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# Assessment of the Tailing Dumps State of the Gold Processing Enterprise

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***Abstract***

The purpose of the study is to assess the current state of the tailings as a source of technological impact on the environment and to determine the possibilities of using gold processing enterprise waste as a raw material for production.In carrying out this study, we used the following set of basic methods and methodological techniques such as system analysis, the generalization of theoretical and experimental studies, scientific forecasting, cartographic modeling, landscape zoning, the method of logical abstractions, physicochemical methods, and other general scientific methods of analysis and generalization. The systematization of literature data and patent search materials indicate that scientific research aimed at ensuring the environmental safety of mining facilities, including tailings, have only begun to develop in recent years [5–9].In the course of the study, it was found that the protective dam of the tailings of the gold mining factory is unreliable and it is necessary to take measures for the processing and disposal of tailings, to organize a systematic approach to identifying ways and means of preventing violations of the regulatory environment and ensuring environmental safety.For the first time, an approach has been developed to the level of assessment of the hazard level of the tailing dump on the environment and the justification for the feasibility of utilizing the tailings of the enrichment of the Muzhievsky deposit in the Beregovsky district of the Transcarpathian region.The proposed scheme for processing and enrichment of the tailings of a gold processing enterprise using an installed modular processing plant. According to the results of the factory, tailings will be used for the production of building ceramics and restoration of the lost shape of the relief.

**Keywords:** *European Union, Carpathians, gold, tailings, ecology, processing.*

## I. Introduction

According to experts, the global consumption of minerals has reached 12 billion tons per year, and the extraction of minerals and metals annually is 100 billion tons. Ecological problems of our time cause the danger of human existence at all levels: from the region to the state and the world as a whole. The analysis of the current state showed that for Ukraine these problems are especially acute since there is a significant concentration of hazardous industries, a significant transformation of landscapes, and inefficient use of natural resources. In Ukraine, there are enterprises in which waste from the extraction and processing of raw materials is 1 billion tons/year, of which only 10-15% is used as secondary resources. 160 thousand hectares were allotted for waste storage, and their total volume exceeds 25 billion tons. As a result of this, tailing dumps arise [1, 2], which poses a threat to the environment. Transcarpathia is the only region in the world bordering four countries: Poland, Hungary, Romania, and Slovakia - the countries of the European Union. The macroregion of the Carpathians, which includes the Transcarpathian region, can be classified as a geographical area, covering various countries and regions and are characterized by common features and problems. After all, the Carpathians are one of the largest mountain ranges in Europe, which covers seven


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European countries: the Czech Republic, Hungary, Poland, Romania, Serbia, the Slovak Republic, and Ukraine. The territory of the region is the catchment of the Tisza River, the left tributary of the Danube. All rivers and streams that form along the valleys and gorges of the mountains, and there are 9426 in Transcarpathia, belong to the Tisza river basin and are its tributaries. The largest of them are the Teresva, Tereblya, Rika, Borzhava, Latoritsa, and Uzh rivers. The latter two flow into the Bodrog River in Slovakia, which later also flows into Tisza. On its way 2800 km long from the Black Forest of Germany to the Black Sea, the river and its tributaries cover 18 countries [3].

Transcarpathia is rich in various industrial minerals: non-ferrous, rare and precious metals (gold, silver, mercury, germanium, zinc, etc.), non-metals (barite, zeolite, bentonite, dolomite, alunite), salt, coal, gas, building materials (marble, basalt, andesite, expanded clay, perlite, etc.), mineral and thermal waters. The formation of most mineral deposits is associated with the last stage of development of the Carpathians. Given that the region's mineral resource base includes 271 deposits of more than 30 types of minerals, there is a risk of inefficient use of natural resources, one of which is gold, which belongs to the most studied gold-bearing province in Ukraine. The extraction and processing of ores of the first gold and polymetallic deposit in Ukraine led to a negative environmental impact. Especially the source of environmental hazard is the tailing dump.

Over the past ten years, between 2008 and 2018, 31 major accidents at the tailings dams were recorded; on January 30, 2000, due to an accident at the tailings at the Aurul SA plant in Baia Mare, Romania, 100,000 $m^3$ of cyanide-contaminated liquid were Lapus stream, a tributary of Soames, Tisza and the Danube River, killing tons of fish in these rivers and poisoning drinking water for more than 2 million people in Hungary [4].

## II. Object and subject of research

The tailings dump of the gold plant "Zakarpatpolymetal" LLC established in 1999, the first and only one in Ukraine, was chosen as the object of study. The production activities of the enterprise "Zakarpatpolymetal" LLC, which in 2007 ceased operations, led to environmental pollution, in particular, soil, surface and groundwater. There are 5 dumps of clogged and empty rocks on the industrial site with a total volume of up to 164 thousand tons and a place for ore treatment in semi-liquid mass in an amount of up to 168 thousand m3, located in an exhausted quarry. According to the Transcarpathian Exploration Expedition, the indicated dumps contain impurities of sulfites and minerals of heavy metals, which are toxins. Under the influence of atmospheric factors, the processes of oxidation of heavy metal sulfites occur; as a result, waters with increased mineralization and low pH, saturated with heavy metal sulfites, which are washed out into surface and underground waters, are formed in the bottom of the dumps. In the territories adjacent to the enterprise, according to monitoring data, an excess of lead and copper in soil samples was recorded, and in the water there was increased cadmium content [3].

In order to accelerate the launch of the processing factory, a scheme was developed that provided for the transportation of the actually extracted gold ores by vehicles (through the village of Muzhievo) to the processing plant at a distance of 8 km. The site for the factory was a spent perlite quarry. The factory itself was built on reclaimed dumps, and the tailing dump - in a spent quarry. No waterproofing measures were taken during the construction of the tailings dump by "Zakarpatpolymetal" LLC. This was explained by the fact that this facility is quite environmentally friendly, since only clean water without reagents is used in the gravity process.

Technological studies conducted by the Transcarpathian geological exploration expedition during the exploration of the Muzhievo deposit, it was proved that the optimal ore processing scheme is a combined one - gravity-flotation. It allowed withdrawing up to 90% of gold and other components. At the same time, concentration tailings were qualified as dump tailings and were intended for the production of building ceramics (bricks, tiles, etc.).


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Ignoring the data and recommendations of the State Commission for Mineral Reserves of the USSR, a decision was made, based on the business plan, that satisfactory results in the extraction of gold can be obtained using only the gravity scheme. It was envisaged that the use of modern Nelson concentrators would make it possible to achieve a total gold recovery of up to 80-82% in gravity concentrates. But under industrial conditions, the results were different. The gravity factory "Zakarpatpolymetal" LLC was able to withdraw on average no more than 50% of gold. Extraction of other metals (Ag - Pb - Zn) was not even planned.

As a result, a certain amount of gold and other heavy metals fell into the concentration tailings, which did not allow qualifying them as dump, and, accordingly, to use them for construction purposes.

The construction and operation of the tailings dump was carried out arbitrarily without taking into account the requirements of waterproofing. Therefore, from the very beginning of the factory's activity, sludge flowed both through the bottom of the career and under the dam. This process continued afterwards.

If consider that the bulk of the tailings is in a state of floats and the dam is fragile, it is necessary to provide for a possible breakthrough of the dam and runoff tailings down the slope. As a result, projected losses can be significant. All sludge can reach the industrial sites of the perlite plant, railway track and vineyards. Today, the tailing dump is environmentally problematic for the environment of the Berehovo district and is of concern to the local population, especially after the dam broke in neighboring Hungary.

In carrying out this study, we used the following set of basic methods and methodological techniques such as system analysis, generalization of theoretical and experimental studies, scientific forecasting, cartographic modeling, landscape zoning, the method of logical abstractions, physical-chemical methods, and other general scientific methods of analysis and generalization. Systematization of literature data and patent search materials indicate that scientific studies aimed at ensuring the environmental safety of mining facilities, including tailings, have only begun to develop in recent years [5-9].

## III. Results and discussions

Today, it is practically impossible to reliably determine the volume of accumulated tailings due to their underground drainage and outflow to the surface (filling the reservoir in the valley part) during the entire period of operation of the processing plant.

The tailings from the processing of the actual gold ores were stored directly at the processing plant in a spent quarry for perlite extraction (Fig. 1).

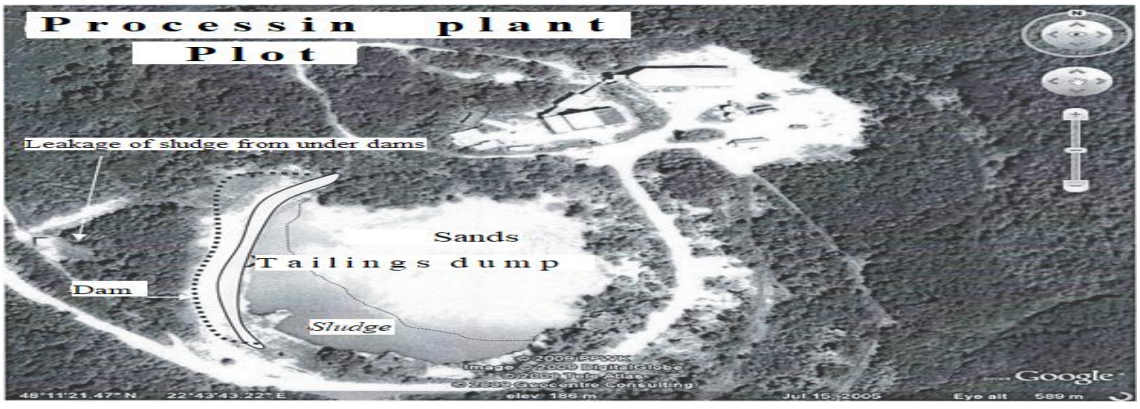


**Figure 1 – Situational plan for the location of the tailings dump**


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Given that tails contain certain concentrations of gold, they cannot be considered dumps and be used as material for reclamation or other purposes. According to the legislation of Ukraine, such material is subject to additional processing in order to maximize the extraction of gold from it. The accumulated tailings, like ore, belong to the type of low-grade sulfide gold ores that contain heavy metals in especially dangerous concentrations.

**The material composition of the concentration tailings**

| Number | Chemical analyzesresults | | Number | Spectral Analysis Results | |
|---|---|---|---|---|---|
| | Component | Content(%) | | Element | Content(%) |
| 1 | $Si0_2$ | 71,2 | 1 | *Pb* | 0,01 |
| 2 | $Al_2O_3$ | 13,0 | 2 | *Cu* | 0,004 |
| 3 | $Fe_2O_3$ | 5,3 | 3 | *Zn* | 0,008 |
| 4 | *FeO* | 0,8 | 4 | *Mo* | 0,002 |
| 5 | $Ti0_2$ | 0,4 | 5 | *Cr* | 0,0006 |
| 6 | *MgO* | 0,28 | 6 | *V* | 0,0050 |
| 7 | *CaO* | 0,50 | 7 | *Be* | 0,0004 |
| 8 | *MnO* | - | 8 | *Nb* | 0,002 |
| 9 | $K_2O$ | 0,07 | 9 | *Zr* | 0,008 |
| 10 | $Na_20$ | 0,04 | 10 | *Y* | 0,0010 |
| 11 | $P_20_3$ | 0,11 | 11 | *Vb* | - |
| 12 | $SO_3$ | 0,4 | 12 | *Li* | - |
| 13 | $S_{sulph}$ | - | 13 | *P* | 0,07 |
| 14 | *BaO* | 0,12 | 14 | *As* | 0,016 |
| 15 | $CO_2$ | 0,10 | 15 | *Sb* | 0,016 |
| 16 | *Carbon Organic* | 0,35 | 16 | *Hg* | - |
| 17 | $H_2O$ | 7,33 | 17 | *B* | - |
| | | | 18 | *Bi* | - |
| | | | 19 | *Ti* | 0,044 |
| | | | 20 | *Sn* | - |
| | | | 21 | *Mg* | 0,120 |
| | | | 22 | *Mn* | 0,020 |
| | | | 23 | *Ba* | 0,050 |

According to “Zakarpatpolymetal” LLC, the processed ore accounts for the weight of tailings amounted to about 317,000 tons. The average gold content in them was determined based on system testing using an automatic sampler during the operation of the factory and amounts to 1.45 g/t.

But, due to the lack of waterproofing measures, a significant amount of sludge through faults and cracks was drained from the tailings dump to the low part of the region. As a result, the fish breeders located there (especially the upper one) were completely slammed.

According to the gold content in the tails, this parameter can be taken to be reliable, since similar gold contents were found in technological samples taken in previous years.

To determine the actual mass of the tails themselves, control calculations were performed based on aero-topographic maps.

Since the upper reservoir (fish breeder) is completely filled with sludge, the filling volume is easy to determine, and it amounted to 16,000 m3, or 28,000 tons. Today, these sludge cannot be used for re-processing, since they are contaminated with man-made and organic (algae, reeds, other) material.


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Total tail losses from tailings of "Zakarpatpolymetal" LLC, through the absence of a waterproofing system and side reinforcement, is 54,945 tons. Accordingly, the volume (stock) of tailings suitable for recycling is approximately 261 62 tons.

## IV. Ecological aspect of concentration tailings re-treatment

This material, that is, tailings, is a rock mass crushed to -1 mm, the upper part of which has been compacted during the period of inactivity. In addition, in summer, in the "beach" sandy zone, the tailings are dehydrated to a depth of 3.0 m, and in the clay zone to a depth of 0.5 m. At a depth of more than 3 m, the tails are flooded and are in floating condition.

It is the latter fact that causes the greatest concern, since the protective dam was constructed in violation of the construction technology of such facilities for temporary storage of tails and is not reliable enough (Fig. 2). For its construction, clay material was not used, but dumps of a perlite quarry, consisting of more loosened volcanic rocks. Therefore, in a short period of time (3-4 years), holes were formed on the sides of the dam and, as a result, erosion processes began.

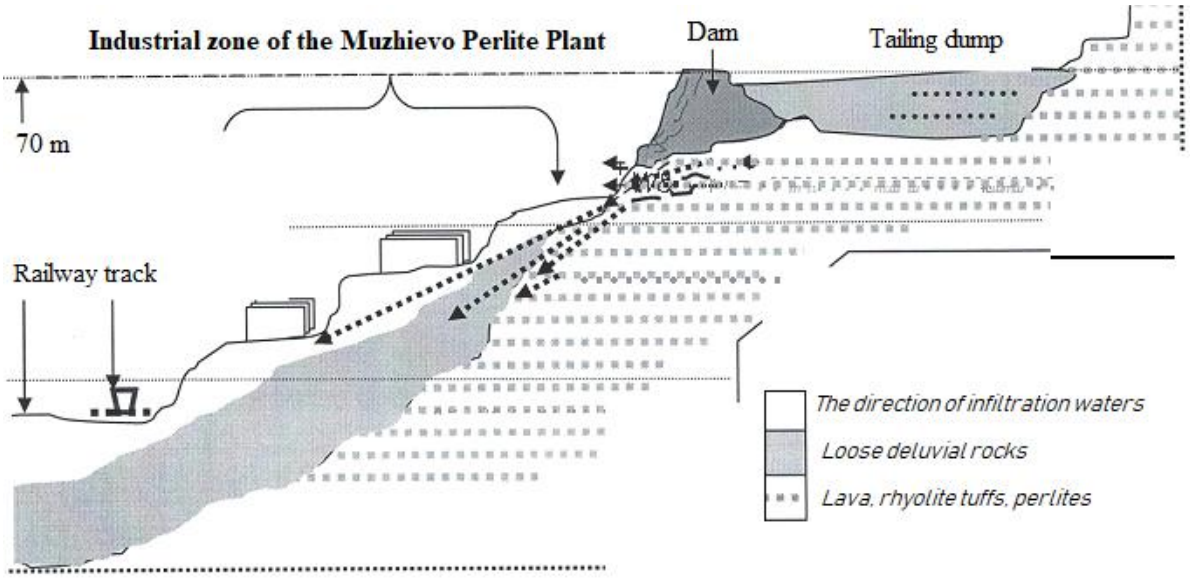


**Figure 2 – Tailings dump position relative to other facilities**

Over time, the intensity of such erosion will progress in direct proportion to the amount of precipitation and may lead to the destruction of the dam. Accordingly, the possibility of breaking the liquid mass of the tailings down the slope is not excluded. Given the height difference and the steepness of the slope, the accumulated mass of tailings can destroy the infrastructure of the existing plant.

The program of work of "Zakarpatpolymetal" LLC supposed to process tailings in the future in order to obtain lost gold and its subsequent use. It was planned to change the treatment scheme and exclude gold residues from the tailings, after which they would become dumped and could be used for the production of building ceramics, reclamation, or other purposes.

But, in connection with the termination of activity of "Zakarpatpolymetal" LLC, this problem remains open and requires urgent resolution.


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## V. Practical suggestions on concentration tailings

For processing and disposal of tailings accumulated by "Zakarpatpolymetal" LLC in a pearlite quarry, it is proposed to apply the following treatment scheme. The tailings, which are crushed quartz clay mass, generally are easily loosened. The upper part of the tailing section is anhydrous and it is denser, and with depth it is gradually replaced by waterlogged layers and has the properties of quicksand. The bulk density of 1 x in the wet state is 2.0 t/m$^3$, and in the dry - 1.70 t/m$^3$. The coefficient of loosening - 1.5; about 90% of the tailings are located in the flooded area.

Since the tails are in a crushed condition, a ball mill is used in the scheme. This will allow to release that part of gold that was not previously disclosed by the "Zakarpatpolymetal" LLC factory and to withdraw its concentrate. According to conducted scientific studies, it was found that up to 50% of free gold can be extracted using Nelson concentrators, and the other part (fine and finely dispersed gold) only by applying the flotation process. Therefore, in the scheme of a modular factory, gravity tails will be directed to flotation. The flotation regime in the actual gold ores of the Muzhievo deposit was also determined by the results of technological studies.

## VI. Conclusions

1. The tailings accumulated in the tailing dump (quarry) must be stored at the site of the spent perlite quarry for dehydration and subsequent processing according to a more advanced technological scheme.

2. Install a modular concentration plant on a quarry site.

3. Recycle stocked tailings.

4. After dehydration, the concentration of reagents in the tailings will not exceed the permissible rate. In terms of gold content, they will be dumped and suitable for the production of building ceramics (bricks, etc.) and the restoration of spent perlite quarry, as well as the restoration of lost relief forms.

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