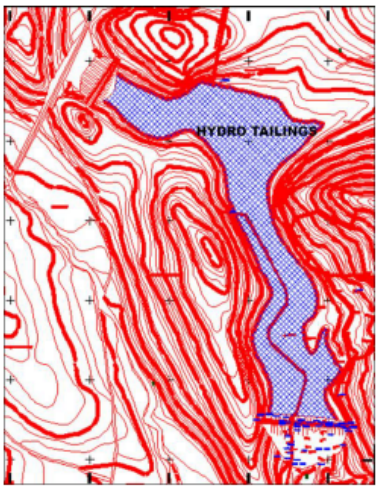

Figure 1. *Hydro tailings "Zletovo"*

4. PREVENTION OF RISKS AND MEASURES OF PROTECTION

The environment is a complex system whose components are interconnected and dependent on each other, so that changes in one part can cause changes in other parts. Therefore, the issue of protecting the environment from harmful influences, can be resolved with an integral systematic approach.
In order to ensure maximum effectiveness of the proposed measures and to ensure their successful implementation, it is necessary to integrate them into a comprehensive plan for control and environmental management (ETS) in the zone of influence. The system of environmental management (ETS) is a comprehensive tool that enables the management of the mine to meet the current and future problems in the field of environment. Proper implementation of the ETS system results in many benefits.
Based on the results obtained by assessing risks in the construction phase of the tailings dam, there are proposed measures for its reduction of negative environmental potential [1,4,5,8].
Measures to protect the environment are classified into several groups:

1. Measures of water protection
2. Measures for the protection of air
3. Measures to protect the land
4. Measures to ensure stability of the tailings dam
5. Measures to protect the environment in case of accidents
6. Administrative measures

4.1. Measures of water protection

In the process of environmental protection, the biggest attention should be focused in reducing the pollution of watercourses in which is discharged the water from the hydro tailings. The contemporary practice, usually is carried out by recycling the large amount of water, where the input of fresh water is reduced to a minimum and not more than 5%. Despite the return of water from the sedimentary lake it is also recommended to return the drainage water in the system. For this purpose is formed auxiliary reservoir, in which will be collected the drainage water and excess water from the collector. These waters will again return to the main accumulation or if the quality meets would be returned directly to the flotation plant process. Bearing in mind the toxic reagents used in the flotation process, in particular NaCN, in order to protect waters from harmful effects of cyanide is necessary for proper processes (measures) to control the concentration of cyanide in surface and underground water. Measures to protect underground water include: coating the bottom of the tailings with an impermeable material such as clay, setting up geomembranes for protection of underground water, etc.

The plain terrain is characterized by the appearance of ponds in the surrounding land and it is a problem for many tailings that are formed on alluvial terrains and terrains with a high level of underground water. Formed ponds contributes to degradation and diminution the value of the land. Measures to prevent the formation of ponds include: tailings dam to be isolated from the surrounding terrain, in the surroundings of the tailings dam to be build reception channels, if the reception channels are not sufficient protection then it is necessary to build drainage channels, etc.

4.2. Measures for the protection of air

Measures for the protection of air includes: spraying water on the crown and slope of the dam, control the water level in the accumulation, spraying with certain suppressants, etc.

Technology to control fugitive dust that occurs as a result of aeolian erosion, can be grouped into three basic groups: technology for reduction the speed of airflow, technology for isolation of potential sources of fugitive dust and technology for surface stabilization.

Technology for reduction the speed of airflow can be: setting up a system of wind fences, raising protective vegetation belt (high vegetation) and reclamation of inactive surfaces.

4.2.1. Technology for isolation of potential sources of fugitive dust

These technologies use some form of physical barrier that prevents the contact between the transport medium (air power - wind) with potential mobile particles (dust particles from the slope and the crown of the dam). This prevents the suspension of particles, or raising dust.

Technology for isolation of potential sources of fugitive dust can be: covering with earth materials, covering with synthetic membranes (geo-membranes), cover with asphalt, asphalt-concrete, lean concrete, covering with plastic sheeting, etc.

All of the above technologies basically have a lasting effect (with the exception of the plastic foil), but their installation is costly and usually they require some maintenance.

4.2.2. Technology for surface stabilization

These technologies include the use of certain techniques to change the properties of the deposited material in the surface layer, in order to reduce the mobility of the particles that would increase the resistance of aeolean erosion. Technology for surface stabilization can be: spraying with water (pure or with the chemical additives), use of binders to create a surface crust, thermoplastic stabilization, cryogenic encapsulation, surface fixation, etc. Spraying with water, and lately the use of binders to form a surface crust is methods widely used for anti-erosive protection. From the chemical additives to create temporary cover the most commonly used are: polyacrylamide, polybutadiene, physical stabilizers of soil – geosynthetic and polyvinyl acetate co-politer.

4.3. Measures to protect the land

The measures to protect the land include: implementation of measures for water and air protection to prevent an indirect contamination of land, measures to prevent spillage of flotation waste from the tailings dam, technical and biological reclamation of land, etc.

4.4. Measures to ensure stability of the tailings dam

The measures to ensure stability of the tailings include: full attention of the projected parameters for the tailings dam, proper dimensioning and attention of the geometry of the tailings dam, construction of the tailings dam with the proposed projected material, maintaining the level of clarified water in the sedimentary lake, greater beach length (the distance from the dam to the sedimentary lake), providing permanent and professional supervision during the construction of the tailings dam, etc.

4.5. Measures to protect the environment in case of accidents

The measures to protect the environment in case of accidents include: acting according the emergency instructions, opportunity to build temporary levees to protect some endangered settlements, examining the quality and long-term monitoring of surface and underground water, etc.

4.6. Administrative measures

The administrative measures include: keeping accurate records, selecting the appropriate personnel and providing training for the personnel, documentation of all emergency cases, etc.

5. CONCLUSION AND RECOMMENDATIONS

Based on the above stated data on the manner of disposal of waste material from exploatation and processing of mineral resources in the mine “Zletovo”, we can conclude the following:

- According to the dynamic plan for production of mine "Zletovo" for the period from 2016 to 2020, for working with one flotation plant it was calculated that the level of the lake from the hydro tailings will not exceed the level of the dam, from where can be concluded that it will not overflow the flotation waste.
- The method of exploitation, preparation and concentration of the ore as well as the disposal of waste from excavation and processing of mineral resources in the mine “Zletovo” do not contribute to the generation of excessive air emissions, pollution of surface and underground water and land that can have a negative impact on the environment and human health.
- Joint disposal of excavated waste rock and flotation waste of the unique location meets the requirements of VAT, the best available technology, and is beneficial in terms of reducing the surface for disposal and storage of mining waste, ie not occupy a new surface for the disposal of waste. This prevents degradation of the new areas, thereby reducing the negative environmental impact. The waste rock which is deposited in hydro tailings provides improved physical and technical characteristics, that enhance the stability of the hydro tailing.
- The length of the dry beach, distance from dam to the water of the sediment lake is big which directly affect the stability of hydro tailing.
- The water level in the sediment lake and the downstream slope of the dam and also the installed piezometric system indicate that there is no indications of any anomalous phenomena that could threaten its stability.
- Air pollution and contamination of surface and underground water is probable, but will not have a significant impact if applying all provided measures of protection.

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