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Critical study of current situation of Vrănicioara tailing pond on Cavnicului Valley, risks and consequences

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Abstract. In northern Romania, there are numerous tailing ponds, resulting from mining activities that present significant environmental risks. Some of them, including Vrănicioara tailing pond, were the subject of technical projects for ecological rehabilitation. Vrănicioara pond is located on the right side of Cavnic Valley, downstream Cavnic town, about 4 kilometers far. It has about 500 m length and is located parallel to the road linking Baia Sprie and Cavnic localities. Chemical and physical stability of the tailing pond before rehabilitation interest the research, analysis and conclusions were published in several scientific meetings. In addition, close to the pond at less than 100 m, an open pit has developed, exploiting andesite by mining blast, increasing the risk of physical stability by continuous exposure to vibration. This activity currently continues, advancing towards the tailing pond body. The critical study addresses the current state of Vrănicioara Tailing Pond, analysis of some rehabilitation works done incorrectly, analysis of chemical stability that was not a priority during rehabilitation. Research intention is heading to water analysis confirming the existence of acid drainage that was not stopped or at least reduced. The scientific approach is based on the Technical Standards for Waste Deposits, in force in Romania, providing the rules to ensure physical and chemical stability.

1. Introduction

Mining closure in Romania has had and continues to have a strong social, economic and environmental impact, due to the fact that it has not been carried out on the basis of skilled and responsible specialists analysis. These aspects have been studied and presented in numerous works and attitude by authors, in scientific events, specialized journals and media with the intention to draw attention upon these serious environmental problems [1-3].

By analyzing, in the last period of time, a part of rehabilitation works in Baia Mare mining area we continuously find disparities between the rules of good practice for waste deposits and the execution. Such a case is presented in the current work by analyzing the principles of minimum requirements imposed by Technical Normative and theoretical and practical foundations which have led, along the time, to these rules and the manner of Vrănicioara tailing pond rehabilitation which presents a multitude of vulnerabilities, meaning risks with major consequences.

2. Situation of Vrănicioara tailing pond before rehabilitation

2.1. Location and construction of Vrănicioara tailing pond

Vrănicioara tailing pond is located on the left bank of the Cavnicului Valley, 3,5 kilometres downstream Cavnic city. It has been in activity in the period 1957…1977. As a result of stability problems of Plopiş tailing pond, located in the vicinity, in 1985-1986 and 1988, Vrănicioara has been used as reserve deposit.

Figure 1. Vrănicioara tailing pond location, open pit placed at less than 100 m distance

The construction of the pond was accomplished by simple settling with an average slope of 16^{o} on the bottom and a slope much more accentuated 25 ... 26^{o} toward the top. The tailing pond location land has a slope of 8 ... 9^{o}, with an inclination from N to S. The tailing pond capacity was exceeded by the additional storage, representing more than 2,5 million m^{3}, with a height of 39 m and extending on 15,5 ha surface. In the upper part the deposit was streaked by numerous ravines generated by precipitation waters and the complete absence of vegetation. In the lower area, a part of the material entrained by water has covered existing vegetation.

Figure 2. The effects of surface water

2.2. Physical and chemical stability before rehabilitation

External erosion could be seen all over the pond embankment being more relevant on the upper part of the slope because of material deposition emphasized in last years of the deposit activity. In the case of tailings ponds, surface erosion is caused by the presence of rainfall waters and exfiltrations. Rainfalls produce the phenomenon of gully erosion, meaning dragging different-sized particles in the direction of water flow. Exfiltrations produce numerous erosions on the embankment surface, some with important dimensions.

Laboratory tests have shown that the material particle size distribution is below 50 microns in variable proportions, 3 ... 24%, which leads to difficulties in draining the water from the pond body with consequences on stability.

The calculations of physical stability achieved by analytical and numerical methods have shown that for static loads the stability coefficient was around 1,1 (close to the limit stability and lower than the value of the safety coefficient) and for dynamic loads less than 1 (stability range). For dynamic loads (seismicity) or special weather events appears the risk of tailing pond rupture [4].

Close to the tailing pond, at less than 100 m, it has been opened an andesite mining exploitation which use perforation and mining blasting. The seismicity calculations have taken account the vibrations generated by explosions showing that in the situation of a classic blasting the stability risks of the pond are imminent. The dynamic loads increase the risk of liquefaction or thixotropic phenomena appearance [4].

Tailings ponds formed by the deposit of mining wastes resulted from complex ore processing have the particularity of generating acid drainage due to the presence, in significant amounts, of sulphates. Vrănicioara tailing pond is a regular deposit of polymetallic sulphides, chemically active: the water collected at the base of the pond is acid and loaded with heavy metals, visible phenomenon due to the formation of a precipitate [4].

Figure 3. a) Vrănicioara Tailing Pond before rehabilitation

Figure 3. b) Vrănicioara Tailing Pond after rehabilitation

These aspects were included in numerous research papers, along the time, by the authors, underlining the gravity of physical stability (for static and dynamic loads – seism and blasting) and chemical stability problems generated by Vrănicioara tailing pond.

3. Actual situation of the tailing pond after rehabilitation and discrepancies with Technical Normative rules concerning waste deposits

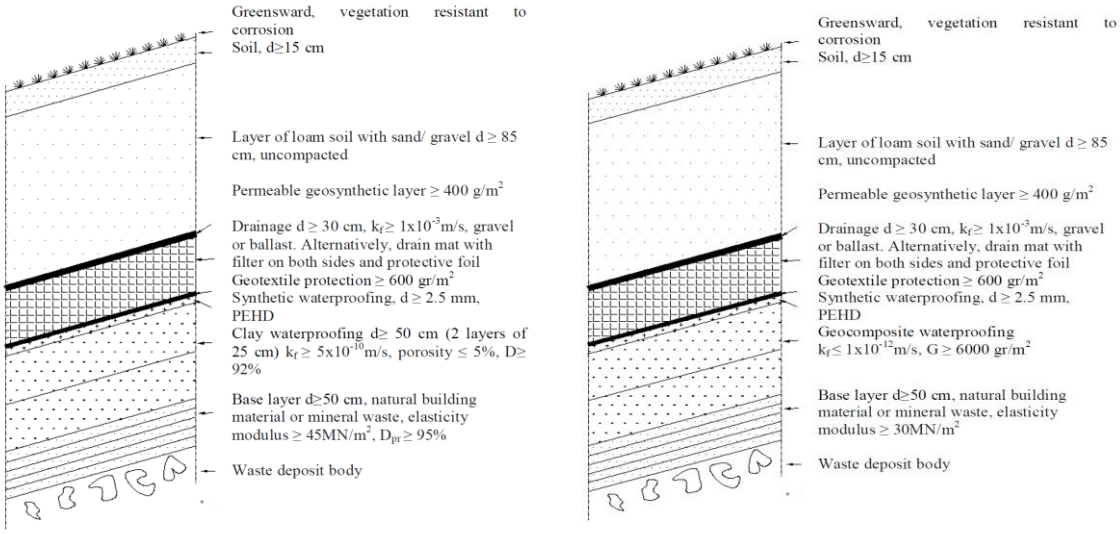
Vrănicioara tailing pond was the subject of a project funded by the European Union through the European Regional Development Fund in the total amount of 6 432 311 lei without VAT. Contract denomination: "Greening Works and Mining Closure of Upper Bolduț-perimeter - Vrănicioara Tailing Pond, Maramureş County".

3.1. Technical Normative

Implementation of solutions for the tailing pond rehabilitation is subject of regulations in the construction, management and rehabilitation of mining wastes deposits: Judgment No. 856/2008 on the management of waste from extractive industries that provides a general legal framework and the provisions of Technical Normative concerning the waste storage from Romania which transposes the European Directive in this field [Order No. 757 of 26/11/2004, published in Official Monitor No. 86/26 I 2005] [5]. This regulatory framework provides some very strict rules which involve a large volume of cover material and hence, significant costs.

According to the Official Monitor of Romania, part I, no. 86bis/26.01.2005 the Methodology Rules detail the stratigraphy for closing cover material of hazardous waste. There are presented and accepted two variants, differentiated from each other by waterproofing layer nature: clay in first version (Figure 4a) and geocomposites in second version (Figure 4b).

For hazardous waste deposits, the coverage options provide minimum 2,3 m for successive layers - from the carrier layer up to soil in case of clay weatherproofing (Figure 4a) and minimum 1,8 m in the case of weatherproofing with geocomposites (Figure 4b). These rules applied to areas exceeding tens of hectares lead to the necessity of finding viable technical solutions that optimize the realization of rehabilitation.



(a) Clay waterproofing *(b) Geocomposite waterproofing*

Figure 4. Stratigraphy of cover material for hazardous waste deposits

The most important issues that arise are: identification of sources of material, meaning carrier layer, waterproofing clay layer, drain layer, loamy soil layer with sand/gravel, soil; the distance of materials transportation; the implementation, etc.

3.2. The slope and the final geometry of the deposit

Using a GPS Garmin Montana 650t type with topographical map it was established measure points as in Figure 5. In each point altitude was measured as in and the values were used to calculate inclinations in different zone of the slope.

Figure 5. Measure points to identify slope inclination (system WGS 84 – EPSG:4326)

Table 1. Elevation values in measurement points

No.	Name	Elevation
1	laz00	491.599121
2	laz16	528.486816
3	laz15	532.483276
4	laz14	527.540588
5	laz13	516.193359
6	P12	511.677063
7	laz11	499.605347
8	laz01	508.326782
9	Iaz0	497.110168
10	laz10	500.052826
11	laz9	531.369446
12	laz8	530.373657
13	laz7	529.049072
14	laz6	528.88031
15	laz5	532.326843
16	laz4	532.27002
17	laz3	534.102112
18	laz2	531.896851
19	laz1	517.903137
20	Car	511.080078

It was found that:

- on the top of the slope there are areas where the slope exceeds the Technical Normative, requirements i.e. under max 33% (1: 3) in absolute 18,26^{o};
- the final slope after stopping settlements, according to Technical Normative, must be at least 5%, but the tailing pond geometry remained the same with canopy, beach (slope reverse) and lake/sink (between points Iaz3 Iaz 4 and 5 in Figure 5) .

3.3. Surface waterproofing system

Being given the fact that the tailing pond is composed of reactive material - sulphides are oxidized in the presence of rainwater and oxygen - it is necessary, according to Technical Normative [5], a waterproofing meeting the requirements for closing dangerous waste deposits (Figure 4a and b).

The reality on the field proves the absence of any cover layer (of support, of mineral or artificial waterproofing, textile as a protective layer for the membrane, layer for rainfall water drainage, textile as separating layer (Figure 6).

Figure 6. ”Rehabilitation works”

The ultimate goal of waterproofing layers imposed by Technical Normative is to confine the tailing pond over a long period of time and ensure vegetation restoration, so that the reactive material has no interaction with the environment and the deposit reintegrates in landscape.

3.4. Recultivation layer

Technical Normative [5] provides that the re-cultivation layer must have a minimum thickness of 1 m and bushes and trees shall be planted. On the slope surface the existence of re-cultivation is not relevant and an acacia plantation was made (Figure 6 and Figure 7).

Figure 7. Acacia plantation on the tailing pond slope

Trees do not contribute to stability because landslides occur at greater depths than fixing root area; instead they contribute to raising hydrostatic level, having as consequence the reduction of stability coefficient. If the waterproofing - drainage layers would be properly placed (Figure 7), the tree roots would affect their structure.

In the case of granular materials deposits (as mining waste deposits) with thicknesses of tens of meters where the sliding bed forms at greater depths than the roots length, soil erosion may occur at important depths, dragging granular material.

The apparent rehabilitation of slope surface with trees, in the cases of inclination angles close to the limit stability is proven as an improper solution (Figure 8).

Figure 8. The case of Berbeşti tailing pond, Vâlcea county– instability phenomenon in area cultivated with acacia

Figure 8 highlights phenomena of sliding and erosion in a mining waste deposit (tailing pond) rehabilitated by acacia plantation, without correcting the slope embankment in the area of safety.

3.5. The hydrostatic level in the tailing pond body

Piezometers were placed in the deposit to indicate the water level in the tailing pond body, although it consists of reactive material, showing the nonsense of this way of rehabilitation. The measurements have shown a high hydrostatic level on an alignment of 1,5 – 2,5 m from the slope surface, affecting both physical stability to static and dynamic loads and chemical stability by reactivating sulphide oxidation, causing acid drainage.

3.6. The ditch guard location

The ditch guard is designed to collect surface water from the slopes upstream the deposit and is to be placed around the deposit body, outside its perimeter. In the case of Vrănicioara tailing pond, the ditch guard is positioned in the body (length 500 m) in the area where the material has minimum particle size (Figure 9).

Before rehabilitation there was a ditch guard securely positioned upstream of the dam body with a length of over 700 m, that in time was clogged and partially destroyed. If rehabilitation would be made under the Technical Normative rules, after a new geometrization respecting minimum and maximum slope, the new ditch guard position could be changed by location upstream of the dam body plus the overlays. The construction of a ditch guard in the tailing pond body just increases the contact surface between the reactive material, water and oxygen.

Figure 9. Old (711m) and new (574m) ditch guard

4. Conclusions

Vrănicioara tailing pond is composed of a reactive material with content of sulphides, located on a hill side where downstream exist strategic objectives, a county road heavily traveled, which links to the tourist resort of Cavnic and sights of historical Maramures, the gas pipeline, River Cavnic and downstream localities ([6], [7]).

Ensuring stability of this deposit is of utmost importance and imposes the consideration of the most demanding requirements to ensure physical and chemical stability.

This tailing pond was the subject of a rehabilitation project with a considerable financial value, but numerous deficiencies in design and execution. The project should be made public, but we did not have access to it, and therefore we analyzed the execution works which were compared with the requirements of the technical standards [5] on waste disposal.

In this way, many inaccuracies were identified on geometrization and waterproofing of this deposit: geometrization does not comply with the minimum and maximum slopes; lack of cover layers (waterproofing and re-cultivation); lack of construction of a perimeter ditch guard; lack of berms gutters every 10 m high; inadequate acacia plantation; construction of a ditch guard in tailing pond body, in fine material area; high hydrostatic level at depths of 1,5 – 2,5 m from the slope surface, etc.

In the same time, it was found not satisfied physical stability but only reducing of surface erosion and to ensure chemical stability it has not been taken any measure, pointing out the seepage phenomena at the base of the pond through the retaining wall and the embankment, flushing directly into the Cavnic River.

The existence of an open pit in the proximity of the tailing pond endanger its stability, particularly when mining drilling and blasting are happening, because hydrostatic level is high and increase the liquefaction and thixotropic risk.

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