# GEOMECHANICS SURVEYS ON THE STABILITY OF SOME ACTIVE WASTE DUMPS IN JIU VALLEY

**Oana BĂRĂIAC,** *Ph.D. Student, University of Petroşani*
**Victor ARAD,** *Prof. Ph.D., University of Petroşani*
**Susana IANCU (APOSTU),** *Ph.D. Student, University of Petroşani*
**Gheorghe LASC,** *Ph.D. Student, University of Petroşani*
**Vlad COSMA,** *Ph.D. Student, University of Petroşani*

***ABSTRACT:***
*In the research of stability conditions of waste dumps, effectiveness and accuracy of the methods chosen and outcomes depend on the degree of explanation and integration of the stratigraphical, structural, morphological, hydrogeological, hydrological and geotechnical situation, of the studied area and surrounding territory.*
*In this paper we refer to the geomechanical characteristics of active waste dumps, how they affect stability, starting from the premise that mechanics and geomechanical factors are largely responsible for slope instability phenomena.*
*Geomechanical factor must be considered, starting from the procedure of determination, in the laboratory or in situ, of the main rock strength parameters (cohesion and angle of internal friction). Consideration of geomechanical factor always involves determination of strength parameters on the weakest resistance surface of the slopes, or the versant, where the sliding forces are concentrated.*
*The more physical and mechanical characteristics identified are real, the easier becomes the interpretation of deformation processes that may be encountered in practice, the resistance and stability calculations become more clear.*
*For the geomechanical analysis were studied 4 dumps, from the administrative territory of the Jiu Valley basin, with the presentation of geotechnical and hydrogeological particularities of the rocks from foundation and from the waste dump body.*

***KEYWORDS:*** *geomechanical characteristics, stability, waste dumps, slope instability.*

## SOME ASPECTS REGARDING THE STABILITY OF SLOPES

In the study of stability problems of natural or artificial slopes there are two directions of research: analytical verification of stability and geomorphological analysis of the potential conditions of instability. In the first case mechanical aspects prevail, the second is based on evolving geomorphologic criteria of the physical environment [6].

Stability analysis is carried out for three hypotheses on the possibilities of sliding of the heap:

a). Sliding through the body of the waste dump, in which case are used the geotechnical parameters of the dumped rocks;

b). Sliding on the contact between the direct foundation and the waste dump, in which case the resistance characteristics of the contact surfaces (dumped rocks on the topsoil) are used;

c). Sliding through the direct foundation represented by the topsoil (adobe clay), in which case the resistance characteristics of the direct foundation are used.

In comparing the results obtained from the analysis of stability after sliding through the landfill areas (cilindrico-circular) and after the contact surfaces (topsoil-dump) or through the direct foundation (topsoil), it follows that most likely slidings may occur through the dump, according to sliding curved surfaces [9].

## 1. ASSESSMENTS ON THE STABILITY OF THE ACTIVE WASTE DUMPS

### 1.1. Factors influencing the stability of slopes

Slope sliding phenomena usually takes place when the local or overall balance between the forces that stress the slopes and the inner forces of resistance that oppose sliding under the action of external or internal factors, natural or artificial ones is destroyed.

Sliding of a slope manifests itself in the form of the movement of the material it is made of along finite sliding surfaces on which the tangent efforts (shearing) overtake the amount of resistance forces of rocks or of the mixture of which that very slope is made of [6].

Agents that influence the stability of a slope are the following [2], [4]:

- *Geological and geomorphological agents*

The geological agent has a special role in formation of landslides and therefore, schemes and methods of slope stability estimation should be chosen depending on the geological conditions: stratigraphy, tectonics, structural convergence, etc.

There are methods that consider uniform slope, lacking layers and methods for layered massive, enabling the taking into account of the meaning of strata falling [4], [6].

For example, if the waste dump in the auxiliary enclosure of Maleia, the geologic agent has no influence as it is a sterile dump consisting of a mixture of rocks from the heterogenic sterile product of some underground mining works. It appears, however, the influence of geomorphological factor by surface morphology of the land on which the dump have been built.

Waste dump inside Maleia is formed on the slopes that converge towards the valley of Maleia form the south to the North-North East. Convergence of the running direction of the heaping fronts with the inclination of the base could lead to the emergence of consistent slides on, or through, the land base.

- The *hydrogeological agent*

Hydrogeological agents play an extremely important part in the formation of sliding surfaces, and the presence of water in rocks affects the state of the united efforts through the humidity variation of the unsaturated rocks, the water pressure in pores, and hydrodynamic pressure of groundwater and modifying the characteristics of rocks resistance.

Water in the pores creates a pressure that leads to a drop in the shearing resistance of rocks, as a result of the dropping in the effective pressure on the sliding surface, and at the lowering of the water level, there can be recorded an increase in the volumetric weight of rocks due to the positive effect of elimination of water. This phenomenon manifests itself in particular in the case of leaking rocks.

Hydrodynamic pressure manifests itself in case of heavy rainfall as well, when through the dumper rocks saturation and the direct foundation it is formed aquifer underground water which tends to drain freely in the form of former conductivity. The soaking with water of the dump material presents importance due to the influence of the moisture content on the mechanical properties of rocks or mixture of rocks.

The soaking with water of the rocks apart from the heap wetting leads to an increase in its weight with the weight of water that occupies pores and free spaces. This phenomenon has negative influence on stability due to the fact that the increasing weight through soaking with water occurs only at the top, above the hydrostatic weight, and under the hydrostatic the weight is reduced by water pressure acting on bottom-up. All these require the carrying out of drainage of the dumps by removing completely the accumulated water and lowering the levels in their body, hydrostatic, which leads to increasing the overall stability of the sterile material stored.

When determining the geometrical parameters of heaps, both geotechnical characteristics of the mixture and those of rocks that form the land base should be taken into account.

- *Mechanical and geomechanical agents*

Mechanical natural agents relate to natural running waters, lakes, torrents, which can cause erosion on slopes and at the base of them. In most cases, the bearing of the erosion at the base of a slope has caused the sliding process, because of the affecting of effort state, which occurs from the very first erosion actions.

At some level of erosion, efforts state changes so much that plastic yielding areas appear and they extend and trigger the landslide. When erosion causes the generation of slipping, it depends largely on the initial efforts and tensions [1], [2], [4], [6].

Geomechanical agents must be taken into consideration starting from the determination, in the laboratory or on the field, of the main parameters of mechanical durability of rocks: cohesion and the angle of internal friction. Considering the geomechanical agent always implies determining the strength parameters on the weakest strength areas of the slope, or versant, where the sliding forces bundle. Such areas may be considered the stratification surfaces and planes of cracking or fault for “in situ” slopes or contact surfaces of the material dampened with the basic ground in case of heap of debris.

By highlighting the geomechanical indices of rocks, you can draw conclusions about their behaviour in different loading situations, force, made up and placed [1], [2], [4], [6].

According to Coulomb's law, the relationship between the shear resistance, uniform pressure, cohesion and effective angle of inner friction, is as follows:

$$\tau_r = \sigma_e \mathrm{tg}\varphi + c_s + c_w \tag{1}$$

*a). Effective pressure* $\sigma_e$ depends on the one hand of the total pressure, which for given loading and a particular position of a point considered in the heap or in the base land is constant, and on the other hand of the pressure of water in the pores u, the value of which may vary depending on the circumstances. It is noticed that the size of the value of u leads to the decrease of $\sigma_e$, and of the agent $\sigma_e \mathrm{tg}\varphi$ and in consequence, to the decrease of the resistance to cutting $\tau_r$ of rocks, or mixtures of rocks.

$$\sigma_e = \sigma_t - u \tag{2}$$

This process is specific to the waste dumps, especially if we take in consideration that in the mixture of rocks in their body sandy-silty rocks predominate, for which values of $c_s$ and $c_w$ are very small or negligible.

*b). The angle of internal friction φ* belonging to the rocks from base land and to the mixture of dump material, is determined by the size and surface roughness of pieces of grain and stockpile rocks, by the degree of non-uniformity of the material, and by the existence and thickness of the adsorbed water coverings around this material.

To the rocks and to the mixture from waste dumps, where sandy rocks predominate, the adsorbed water coverings, which can appear are reduced, so that the laboratory tests have shown that the influence of water on the angle of internal friction is negligible in such cases.

Meanwhile, to the rocks and to the mixture from waste dumps, where argillaceous rocks predominate, with the increasing of humidity, the value of angle of internal friction is decreasing very much because of the fact that in this case the water film has the role of a lubricant, which is in the disadvantage of stability.

*c). The structural cohesion* $c_s$ of rocks may be influenced by the action of water through the washing of salts that act as a binder.

This phenomenon is characteristic to loess, the slides occurring after surfaces closer to vertical, as a subsidence.

*d). The hydrocolloid cohesion of rocks* $c_w$ can be reduced due to increased of humidity, by thickening the water coverings, the effect being the weakening of attraction between particles and at the same time reducing the capillary pressure. In nature, changes does not occur only on friction or cohesion, but, both factors are simultaneously affected to different degrees.

- *Anthropogenic factors*

It refers to changes of stress state and tensions from slopes and embankments due to the action of human engineering. Among these factors the overloading of slopes and embankments to the upper part is mentioned, by the deposit of rocks or circulation of technological equipments, respectively the rocks excavation at the bottom of slopes or embankments. These factors or activities change the relationship between resistance forces and forces that stresses the slope to sliding.

- *Hydro-meteorological and climatic factors*

Rainfall leads to increased moisture of rocks of which it consists the waste dump and implicitly reduce the reserve of stability, or even its slipping. It was found that most landslides occur during heavy rainfall. Heavy rains increase water infiltration into the rocks, which causes a decrease in their resistance. As a result of tests performed in the practice of construction of the artificial slope, was found that the moistening of the material due to rainfall is highest at the foot slopes, where humidity varies on a depth of 2-3 m from the surface.

The unfavorable influence of rainfall manifests both in waste dump, where the dissagregated structure of rocks mixture facilitates water infiltration, and contact area with base land where the presence of top soil with a high content of clay leads to the phenomenon of "wetting" of rocks and to the reducing of their resistance.

Through *the phenomenon of freezing and thawing* the rocks suffer a series of significant deformation refering to damage of their structure, reducing the mechanical strength properties. Through freezing it increases the amount of water present in the rocks, and as such, rocks suffer a dilatation which can be noticed by a slight lifting of the relief, accompanied by an incipient movement, which develops along the line of greatest slope. This movement is, in fact, a start of the sliding process of the slope.

- *Seismic factor*

Seismic shocks caused by earthquakes or massive explosions exerts on slopes both vertical and horizontal forces, that can cause slip phenomena. Vertical forces reduce the effective normal pressure on the sliding surfaces, while the horizontal forces, much stronger, play a critical role in the stability of the slope.

- *Biotic factor*

Biotic factor interferes in the situation of playing back into the economic circuit of the waste dumps, and is represented by different types of cereal crops, vegetable crops, orchards and forests. The loading of slopes on the outline, especially due to the weight of the trees, is equivalent to a uniformly distributed load of the order 250-450 daN/cm$^2$.

However, biotic factor has a positive effect on the stability of the slopes, manifested through the reinforcing effect of the land due to the trees' roots.

### 1.2. E.M. Livezeni waste dump – main establishment

#### 1.2.1. Geotechnical and hydrogeological peculiarities of the base land

The direct foundation of E.M. Livezeni waste dump is composed of a top soil cover layer, whose thickness varies between 0.3 - 1.0 m.

Laboratory tests carried out in the Laboratory of Analysis and Testing for Construction - Level I, University of Petrosani, revealed that, in terms of lithology, the topsoil is a mixture of fine clay, dust, sand and gravel.

The large share of fine particle size fractions with diameters less than 0.05 mm, of 56.7 to 67.6%, causes increased sensitivity of topsoil to water. The high capacity of water retention can significantly affect the consistency and mechanical resistance characteristics of the soil the plant [7].

Base land consists of the following types of rocks: conglomerate; sandy clays, clays with no stratifications and sandstones.

**Table 1. Geotechnical characteristics of rocks from direct foundation (topsoil) and base land [7], [8]**

| Rock type | Indici geotehnici | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $\gamma_s$ [kN/m$^3$] | $\gamma_a$ [kN/m$^3$] | W [%] | $E_c$ [kN/m$^2$] | $e_p \cdot 10^{-2}$ [m$^2$/kN] | $e_c$ [cm/m] | C [kN/m$^2$] | φ [°] |
| Direct foundation (Topsoil) | 24,9÷25,6 | 14,4÷18,3 | 16,72÷26,33 | 2439÷3574 | 2,80÷4,10 | 6,6÷9,2 | 12,0÷51,0 | 15,0÷27 |
| Base land (Microconglomerates) | 26,0÷26,8 | 20,1÷22,4 | 1,4÷2,28 | - | - | - | 103,0÷475,0 | 48÷59 |

Analyzing the calculated values shown in Table 1, it may be established that, direct foundation has relatively small strength characteristics, which may cause plastic deformation and moderate subsidence of the base land, while the base land is composed of rocks that have high strength characteristics, providing good conditions of stability in the case of static loads. Any plastic deformation of direct foundation may affect the stability of waste dump by producing discharge and landslides at the level of the topsoil.

From the hydrogeological point of view, for the structure of formations from foundation, it is not indicated the presence of groundwater leading to the formation of static resources. Some springs or swampy portions which are reported in the area belong to water infiltration due to precipitation and to the presence of eluvial deposits in the area or the existence of depression areas where water from precipitation accumulates [6].

From the hydrographic point of view, the dumping surface area is not affected by water courses or local accumulations of water, a favorable aspect for building waste dump in terms of stability.

### 1.3. P.A. no. 2-3 waste dump – Maleia establishment, E.M. Livezeni

#### 1.3.1. Geotechnical and hydrogeological peculiarities of the foundation rock

The presence of slopes, although variable, facilitates the flow of water from the slopes to the stream from the area, and the occurrence of instability phenomena on the waste dump site, to the crossing limit between the base land and deluvial clay package [9].

Geotechnical investigations carried out, attests the presence of groundwater in the base land at depths of 1.8 ÷ 2.3 m. This groundwater is the source of exfiltrations that manifests on the northern slopes of the waste dump [6].

It is estimated, however, that the existence of open geological structures it is not favorable to significant accumulations of groundwater, and therefore the local hydrogeological conditions are not likely to affect the existence and stability of the waste dump. However, infiltration of water from rainfall in the waste dump's body, especially in the contact area of dumping rocks with the direct foundation, due to the lack of permanent work levelling and compaction of the waste dump, and safety channels, may results in some instability phenomena, and especially in plastic failure of the rocks from the direct foundation, by reducing their carrying capacity.

In the western part of the waste dump, we notice the presence of a ravine, where water accumulates after the snow melting or after heavy rains. These waters drain on the western limit of the waste dump, but it can also infiltrate into the waste dump's body, reducing the strength characteristics of the dumped material and of the rocks from the direct foundation (delluvial clay).

Waste dump's foundation is composed of delluvial clay deposits with thickness between 0.5 ÷ 2.5 m, that in the north part incorporates throughout its mass boulders and gravel coming from degradation of the bedrock, consisting of a alternation of cemented sands with sandstone aspect and marl schist [6].

Among the deformations present in the waste dump's body, subsidence of the dumped material, erosion and discharge of the slopes and base land are mentioned.

So far, it were not mentioned instability phenomena of the dump, except some non-uniform subsidence of the land, erosions and some pressure side of the base land, reported on the west and north part of the waste dump. Those on the north side are accompanied by exfiltrations of water, which shows that precisely the presence of water facilitates the reduction of resistance characteristics of rocks and production of these phenomena.

### 1.4. Waste dump from Lupeni

#### 1.4.1. Geotechnical and hydrogeological peculiarities of the foundation rock and from dump's body

Because of the formation of waste dump's bodies with irregular geometry and different alignments, in the nearby of them, lakes were formed, without the possibility of natural drainage. The waters on the slopes drain into these lakes, thus constituting the sources of infiltration into and under the waste dump's body, which may influence the stability by changing the physico-chemical properties of dumped rocks and of the base land.

So, it manifests the erosion phenomena, which in time can cause accumulation of hydrostatic and hydrodynamic pressure, underlying landslides and plastic flows.

Lupeni dump manifested instability phenomena, largely due to its formation, into one level, on sloping land surface with varied morphology. The high height of the deposits in some areas determined the material to move in slope, breaks appearing at the upper part of the dump, with displacements of the material to downstream.

The dump's foundation is composed of topsoil and colluvial material of the slope, with a strong loamy character. Mineralogical composition of the base land – a psamito-pelitic structure, with a predominance granulometric fractions ř ≤ 2 mm (70%) composed of sand, dust and clay, of which approx. 20% powder and clay [5].

**Table 2. Calculation values of the physical and particle size characteristics from the base land [5], [8]**

| Physical characteristics | | UM | Limits of variation |
|---|---|---|---|
| Size composition | Clay (< 0,005 mm) | % | 10,2-10,9 |
| | Dust (0,005 – 0,05 mm) | | 9,1-9,8 |
| | Sand (0,05 – 2,0 mm) | | 51,8-69,2 |
| | Gravel (2,0 - 20 mm) | | 8,2-28,2 |
| Specific density | | $cN/cm^3$ | 2,61-2,62 |
| Volumetric density | | $cN/cm^3$ | 1,58-1,63 |
| Natural humidity | | % | 13,12-14,24 |
| Porosity | | % | 45,74-46,48 |
| Saturation coefficient | | - | 0,39-0,44 |
| Plasticity | Yield strength | % | 27,50-29,50 |
| | Kneading strenght | | 15,61-17,05 |
| | Plasticity index | | 11,45-13,89 |
| | Consistency index | | 0,95-1,15 |

The plastic pronounced character of rocks from base land, as well as the large height of landfill's level, determine them not to provide the necessary carrying capacity, plastic weakening, the consequences being the discharge of material through base land, followed by landslides.

All kinds of deformations, namely: discharge of material, erosion, landslides and flows are present in waste dump body from Lupeni. Here, landslides occurred in the topsoil, as dump material combined with the top soil under its own weight, so has not been kept the contact surface [5].

The causes of instability are varied: improper filing technology, geo-morphological and topographic conditions of the land, especially the physical characteristics of the mixture of stockpile rocks, presented in Table 3.

The values obtained from the granulometric analysis, shows that the predominant fraction of dumped material varies between 2-20 mm size, with a percentage of 31.3 to 53.0%, followed by psamitic fraction with a share of 18.6 to 39.3%, under these conditions water can easily infiltrate.

**Table 3. Calculation values of the physical and particle size characteristics from the dump material[5], [8]**

| Physical characteristics | | UM | Limits of variation |
|---|---|---|---|
| Size composition | Clay (< 0,005 mm) | % | - |
| | Dust (0,005 – 0,05 mm) | | 2,5-4,0 |
| | Sand (0,05 – 2,0 mm) | | 18,6-39,3 |
| | Gravel (2,0 - 20 mm) | | 31,3-53,0 |
| | Boulders (> 20 mm) | | 8,4-47,5 |
| Specific density | | $cN/cm^3$ | 2,60-2,69 |
| Volumetric density | | $cN/cm^3$ | 1,74-2,10 |
| Natural humidity | | % | 11,28-17,55 |
| Porosity | | % | 27,97-42,88 |
| Pore index | | - | 0,52-0,75 |
| Saturation coefficient | | - | 0,42-0,82 |

**1.5. Valea Arsului waste dump, E.M. Vulcan**

**1.5.1. Geotechnical peculiarities of the foundation rock and from dump's body**

The main phenomena of instability that have been reported are the subsidence, as a result of underground exploitation, and plastic sliding in the areas of waste dump's expansion to the lake formed. The presence of the lake locally formed, is an unfavorable factor in terms of stability, since water saturates the rocks at the base of the waste dump and modifies the physico-mechanical properties of rocks and of the base land.

Geotechnical study shows that waste dump's foundation is composed of a loamy-dusty sand which includes in its mass gravel fragments coming from bedrock degradation. It appears that rocks from waste dump's foundation have a reduced load capacity, that with the increasing humidity change their strength characteristics and are subject to plastic changes, a fact that can be justified by the presence of fine granular particles: dust and clay [3].

Geotechnical study of the physico-mechanical properties allowed the determination of their limits of variation, and adoption of the geomechanical indices necessary to stability calculations, design and geometry of the waste dump.

The limits of variation of the physical-mechanical characteristics are shown in Tables 4 and 5.

**Table 4. Calculation values of the physical characteristics from topsoil and dump material [8]**

| Physical characteristics | | U/M | Limits of variation | |
|---|---|---|---|---|
| | | | Top-soil | Dump material |
| Size compo-sition | - clay (< 0,005 mm) | % | 13,2 | 0÷1,7 |
| | - dust (0,000 – 0,05 mm) | | 28,0 | 2,1÷10,1 |
| | - sand (0,05 – 2,0 mm) | | 37,8 | 15,6÷67,2 |
| | - gravel (2,0 – 20 mm) | | 15,2 | 14,80÷43,4 |
| | - boulders (> 20 mm) | | 2,8 | 6,2÷14,80 |
| Specific density | | cN/cm | 2,61 | 2,53÷2,61 |
| Volumetric density | | cN/cm | 1,675 | 1,76÷1,805 |
| Natural humidity | | | 18,55 | 13,87÷16,88 |
| Porosity | | | 45,86 | 40,83÷41,23 |
| Pore index | | - | 0,85 | 0,69÷0,70 |
| Saturation coefficient | | - | 2,8 | 0,50÷0,64 |

**Table 5. Mechanical characteristics of the mixture of dump material [8]**

| Rock type | Humidity W % | Saturation coefficient S | Cohesion C daN/cm $^2$ | Angel of internal friction [$^o$] |
|---|---|---|---|---|
| Dump material | 13,87÷18,55 | 0,50÷0,57 | 0,32÷0,38 | 19÷21 |
| | 17,40÷23,03 | 0,62÷0,70 | 0,18÷0,29 | 14÷22 |
| | 20,47÷27,39 | 0,74÷0,84 | 0,12÷15 | 12÷15 |
| Topsoil | 18,55÷23,03 | 0,57÷970 | 0,18÷0,38 | 21÷22 |
| | 23,03÷27,39 | 0,70÷0,84 | 0,12÷0,18 | 15÷22 |

After the physico-mechanical analysis we can draw the following conclusions:

a). The topsoil is represented by a sandy-loam dust with a psamito-peltic structure in which appear gravel fragments with θ = 2-20 mm size. The presence of fine particles (dust and clay) in the topsoil structure leads to a higher water retention capacity than in case of dumped rocks.

b). the heterogeneity of rocks from waste dump leads to a pronounced variation of geotechnical characteristics.

c). compressibility parameters of the topsoil reflect a lower bearing capacity than of the dumped rocks, which indicates the availability for plastic deformation of the direct foundation of the waste dump.

## CONCLUSIONS

As a result of "in situ" observations and geotechnical research carried out, resulted that the overall condition of *Livezeni main enclosure waste dump* is good, it is not affected by instability phenomena. The only observed phenomena are some small areas of erosion caused by rainfall waters. It are located on the side slopes, and are not major processes, without tendency to cause some local slides. The waste dump top surface is relatively flat, and marginal slopes (Western and Eastern), are in good condition.

From the stability study of *Lupeni dump*, we can draw the following conclusions:

- the technical condition of the waste dump is a precarious one, evidenced by: subsidence, pressure side, erosion, landslides and plastic flows;
- the pronounced slope of the terrain where the landfill is located favors the production of slip phenomenon;
- the direct foundation of the waste dump is represented by topsoil and delluvial deposits with a strong loamy character, whose strength characteristics are reduced in the presence of water;
- after the expansion of waste dump bodies transversely to the valleys in the area, natural courses were barred, as a result, lakes appeared upstream.
- the main factor of instability is the infiltrated water in the waste dump.

*Arsului Valley dump* was classified in the category of waste dumps with displacements that can be limited through planning / drainage, or new dump technology, and that in area of influence have communication pathways with limited or restricted traffic of people.

The dump is relatively stable and does not indicate landslides. For the drainage of Arsului Valley stream a safety channel was executed.

## REFERENCES


1. Arad, V., Arad, S., Apostu, S., Bărăiac, O., 2012, *The impact of coal mining in Jiu Valley on environment and rehabilitation of the area*, 12th International Multidisciplinary Scientific GeoConference SGEM 2012, Albena.

2. Arad, V., Arad, S., Bărăiac, O., Radermacher, L., 2013, *The stability analysis of the civil engineering from Oltenia mining area*, INTERNATIONAL JOURNAL OF GEOLOGY, NAUN/University Press journals, Issue 3, Volume 7, 2013, p. 63 - 71.

3. Iancu (Apostu), S., Arad, V., Bărăiac, O., Nistor, D.C., Lasc, Ghe., 2014, *Geotechnical study and possibilities of recovery of the useful components from tailings ponds*, Papers SGEM 2014 / Proceedings, Albena, Bulgaria, Vol. III, p. 277-284.

4. Lazăr, M., 2010, *Rehabilitation of degraded lands*, Universitas Publishing House, Petroşani.

5. Rotunjanu, I. et al., 2001, *Stability study for the active R-3 waste dumps belonging to the Lupeni mining subunit*, University of Petroşani and National Company of Hard Coal Petroşani.

6. Rotunjanu, I., 2005, *The stability of slopes and embankments*, Ed. Infomin, 351 p., Deva.

7. ***, 2009 - 2010, *Stability study for the waste dumps belonging to the former Livezeni Preparation plant.*

8. ***, Geotechnical surveys - Laboratory of Analysis and Testing in Constructions - Level I, Petrosani.

9. ***, 2001, Geotechnical survey, development and consolidation of waste dump belonging to EM Livezeni – Maleia enclosure.