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# CONTENTS

# STABILITY ANALYSIS OF THE ROCK SALT ROOMS AND PILLARS OF THE OCNELE MARI SALINE WITH THE AID OF THE 2D FINITE ELEMENT MODELLING

**ILIE ONICA*** 
**EUGEN COZMA*** 
**DUMITRU MARICA****

**Abstract:** *Ocnele Mari rock salt deposit is among the main exploited deposits in Romania, with a balance reserves of about 4 824 million tonnes. The rock salt mining, actually applied in the case of Ocnele Mari Saline, is by small rooms and square pillars. The mine in use is confronted with the problems generated by the increased levels of mining, and the ancient part of the saline for the touristic use and other purposes. Therefore it is needed to be analysed from the point of view of their stabilities. The stability analysis of the rock salt structures of Ocnele Mari Saline using the modelling based on the finite element method is presented in this paper***.**

**Keywords:** rock salt, rooms and pillars, finite element modelling, strain, stress

## 1. OCNELE MARI ROCK SALT DEPOSIT

The researches – exploration workings of the Ocnele Mari rock salt deposit have been operating since 1952 and were enhanced between 1988 and 1991, leading to an assessment of the balance reserves of about 4 824 million tonnes (Almăşan, 1974 [1]; Cozma et.al., 2006 [3]; Hirean & Georgescu, 2009 [5]).

The Coceneşti mining field involves the eastern part of the rock salt lens of Ocnele Mari deposit. The deposit inclines toward the north – east with 21-17$^{o}$. In the southern zone, the rocks layers thickness is about 20-50m, increasing toward northern part to 540-800m.

The sedimentary deposits, from the lens roof, belong to Upper Badedian and the Sarmatian and are composed from: compact grey marls (Badedian); argillaceous sands (Sarmatian); fine sandy clays (Sarmatian); fine sandy marls. Inside the rock salt lens certain sterile intercalations exist, with the thickness ranging between 1m and 1.5m**.** The black marls sterile intercalations sometimes have hydrocarbon odour (***,2007a) [11].

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* *Prof. Ph.D. Eng. University of Petroşani*
** *Student PhD. Eng. University of Petroşani*

The Ocnele Mari rock salt deposit is flanked, on the north and south, by two major discontinuities: Stoeneşti fault and Bisericii fault. Inside the rock salt massive the micro-tectonics phenomenon takes place, with local effects on the salt deposit.

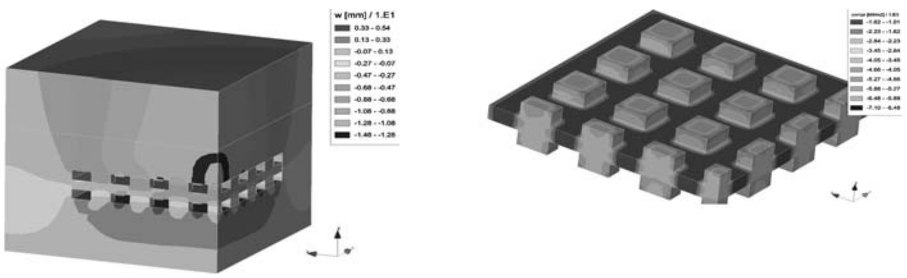
From a macroscopic point of view, the rock salt has the aspect of white and dark grey or sooty alternating bands, including fragments of marls and anhydrite.

The mineralogical composition of the rock salt is composed, mainly, of gypsum and anhydrite, in proportion of 1-5%, and 0.02-0.3% of kieserite and the argillaceous and carboniferous minerals, with a percentage of about 5-35%. The chemical composition of the rock salt shows an average content of NaCl of 99% and 0.91- 4.21% of insoluble.

The solid way rock salt mining was achieved with the small rooms and square pillars method on two levels, namely at: a) level +226m, where the pillars have 14m/14m sizes, and the rooms' width of 16m; b) level +221m, with pillars sizes of 15m/15m and the rooms' width of 15m. Between these two levels the ceiling average thickness is about 8m.

## 2. DESCRIPTION OF THE FINITE ELEMENT MODELS

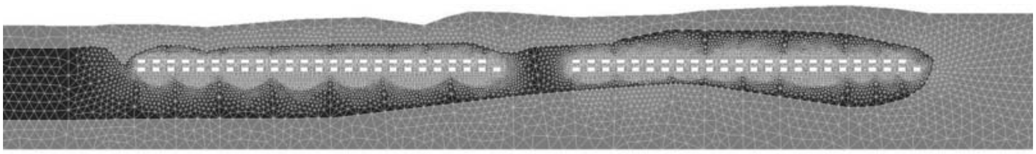
Referring to Ocnele Mari rock salt deposit, over time several stability, dimensioning and checking studies were made, using different analytical methods which couldn't include the entire size of the deposit. Also, because the important sizes of the models a 3D modelling is very difficult to be made (Fig.1) (Onica & Cozma, 2009) [8].



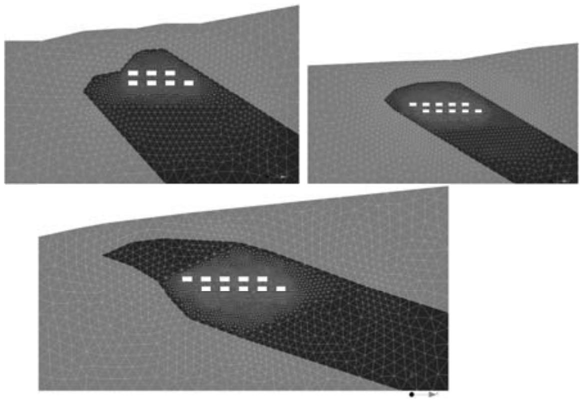
a) b)

**Fig.1. 3D finite element modelling of the rooms and pillars in the case of the rock salt mining**
**a) Vertical displacement; b) Compressive stresses**

Therefore, for the stability analysis of the entire mine structures, the 2D finite element method was utilised with the aid of CESAR-LCPC code (***,2007) [10]. This 2D finite element code was used to build the computational models with finite elements, in the plane strain and Mohr –Coulomb elasto - plasticity behaviour hypothesis. The achieved models were: one vertical longitudinal east –west cross section and three significant transversal cross sections (fig.2), in conformity with the geological and mining documentation of the Ocnele Mari Saline (***, 2007a) [11].



**a)**



**b) c) d)**

**Fig.2. Finite element models of Ocnele Mari rock salt deposit:**
**a) Cross section East-West; b) Cross section I-I; c) Cross section II-II;**
**d) Cross section III-III**

So as to set up the 2D models, in the plane strain hypothesis, the following simplifying assumptions were made (Onica, 2001 [7]; Onica & Cozma, 2009 [8]):

1) The finite element models are in conformity with the vertical cross section (longitudinal and transversal) from the mining project, at the maximum limit of the mining activity (considered to be the critical situation from the point of view of underground excavations stability) and which could be generated in the plane strain hypothesis;

2) The pillars and rooms sizes are supposed to be equal on the entire mining level, respectively squares with the sizes of 16m – the rooms and 14m - the pillars (at the level +226m) and of 15m – the rooms and 15m – the pillars (at the level +210m);

3) The superposed pillars at the two levels (+210m and +226m) are considered perfectly coaxial;

4) Both the surrounding rocks and the rock salt massive are supposed to be continuous, homogeneous and isotropic and the geo-mechanical characteristics used in calculus are medium ones and representative for the entire rocks massive, respectively the rock salt;

5) The in situ rock mass and rock salt deposit behaviour is supposed to be elasto - plastic without hardening, which respects the Mohr-Coulomb law;

6) The natural state of stress is the geostatic one.

The achievement of the 2D modelling, in the plane strain hypothesis, for every previous defined model, required the following stages: I) establishment of boundaries, interest zones and meshing of the model; II) determination of zones (regions) and computational hypothesis and the geo-mechanical characteristics input; III) boundaries conditions establishment; IV) initial conditions and loading conditions establishment; V) achievement of calculus and stocking of results (Onica, 2001 [7]; Arad et.al., 2010 [2]; Cozma & Onica & Hirian, 2009 [4]).

I) Having in view the underground excavations sizes, for a good precision of the results the models were made with the sizes presented in Table 1. Also, the sizes of the interest zone, around the excavations, were established so as to involve the model surface where the stresses and strains variation is maximum. 2D model meshing, respectively of every surface region, was made by triangular surface finite elements with quadratic interpolation.

**Table 1.** *Meshing statistics of the finite element models*

| Specification | | Finite element models | | | |
|---|---|---|---|---|---|
| | | A)Cross section East-West | B) Cross section I-I | C) Cross section II-II | D) Cross section III-III |
| Model sizes, (m) | X | 2160 | 476 | 530 | 625 |
| | Y | 294 | 290 | 360 | 330 |
| Number of nodes | | 61 845 | 8 231 | 14 432 | 12 477 |
| Number of triangular surface elements | | 30 840 | 4 086 | 7 180 | 6 200 |

II) In order to make a qualitative description of the models, there were taken into consideration 2 regions with various geo-mechanical characteristics which, in the conditions of a Mohr-Coulomb without hardening type of behaviour model, were defined thus:

a) The surrounding rock mass: apparent specific density $\rho_{ar}$ =1900kg/m$^3$; linear elasticity modulus $E_r$=7.10$^5$ kN/m$^2$; Poisson ratio $\nu_r$ =0.22; uniaxial compressive strength $\sigma_{cr} = 4000$ kN/m$^2$; tensile strength $\sigma_{tr} = 500$ kN/m$^2$; cohesion $C_r$=1000kN/m$^2$ and the internal friction angle $\varphi_r$ =18$^o$ (Hirian, 1981 [6]; Todorescu, 1984 [9]);

b)The rock salt massive: apparent specific density $\rho_{ar}$ =2150kg/m$^3$; linear elasticity modulus $E_r$=15.10$^5$ kN/m$^2$; Poisson ratio $\nu_r$ =0.25; uniaxial compressive strength $\sigma_{cr} = 21700$ kN/m$^2$; tensile strength $\sigma_{tr} = 1200$ kN/m$^2$; cohesion $C_r$=4000kN/m$^2$ and the internal friction angle $\varphi_r$ =30$^o$ (Hirian, 1981 [6]; Todorescu, 1984 [9]);

III) The superior side of the model is considered free and the lateral sides, blocked.

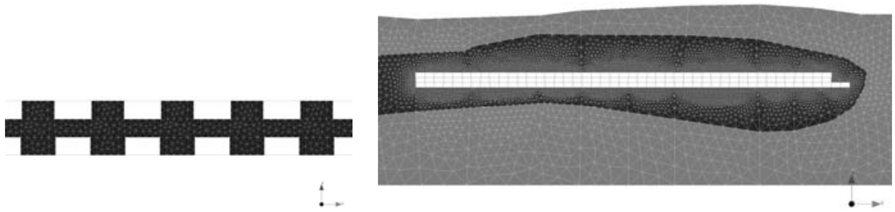
IV) The initial loading conditions of the model were considered as geostatic $[\sigma_o]$, corresponding with about $H$=100m depth (the average cota of the surface being about +334m): the vertical geostatic stresses $\sigma_{oy}$ = 19600kN/m$^2$, the horizontal geostatic stresses $\sigma_{ox}$ =5488kN/m$^2$ (where: $k_o = \frac{\nu}{1-\nu} = 0.28$ ). The induced stresses by the excavation presence were $[\sigma_e]$ (tractions on inside surfaces of the excavations) are represented by the horizontal stresses $\sigma_{ex}$ and vertical $\sigma_{ey}$. Thus, the loading of the model was performed in the total stress: $[\sigma_T] = [\sigma_o] - [\sigma_e]$.

Regarding the previous models, from the point of view of the geostatic loadings, two calculus situations were generated, namely: case *A*) – for $\sigma_o \lfloor 2 \cdot \sigma_{oy}, \sigma_{ox} \rfloor$ and case *B*) – for $\sigma_o \lfloor \sigma_{oy}, \sigma_{ox} \rfloor$ (Onica, 2001 [7]).

Case *A*) For to assess the stress and strain state in the pillars, situated at the level +226m and +210m and the ceiling between these two levels, in the plane strain hypothesis, the results would have been both underestimated and in conformity with the rooms and continues long pillars mining. But, in the case of the small rooms and square pillars mining (the case of Ocnele Mari saline) it is necessary to increase the vertical stresses $(2 \cdot \sigma_{oy})$ twice, depending on the ratio of the rooms and pillars sizes, measured following the perpendicular direction *z* on the model's surface. Therefore, the models loading were made with a natural geostatic state of stresses $\sigma_o \lfloor 2 \cdot \sigma_{oy}, \sigma_{ox} \rfloor$. In this case, the obtained results, regarding the stresses and strains from the pillars and ceiling, being real and the stresses and strains, following the *y* axe of the models (corresponding to the roof of rooms at level +226m and the floor at level +210m), being approximately doubled.

Case *B*) For to assess the stress and strain state, from the roof of the rooms (situated at the level +226m), the floor of rooms (situated at the level +210m) and in the rest of the model (least in the pillars and the ceiling between them) it is necessary to load the models with the normal geostatic state of stresses $\sigma_o \lfloor \sigma_{oy}, \sigma_{ox} \rfloor$.

The results obtained from the two calculus cases could be considered real for the regions shown in the fig. 3.a (case *A*) and fig.3.b (case *B*).



**a) b)**

**Fig. 3. Models regions for which are valid the results from the: a)case *A* of calculus; b) case *B* of calculus**

V) The calculus results were stocked in the graphical form on the model surface (isovalue, vector and tensor representation) and in the predefined cross sections (following the planes of two mining levels: +226m and +210m). The results obtained corresponding to the following parameters: the vertical displacement *v* and horizontal (in mm); the horizontal stress $\sigma_{xx}$ and vertical $\sigma_{yy}$, the shear stress $\tau_{xy}$, the maximum principal stress $\sigma_1$ and minimum $\sigma_2$, the maximum shear stress $\tau_{\max}$, the compressive stress $\sigma_c$ and the tensile stress $\sigma_t$ (in kN/m$^2$).

## 3. ANALYSIS OF THE NUMERICAL MODELLING RESULTS

In this way, the stresses concentration rate $\sigma_{yy} / \sigma_{xx}$ and $\sigma_1 / \sigma_2$ could describe the stresses disequilibrium and implicitly the arising possibility of failure and deformation phenomenon. A bigger rate leads to the fact that the principal stresses circle intersects the rocks characteristic curve, thus developing the failure phenomenon and the opening of certain fissures and cracks inside the rocks mass or the rock salt. Also, from the point of view of stability, the tensile and shear stresses study is very significant because the rocks and the rock salt have very reduced limits of the tensile and shear strength and, frequently, the failure arises when these strength limits are surpassed.

The vertical and horizontal displacement values analysis and the vectors orientation of these could indicate the amplitude and the sense of the deformations phenomenon development.

Because of the presence, in the models, of the eastern limits of the rock salt deposit and because the rock salt characteristics are more competent by report to the surroundings rocks, it was observed the fact that the total displacement vector has an orientation from east toward west and from floor to roof of the rock salt deposit. These have a certain influence on the orientation and distribution of the stresses and strains inside of the supports structures, the rock salt massive and the surrounding rocks.

Using the calculus results, obtained from the four models and two study cases, hereinafter, there will be made some succinct analysis concerning the support structure and rooms' stability.

### 3.1. Stability analysis of the pillars and the ceiling between the level +226m and the level +210m

This analysis could be performed studying the stresses (fig.4) and strains obtained from these four models, in the case *A* of calculus, respectively the loading of the models with state of stresses of $\sigma_o \lfloor 2 \cdot \sigma_{oy}, \sigma_{ox} \rfloor$=[39.2MPa; 5.49MPa].

Analysing the horizontal displacements distribution, by east-west direction, it is observed an increasing towards centre of deposit, reaching about 100 ÷ 120mm, decreasing at 40 ÷ 50mm at the western limit and maintaining an average of 80mm, at the east wing of the salt deposit. Transversally at the rock salt deposit, the horizontal displacements have average values of 40 ÷ 50mm. Also, comparative between the levels, it observed an increasing with about 20% of the horizontal displacements at the lower level.

The vertical deformations (fig.5) of the pillars decrease on the deposit's strike, from the east to west, from the 80 ÷ 100mm (the level +226) and 50 ÷ 70mm (the level +210mm), at about 80mm (level +226m) and 20 ÷ 40mm (level +210m).

The compressive stresses, in all the pillars, are approximately constant, ranging between 7000 and 8000kN/m$^2$ (with more than 2 times under the value of the rock salt compressive strength). In every pillar, these compressive stresses increase from the pillar' centre to the paraments with the maximum values at the corner zones with the roof (at the level +226m) and with the floor (at the level +210m) and which reach a maximum of 18000kN/m$^2$. These values are near the limits of the rock salt strength and can lead to rounding of the pillars' corners, in these local zones.

If the shear stresses are studied, developed inside of the pillars, it is observed that there exists a danger of failure and detachment of the pieces of rock salt from the pillars' surfaces, where the overcoming the shear strength is possible, especially nearby the roof of the level +226m and the floor of +210m (where the combined phenomenon of failure appear, by shear and compression).

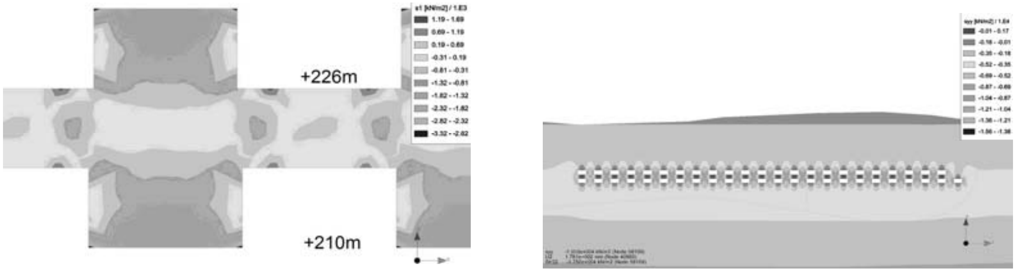
With regards to the tensile stresses in the pillars, these are insignificant in terms of pillars stability, the tensile stresses being under 350kN/m$^2$ (3÷4 times less then the tensile strength of the rock salt massive).

Analysing the stress distribution of the pillars, including the ceiling between pillars, as a whole, the behaviour of this is like an entire pillar. Therefore, in the following only the ceiling parts with two free surfaces will be studied, respectively between the rooms' floor (level +226m) and the rooms' roof (at level +210m). Thus, on the strike of deposit, the vertical displacements of the ceiling increase from east to west, beginning with 30 ÷ 40mm (at the floor of level +226m) and with 50÷60mm (at roof of the level +210m) at 60mm for the floor and 80mm for the roof, toward the east of rock salt deposit.

The maximum shearer stresses (fig.6) are insignificant in the ceiling body, suddenly increasing at over 1500 ÷ 2000kN/m$^2$, at the limits with the pillars paraments (where is possible to appear a shear failure phenomenon).

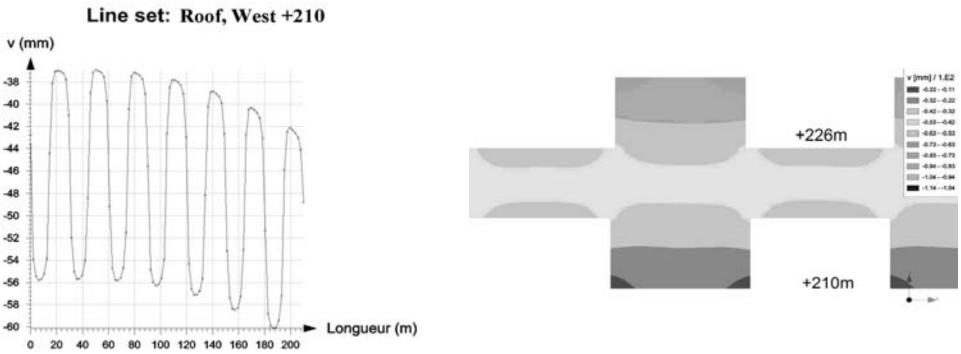
At the 2÷3m distance from the pillars, both at the floor level and the roof level of the ceiling the insignificant fissure could appear, on the few centimetres deep, resulted by increasing tensile stresses over 1200kN/m$^2$. In the rest of ceiling, the tensile stresses are insignificant, with the maximum values of 350kN/m$^2$ (fig.7).

The compressive stresses in the ceiling body are of maximum 2000kN/m$^2$ (over 10 times less then compressive strength of rock salt massive), increasing at the maximum 500÷700kN/m$^2$, at the corner' limit, between rooms and pillars.



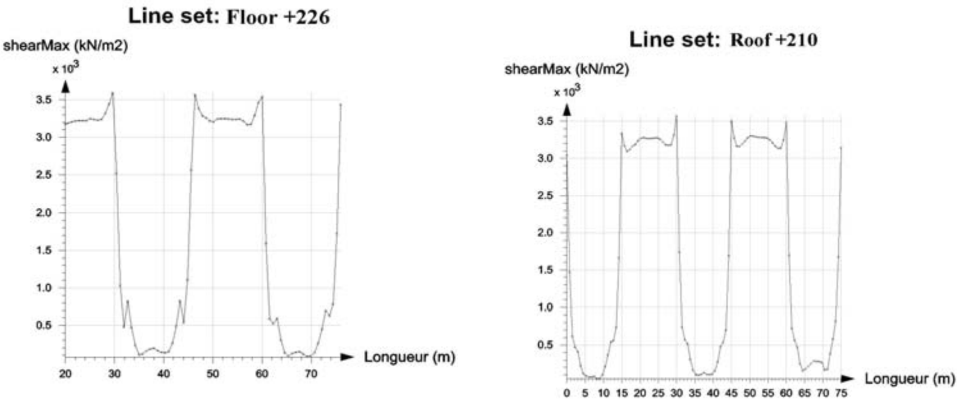

a) b)

**Fig.4. Maximum principal stresses $\sigma_1$ (a) and (b) Vertical stresses $\sigma_{yy}$, in kN/m$^2$ - cross section E-W**



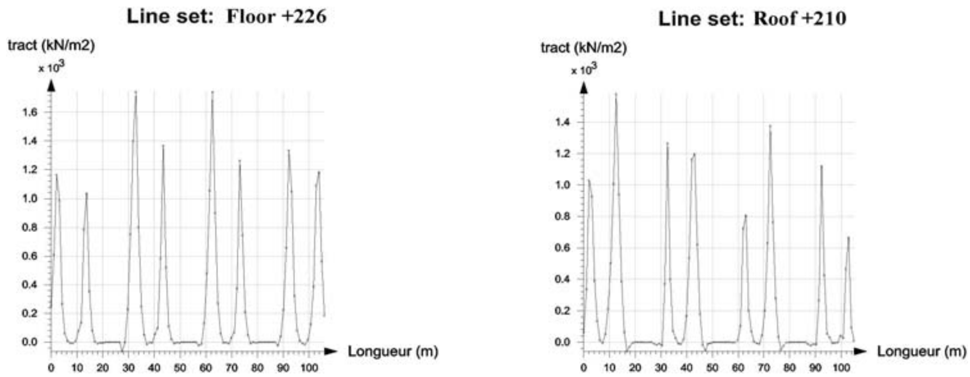

a) b)

**Fig.5. Vertical displacement (*v*, in mm) - longitudinal cross section E-W**
**a) Scalar representation; b) Section at the west wing roof level +210m**




a) b)

**Fig.6. Maximum shear stress $\tau_{max}$, in kN/m$^2$- cross section I-I**
**a) Floor level +226m; b) Roof level +210m**




**a)** **b)**

**Fig.7. Tensile stress $\sigma_t$ , in kN/m$^2$- cross section IV-IV**
**a) Floor level +226m; b) Roof level +210m**

**3.2. Stability analysis of the rooms' roof of the level +226m and the rooms' floor of the level +210m**

This analysis could be made studying the stresses (fig.8) and strains values distributions, obtained from these four models, in the situation of case B, respectively when the models are loaded with stresses state $\sigma_o \left\lfloor \sigma_{oy}, \sigma_{ox} \right\rfloor$=[19.6MPa; 5.49MPa]. In this situation it was analysed the obtained results only on the roof' level of +226m and the floor' level +210m (ignoring the results for pillars and ceiling).

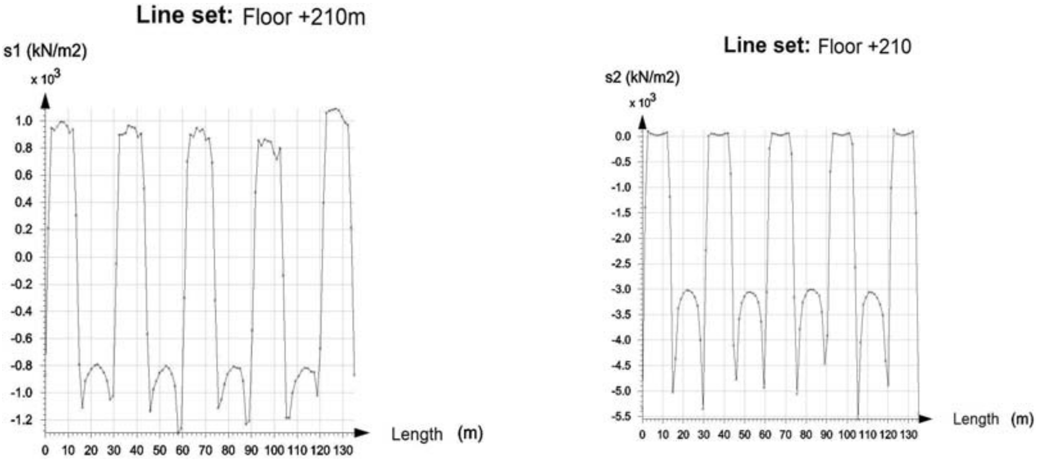
With regards to the vertical displacements (fig.9) of the rooms, situated at the level +226, there is an increase of vertical deformations from the roof to the floor, reaching the maximum values of -25÷ -30mm. Along the deposit strike, the vertical displacements of the rooms suffers a decreasing from of max. -28÷ -30mm (at western limit) to -15mm (in the centre of deposit); and a new increasing, towards the east of salt deposit, at of -15mm ÷ -20mm.

With regards to swelling phenomenon of the room' floor of the level +210m, it is found an increase of deformations towards the roof rock salt deposit of max.+28÷+40mm. Following the deposit strike, the floor deformations increase toward the deposit centre and in the east wing reaching about +40 ÷ +43mm.

The maximum shear stresses (fig.10), both in the rooms' roof at the level +226m and in the rooms' floor at the level +210m, are constants along the deposit strike, with a slight increasing tendency towards the roof and the floor of the rock salt deposit. These values asymptotically tend to the shear strength of rock salt, of about 2000 ÷ 2300 kN/m$^2$, towards the pillars, on a reduced surface, and there is the risk of failure of the small rock salt pieces and formation of the little cavities at the walls limits. In the rest of the rooms' floor surface the shear stresses are maintained at about 300 ÷ 500kN/m$^2$.

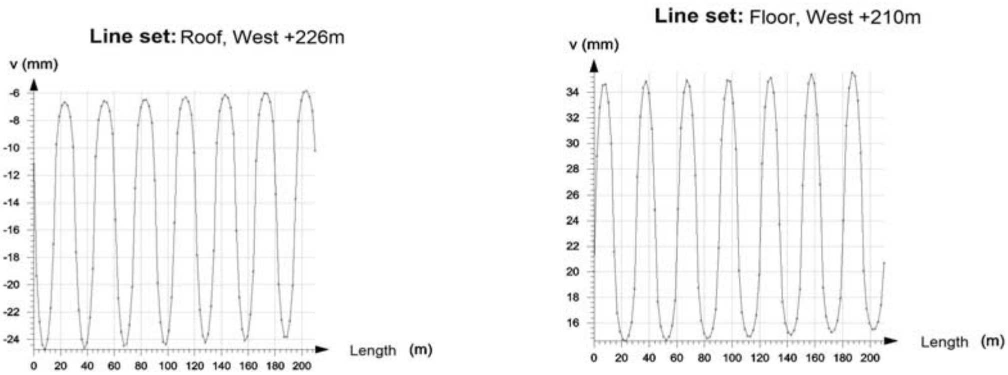
The tensile stresses (fig.11) are in medium of 700 ÷ 800kN/m$^2$, in the rooms' roof at the level +226m (which means a strength reserve of about 30 ÷ 40% by report to the rock salt tensile strength); and in the rooms' floor, a medium of about 900 ÷ 1000kN/m$^2$, tending toward the tensile strength limit of the rock salt (which can lead to a fissure arising in the rooms' floor at the level +210m or could explain the elasto - plastic rock salt deformation of about 40mm).

The compressive stresses, both in the roof and in the floor of studies rooms, are maintained around the values of 500 ÷ 600 kN/m$^2$, well below the compressive strength of the rock salt deposit (about 20000 ÷ 22000 kN/m$^2$).



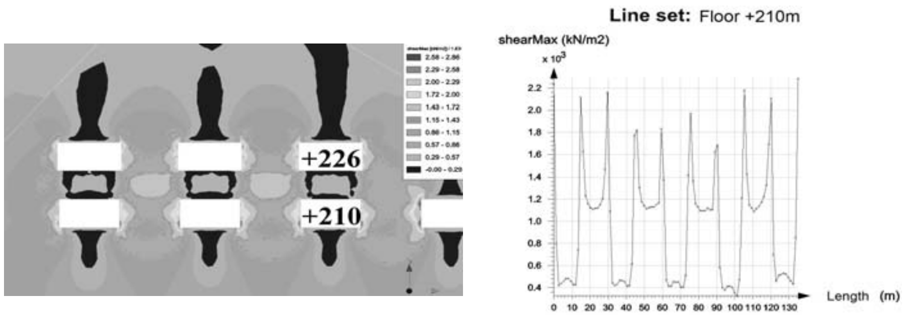

**a)** **b)**

**Fig.8. Maximum $\sigma_1$ (a) and minimum $\sigma_2$ (b) principal stresses, in kN/m$^2$ - cross section III-III**




**a)** **b)**

**Fig.9. Vertical displacement (v, in mm) - longitudinal cross section E-W (east wing)**
**a) Roof level +226m; b) Floor level +210m**




**a)** **b)**

**Fig.10. Maximum shear stress $\tau_{max}$ , in kN/m$^2$**
**a) Scalar representation- cross section I-I; b) Roof level +210m - cross section III-III**

a) b)

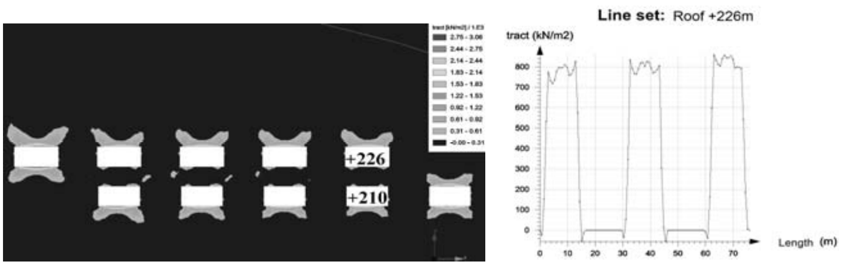



**Fig.11. Tensile stress $\sigma_t$ , in kN/m$^2$**

**a) Scalar representation - cross section IV-IV; b) Roof level +226m - cross section III-III**

## 4. CONCLUSIONS

Especially, because the post-mining use of the underground spaces, from the Ocnele Mari Saline, it was necessary to made a stability analysis of the support structures of the underground excavations.

The stability analysis of the rock salt support structure (ceiling, rooms and pillars), beside other methods of study, was achieved by using the CESAR-LCPC 2D finite element code. The 3D modelling was avoided because of the important required sizes of the models (X=625m; Y=2160m; Z=360m), respectively the necessary magnitude of the computational resources.

The calculus was performed in elasto-plasticity of Mohr-Coulomb without hardening criterion, in the plain strain hypothesis. There were generated four models (one longitudinal cross section and three transversal cross sections). For to simulate the rock salt mining with rooms and square pillars on two mining levels (+226m and +210m), the loading of the models was realised in two geostatic manners: A) with $\sigma_o\lfloor 2\cdot\sigma_{oy},\sigma_{ox}\rfloor$, for ceiling and pillars stability analysis and B) with $\sigma_o\lfloor\sigma_{oy},\sigma_{ox}\rfloor$, for rest of the massive.

The calculus results (stresses and displacements) were compared with the rock salt strength characteristics and there were indicated the possible rooms' and pillars' zones of failures.

Finally, it could be concluded the fact that, in the conditions of the maximum extension of mining activity (in conformity with the mining project), the rooms and pillars are in a good state of stability.

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Scientific Reviewers:
Prof. PhD. Eng. Victor Arad

# 2D AND 3D FINITE ELEMENT MODELLING OF THE JIU VALLEY SUBSIDENCE PHENOMENON

**MARIAN DACIAN*
ONICA ILIE**
COZMA EUGEN****

**Abstract:** *In this paper, it is presented the analysis of the complex deformations of the ground surface, over time, as a consequence of the coal longwall mining in certain mining fields of the Jiu Valley Coal Basin. Also, it is analysed the ground surface subsidence phenomenon using the CESAR-LCPC finite element code. The modelling is made in the elasticity and the elasto-plasticity behaviour hypothesis. The obtained results are compared with the in situ measurements data basis.*

**Key words:** *subsidence, displacement, profile function, finite element method, elasticity, elasto-plasticity*

## 1. GENERALITIES

The Petroşani Hard Coal Basin contains the most important hard coal deposit of Romania, with a balance reserve of about one billion tonnes of coal.

Due to Romanian industry reorganisation, after the year 1990, in conformity with the new demands of the market economy, the coal production of this basin was reduced to about 3.5 million tonnes per year.

From the beginning this coal deposit was split into 16 mining fields, from which following several successive reorganisation and closing stages, only 7 mining fields are left in activity.

The complicated deposit tectonics determines the delimitation in geological blocks of reduced extent (most of them varying between 200 and 300 m) and an equally technical difficulty in mining.

In this coal basin, through the geological research works, there was identified a number of 18 coal seams, of which the most economical importance having the coal seam no.3 (48%) and coal seam no.5 (12%). The sedimentary rocks complex, in which these coal seams are present, consists in rocks deposits which belong to Superior Cretaceous, Neocene and the Quaternary.

* *Student PhD. Eng. University of Petroşani*
** *Prof. PhD. Eng. University of Petroşani*

As the deposit genesis is sedimentary, the most frequent rocks in the basin are: limestones, marls, argillaceous or marly sandstones, conglomerates, etc., their strength ranging between 15–16 MPa up 50–60 MPa, sometimes even more. Mainly, they are rocks of relatively low stability (Oncioiu & Onica, 1999 [2], Onica & Cozma, 2008 [6]).

The subject of this study consists in the underground mining influence analysis on the ground surface of the coal seam no.3 in the case of the Livezeni and Uricani mines. In these cases we have made a numerical modelling of the subsidence phenomenon using the CESAR-LCPC 2D and 3D finite element software.

## 2. SUBSIDENCE ANALYSIS IN THE CASE OF THE COAL SEAM NO.3, BLOCK V, PANEL 1, URICANI MINE

### 2.1. Ground surface deformation monitoring

The ground surface displacement and deformation monitoring under the underground mining influence at the Uricani Mine is achieved by the medium of the monitoring station composed of 10 observation benchmarks (the station length is of 563.6m).

The topographical measurements were three in three months, beginning with October 2007. This monitoring station provides data concerning the ground surface displacements and deformations by consequence of the underground mining of the coal seam no.3, block V, panel 1 (Fig.1).

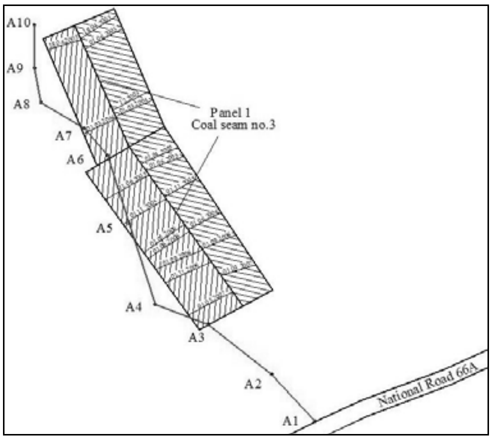



**Fig.1. Monitoring station for the ground surface subsidence at the Uricani Mine**

The mining of the thick and gentle inclined coal seam (of under $10^o$) was achieved with top coal caving longwall mining (with a length of 90m) on the entire seam thickness and on the panel length of 354m. This panel mining began in 2003 and was completed in the second half of the year 2007.

### 2.2. Statistical approximation of the measurements with the aid of the profile functions

Besides the horizontal displacement *U*, in mm, and the horizontal strain $\varepsilon$, in mm/m, other important parameters which define the subsidence basin are: the subsidence or the vertical displacement, *W*, in mm; slope, *T*, in mm/m; curvature, *K*, in $m^{-1}$ (Onica, 2001b [4], Onica et al., 2006 [5]). Thus, the measured subsidence basins were statistically analysed with the aid of a new developed profile function which has the following form (Marian, 2011) [1]:

$$W(x) = a \cdot x^{b} \cdot e^{-c \cdot x} \quad (1)$$

Where: *a*, *b* and *c* are the regression coefficients.

To introduce the time variable into this profile function, the regression operation of the all regression coefficients depending on the time *t*.

Thus, there resulted a new generalized profile function, time dependent, which has the form (Marian, 2011) [1]:

$$W(x,t) = a_1 \cdot t^{a_2} \cdot x^{b_1 \cdot \ln(t) + b_2} \cdot e^{-(c_1 \cdot \ln(t) + c_2) \cdot x} \quad (2)$$

Where: *x* is the distance measured from the limit of the subsidence basin; *t*–time; $a_1 = 2 \cdot 10^{-31}; b_1 = -2.593; c_1 = -0.0074$ ; $a_2 = 12.936; b_2 = 15.365; c_2 = 0.0435$ ($R^2$=0.97) are the regression coefficients of the generalized profile function.

The real subsidence curves, depending on the time, and the results of the time dependent profile function are presented in Figure 2.

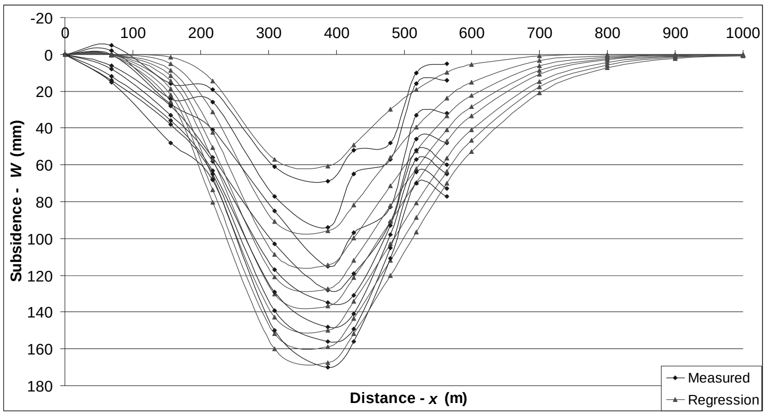



**Fig. 2. Real curves of the ground subsidence and the corresponding profile functions, in the case of the coal seam no.3, block V, panel 1, Uricani Mine**

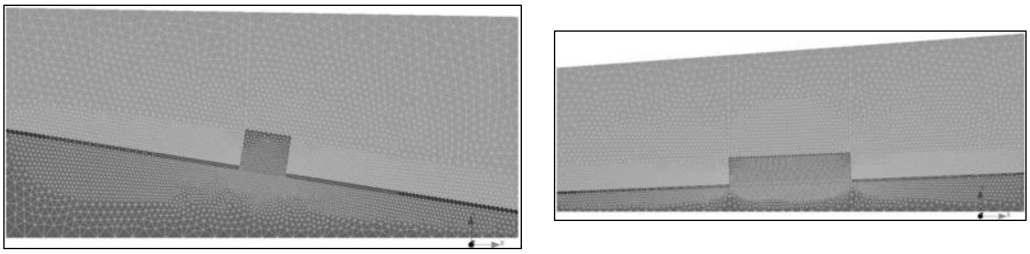
### 2.3. Numerical modelling of the subsidence phenomenon, in the case of the Uricani Mine

2D and 3D modelling achievement, for every previous defined model the following steps were necessary: a) establishment of boundaries, interest zones and meshing of the model; b) determination of zones (regions) and computational hypothesis and the geo-mechanical characteristics input; c) boundaries conditions establishment; d) initial conditions and loading conditions establishment; e) achievement of calculus and stoking of results (Onica, 2001a) [3].

#### 2.3.1. 2D finite element modelling

For to achieve the 2D finite element computational models, the CESAR-LCPC code was used, version 4 (developed by the Roads and Bridges Central Laboratory of Paris).

For to determine the ground surface subsidence and displacement, in the case of the Uricani Mine, two different models were made, in the plane strain hypothesis, namely: the first model following the seam dip (Fig. 3.a), representing a vertical cross-section by the point A6, shown in the Figure 1; the second model, on the seam strike (Fig.3.b), representing a directional cross-section by the middle of the goaf space.



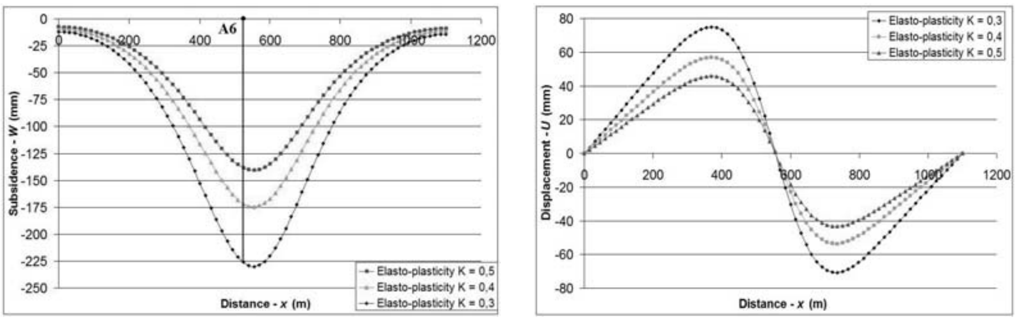
a) b)

**Fig.3. Plane strain numerical modelling of the subsidence phenomenon, in the case of the Uricani Mine: a) dip model; b) strike model**

The calculus was made in the elasto-plastically behaviour hypothesis without hardening, assuming that both the surrounding rocks and the coal seam are continuous, homogeneous and isotropic and geo-mechanical characteristics used in the calculus are the average ones. Also, the caved roof rocks were equated with a very compressible medium with $E$=15 000kN/m$^2$ and $\nu = 0.4$.

The initial loading conditions were considered as geostatic $[\sigma_o]$, corresponding to a depth of about $H$=390m, namely: the vertical geostatic stresses $\sigma_{oy}$=102,4MPa; the horizontal geostatic stresses $\sigma_{ox}$ = 24,6MPa. The corresponding stresses induced by the excavations are $[\sigma_e] = [-102.4; -24.6]$ MPa. Finally, the models' loading was provided in the total stresses: $[\sigma_T] = [\sigma_o] - [\sigma_e]$.

In Figure 4, there are presented the subsidence profiles and horizontal displacement obtained by the "dip model" (for the structural weakness coefficient $K$ = 0.5; 0.4; 0.3), and in Figure 4.b, the curves of the corresponding.




a) b)

**Fig. 4. Subsidence parameters for the finite element "dip model": a) subsidence b) displacement**

From Figure 4, it could be observed that the model closest to reality, is the case of the "strike model" ,calculated in the Mohr-Coulomb elasto-plastic behaviour hypothesis, taking into account a structural weakness coefficient $K$ = 0.4. Also, for to represent the third dimension (the panel width) $\lambda = 0.4$ was introduced, a coefficient for reducing the stresses of mining void $[\sigma_e]$ with about 60%.

The subsidence basin of the numerical model was compared with measured subsidence (Fig.5), resulting an equal maximum subsidence but with certain deviation from the general subsidence profile.

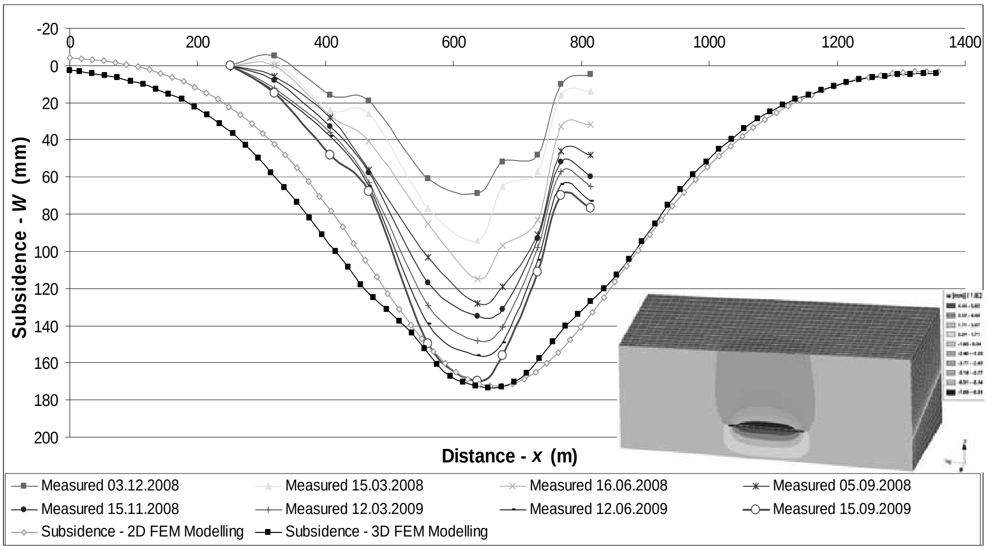



**Fig. 5. Subsidence basin obtained from the numerical modelling compared with the real measured subsidence profiles**

**2.3.2. 3D finite element modelling of the subsidence phenomenon at the Uricani Mine**

As in the previous case, from the Livezeni Mine, for to achieve the 3D analysis of the ground surface stability, affected by the underground mining of thick coal seam no.3, panel 1, block V, at the Uricani Mine, the same computational code was used. Thus, a single model was created, with "mining voids", in the hypothesis of the elastic behaviour of the rock massive.

For a better precision of the calculus the models were made with the sizes of X=1354m, Y=1100m and Z=470m, taking a distance of 500m from the nodel ends to the edge of goaf. The model meshing, respectively of every region, was realized by hexahedral finite elements with linear interpolation (with 48 711 nodes and 44 800 volume elements) – Fig.6.

Also, there were taken into consideration 3 regions with different averages (pondered with every rocks' thickness), corresponding to the roof and floor rocks and the coal seam, for to simplify the 3D model geo-mechanical characteristics.

On the basis of the same arguments, as in the previous modelling cases, the initial loading conditions of the model were geostatic.

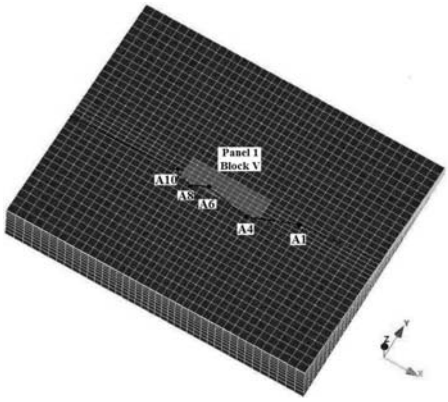



**Fig.6. Monitoring station trail in report to the "mining void" location**

The subsidence basin obtained by the numerical modelling, with 3D finite elements, following the ground surface monitoring station trail (Fig.6) is shown in Figure 5, in comparison with the measured subsidence and the results from the 2D numerical modelling (in the principal profile). Also, in figure 7 is represented the variation of the horizontal displacements after X axis.

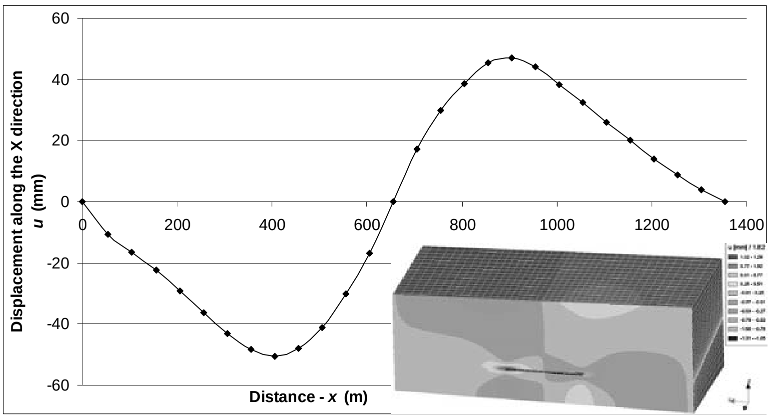



**Fig.7. Horizontal displacements after X axis, obtained from 3D numerical modelling**

## 3. GROUND SURFACE DEFORMATION AS EFFECT OF LONGWALL MINING OF THE COAL SEAM NO. 3 OF THE LIVEZENI MINE

### 3.1. Ground surface deformation monitoring

The subject of this study consists in the underground mining influence analysis on the ground surface of three adjacent mining panels (panel (3-4), panel 5 and panel 6 – Table 1), situated on the coal seam no.3, block VI A, Livezeni Mine. Coal seam no.3, for these panels, was mined in inclined slices (about 2.5m thickness), with the longwall mining system and roof control by caving.

**Table 1** *The average sizes of the mining panel of the coal seam no.3, block VI A, Livezeni Mine*

| Panel | Slices number | Total thickness of mined seam (m) | Longwall face length (m) | Panel extent (m) |
|---|---|---|---|---|
| Panel (3-4) | 4 | 10 | 119 | 346 |
| Panel 5 | 5 | 12.5 | 87 | 440 |
| Panel 6 | 1 | 2.5 | 137 | 362 |

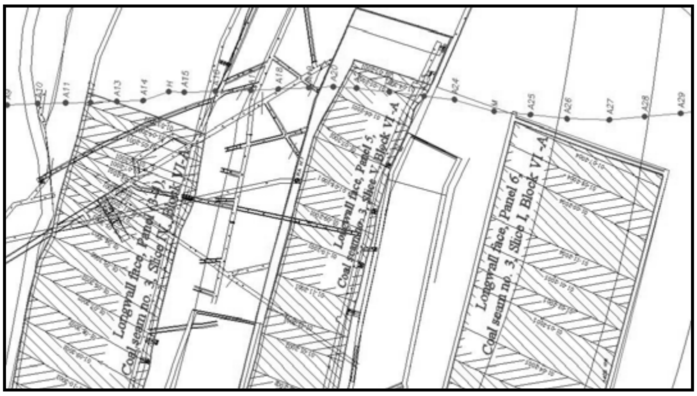



**Fig.8. Monitoring station of ground displacement and deformation of Livezeni Mine**

Now, the monitoring of the ground surface deformation parameters under the underground mining influence at the Livezeni Mine is made using a monitoring (surveying) station that consists in 50 benchmarks. The benchmarks' emplacement is along the access road toward the Parâng Mountains tourist area. The topographical measurements were made every three months, beginning with the year 2001 (Marian, 2011) [1].

The subsidence basin from the Figure 2 is a composed basin, resulted from the superposition influence of the three panels. This subsidence basin has an irregular shape due the fact that the three individual basin are intersected, and also because the monitoring station is situated toward the mining boundaries of the panels (Fig.8).

In the case of this monitoring (surveying) station, the maximum measured subsidence is of $W_{max}$ = 924mm and the horizontal displacement ranges between the value of $U$ = + 3712mm and $U$= - 3625mm. The average of maximum subsidence is $W_{max}$ = 524mm (the reference value in the case of numerical modelling).

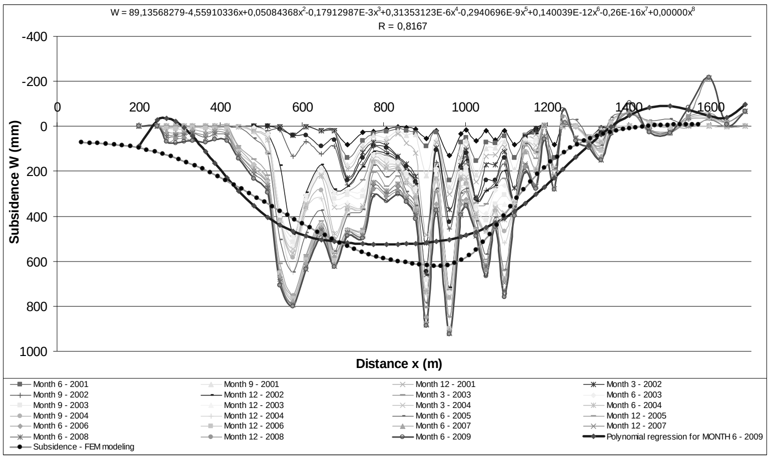



**Fig. 9**. **Subsidence profiles at the Livezeni Mine**

### 3.2. Numerical modelling of the subsidence phenomenon

#### 3.2.1. 2D finite element modelling of the subsidence phenomenon

To determine the displacement and the ground surface deformation in the case of Livezeni Mine, where the ground is affected by the three panels, there were made two different models, in the plane strain hypothesis, namely: 1) the model "with mining voids" resulted as a consequence of underground coal mining; 2) the model "with caved zones" - on a height equal to eight times the mined height - (Fig. 10).

The calculus for these two models was performed in two hypotheses: a) in the elastic behaviour of the rock massive and b) in the Mohr–Coulomb elasto–plastic without hardening behaviour.

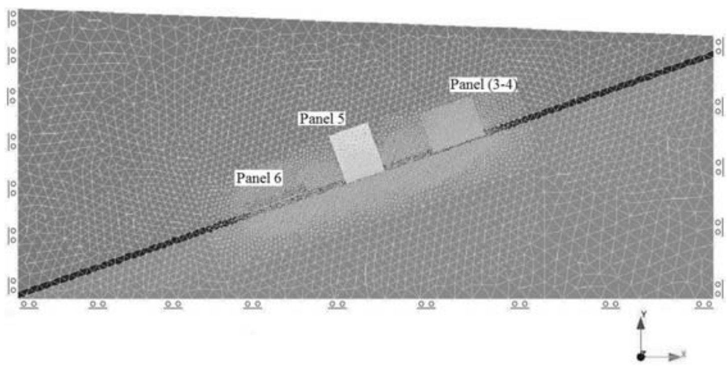



**Fig. 10**. **Finite element model "with caved zones"**

In all of the modelling cases, both rocks and coal seam no.3 were supposed to be continuous, homogenous and isotropic and the natural state of stresses was estimated being geostatic.

For a better precision of the calculus, the models were performed with sizes X=1500m and Y = 690m. Model meshing, respectively of every region, was made by triangle finite elements with quadratic interpolation. Respectively, the model meshing was performed with a total number of nodes of 23 448 and surface elements of 11 661.

In order to make a qualitative description of the models, there were taken into consideration 3 regions with various geo-mechanical characteristics, in the case of the models "with mining voids", respectively 4 regions in the case of the models "with caved zones", adequate at the roof and floor rocks, coal seam and the caved rocks of the goaf (Marian, 2011) [1].

The rocks characteristics, considered to be homogenous and isotropic and taken in the calculus in the elastic behaviour hypothesis, respectively elasto- plastically without hardening behaviour Mohr-Coulomb hypothesis, were reduced successively, taking into account the structural weakness coefficient. The caved rocks of the goaf was considered being a very compressible elastic body, characterized by the elasticity modulus of 5 000kN/m$^2$, Poisson ratio of 0.4 and specific density of 1800kg/m$^3$.

The superior side of the model is considered free and the lateral sides, blocked. Initial loading conditions of the model were considered as geostatic $[\sigma_o]$, corresponding to an average mining depth of $H$=337m, namely: the vertical geostatic stresses $\sigma_{oy} = 87.8$MPa and the horizontal geostatic stresses $\sigma_{ox} = 21.076$MPa. (Onica, 2001a) [3].

The calculus was made taking 60 iterations per increment and a tolerance of 1% of the results, using for the resolution the initial stress method with non-linear behaviour of geo-mechanical problem.

Analyzing the obtained results from the numerical modelling it is observed that the surface basin has a simple shape, different by report to the real basin, because of their emplacement toward the goaf boundaries. In contrary, in the case of FEM modelling, the profile is situated in the middle part of the subsidence basin.

From the previous table it could be observed that, there are very small differences between the models computed in elasticity and the same ones in elasto-plasticity behaviour (the rocks having behaviour to the limits between these). The results more appropriate to the in situ measurement are for the "caved zones" models, in elasto-plasticity behaviour, for a structural weakness coefficient of $K$=0.5.

The subsidence basins obtained from the numerical (FEM) modelling on the model "with mining voids" and on the model "with caving zones", for all that three mining panels, in elasticity and elasto-plasticity, for a structural weakness coefficient of $K$= 0.5 are presented in the Figure 11 and the horizontal displacement curves in the Figure 12 (Marian, 2011) [2].

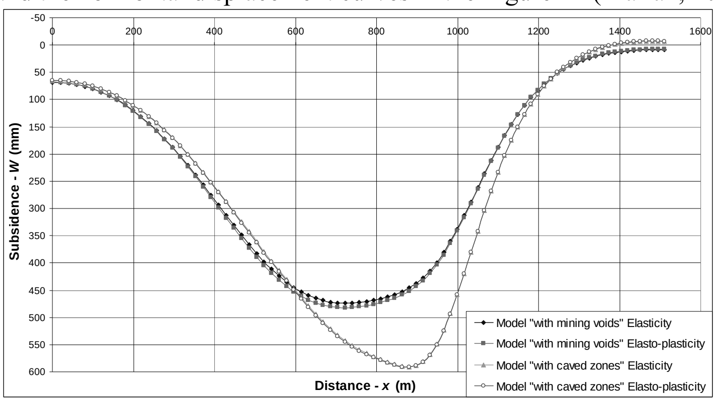



**Fig.11. Subsidence basins obtained from numerical modelling in elasticity and elasto-plasticity rocks behaviour**

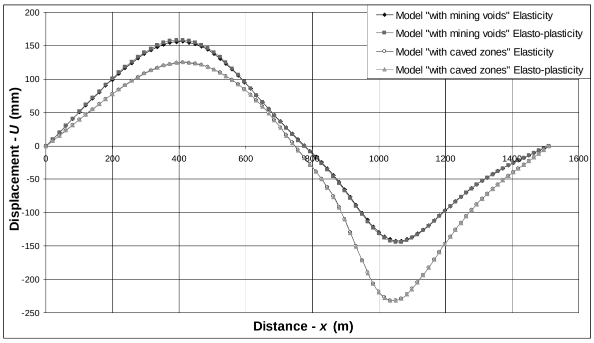



**Fig.12**. **Horizontal displacement graphics obtained from numerical modelling**

From the Figure 11 can be concluded the fact that between the model "with mining voids" and the model "with caved zones" there is a small difference, about of 200mm. Also, between the same type models, computed in elasticity and elasto-plasticity, the difference is very small (negligible).

As a result of the 2D finite element modelling (CESAR-LCPC code), it is observed that the development of the subsidence basin is dynamic -for example, the case of the panel (3-4)-, in function of the various sizes of the panel mining (figure 13- the subsidence curves; figure 14 – the horizontal displacement graphics). It is established that at the maximum size of the mined panel of about 346m (the real panel (3-4) length) the maximum subsidence (critical subsidence) is not reached. The critical subsidence could be achieved at the 1500m panel extension of the mining; over that size, the subsidence becomes supercritical (similarly, for the panels 5 and 6, this distance being 2000m) (Marian, 2011) [1].

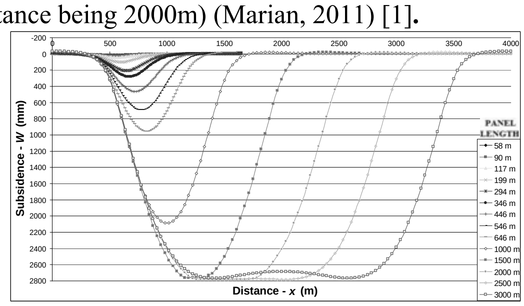



**Fig.13**. **Dynamic subsidence basin (coal seam no.3, panel (3-4), Livezeni Mine)**

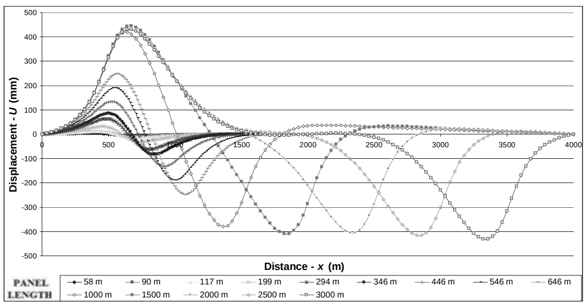



**Fig. 14. Dynamic horizontal displacements (seam no.3, panel (3-4), Livezeni Mine)**

In the Figures 8 and 10 was represented the maximum subsidence depending on the panel (3-4) length. The successive periods of the panel mining are the following: $t$ = 5; 9; 13;

17; 21; 25 months (corresponding for an average face advancement speed about 14m/month) (Marian, 2011) [1].

**3.2.2. 3D numerical modelling of the subsidence phenomenon at the Livezeni Mine**

Because of the important sizes of the model it was necessary to make a simplification. Therefore, there were made the following suppositions: it was considered the coal seam having a constant dip and thickness; the shape of the mining goaf was supposed to be a rectangular one; these three adjacent mining panels were represented as perfectly parallel; the ground surface was generated as a polygonal shape, near the real curvatures, respecting the real monitoring station levels and of the most interesting ground surface points.

From the previous 2D modelling experience resulted the inexistence of significant differences between the results obtained in the "elastic behaviour" hypothesis calculus and the "elasto-plastic behaviour" or between the two types of goaf representations (with the "mining voids" or "caved rocks"). Therefore, because of the 3D model complexity and the big computational resources, required by the elasto–plastically behaviour hypothesis of the rock massive, it was preferred to take into consideration a single model with "mining voids" in the elastic behaviour hypothesis.

The subsidence phenomenon modelling, with 3D finite elements, for the case of the Livezeni Mine, requires completion of the same stages, similarly with the 2D modelling (Onica, 2001a [3]).

For a good approximation of the results the extensive models were made with sizes of about X=1440m, Y=1500m and Z=650m (taking into consideration the distance of 500m, measured from the model ends until the goaf limits, to avoid the model limits' influences on the modelling results). The model meshing, respectively of every region, was achieved by hexahedral elements with linear interpolation, resulting a total number of nodes of 95 611 and 89 244 volume elements (Fig. 15). In figure 15, there are represented only the floor rocks and the coal seam with three "mining voids", corresponding to the mining panels (3-4), 5 and 6.

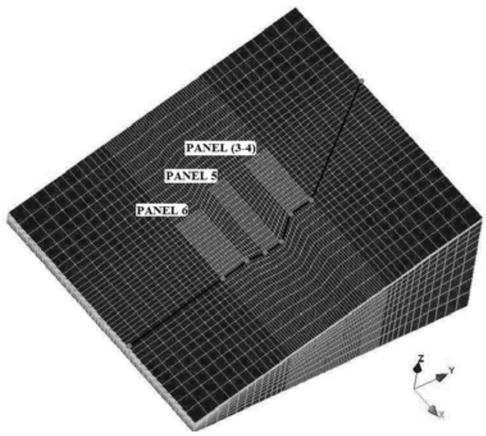



**Fig.15. 3D representation of the floor rocks, of the thick coal seam no. 3 and the "mining voids" (the black line is the monitoring station trail)**

For to simplify the 3D models, were taken into consideration 3 regions with different geo- mechanical characteristics, corresponding to the roof rocks, floor rocks and the coal seam. The rocks and the coal are considered to be homogenous and isotropic and are presented as average values, reduced with a structural weakness coefficient $K = 0.3$.

To impose the limit conditions the surface of the model was considered free and the inferior and lateral sides blocked.

In all cases of the numerical modelling, achieved in this work, the initial conditions of the model loading were considered as geostatic (Onica 2001a; Onica et. al., 2010).

The subsidence basin obtained from the 3D numerical modelling is represented in Figure 16, by report to the measured subsidence, following the monitoring station (Fig.15), and with the one computed in 2D modelling. Also, in Figure 17 is represented the horizontal displacement watching the Y axis (following the monitoring station trail – drawn with black line in Figure 15).

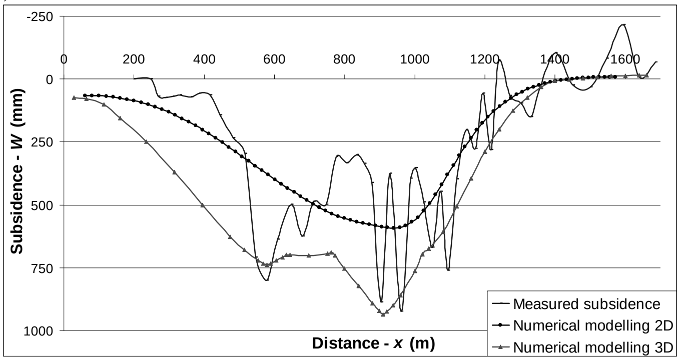



**Fig.16. Subsidence basin obtained from 2D and 3D numerical modelling, by report to the measured subsidence**

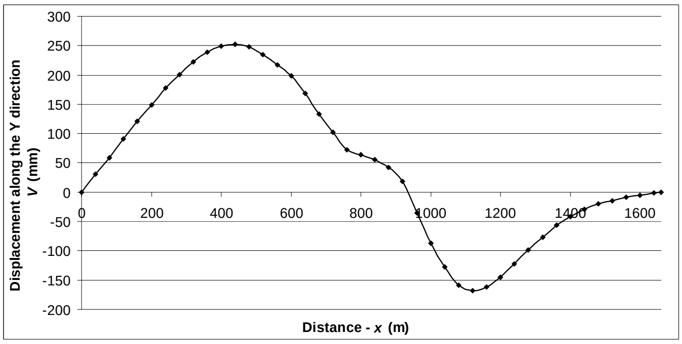



**Fig.17. Horizontal displacement curve after Y axis, obtained from 3D numerical modelling**

In Figure 16, it could be observed that the subsidence basin obtained from numerical modelling with 3D finite elements is much closer to the measured, by report to the 2D numerical modelling subsidence. The explanation is that the 2D numerical modelling subsidence is following the principal profile and the 3D subsidence is along the real measured profile (impossible to represent by 2D finite element modelling). The differences existed between the 3D modelling because of the fact that the subsidence measured at the monitoring station points is affected by a certain horizontal slip, being situated at the goaf limit.

In Figure 18 is represented the horizontal displacements after the X axis, following the monitoring station, or the transversal displacements of the points corresponding to the monitoring station. Also, the scalar representation of the subsidence (Fig.19) and the horizontal displacements, in the principal profile, after Y axis (Fig.20).

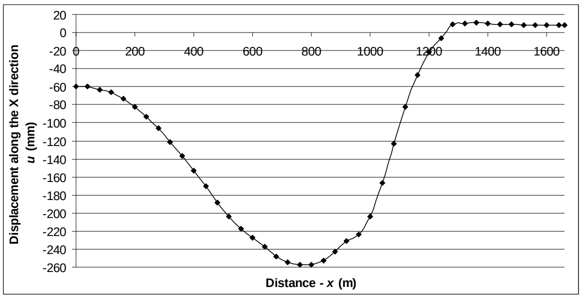



**Fig.18**. **Horizontal displacement curve after X axis, from 3D numerical modelling (according to the monitoring station profile)**

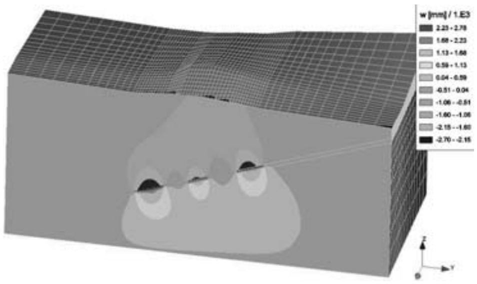


**Fig.19. Scalar representation of the subsidence, following the principal profile (in the centre of the "mining voids")** ***w*****, in mm**

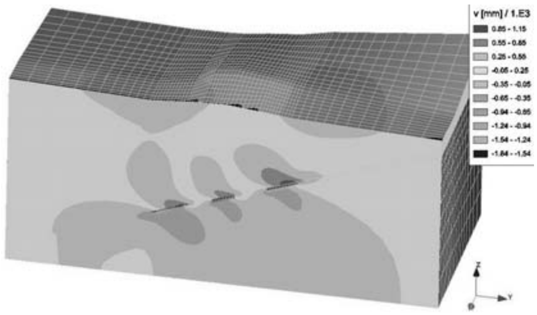


**Fig.20**. **Horizontal displacements in the principal profile after Y axis** ***v*****, in mm**

### 4. CONCLUSIONS

At the same time with the reconsideration of the mining of Jiu Valley hard coal deposit, because of the closing programme of several mines and the beginning of a new panels' mining and the need for the revalorization of the surface lands and the assessment of the constructions' integrity, the requirement of assessment of the ground surface stability has arisen, in the mining fields influence areas.

Therefore, an immediate assessment of the measurements provided over time was tried, in the different Jiu Valley mining fields and the analysis of this data base, stored by the Hard Coal Company of Petroşani (some significant case studies are presented in this paper).

We mention that the data analysis was difficult because the ground surface monitoring was made following the alignments that were not always relevant from a scientific point of view. Over time, the purpose of this monitoring was to observe the stability of certain roads, land areas and other targets of immediate interest.

By consequence, a time dependent profile function was elaborated, which predicts very well the development in time of the subsidence basins produced as an effect of the underground mining of the thick coal seams of the Jiu Valley coal basin. Along with the profile function method, in some case studies, we called upon the numerical modelling with the aid of the 2D plain strain and 3D finite element method. The calculus was made in elasticity and elasto-plasticity with the models “with mining voids” and “with caved zones”. After the sensibility analysis and the fitting of the models, significant results were obtained for the geo-mining conditions of the Jiu Valley coal basin.

The subsidence phenomenon analysis by the profile functions methods, by numerical modelling and other researches tools will be further developed, at the entire coal basin level. These are the prediction and control methods, necessary for the new panels mining design and the measures required to mitigate the degradation phenomenon of the lands situated under the influence areas of the underground mining fields.

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# PROCEDURES AND TECHNIQUES FOR CHECKING THE BEHAVIOR OF MINING CONSTRUCTION EXECUTED IN HARD ROCKS BY NON-DESTRUCTIVE TESTING

**BOYTE ARISTID***
**PREDOIU IONUŢ****

## 1. INTRODUCTION

Development of quality mining engineering is a research activity and an economic concern. Mining construction works to be executed in a mining massive quality, suitable for a particular purpose, related to durability and technical performance, usually provides the most advantageous technical and economic indices.

Sustainability as an attribute of quality construction and economic as well provides, for "final" mining construction, synonyms of the meanings of verb "to last" namely to build and last.

The need for development of some quality mining construction must be strongly impose by disadvantageous consequences in case of failure. The fix of structural elements of the mining massive are very hard to do and very expensive, recovery of the compromise materials is virtually zero and the risk of loss of lives in case of serious accidents (crashes, building collapses) has worst psychological effects and severe social consequences.

The probability of risk for mining construction can be greatly reduced when is reached the desired quality.

This paper analyzes the determinants of their quality construction and modern methods of checking them in the laboratory or in situ.

## 2. DETERMINING THE STATE OF ROCK MASSIF

The physical and mechanical features of rock massif are determined by setting the physical and mechanical characteristics on specimens and standard forms, which can give the more realistic data.

In general, however, the quality of mining work differs from that of specimens made in the laboratory, because of different causes (method of compaction, lack of wall effect, different support conditions). This often makes the resistance determined on specimens to not match with those of the mining work, "in situ" (put into practice).

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* *Prof. PhD. Eng. University of Petroşani*
** *Student PhD. Eng. University of Petroşani*

In addition to knowledge the mining massive resistance in an executed construction element, it is often necessary to determine the elastic and dynamic properties, internal fault rocks, thickness of different layers, density of rocks, the position of cracks, etc.

These measures can be determined using non-destructive testing methods of mining construction. Nondestructive testing are those with which data are obtained on a massive rock properties without disrupting the internal structure.

According to references [7], the non-destructive testing methods of hard rocks, can be classified according to the nature of the test method and test object, as shown in Figure 1.

To obtain more precise information, usually, is used the combined non-destructive methods such as mechanical recoil method and ultrasonic pulse method [6] or the use of non-destructive methods in combination with destructive method by extracting the well core.

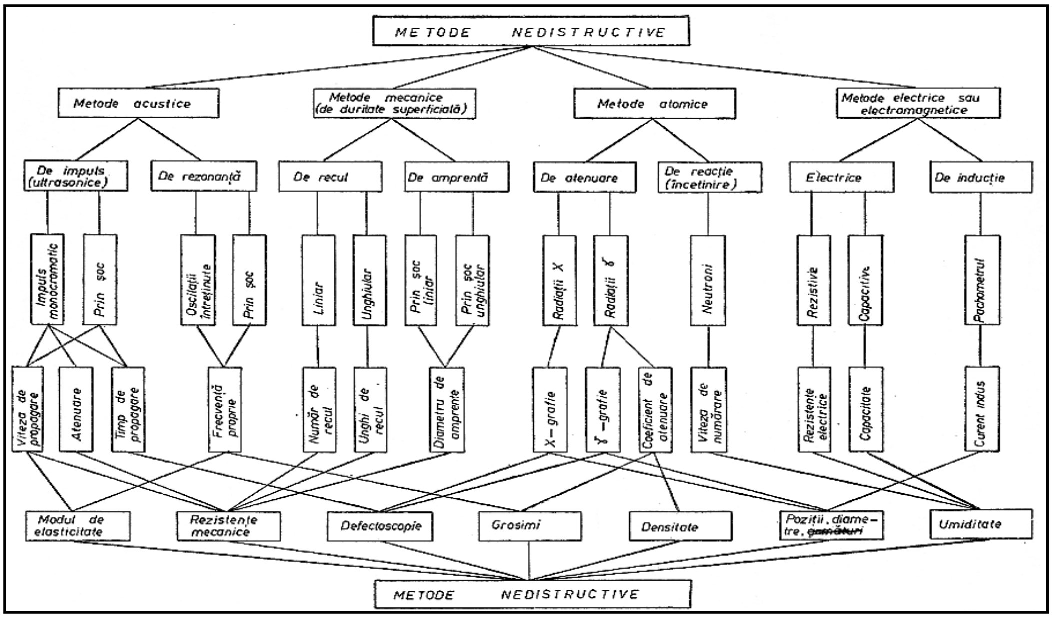


**Figure 1. Classification of non-destructive test methods for rock samples**

### 1.1. Determination of rock's resistance of hard rocks massive. Mechanical methods (slight hardness)

**A. Mark method**

Principle is to design a steel ball ends on a flat surface of a sample of rock with a hammer with a pendulum, or a weight driven by a spring (Figure 2) and then measuring the diameter of the obtained mark. Between the mark diameter and the resistance of rock there is an empirically determined relation.

Mark's diameter is measured using a micrometer magnifier.

Figure 2 shows a cross section through a device (type HPS Gerhard Zorn) using the method of determining the resistance of rock's resistance to the mark method. Diameter of spherical endings is 10 mm.

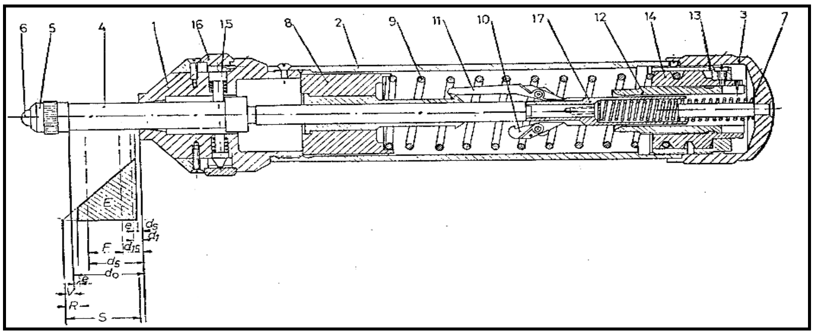


**Figure 2. Device (HPS type Gerhard Zorn) for determination of hard rocks resistance with mark method**

1 - piece end, 2 - carcass, 3 - cove's bonnet, 4 - percussion rod, 5 - fixing sleeve of spherical endings 6, 7 - spring, 8 - hammer, 9 - spring, 10 - short ratchet attachment for Step 1 / 1, 11 - long snap ratchet up 1 / 2, 13 - truncated cone bush , 23 - threaded sleeve, 14 - bush for spring adjustment 9, 15 - pin stop; 16 - segment for switching step, 17 - ratchet support 10 and 11

**Table 1 Resistance of hard rocks depending on the diameter of mark**

| Diameter of mark (d) mm | Step 1/1 | | Step 1/2 | |
|---|---|---|---|---|
| | Medium resistance (Rc) daN/cm2 | Minimum resistance (Rc 90%) daN/cm2 | Medium resistance (Rc) daN/cm2 | Minimum resistance (Rc 90%) daN/cm2 |
| 4,0 | 840 | 697 | 214 | 200 |
| 4,1 | 758 | 625 | 187 | 173 |
| 4,2 | 686 | 562 | 164 | 152 |
| 4,3 | 621 | 504 | 148 | 134 |
| 4,4 | 564 | 455 | 131 | 117 |
| 4,5 | 514 | 411 | 117 | 102 |
| 4,6 | 469 | 373 | 103 | 88 |
| 4,7 | 429 | 339 | 92 | 78 |
| 4,8 | 393 | 308 | 83 | 68 |
| 4,9 | 361 | 280 | 74 | 60 |
| 5,0 | 332 | 255 | 67 | 53 |
| 5,1 | 305 | 232 | 61 | 47 |
| 5,2 | 282 | 212 | 55 | 41 |
| 5,3 | 260 | 192 | 50 | 36 |
| 5,4 | 240 | 175 | 46 | |
| 5,5 | 223 | 160 | 42 | |
| 5,6 | 207 | 144 | | |
| 5,7 | 192 | 130 | | |
| 5,8 | 179 | 118 | | |
| 5,9 | 166 | 106 | | |
| 6,0 | 155 | 96 | | |
| 6,1 | 145 | 87 | | |
| 6,2 | 135 | 78 | | |
| 6,3 | 126 | 70 | | |
| 6,4 | 118 | 63 | | |
| 6,5 | 111 | 56 | | |
| 6,6 | 104 | 49 | | |
| 6,7 | 98 | 44 | | |
| 6,8 | 92 | | | |
| 6,9 | 86 | | | |
| 7,0 | 82 | | | |

The connecting curve shape between mark's diameter and Brinell hardness is shown in Figure 3. Table 1 shows the values of hard rocks resistance depending on the mark's diameter.

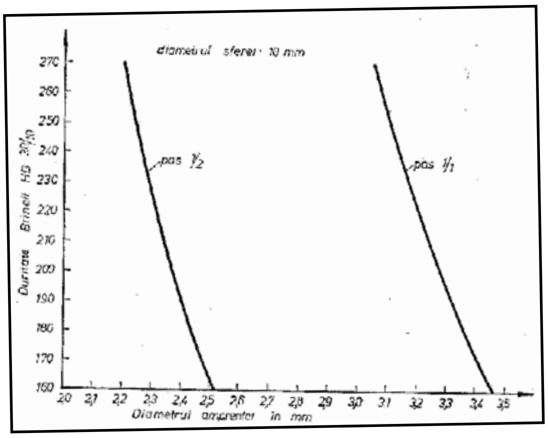

**Figure 3. Calibration diagram of the device HPS Gerhard Zorn**

**B. Rebound method**

The principle of devices operation based on the energy return of a certain body, consists in measuring linear or angular back stroke of a mobile device under the action of a springs system, after its collision with the surface of testing rock.

These devices, generally known as scratch hardness testers have different compositions. A widely used type and in our country as well, is the Schmidt type N scratch hardness tester (Figure 4) whose method of use is given in the technical instructions C 30-67 [8].

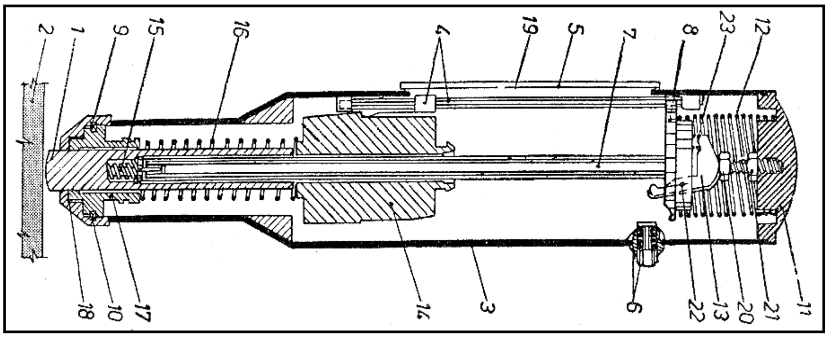

**Figure 4. Scratch hardness tester Schmidt**

1 - percussion rod, 2-plate of rock, 3-aluminum cylinder 4 - he benchmark indicator rod, 5 - scale, 6 - stop lock, 8-guide disc, 9 - back cover of the appliance, 10 - ring from two halves, 11-bed of unit cylinder, 12 - spring pressure, 13-hangers, 14-hammer, 15 -damper spring; 16 - recoil spring, 17 - fixing cartridge, 18 - seal damping, 19 - window with graduations from 10 to 100, 20 - Screw, 21 - nut, 22-pin, 23 – fouling spring.

Schmidt scratch hardness tester is not intended to determine the resistance of thin plates rocks (less than 10 cm) or massive blocks of rocks, which are indicated other types of scratch hardness testers with incident energy, larger (type M). It is not recommended to use such devices to attempt any small or medium-strength rocks (with f <5), for which is used scratch hardness testers with smaller incident energies (such as type L with linear recoil and the type P with recoil angle).

The thickness of rock specimen for which the test results with scratch hardness tester are representative, is about 3 cm from the tested surface.

Test areas will be chosen so that:

- test area does not coincide with the opposite
- specimen made in a laboratory from the test area should be as representative of the entire rock massive in terms of homogeneity and quality;
- include highly requested areas and parts suspected of being unstable;
- made specimen surfaces should be perfectly flat and smooth.

Surface of a test area that determines the quality of rock massive should not exceed 400 $cm^2$ and minimum 100 $cm^2$.

The number of test points needed to establish a single specimen resistance in one area, should correspond to at least five correct measures.

Test points will be chosen so as to avoid areas where are cracks or other structural defects visible on the surface.

During the test, the device must be held perfectly perpendicular to the test surface.

Test results on inclined or horizontal surfaces, turn into results on vertical surfaces, taking into account the angle of the camera to the horizontal (position considered normal).

Determination of rock specimen with scratch hardness tester is based on the relationship between the hardness of the rock surface expressed by the index rebound and its resistance to compression.

For standard norm, the transformation of index rebound in compressive strength is made with the curve, for CT = 1.00.

The calculation of compressive strength for a rock, different from any standard, is made by calculating the unique influence total coefficient (Ct) using the relationship:

$$C_t = C_n C_d C_v C_u C_a$$

Where:

$C_n$ - influence coefficient of the petrographic nature;
$C_d$ - coefficient of petrographic influence;
$C_v$ - influence coefficient of age;
$C_u$ - influence coefficient of rock moisture;
$C_a$ - influence coefficient of petrographic composition of nature.

The values of the Cn, Cd, Cu and Cv coefficients are shown in the tables 4.2., 4.3., 4.4. and 4.5.

Accuracy of the compressive strength by using N-type Schmidt scratch hardness tester is between ± (25-35) % and the test conditions required by the method's technology are known.

If these data are not known, the errors can exceed these limits. Also, in case of very small recoil index (between 10 and 20) the possible maximum error can increase to ± (35-45) %.

Among the main drawbacks of mechanical methods for determining the resistance of rocks, quote:

- the difficulty of accurate measurement of marks;
- rock strength refers only to a superficial layer (about 3 cm thick);
- recording a disturbing dispersion of results due to surface heterogeneity the rock;
- the difficulty of calibration, by establishing a relationship between the diameter of marks or the recoil index and the resistance of tested rock.

**Table 2Influence coefficient of cement type ($c_n$)**

| Type of cement | $c_n$ |
|---|---|
| P 300, P 400, P 500 , M 400 | 1,00 |
| F | 0,87 |

Note: the values from table 3 will be linear interpolated

**Table 3Influence coefficient of petrographic composition**

| $\gamma_v$ kg/m$^3$ | $C_d$ |
|---|---|
| 100 | 0.66 |
| 150 | 0,76 |
| 200 | 0,85 |
| 250 | 0,93 |
| 300 | 1,00 |
| 350 | 1,06 |
| 400 | 1,12 |
| 450 | 1,18 |
| 500 | 1,24 |

**Table 4Influence coefficient of rock age ($C_v$)**

| Age from the first moment of making the specimen | $C_v$ |
|---|---|
| 6-10 days | 1,07 |
| 14-56 days | 1,00 |
| 100-360 days | 0,92 |
| 5 years | 0,80 |
| ≥10 ani | 0,70 |

Note: the values from table 4 will be logarithmic interpolated

**Table 5 Influence coefficient of specimen humidity ($C_u$)**

| The way of storage and cementation of specimen | $C_u$ | |
|---|---|---|
| | For n= 20 | For n= 40 |
| Storage under water | 1,52 | 1,12 |
| Storage according to STAS 1275 (for 28 days) | 1,00 | 1,00 |
| | 0,94 | 0,96 |
| Storage in open-air | 0,82 | 0,84 |
| Tested in stove for minimum 30 days | | |

**Acoustical methods [2, 4]**

**A. Principle of the method**

The ultrasonic testing means those trials that measures the characteristics propagation of some pulses consist in vibration of variable frequency, ranging usually the ultrasonic (elastic oscillation frequency exceeds the limit of audibility of 15-20 kHz). Characteristics can be measured: the time or speed of propagation of longitudinal waves, expansion waves, disk waves, transverse waves, or surface waves and attenuation of ultrasound.

Technical instructions for testing rocks with ultrasound C.26-72 [9], deals only with the tests based on measuring the propagation velocity of longitudinal waves.

With a device, built specifically for this purpose, the travel time $t$ is measured in microseconds necessary for a ultrasonic impulse to travel the distance $I$ in the rock sample.

The $l$ distance traveled by the impulse into the rock, between the transmitter and receiver of the impulse is measured in mm using a scale rule.

Errors of measurement the travel time and distances should not exceed ± 1%.

Longitudinal propagation velocity of ultrasound $V_L$ is calculated by the ratio:

$$V_L = l / t \qquad (1)$$

Where:

$V_L$, - propagation speed (m/s);

l - traveled space (distance) (m);

t - time (s) (the device shows microseconds, that means $10^{-6}$s).

Knowing the longitudinal propagation speed, the rock's resistance to compression can be calculated by a transformation ratio.

**B. Measurement devices**

The devices used for measuring the characteristics of rocks using ultrasound are composed by three distinct parts (Figure 5):

- transmitter with power source;
- receiver;
- device for measuring the travel time and eventually damping vibrations.

Transmitters are power transformers of alternating electric or magnetic field in oscillations of an elastic material medium. They work on the piezoelectric effect and the magnetostrictive effect.

Receivers are the same type of transmitters, but they work by complementary effects through piezoelectric effect and inverse magnetostrictive effect.

The device itself which measure the time propagation works by impulses method and is built generally of the following blocks:

- power source;
- impulse generator;
- receiver amplifier;
- cathode-tube;
- time-clock consisting of: amplifier trigger , time base and timer (device delay).

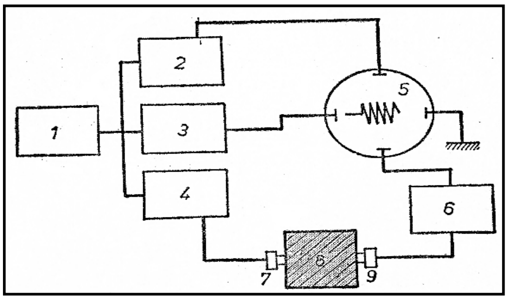


**Figure 5. Circuit of piezoelectric device [1]**

1 - impulse generator; 2 - timer; 3 - time base; 4 - impulse emitter; 5 - cathode-tube; 6 - amplifier; 7 - piezoelectric emitter; 8 - test specimen; 9 - receiver.

Of ultrasound devices currently used in our country we quote:

• dynamic receiver type SBC-4 made by Electro-acoustic laboratories (LEA) in France, can be used in elements of rock and concrete with minimum thickness of 7 cm and maximum 20 m. The measurement accuracy is ± (1-2) %, has five scales of time (80 µs, 100 µs, 2 000 µs, 8 000 µs and 40 000 µs) and adjustable pulse repetition frequency.

• dynamic receiver SBR-2 type, made by LEA (France), can be used in a thickness of 2-3 cm and maximum 1 m. Measuring accuracy is ± 1%, has four time scale (0 µs, 150 µs, 300 µs and 1500 µs) and frequency of pulse repetition: 50 Hz. Characteristic frequency of the piezoelectric transmitter is 100 or 500 kHz.

• RECO elastometer, produced by W. Rentsch Pirna - Copitz (Germany) can be used for the thickness of rocks between 10cm and 2m. Characteristic frequency of the transmitter: 46 kHz and frequency of impulse repetition is variable. Measuring accuracy is ± 1%.

• USME 6 ultrasonic device, made by Günter Krompholz Elektronik in Germany [11] for testing rocks in the frequency range 20 ... 150 kHz. Measuring accuracy is ± 0.1 µs.

The device is equipped with a shooting opportunity of the ultrasonic pulse oscillogram.

**C. The option of test zones and the measurement technique**

To determine the resistance of rocks will choose those areas of mining construction strongly requested that influence the achievement of a state mining construction limit.

The most required elements that must be taken to control with ultrasonic are the stumps (centered compress or low eccentricity) and then stretched elements (centered or eccentric) areas where are not permitted any cracks, inflection elements (tiles, separation floors of the open pits works from underground mining, squares) or compressed with high eccentricity and also the elements which are central or eccentric stretched where is allowed the crack of rock.

The number of test points, to obtain a general view of rock quality, varies between 10 and 20.

Measuring the longitudinal wave speed can be achieved by transparency (in depth) or on the surface.

The measurements of the "transparency" or deep, the transmitter is positioned on one side and the receiver element of the test on the other side, or on the same normal, or delayed at a distance known before (figure 6).

Placing in delayed position is used when the specimen thickness is less than 30 cm, when there is a danger of meeting some structural defects and when is working with magnetostriction devices.

Direction of rods, transmitter and receiver has to be in extension (for the receiver to be inside the beam of waves).

When there is accessible only one side of research element, both the transmitter and receiver are positioned on the same face with an inclination of 20-30° (figure 7).

Such measurements, called "by surface" are made easier using devices whose magnetostrictive transmitter and the receiver is electromechanical (piezoelectric devices have flat surfaces and can not ensure an intimate contact between the tested element and transmitter, or the receiver device).

A special importance should be provided on measuring the distance between transmitter and receiver. Accuracy of measurement must be as large as the distance is smaller.

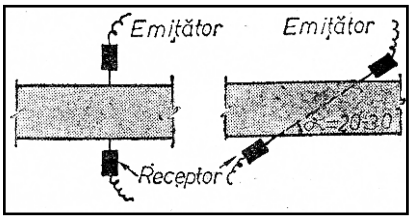


**Figure 6. The display mode for emitter and receiver for “transparency” measurements *(deep)***

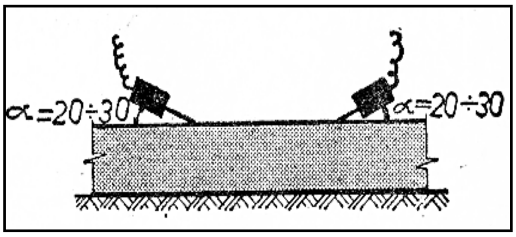


***Figure 7. Measurements ' on surface"***

For testing the rocky rocks, can be produced adverse effects on resistance evaluation, namely:

a) The effect of reinforcement of longitudinal mining beside the test direction can produce errors in determinations up to 100%. It is overcome by avoiding coincidences between test direction and the direction of reinforcement, or by placing away the impulse trajectory from the valve, which satisfies the inequality:

$$a \geq l/7 \quad , \text{cm} \quad (3)$$

where *l* is the distance between the testing points (cm ).

**D. Determination of compressive strength of rocks**

The compressive strength of rocks (**$R_c$**) can be expressed based on longitudinal ultrasound propagation speed v, by an exponential ratio:

$$R_c = a * e^{bv} \quad (4)$$

Where the coefficients *a* (daN/cm2) and *b* (s / km) depend on a series of data that is rock biography (petrographic composition, making specimens, preservation, etc.).

To determine the coefficients *a* and *b* are used the characteristic curve of a "standard" rock. The characteristic curve (equation 4) of the standard rock is represented in Figure 8, corresponding to the value $C_t$ = 1.0

Compressive strength of rocks, different from the "standard", is obtained by calculating the total coefficient ($C_t$) by the ratio:

$$C_t = C_d \, C_c \, C_a \, C_{\emptyset} \, C_g \, C_u \, C_m \, C_p \quad (5)$$

and by using the graphic from figure 8, on the curve of the related value.

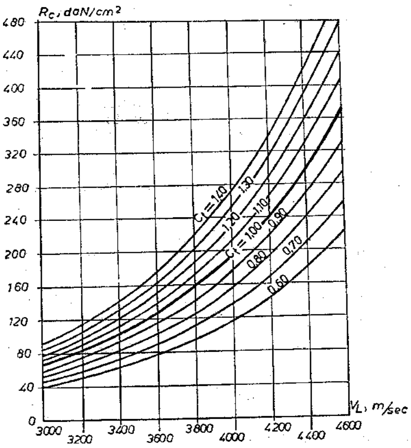


**Figure 8. The transforming curves speed propagation - compressive strength, according to the total influence coefficient Ct**

Values of correction coefficients are given by "Technical Instructions for testing ultrasound rocks." [7].

In case of having cubes to counter, they must be checked by using the obtained equation and in cases of discrepancy shall be adopted as final transformation curve between the results obtained on the median curve and the calculated curve.

Sometimes, to verify the transformation ratio, (ratio 4) are used samples (cores) extracted from the rock to be tested.

**E. Accuracy of determination**

Errors in determining the compressive strength are:

± (15-20) % in case of complete data and real characteristic of rock biography and some cubes of counter that can be checked and eventually corrected, the results obtained by method of influence coefficients;

± (20-30) % in case of full-featured and real data (molding record) but lack of counter test cubes;

± (30-40) % in the absence of the characteristic data and the counter test cubes and their need for replacement by operator experience and verbal information obtained.

### 1.2. The determination of rock internal defects using ultrasound

Following internal defects can be identified: gaps, cracks or defects of some structural depth, frost, and thaw.

Gaps can be highlighted by a sudden variation in delay time read from the device as a result of that impulse, meeting a gap, must avoid it.

Gap size (figure 9) can be determined by the ratio 6:

$$b = l\sqrt{\left(\frac{t_1}{t_0}\right)^2 - 1}\text{ , cm} \quad (6)$$

Where:

$l$ - distance between the testing points (cm);l

$t_1$ - time read on the device for the section gap, $\mu s$;

$t_0$ - the average time read on the device, for the current section of the item without gaps, between points located at the same distance, $\mu s$.

For more accurate determination of shape and size is recommended to use attempts in several directions.

Position and depth of cracks can be determined assuming, as for gaps, that ultrasound impulse avoids the crack on the shortest physical path.

The crack depth, $h_f$ (Figure 10) can be determined by the ratio:

$$h_f = \frac{1}{2}\sqrt{\left(\frac{t_1}{t_0}\right)^2 - 1}$$

The terms have the same meaning as in equation (6).

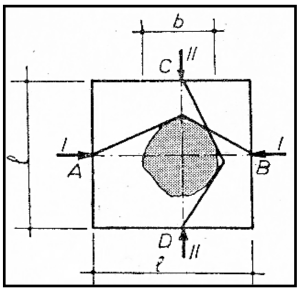

**Figure 9. Diagram of rock's gaps determination**

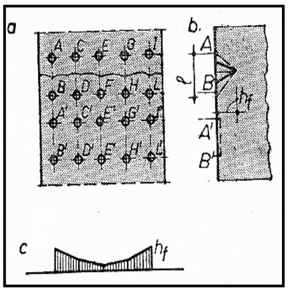

**Figure 10. Diagram of determination the depth of gaps**

a - panoramic view; b - section;
c - variation diagram of the crack's depth

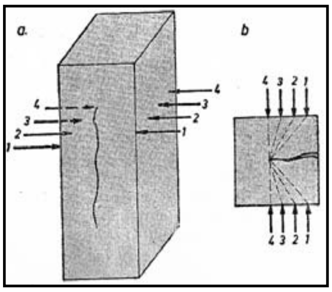

**Figure 11. Determination of depth for cracks to the elements with accessible opposite sides**

a - perspective
b - horizontal section.

Tests should be oriented perpendicular to the direction of cracking and recommended to be made on relatively small distance (20-30 cm) to increase the sensitivity of the method.

If the crack plane is parallel to opposite sides of the available tested element (Figure 11), crack's depth is determined by a successive series of measurements in a plane perpendicular to the crack, from the cracked side to the opposite (from 1 to 4). Crack's depth is given by the distance from the cracked side to the point where the ultrasonic impulse propagates free.

The section of weathered rocks (Figure 12) is determined by ratio:

$$a = \frac{1}{2}\sqrt{\frac{v_2 - v_1}{v_2 + v_1}} \quad (8)$$

where:

a - depth of unaltered rock plate (cm);

$v_2$ - speed propagation in unmodified rock (m / s);

$v_1$ - speed propagation in weathered rock (m / s);

l - distance between the transmitter and receiver (m).

The presented ultrasonic method can be used in combination with gamma-graphic method [5].

### 1.3. Determination of rock density by using γ-rays

γ rays used to determine the density of rock (one of the most important physical and mechanical features of the material) are produced by artificial isotopes (cobalt 60, cesium 137, tantalum 182 or iridium 192). Their wave length is less than X rays, produced at a medium voltage. This is why they have a very high penetration power and can be used to research thick elements. γ ray spectrum is between 0.01 and 1.4 Å (1 Å = $10^{-s}$ cm ).

γ ray intensity is proportional to the amount of radioactive material and is expressed, for radium, in fraction of curie (or weight of radium as appropriate) and for other radioactive substances in equivalent grams. An equivalent gram is equal to γ radiation of a pure gram of radium.

It was observed that passing through a certain body, γ ray flux decreases its intensity. This phenomenon is the base of measuring the rock density.

For the simplest case when using γ rays in parallel monochrome bundles, the interaction with the contact body, can be written as follows:

$$I = I_0 e^{-\mu x} \quad (9)$$

where:

I - flux intensity of γ rays at a x depth of investigated rock;

$I_0$ - intensity of initial radiation;

e - base of natural logs;

μ - linear attenuation coefficient, which represents the variation of intensity of flow radiation passing through a 1 cm thickness body.

Basically, as characteristic of γ ray attenuation it is used the so-called mass coefficient for attenuation, expressed by the ratio:

$$\mu' = \frac{\mu}{\sigma} = const \quad (10)$$

where: γ – unit density of the investigated rock.

In this situation, the ratio (9) will be written:

$$I = I_0 e^{-\mu'(\sigma x)x} \quad (11)$$

where: *(ρx)* – represent the passing mass quantity (also named surface density) measured in gr/$cm^2$.

Graphical representation of equation (11) in a semilogarithmic diagram is a right, regardless of the nature of the researched material.

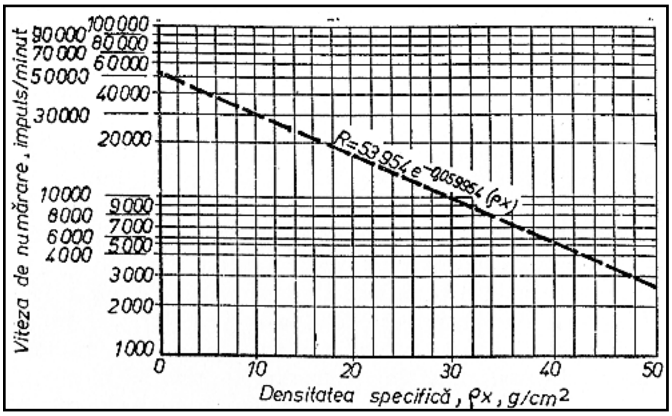


**Figure 13 Graphic representation of the ratio (11), [3]**

For a typical rocky rock, the ratio (11) is represented in diagram of Figure 13, where it was chosen a logarithmic scale for speed of impulses counting and for surface (ρx) a linear scale.

Mass attenuation coefficient for a rock and for most of the construction materials is a constant construction unit, which enables the radiometric method to determine the volumetric density with a maximum error of 1.5 ... 2%.

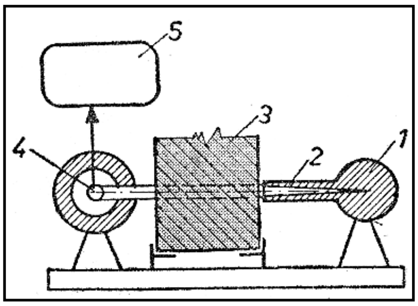


**Figure 14. Radiometric test of rock or concrete [3]**

Schematically, the radiometric test of concrete is shown in Figure 14.

Radioactive source (Co 60) placed in a lead container, emits a γ ray beam directed on the item of rock through a narrow tube (collimator). On the other side of the concrete is also placed in a lead container a Geiger-Müller counter, linked to a particles counter, which determines the counting speed of impulses for the attenuated beam.

Knowing that speed is entered in a diagram like the one shown in Figure 13 and at the intersection with the draw right is established the abscissa (ρx) which then the material density (of rock) results immediately by dividing the x thickness of specimen.

For a determination are required 2-3 minutes.

Besides the "transparency" measurements described above (possible if the two opposite sides of the studied element are available) can be used "surface" measurements. In this case the place of radiation source and meter must be properly protected with lead plates.

Measuring the rocks density with γ rays is practically independent of the mineralogical nature, but can not be used if they are radioactive. This method is used to determine both: position of petrographic composition diameter and identify internal defects of the rock [5].

## 2. CONCLUSIONS

The information of this paper is presented as an extensive documentation from the attached bibliography, which increases the amount of documentary data and the results recorded. The ability of authors proves that they have retained only official documents and information from the indicated references which indicates sources without any doubt. Inevitably, where the data differ, they have indicated all sources which has been used, so as not to register any omission or distortion.

Naturally, in this brief review, we can't write the technical and economical details, even in an example, but to provide an image of the 300 pages of documents from the given period, documentation representing the work of "circulatory system" of an applied documentation - despite the hard times - kept alive a scientific field from the surface and underground mining, in its efforts to overcome the inherited backwardness from the revolution times and registered on line of economical development and technical-scientific progress.

There are a few considerations which recommend the paper not only for those involved in working activities of safely minerals extraction, but also to all those for whom this field is a source of inspiration for their own work and for perennial causes of our country, where we were born, lived and created.

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With this paper, the authors have tried to help the professionals researchers showing the most modern methods of checking the quality of mining construction elements made in rocky rocks, in the spirit of normative acts from our country, but also the accumulated experience over the years in the Lab of Mechanical Rocks from the Faculty of Mines Petroşani - Department of Mining Engineering.

## 3. REFERENCE

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# GEOTECHNICAL RISKS IN STERILE DUMPS CONSTRUCTION AT THE LIGNITE OPEN PITS FROM ROMANIA

**LAZAR MARIA**[*]
**ROTUNJANU ILIE**[*]

## 1. GENERAL CONSIDERATIONS

Oltenia lignite deposits are located in the south-western Romania and they are situated in the structural unit within Subcarpathian Depression, the area between the Danube and Olt Rivers (Figure 1). In the pliocene deposits of this area (dacian, romanian and pleistocene) were highlighted 21 layers of coal, stationed in clay-sandy formations, from which are exploitable strata V - XII.

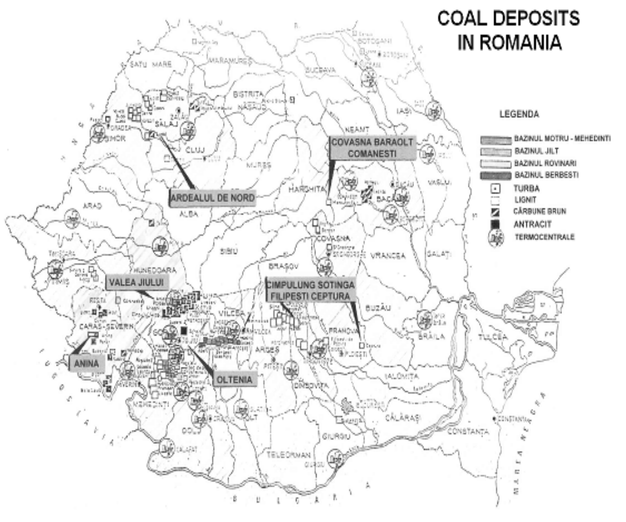


**Figure 1 Coal deposits in Romania**

Current reserves of coal of the deposit amount to approx. 1250 million tons and are subject to exploitation in underground mines and open pits. Since the commencement of exploitation and recovery of lignite deposits in mining basins of Oltenia (1965 - 1967) were extracted over 800 million tons of lignite. Also, from open pits and underground exploitation have been extracted and stored large quantities of sterile rocks, up to over 4800 million $m^3$.

The sterile resulting from operations of lignite exploitation was originally deposited in exterior waste dumps, and as the bottom of the open pits was uncovered in interior waste dumps.

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[*] *Prof. Ph.D. University of Petrosani, Romania*

Deposition of the sterile material is performed with continuous technology, being used for this purpose various types of deposition installations (Figure 2).

**Figure 2 Deposition installation**

Both internal dumps, but especially the external ones face major geotechnical problems such as showing their instability. For external dumps, instability problems have a greater impact, since in their area of influence are some social or of economic interest objectives. The causes of waste dumps instability are linked to their location, stored and foundation rocks nature, building method, geometry and others. In terms of location, they are built on horizontal ground, valleys and on slopes. Of these, the largest geotechnical risks appear for the dumps built in valleys and on slopes.

In terms of nature deposited rocks, it is mentioned that they are a homogeneous mixture. Share of different types of rocks varies quite widely, depending on the deposit's lithology:

- rocks of sandy nature (non-cohesive) - 20-30%;
- rocks of dusty nature (low cohesion) - 7-15%;
- rocks of clayey nature (cohesive rocks) - 55-60%.

Physical and mechanical properties of dumped material vary in very large limits, according to the values presented in Table 1.

**Table 1 Physical-mechanical characteristics of the sterile**

| **Rocks type** | **Specific weight, (daN/cm$^3$)** | **Cohesion, (daN/cm$^2$)** | **Angle of internal friction, ($^o$)** |
|---|---|---|---|
| Clay | 1,8-2,05 | 0,4-0,7 | 23-27 |
| Clay-marl-dust mixture | 1,93-2,14 | 0,3-0,49 | 22 |
| Clay-sand-dust mixture | 1,88-2,05 | 0,37 | 26 |
| Sand-clay mixture | 1,63-1,94 | 0,02-0,06 | 26-29 |

Foundation rocks are represented by argillaceous rocks or unconsolidated alluvial materials, which favors the occurrence of negative geomining phenomena.

In terms of design, the waste dumps are of height (30-100 m) and of great high (over 100 m), built in several steps, sometimes on sloping lands (natural slopes), affected or prone to local sliding phenomena.

## 2. INSTABILITY PHENOMENA FOR THE WASTE DUMPS OF OLTENIA

Over time, many sliding events of the waste dumps occurred, with consequences more or less severe over the environment, over the objectives in their area of influence or on the production activity. Below are two case studies, for a waste dump located outside along a valley, respectively for a waste located on an inner inclined foundation, where landslides have affected the whole deposit.

### 2.1 Rogoazelor Valley waste dump – Rosiuta open pit

He was fired in 1985 and occupies the upper valley of the same name which was mostly covered with forest, which ensured a high degree of stability. Subsequently, forest clearing reduced the slopes degree of stability. In terms of morphology, Rogoazelor Valley was a large valley that yields more streams with permanent or non-permanent water regime.

Under the original draft, dump Rogoazelor Valley was scheduled for a volume of 54.5 million $m^3$ over an area of 189.25 hectares, with a height of 140 m and overall slope angle of 6°. The waste dump was used until 2006, when it was affected by a major land slide and the depositing process was called off. In the period 1995 - 2006, in this waste dump were deposited approx. 51 million $m^3$ in 6-8 steps, with total height of 120 m and the overall slope angle of 4-8°.

Since the start of work until closure, in the waste dump occurred several negative geomining phenomena, including landslides, being listed three of them which set in motion important volumes of sterile, namely:

***Landslide from September 2001*** occurred along the main valley, on a length of approx. 1000 m, affecting 26 ha of the dump's area. The causes of this slide are related to water presence in the dump's body, being identified as routes of ingress of water into landfill: areas where the artificial slopes are linked with natural slopes, springs in the foundation and water accumulation in uneven areas due to rainfall. From the measures taken to reduce the influence of water on the stability, are mentioned:

- channels that work to shape the final isolation for the dump area surface from water inflow from outside;
- works to acquire and transfer of surface water from the upstream to downstream in the in the waste dump;
- work to drain water from interim and final surfaces of the waste dump and for lowering the hydrostatic level of the deposited material (horizontal drains and drainage wells);
- scarifying works to achieve collaboration between the deposited material and foundation material;
- work of leveling and compaction the steps, artificial slopes and final surfaces.

After this landslide, the sterile depositing activities continued at Rogoazelor Valley waste dump, while executing the following works to improve conditions for stability:

- strengthening the area from the bottom of the waste dump by running a spur of land and a support wall built from tube columns with the diameter of 508 mm and a length of 17 m, from which 3 m long represents the extension column from the land surface. Columns were fitted with metal reinforcements and concrete and the extension columns were connected with metal reinforcements and concrete forming a support wall with a length of 60 m. In the supporting wall at 2 m inside the waste dump was executed and a protective barrier, consisting of boxes filled with ballast;
- execution of six wells, for hydro observations, water level monitoring in the dump's body and its removal by suction;
- systematic leveling of the deposition and respecting geometrical design were also ensured.

***Landslide from May 2004***, had a smaller scale than in 2001, affecting approx. 9.5 hectares of the dump's area. Effects of the landslides were removed by works of remodeling the dump's geometry using classic machines. Causes that were related to landslide were the mitigation of geotechnical characteristics of the deposited rocks, under the influence of water. Six wells for hydro observations were also executed for monitoring water levels in the dump's body. Until producing the next slide, no deformations were noted that could indicate other phenomena of instability (cracks, crevices, diving, drilling movements).

***Landslide from February 2006*** occurred in the conditions of heavy rainfall for a long period (the maximum of 56 l/m$^2$ 24 h). As a result, there was a major landslide determined by the separation of the sudden step +350, affecting an area of 17.6 hectares (Figure 3). Immediately after sliding, there was an effort to stop it by planning interventions with conventional machines, but heavy rainfall did not allow the work involved, so that rain water infiltrated into the dump's body following the path of the fissures and cracks formed, and accelerated slide speed to tens of meters per day, in the valley direction. Heap movement continued in April, when it was reactivated the slide from September 2001 and in early May it was beyond the supporting wall of the waste dump, so it destroyed and blocked a highway (National Road 67). Glide was extended approx. 600 m wide and 2200 m long, and bearing the affected area is currently approximately 75 hectares. Given the volume of material entrained by the difference between detachment rate and the rate of expansion, surface appearance and position of detachment, it was considered the sliding surface affected the foundation of the waste dump. For improving the stability of the dump, in the area downstream smoothing works were executed and were built drainage systems to drain water outside the perimeter of the waste dump. In the middle were performed other wells for hydro observation and it was found a very high level of groundwater, even up to the terrain level. These large landslides led to the stopping of the depositing activities, they will be resumed only after strengthening the dumped rocks.

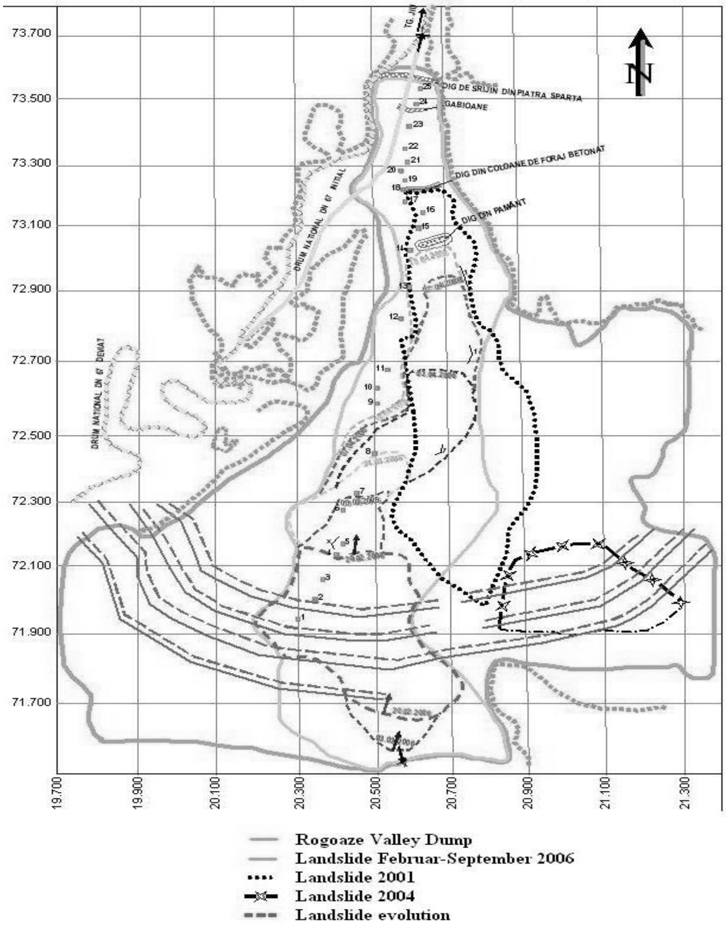


**Figure 3 Landslides in Rogoazelor Valley waste dump**

### 2.2 Olteţu open pit's interior waste dump

Waste dump from Olteţu open pit stores a volume of sterile of approx. 45 million m$^3$ and is constructed in two steps, each 15 meters in height and slope angles of 30 - 40º, against an overall 5 - 6º. Advancing heap is by inclination, from north to south, on the bottom of the open pit. The deposit construction technology is in continuous flow, using for this purpose an A2RsB4400x95 overhanging arm type of installation.

Instability phenomena partial landslides occurred along the depositing front and a large landslide (2005), which covered almost the entire waste dump. Based on field observations and geotechnical research, the research team rated the landslide of the interior waste deposit from Olteţu open pit in a progressive sliding type, the stage extended from the upper strip to the lower one, continued to the contact with bottom plane of the open pit. At the bottom was manifested as a plastic flow (Figure 4), affecting the coal mining front. The presence of multiple fracture zones in sliding material shows that there have been multiple rotational landslides converged on the plane of contact.

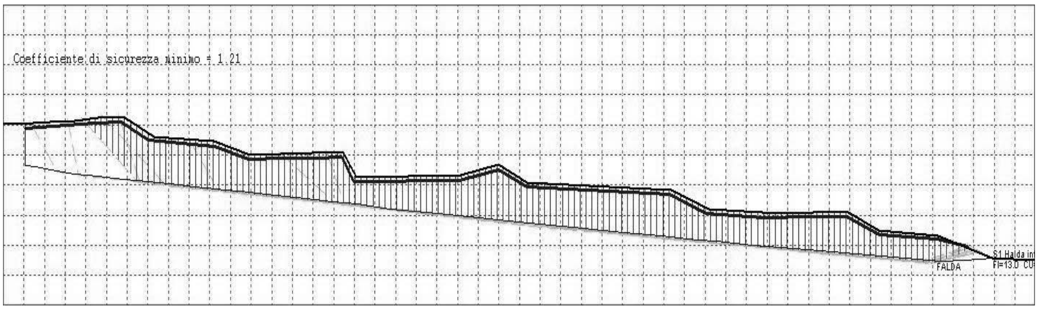


**Figure 4 Plastic flow of the interior waste dump of Oltetu open pit**

Among the causes of this slide are stated: advancing the waste dump along the slope without the construction of linking steps and drain water collection and guidance systems, altering the characteristics of landfill material liquefaction resistance at contact area, infiltration of rain water in the dump's body and others.

From the measures taken to stabilize the dump are mentioned: remodeling the waste dump geometry and execution of linking steps in each extraction entrance (depositing strip), execution of drains on the foundation filled with ballast on the exploitation front direction, partially leveling and compacting the waste dump.

## 3. CAUSES FOR THE INSTABILITY OF THE WASTE DUMPS IN OLTENIA AND PREVENTION MEASURES

From analysis to investigate sliding mentioned and other landslides present in coal pits can highlight the causes for the waste dumps instability and can be identified their main prevention measures.

Thus, we identified three main causes of landslides.

### 3.1 Geotechnical causes

- improper locations as dumps are built on land unsuitable in many cases, namely along valleys with or without water in foundation and slopes of 10-15º or on slopes that are sometimes affected by superficial landslides;
- land of the foundation consists of unconsolidated alluvial materials that favor compaction the occurrence of profound landslides;
- existence of clayey rocks on the bottom of the open pit;

- nature of deposited rocks, predominantly clayey (55-60%), clay-sandy (20-30%) and clay-dusty (7-15%), with high plasticity ($I_p$> 25%), in high humidity conditions (s > 0.8) and small consistence ($I_c$ <0.75);
- reduce permeability and heterogeneity of the dumped material, which does not allow elimination of water from the dumps body and rock consolidation;
- improper drainage and rock heterogeneity favors the manifestation of hydrostatic pressures in certain areas, which leads to different behavior of rocks in terms of effort resistance and the development of areas sensible to plastic slack which in turns leads to the deformation of the waste dump.

### 3.2 Hydrogeological and hydrotechnical causes

- high phreatic groundwater level, with a weak ascending behavior;
- existence of underground water sources that flow on the natural slopes and infiltrates in the waste dumps;
- absence of water collection and drainage works on slopes;
- non-execution or partial works of drainage in the waste dumps and occurrence of water pressure in rocks pores;
- modification of geotechnical characteristics of rocks under the influence of hydro meteorological and climatic factors.

### 3.3 Technological causes

- non-execution of linking steps between the natural and artificial slopes;
- non-execution of scarifying works on the natural terrain and lack of vegetal soil removal;
- descendent deposition of the dumped sterile material in external waste dumps, which does not allow consolidation of the bottom steps, allowing plastic deformations and the initiation of partial landslides in the dump’s the body when the slope angle increases;
- absence of compaction and leveling works for the waste dump’s steps in order to reduce water infiltration and uneven compaction of the dump’s body;
- incorporation of soft plastic clayey rocks and in some cases the existence of accumulating water areas during heavy rainfall periods;
- foundation sinking in the presence of any underground mining activities;
- overcoming the stability angles of rocks by overloading the waste dumps or by increasing the steps height.

### 3.4 Measures to prevent landslides

Preventive and avoidance measures against landslides focuses on diminishing or canceling the affecting factors on the stability of waste dumps slopes and steps, of the overall stability and eliminating the causes specified. Some measures aim the foundation material and others the waste dumps.

Measurements for the waste dump’s foundation:

➢ *for dumps located on the slopes or valleys:*

- clearance of areas with active landslides;
- linking steps for foundation slopes greater than 10 °, tilted by 2 - to 3° on the depositing space, corresponding to each entering (depositing strip);

- performance of hydraulic works in the dump's foundation, located along the valleys, to collect and transfer water outside the waste dump;
- drainage performance under the deposits, for directing infiltrate water to the base hydraulic works;
- excavation and removal of superficial layers of rock or unconsolidated clay, to avoid repressions and plastic disposals;
- upward storage to ensure consolidation of rocks from lower steps, in order to be able to build superior steps.

➢ *for internal dumps:*

- removal of clay material with a tendency to slip or plastic failure from the bottom of the pits;
- drainage performance under the waste dumps by filling old water management channels with ballast, which ensures on the one hand, water draining from the dump, and secondly, increased coefficient of friction between the dumped rocks and the foundation;
- scarifying the bottom of the open pits for inclination greater than or equal to 10°, for better collaboration between the foundation material and the dumped rocks. Scarification will be made perpendicular to the direction of advancement of the waste dump's steps;
- respecting waste dump's geometry and the gap between steps;
- planning the depositing programs in accordance with the excavation programs.

The measures aimed waste dumps will be of design and its maintenance. As measures of constructive design are stated:

- respecting the geometry of the steps and the gap between them;
- compliance with the depositing technology by uniform deposition of the rocks in the dump;
- avoid sorting material and accumulating of clayey material at the base of the steps by directing the submission and the height of filing and providing reduced thickness of turnings on rock excavation;
- avoid forming depression areas in the depositing and leveling processes, after the exploitation front advances;
- execution of compaction work of the deposited material to improve its strength characteristics and in order to reduce water infiltration into waste dumps;
- providing a drainage slope of 2-3 ‰ to collecting canals or to pump stations;
- in situations where it is possible to make a drainage layer at the base of the dump by selective extraction of granular rocks.

## 4. CONCLUSIONS

Waste dumps, as engineering construction, claims since the design phase geotechnical studies on the site and geotechnical and hydrogeological features of the foundation rocks, surface water and groundwater regime of the site, ground stability conditions of foundation engineering works necessary in order to improve the stability, geometric and constructive parameters of the waste dump, the conditions of stability and risk factors that occur during operations. During construction and before passing in conservation or reentering in the economic cycle, studies are needed to assess their stability and measures to prevent instability phenomena.

Highlighting the causes and the measures to eliminate the instability phenomena and stability insurance of coal open pits waste dumps in Romania offers the possibility to adopt such measures and for other open pits with similar conditions.

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# SOLUTIONS TO PROTECT THE EMPTY INTERIOR SLOPES DUMPS WITH REMAINING GAP FILLED WITH WATER

VULPE VIOREL*

**Abstract**: *This article examines the possibilities of protecting the empty interior slopes dumps with remaining gap filled with water.*

**Keywords**: *protection works, building works, reinforcement, Geotextiles, geosynthetic materials, geogrids, ballast cushion, grassing, and submersed slopes*.

## 1. GENERAL

Mining industry contributes greatly to intensive pollution of environmental factors (water - air - ground), so the quantities of waste, and by their diversity.

Some economic units from the mining industry, having the aim of extracting useful minerals through open mining works, in the near future will reach its limits of operating perimeters and therefore will be exhausted its exploitable reserves of useful mineral substances.

With the depletion of this reserve, into the mining perimeter, we find two distinct areas to be rehabilitated:

- a first area where, during the process of extracting mineral substance, was deposited the sterile forming internal dump usually occupying surfaces that can reach up to hundreds of hectares (*the open pits from Rovinari coal basin, Jilt, Motru, Berbesti, etc.*);
- a second area, which lies between the sterile deposit (internal dump) and the marginal slopes of the mining exploitation, called the remaining gap in the literature.

The remaining gap can be used as:

- sterile rocks deposit for other mining perimeters;
- deposit for garbage or toxic substances;
- ash deposit resulting from burning coal in power plants;
- water accumulation, etc.

The first measure to be taken when using the remaining gap is constructive in nature depending on its destination and will focus on eliminating the possibility of producing negative geomining effects that may arise as a result of slope instability.

A second measure is related to the protection and enhancement of the slopes, and in this respect, it is necessary to know the specific works depending on their classification.

* *PhD. Eng. – S.N.L.O. S.A. Tg-Jiu, E.C. Roşia*

## 2. CLASSIFICATION OF SLOPES BUILDING AND PROTECTION WORKS

Classification of slopes building and protection works can be based on:

- lifetime:
  - permanent;
  - temporary;
- nature of used materials:
  - well - compacted clay soil;
  - plantation crops (bushes or trees);
  - humus, becoming overgrown with grass from furrows or sown with perennial grass.
  - gravel pit and open pit products (sand, gravel, ballast, river rocks, crushed stone or rough stone);
  - broken concrete recovered from the dismantling of the buildings and the social precincts concrete platforms of mines or open pits, or by decommissioning of access roads resulting from demolition of rural settlements, roads, etc.;
  - pre fabricated elements of usual and reinforced concrete;
  - mattres of geo composites materials;
  - wood in stick shape and trellis;
  - gauze wire (gabions);
- water course;
  - against waves;
  - against surface waters.
- slopes type:
  - slopes in situ resulting from mining exploitation of a mineral substance;
  - internal dump slopes, resulting from deposition of sterile rocks into exploited area;
- the works scope:
  - continuous or discontinuous local consolidations;
  - consolidations of waste dump benches slopes or of an open pits.

Conducting field and laboratory studies is the first step in designing of building or defense work for slopes and consists of:

- terrain recognition not only for topics completion of the land issues but also for an initial assessment of natural conditions;
- topographic studies consisting of plans and profiles at the appropriate scale for design stage to convey clearly enough the real configuration of the land;
- geotechnical studies made both on work-based exploration and laboratory;
- hydrological and climate studies.

Geotechnical study gives the possibility of knowing the physical and mechanical rocks features and with its help can be determined the benches geometric elements and that work to ensure the desired stability factor.

Hydrological and climate studies are necessary to be able to determine the level of water variation in the artificial lake created in the remaining gap, which can reach very large areas (tens or even hundreds of hectares). They will draw on the basis of repeated measurements in different phases of the natural regime of precipitation and annual average values of temperature during warm and cold seasons for a period of at least 10 years.

Also there will be bulletins of chemical analysis for groundwater, ground and earth to check their level of aggressiveness on the proposed construction.

## 3. THE BASIC PRINCIPLES OF DESIGN SLOPE CONSOLIDATION

Although in the literature is a great variety of composition ways for these works and a wide variety of materials which are included in them, to establish constructive solution for each case must necessarily follow a few basic rules.

These rules refer to:

- *assurance of reinforcement stability;*
- *phasing of work achievement (in some cases);*
- *usually not affected the natural state of a stable slope at the time of execution of work, especially when it is preventive;*
- *environmental protection and conservation.*

***Assurance of reinforcement stability is a fundamental principle of any construction***.

Conceived and designed to ensure slope stability, a work of this kind cannot act as if its stability can be affected by water, slope movement and separation floes having caught in their mass and building elements. This latter danger arises especially in case of dry consolidation, with boulders and rough stone.

In case of the hilly slopes, with slope gradients greater than that building work is settled only by friction with the earth itself, by design is imposed to provide measures to strengthen the attachment. They consist of anchoring the work by various means in stable ground and/or by reducing through excavation strictly necessary of the slope declivity. Another method of ensuring stability is anticipation at the bottom of consolidation with constructions able to support the upper part.

To avoid the occurrence of erosion behind the building should be taken protection measures against stream water, in the upper part of the slope, which is not covered by building.

These measures usually consist of a grassing, or consolidation of headpiece in a more easily system such as concrete slabs, broken stone pitching of 10-15 cm, a drainage layer of 5-10 cm, etc.

***Phasing of work achievement****.* The works to strengthen slopes can be considered as a therapeutic of negative influence on which water has on their stability, they will mostly eliminate the effects and causes of slope instability producing.

If, through geotechnical studies cannot satisfactorily elucidate and quantify both the causes and effects of slope instability generating phenomena, it is recommended the phasing of works based on assumptions on the unknown elements.

The phasing consists in taking at a first step of some solutions to resolve assumptions with highest degree of probability, following subsequently the works to expand or be completed until the final solution. The extension works will be conceived only after establishing the first stage of work efficiency and the influence they have on the general system of drainage.

It emphasizes the need to remove the causes of challenging particularly destructive action of water.

***Not affected the natural state of a stable slope.***

The principle is achieved through the consolidation of a stable slope, no runs other excavations nor slope or close to its foot.

These preventive measures are necessary to avoid the formation of sliding surfaces in the massive ground (flat or cylindrical).

***Environmental protection and conservation.***

Through design will be provided measures and recommendations addressed to both the performer and the user work for environmental protection.

These recommendations underline the following:

- restore land of work to its original state through waste disposal, grading and levelling topsoil thickness at least equal to the original;
- removal of land infested with various polluting materials (petroleum, chemicals, various wastes, etc.)
- the usage not only during work execution both also for implementation, maintenance and repairs works, only materials that do not cause environmental pollution.

### 4. Basic factors in the choice of building constructive scheme.

The establish of constructive solution is the first stage of designation for defence works or building of a slope.

Designation of defending works conceived preventive, as well as the consolidation works for a damaged slope, due water action or from other reasons will follow the principles and design solution will be determined according to the following basic factors of consolidation slope design:

- *terrain profile;*
- *geological structure of terrain;*
- *type of predominant request;*
- *functional goal for which consolidation will be achieved;*
- *conditions of performance with the highest probability (under water or on land);*
- *sorts of material used/available in the area;*
- *the final or temporary character of works;*
- *possibility of an ice bridge formation which operate against slope.*

It further shows how the above factors may influence protection solution.

Through protection and consolidation works it is recommended not to bring significant changes in slope configuration for the new work have only a passive character beside hydraulic created by water.

For this, the solution adopted must be designed so as to keep the general form as constant throughout the work, although in different cross sections, some elements may have different sizes (especially vertically). Important is that the outer surface of the building to be as uniform slope enrolling in the plan.

Geological structure of the land in which the slope is achieved imposes the precinct measures for general stability of whole work according to the revealed geotechnical characteristics of the study. Nature of the soil, depending on size distribution and geological structure data indicate danger under pressure phreatic layer.

The type of predominant request imposes the choice of clothing type should be taken. If the water level has important variations is it possible that value, direction and type of request to vary from one level to another. In this case, the consolidation will be made for each situation, but choosing a single solution covering all cases or, in case of large variations in level, measuring consolidation each level.

The functional purpose of the work decides anticipation or not of constituent elements (layers draining, sealing, concrete walls for breaking waves, etc.).

The conditions of performance of the work must be assessed in the following ways:

a. The access conditions at the site of the construction and transport machinery may limit the weight of some construction elements to values allowing the transport or handling their location manually.

b. Possibility of heavy construction elements storage in incidence of technical equipment execution.

c. It is advisable to perform works under the conditions of low water levels.

The local availability of supply materials to carry out building works must be taken when calculating the economic efficiency, without however to have a decisive role in choosing constructive solution.

The final or temporary character is crucial in establishing constructive work.

Permanent work shall be based on technical-economic optimum standards and is it carry out generally in terms of best conditions of execution.

When is setting constructive solution and put into practice the choice of materials will take into account not only the conservation state of the environment at that time, but as far as possible its improvement.

In the case of water reservoirs in which has formed or follow to form an underwater fauna and flora will avoid the use of materials that may cause water pollution incompatible with the existence of this biogenic. The same recommendation is valid for slopes that are under water during the reproduction periods of ichthyofauna.

## 5. THE CONSTRUCTIVE COMPOSITION OF SUBMERSED SLOPES CONSOLIDATION

In the composition of slope consolidation differ more constructive parts, each with a clearly defined role and is composed of different materials. In this respect will generally be show the role and structure of these elements.

The drainage/filter layer usually runs on all over consolidated surface.

This layer serves to prevent the earth suffosion forming the slope itself or by its involvement arising from slope waters.

The filter/drainage layer is incorporates the successive layers of sand and gravel ballast, the geo textile - single-layer or double layer.

The support layer of clothing or substrate components of building land is to pass through a distribution as uniform the loads from building construction. This layer prevents, for instance, such crude stone or boulders sinking of clothing or spur, the slimy ground or low consistency and provides their stability of the ground roll to the slope.

For slope areas under permanent minimum levels, this layer is made by:

- fascine mats ballasted with broken stone or boulders;
- fascine mattresses ballasted with broken stone or boulders;
- reinforced and multilayer geo textile mattresses ballasted with 15 to 20 cm crushed stone ballast;
- geo grid ballasted with 15 to 20 cm crushed stone or coarse ballast.

For the slope areas that can run in a dry system, the role of this layer can be taken over by layer filter/drainage, made of ballast products, especially in case of pitching.

Clothing or protective layer of the slope is designed to protect against erosion caused by water current, waves and ice. Can be usually made of embroidered or unembroidered pitching from stone, river rocks, concrete slabs or precast concrete poured in place, geo grid filled with clay, etc.. For a good settlement of components is required laying a layer of ballast products/career, if constructive composition layers were not provided for draining or geo textile or geo grid ballast.

## 6. CONSOLIDATION SOLUTIONS AND SLOPES PROTECTION.

The soil reinforcement with geo synthetic materials is a construction method with good results. The technological progress has led to geo synthetic materials that provide technical solutions with a high degree of long-term safety. Today geo grid soil reinforcement is considered in geotechnical engineering a safe and economical method.

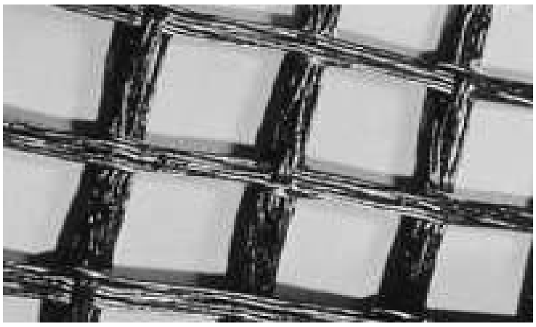
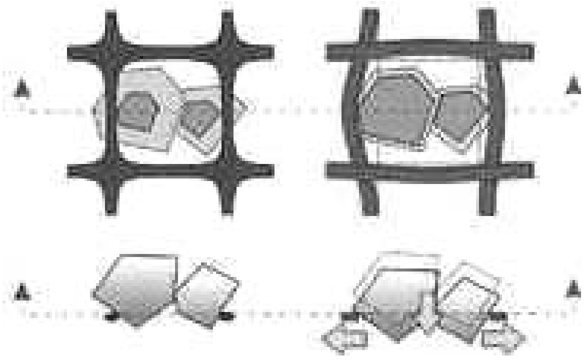


**Photo no. 1. Geogrid polyester fiber**

Geo grid polyester fiber of high strength (photo no.1) are very effective. They are characterized by a high tensile and good behaviour to the handover of slow flow (creep).

This makes geo grid the ideal solution from economic and safety in mining point of view, where are loose ground must reinforcement ballast pillows.

Geo grid is made of high strength polyester fiber that gives great flexibility - compared with extruded geo grid, which are very rigid. Geo grid provides not only better handling but also a better interpenetration (interlocking) with granular material. This happens because the geo grid can adapt more easily to soil irregularities, resulting in optimum composite geo grid system/ground.



a b

**Photo no. 2. Type of geo grid to collect**

a - inappropriate interpenetration to the geo grid with rigid knots;

b - optimum overlap with geo grid, very good resistance, increase stability factor.

The polyester geo grid are recommended for reinforcement of low slope founded on land. Can be used the spatial geo grid filled with clay.

Among the benefits can be mentioned:

- cheap alternative solution beside conventional retaining walls;
- quick and easy installation;
- ensure good long-term performance due to good behaviour to the handover of slow flow (creep);
- uses material from the site (where is applicable);
- flexible geo grid structure ensures optimum interpenetration of granular material (interlocking).

Can be used closing systems by grassing, (photo no.3), especially for marginal slopes and open pit face slope.

**Photo no.3 Closing systems by grassing.**

The measures to strengthen of slopes are to achieve additional works both for waste dump benches and their slopes but also the final benches and slopes involved. Indicating that for the slopes and benches of waste dump the strengthen measures are more complex than for the final benches due to heterogeneity of the material from that is built dump, small value of material cohesion due to the fact that the dump body is loose material deposited. Hence, the conclusion that the works of leveling and consolidation should not be started immediately, but after 6 months from the time of submission. For the dump load tamp it down under the influence of natural geological subsidence is manifested more strongly to a maximum of two years after the compaction caused by geological pregnancy terminated.

The consolidation works and protection of slopes are designed to annihilate the destructive action of water which is manifested mainly by:

- ❖slopes erosion;
- ❖displacement of earth under the dynamic action of waves;
- ❖rainwater effluence after a very strong shower;
- ❖static pressure of ice;
- ❖dynamic action of ice floes, etc.

To the bench slope where water mirror is formed on its entire surface, the water level has a variation of it due to evaporation during the warm season (water level drops) and increase during high rainfall seasons (spring and autumn), which lead to very good „preparation'' of the slope against erosion phenomena. Erosion phenomena is a part of negative geo mining phenomena with very serious implications on the stability of that bench slope and the benches assembly that are above and sometimes below the level affected by this phenomenon.

From practice and literature, in conjunction with the financial and economic aspect an effective prevention measure against negative geo mining phenomena mentioned above, would be „clothing slope'' with concrete rock filling (photo no.4), resulting from the demolition of social enclosures, its surrounding concrete platforms, access roads to be decommissioned from the open pit area, the demolition of housing displaced, on the entire surface of the slope (as in length and also it width). All this being done after completion of levelling-compaction works of the surface subject of consolidation.

**Photo no.4**
**Rockfill laid-down on the protection dam**
**made on Jiu river upstream Rovinari mining coal perimeter**

The terracing works are required because the sterile deposition is made in steps of large heights. For areas in which the slopes will not ensure its stability is proposed to use some solutions, principled separate of works normally performed so far, based on the use of synthetic materials as reinforcing elements (reinforcement) of earth work.

The use of synthetic reinforcement is recommended for slopes that have lost their stability, and shallow landslides in slope areas, the use of reinforcement requires prior removal of the slipped material and bringing the slope or the terrain to the initial shape (or desired), by making filling in layers, in which are carry in the synthetic material called geo grid reinforcement, geo textiles, or geo synthetic (Fig. no.1).

The presence of reinforcement brings to the material from the body slope a certain rigidity and reduced deformability, which makes the interaction of reinforced earth and the land base that comes in contact differ from that of the earth not reinforced.

Sometimes to increase the angle of slope without jeopardizing slope stability of the waste dump benches slopes is recommended a counter bench execution at the foot of slope encapsulated in geo textile material or gabions filled with soil and geo synthetic materials (Fig. 2).

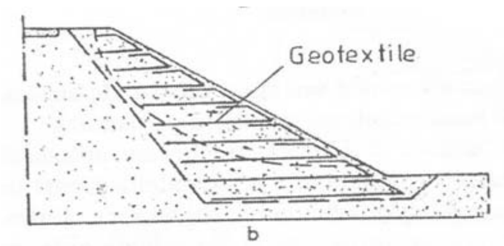



**Fig. no.1 Slope reinforced with geo grids**

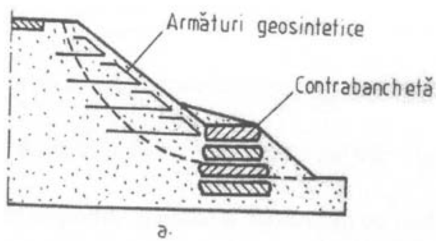



**Fig. no.2 Combined solution with geo grids and counter benches**

For example, in Fig. no.3 and no.4 are presented principle constructive systems and possibilities of execution of the works to improve slope stability of the waste dump benches slopes.

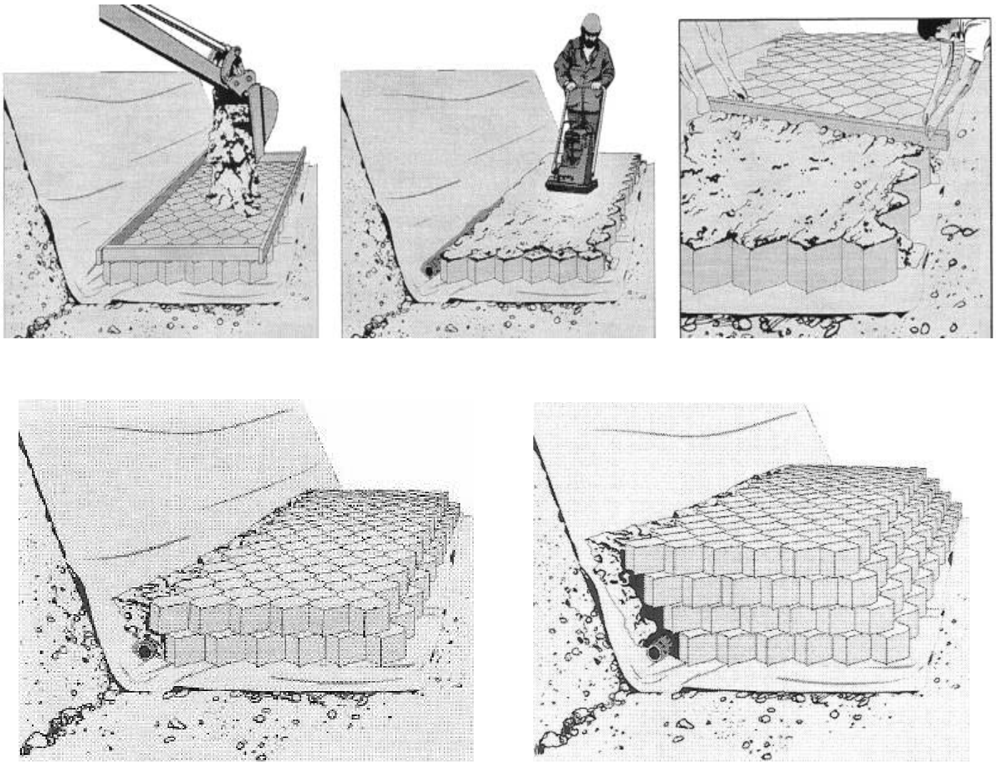


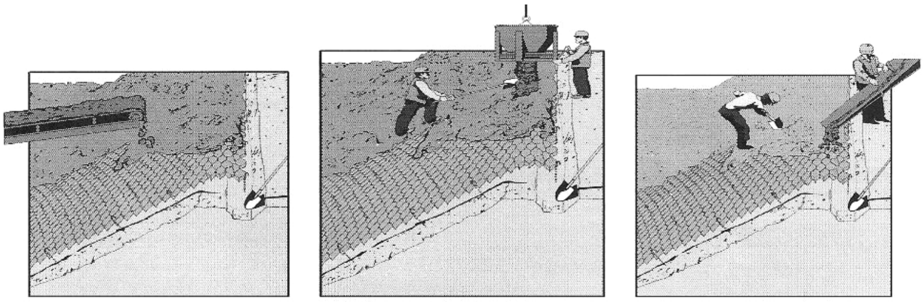
**Fig. no.3 Counter benches with encapsulated material**

As stages of execution are mentioned:

- preparation of slope/slopes surface, eventually removing the slipped earth and bringing the slope/land to a form appropriate to achieve filling in layers;
- levelling the surface of the slopes and the berms;
- preparation of geo synthetic grid tiles and fixing it;
- achieve of clay material filling and compacting it in layers while placing geo synthetic reinforcement;
- surface equalling;
- grassing works with hydrophilic plants of new resulted surfaces;
- maintenance works.

Possibilities for filling material deposition over geo synthetic grid are:

a - mobile conveyors;
b – skips and cranes;
c – manual discharge.



a b c

**Fig. no.4 Slopes protection with spatial geo grid and the possibilities of filling material deposition**

***Grassing*** is natural or anthropogenic process of land cover with vegetation. Through the process of grassing can be achieved the slopes protection can be achieved „in situ'' and the waste dump, which can be done in the following ways:

- slope cover with furrows of grass;
- slope cover with a layer of vegetable earth which is sown with various grass varieties with different growing seasons;
- spreading on slope of a spatial geo grid soil on which is spreaded vegetal soil.

Geo grid is to stabilize the vegetal soil on slope without the need for further preparatory works.

The sowing of vegetable earth, is made with different varieties of perennial herbs depending on climate zone in which is the location of the work.

The grassing of a slope will use several varieties of grass with different vegetative periods, the periods of growth are set according to the zoning climate, and for each climate zone some certain grasses networks are recommended.

To ensure area protection against water accumulation, it is recommended to create a forest belts with a width of at least 10 m, consisting of hydrophilic plant species, water-loving.

Depending on the slope destination, following re-use of the land, must to be taken absolutely all measures of development, so as to remove all factors that could interfere with the appearance of local imbalance.

## 7. CONCLUSIONS

To minimize as possible the risk of liquefaction of the waste dump material during filling with water of the remaining gap, are requiring a series of measures, as it is mentioned:

❖improving the strength characteristics of the waste dump material by compaction and change of structure;

❖reduction of rock pore water pressure through drainage;

❖the balance reduction of the waste dump slopes;

❖taking measures of modelling and stabilization, immediately after finishing of the activity in open pit.

The constructiveness measures will focus on eliminating the possibility of producing negative geo mining effects that could occur during and after filling with water of the remaining gap. As an additional measure is mentioned that to the mining rearrangement and sloping to declivities of 1:3 ($\alpha$ = 18 °) that contribute to increasing the slope stability, ensuring a better mechanization of execution and maintenance works; better grassing, easier water infiltration for untailwater slopes and easier execution of the protection works for submersed slopes.

The proposed solutions have proven technical and economic efficiency in the navvy and water works.

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Scientific Reviewers:
Prof. PhD. Eng. Ilie Rotunjanu

# STUDY OF SULPHYDRIC FLOTATION REAGENTS ISOMERY

**SOLOZHENKIN PETER***
**KRAUSZ SANDA****

***Abstract:*** *A very important quantity of minerals are processed trough flotation, using xanthogenates as collector reagents. Their efficiency for mineral selective recovery depends on the type of bond: is a well known superiority of iso bond related to n bond ones. A study for the explanation of the changes of butyl xanthogenate molecules has been started based on* ***quantum chemistry and computer technology****. The study considers the three potassium butyl xanthogenate as well as the two potassium propyl xanthogenate isomers, respectively isomers having the same terminal group.*

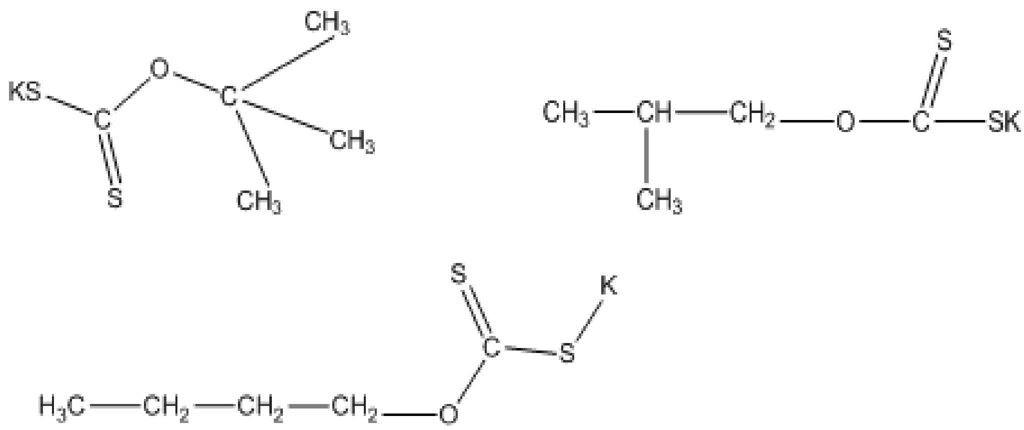
***Key words:*** *isomery, flotation reagents, quantum chemistry, computer technology*

There is a well known superiority of iso bond flotation reagents related to n bond ones for the flotation of minerals and extraction of metals (Han, Gabrielova, Vlasova 1986, Riaboi, 2002). For instance, the proportion of minerals processed through flotation using xanthogenate (for a specific average consumption of 25.6 g/t) is 66.2 % (Dudenkov, Shubov, 1969). The technical literature does not consider this an analysis subject anymore and therefore, a study for the explanation of the changes of butyl xanthogenate molecules has been started based on quantum chemistry and computer technology.

The paper used the ChemBio 3D tool of the specialised chemistry software ChemOffice Cambridge. The studied compound was introduced in ChemBio Draw, graphically representing it or describing it in English. Then, using the automated option, the standard lengths and the angles of valence of the bond were introduced. The optimum configuration of the compound, usually met, was chosen and therefore introduced in ChemBio 3D in order to obtain the models (usually the spheres-bond) and the quantum-chemical parameters, following the minimisation of the structure of the MM2 model.

The study considers the three potassium butyl xanthogenate as well as the two potassium propyl xanthogenate isomers, respectively isomers having the same terminal group. Figure 1 represents the molecular models of the potassium butyl xanthogenate isomer and the antimony complex limited by a Van-der-Waals radius.

* *Acad.dr. - Institute of Comprehensive Exploitation of Mineral Resources, Institution of Russian Academy of Sciences Research*
** *Prof. PhD.Eng, University of Petrosani*



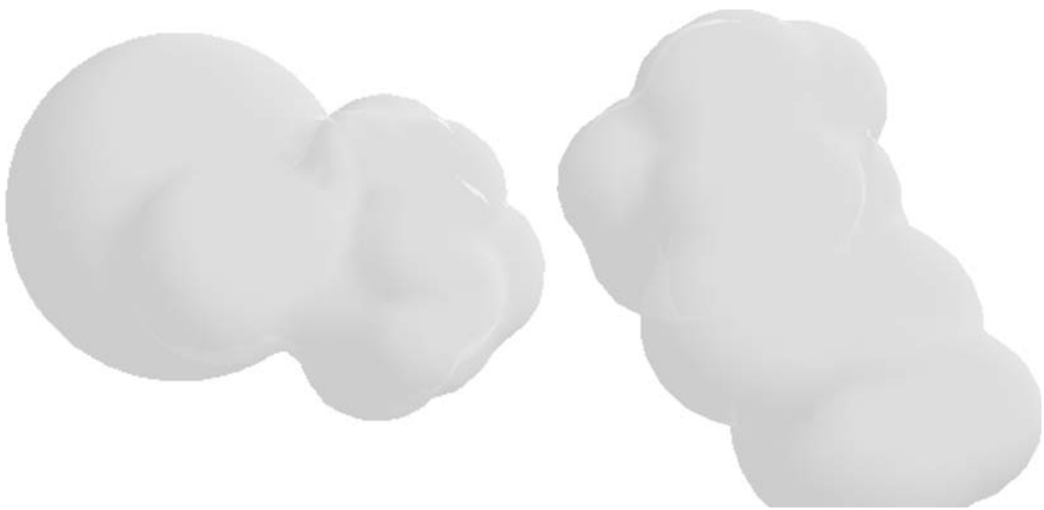



*Figure 1. Potassium 0-third-butylic xanthogenate transparent molecular model (a) also his antimony compound (b), limited by a Van-der-Waals radius.*

The computerised parameters and the total steric energy of the potassium butyl xanthogenate and its compounds with gold, silver, copper and stibium oxide were calculated after having been minimised using the MM2 method. The results obtained are presented in Table 1.

Based on data analysis, it is observed that the steric energy of the metallic compounds increases by changing the radical from 0-third-butyl to n-butyl. The dipolar charge of the metallic compounds is positive. 1,4 Van-der-Waals interaction, the deformity of the angle of valence and the internal rotation are characteristics of the compounds.

**Table 1** Computerised parameters Au, Ag, Cu and SbO compounds with different potassium butyl xanthogenate isomers

| **Reagent, radical** | **Tension of the angles of valence** | **Deformity of the angles of valence** | **Deformity tension correction** | **Interior rotation** | **Non 1,4 VDW rotation** | **1,4 VDW interaction** | **dipole-dipole interaction** | **Total steric energy kcal/mol** |
|---|---|---|---|---|---|---|---|---|
| **Three-butyl xanthogenates of metals** | | | | | | | | |
| Au | 0.7915 | 2.8962 | 0.2639 | -3.2040 | -1.8165 | 5.0558 | 1.6382 | 5.6250 |
| Ag | 0.7915 | 2.8905 | 0.2635 | -3.1972 | -1.7275 | 5.0374 | 1.6288 | 5.6871 |
| Cu | 0.7828 | 2.9139 | 0.2588 | -3.1947 | -1.7242 | 4.9658 | 1.6327 | 5.6351 |
| SbO | 0.7913 | 3.0136 | 0.2700 | -3.1436 | -1.9189 | 5.0708 | 1.6513 | 5.7346 |
| H | 0.7840 | 2.8512 | 0.2600 | -3.0263 | -1.2181 | 5.1001 | **0.6986** | **5.4495** |
| **Iso-butyl xanthogenates of metals** | | | | | | | | |
| Au | 0.5268 | 1.0626 | 0.1405 | 0.0144 | -1.9820 | 5.1454 | 1.6527 | 6.5605 |
| Ag | 0.5001 | 1.0116 | 0.1320 | 0.0828 | -1.8833 | 5.1081 | 1.6594 | 6.6107 |
| Cu | 05182 | 1.0661 | 0.1388 | 0.0644 | -1.8326 | 5.0041 | 1.6577 | 6.6167 |
| SbO | 0.5123 | 1.0702 | 0.1347 | 0.1229 | -1.7544 | 4.8806 | 1.6547 | 6.6211 |
| H | 0.5036 | 1.0736 | 0.1426 | 0.1019 | -1.5262 | 5.1680 | **0.7585** | **6.2220** |
| **Butyl xanthogenates of metals** | | | | | | | | |
| Au | 0.5267 | 3.0287 | 0.2175 | 0.0066 | -0.4811 | 6.5261 | 1.1987 | 11.0232 |
| Ag | 0.5005 | 2.9835 | 0.2131 | 0.0069 | -0.4893 | 6.3883 | 1.1994 | 10.8025 |
| Cu | 0.4559 | 1.1264 | 0.1388 | -0.1835 | -1.5965 | 5.1678 | 1.6034 | 6.7124 |
| SbO | 0.4826 | 2.4914 | 0.1957 | 0.0069 | -0.4539 | 5.7487 | 1.2037 | 9.6751 |
| H | 0.4621 | 1.7758 | 0.1817 | 1.0039 | -1.7977 | 5.4249 | **0.7676** | **7.8182** |
| **Propyl xanthogenates of metals** | | | | | | | | |
| n-propyl-KX | 0.4012 | 2.4173 | 0.1757 | **0.0035** | -0.1630 | 4.3922 | **0.4169** | **7.6437** |
| iso-propyl-KX | 0.4514 | 1.9534 | 0.1825 | **-1.5464** | -0.8561 | 4.1924 | **0.7289** | **5.1061** |

KX- potassium xanthogenate

Similar laws are also applied for the butyl xanthogenic acids. The isopropyl xanthogenic acid has an important interior rotation, a non 1,4 Van-der-Waals interaction, a dipole-dipole interaction considering a smaller total steric energy than that of the n-propyl xanthogenic acid.

The partial charges of the atoms separated from the isomers of the potassium butyl xanthogenate were determined. There are 8 methods for the calculation of the partial charges (Oliferenko, Palyulin, Pisarev, 2001). The results of these calculations are different depending on the used method. The Hükkel method was used for the calculation as it is a faster and widely spread method.

*Potassium butyl xanthogenate*: **O -0.119 [O(4)];** C 0.285 [C(5)]; S -0.275 [S(6)];
S -0.350 [S(7)]; K 0.309 [K(8)];

*Potassium isobutyl xanthogenate*: **O -0.141 [O(5)];** C 0.286 [C(6)]; S -0.273 [S(7)];
S -0.350 [S(8)]; K 0.308 [K(9)];

*Potassium 0-third-butyl xanthogenate*: **O -0.158 [O(5)];** C 0.275 [C(6)]; S -0.295 [S(7)];
S -0.195 [S(8)]; K 0.289 [K(9)];

The charge on the carbonyl sulphide modifies depending on the form of the butyl xanthogenate isomer, the highest being found on the 0-third-butyl xanthogenate {S -0.295 [S(7)]}. The charge of the oxygen in the potassium isobutyl xanthogenate {**O -0.141 [O(5)]**} is higher than the one in the potassium butyl xanthogenate {**O -0.119 [O(4)]**} and smaller than the one of the oxygen in the potassium 0-third-butyl xanthogenate {**O -0.158 [O(5)]**}.

The modification of the charges of the antimony compounds with different butyl xanthogenate isomers is herein after presented:

*Antimonyl butyl xanthogenate*: O -0.154 [O(2)]; **S 0.258 [S(3)];** Sb 0.899 [Sb(8)];
**S 0.380 [S(9)];** O -1.099 [O(10)];

*Antimonyl isobutyl xanthogenate*: O -0.252 [O(5)]; C 0.340 [C(6)]; **S 0.373 [S(7)];**
**S 0.337 [S(8)];** Sb 0.820 [Sb(9)]; O -1.128 [O(10)];

*Antimonyl 0-third-butyl xanthogenate*: O -0.249 [O(5)]; C 0.353 [C(6)]; **S -0.379 [S(7)];**
**S 0.253 [S(8)];** Sb 0.924 [Sb(9)]; O -1.093 [O(10)];

The charge of the carbonyl sulphide of the antimonyl isobutyl xanthogenate {**S 0.373 [S(7)]}** is higher than the one in the antimonyl butyl xanthogenate {**S 0.258 [S(3)]}** and in the antimonyl 0-third-butyl xanthogenate {**S 0.253 [S(8)]**}.

The charge on the tiolic sulphide {**S -0.337 [S(8)]**} on the antimonyl isobutyl xanthogenate is smaller than that of the tiolic sulphide in the antimonyl butyl xanthogenate {**S -0.380 [S(9)]**} and in the antimonyl 0-third-butyl xanthogenate {**S -0.379 [S(7)]**}. The charge of the tiolic sulphide in the antimonyl compounds is partially negative from -0.337 to -0.380, indicating therefore a steady bond with the antimonyl cation. The charges of the butyl xanthogenic acids are herein after presented:

*Isobutyl xanthogenic acid*: O -0.255 [O(5)]; **C 0.351 [C(6)];** S 0.095 [S(7)]; **S -0.409 [S(8)];** H 0.036 [H(18)];

*N-butyl xanthogenic acid*: O -0.131 [O(4)]; C 0.303 [C(5)]; S -0.471 [S(6)]; S 0.111 [S(7)]; H 0.036 [H(8)];

The charge of the oxygen in the isobutyl acid is higher than the one of the oxygen in the n-butyl xanthogenic acid. Therefore the charge increase on the carbonyl carbon, the charge decrease on the carbonyl and tiolic sulphide and the charge decrease on hydrogen. The charges on atoms of potassium n-propyl and isopropyl xanthogenate and the corresponding acids, were determined:

*Potassium n-propyl xanthogenate*: O(2) -0.144566; C(3) 0.287032; S(4) -0.273438; S(5) -0.359740; K(6) 0.307924;

*Potassium isopropyl xanthogenate*: O(2) -0.155098; C(3) 0.250068; S(4) -0.179919;
S(5) -0.359740; K(6) 0.299474;

The charge of the oxygen in potassium isopropyl xanthogenate is higher than the one of the oxygen in potassium n-propyl xanthogenate. It leads therefore to the decrease in charge of the carbonyl sulphide and of the carbonyl carbon, considering the negative charge of the tiolic sulphide and the decrease of the charge of potassium.

The charges of the atoms of n-propyl and isopropyl xanthogenic acids are herein after presented:

*Propyl xanthogenic acid*:

| | |
|---|---|
| O(2) Ethereal O | -0.168735 |
| C(3) Thiocarbonylic C | 0.307405 |
| S(4) Thiocarbonylic S | -0.454888 |
| S(5) Tyolic S | 0.114096 |
| H(6) Tyolic H | 0.0287233 |

*Isopropyl xanthogenic acid*:

| | |
|---|---|
| O(2) Ethereal O | -0.168735 |
| C(3) Thiocarbonylic C | 0.307405 |
| S(4) Thiocarbonylic S | -0.454888 |
| S(5) Tyolic S | 0.114096 |
| H(6) Tyolic H | 0.0287233 |

The negative charge on the oxygen in the iso-propyl xanthogenic acid is higher than the one in the n-propyl xanthogenic acid. The positive charge on the carbon increases leading therefore to the decrease of the charge of the carbonyl and tiolic sulphide and charge increase of the tiolic hydrogen related to their values for the n-propyl xanthogenic acid. The main parameters of the $^{1}H$ and $^{13}C$ nuclei were also determined (Pentin, Vilkov, 2009). The obtained results are presented in Table 2.

Table 2. Chemical changes of the xanthogenate isomers group

| **Isomers** | **Chemical changes, parts per million** | | | | |
|---|---|---|---|---|---|
| | **$CH_3$** | **CH** | **$CH_2$** | **$CH_2$** | **$CH_2$** |
| Potassium butyl xanthogenate | | | | | |
| 0-third butyl xanthogenate | 1.19 | - | - | - | - |
| isobutyl xanthogenate | 0.91 | 1.46 | - | - | 3.31 |
| n-butyl xanthogenate | 0.90 | - | 1.45 | 1.52 | 4.60 |
| Potassium propyl xanthogenate | | | | | |
| n-propyl xanthogenate | 0.90 | 1.68 | - | - | 3.58 |
| isopropyl xanthogenate | 1.13 (1.13) | 4.35 | - | - | - |

Figure 3 presents the IMR spectra of the potassium n-propyl xanthogenate protons.

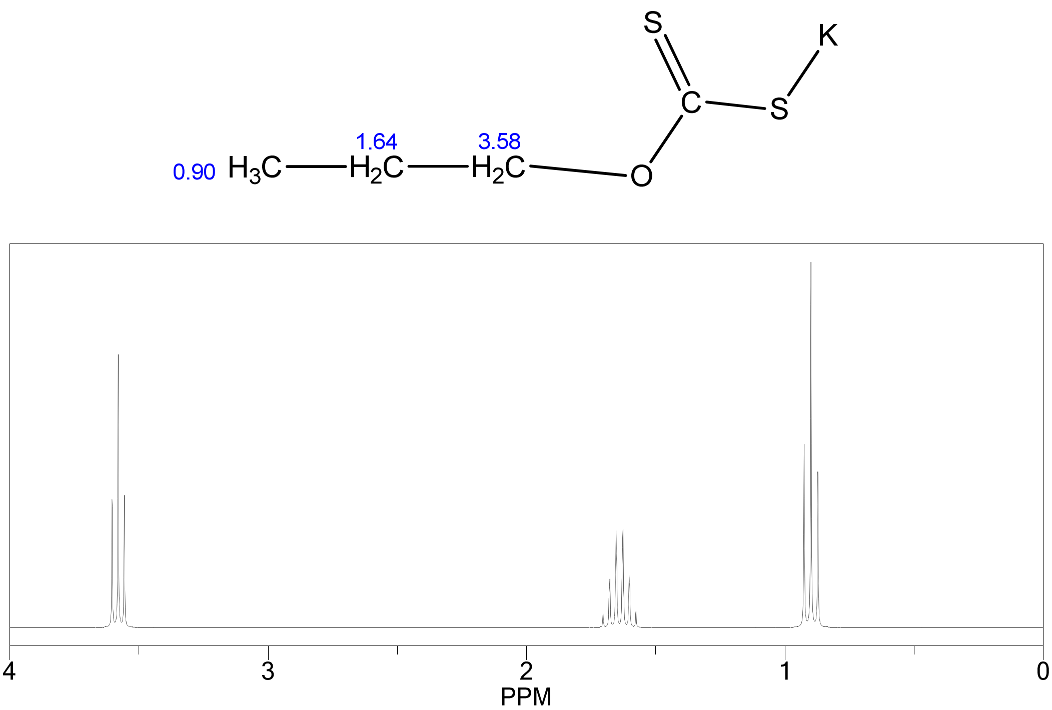



**Figure 3. IMR spectra of the potassium n-propyl xanthogenate protons.**

The 1.64 ppm. (parts per million) multiplet is presented by 6 lines considering the interaction with the 5[th] proton of $CH_3$ and $CH_2$ following on the schema (2Σ5· ½ + 1).

Figure 4 presents the IMR spectra of the potassium 0-iso-propyl xanthogenate protons.

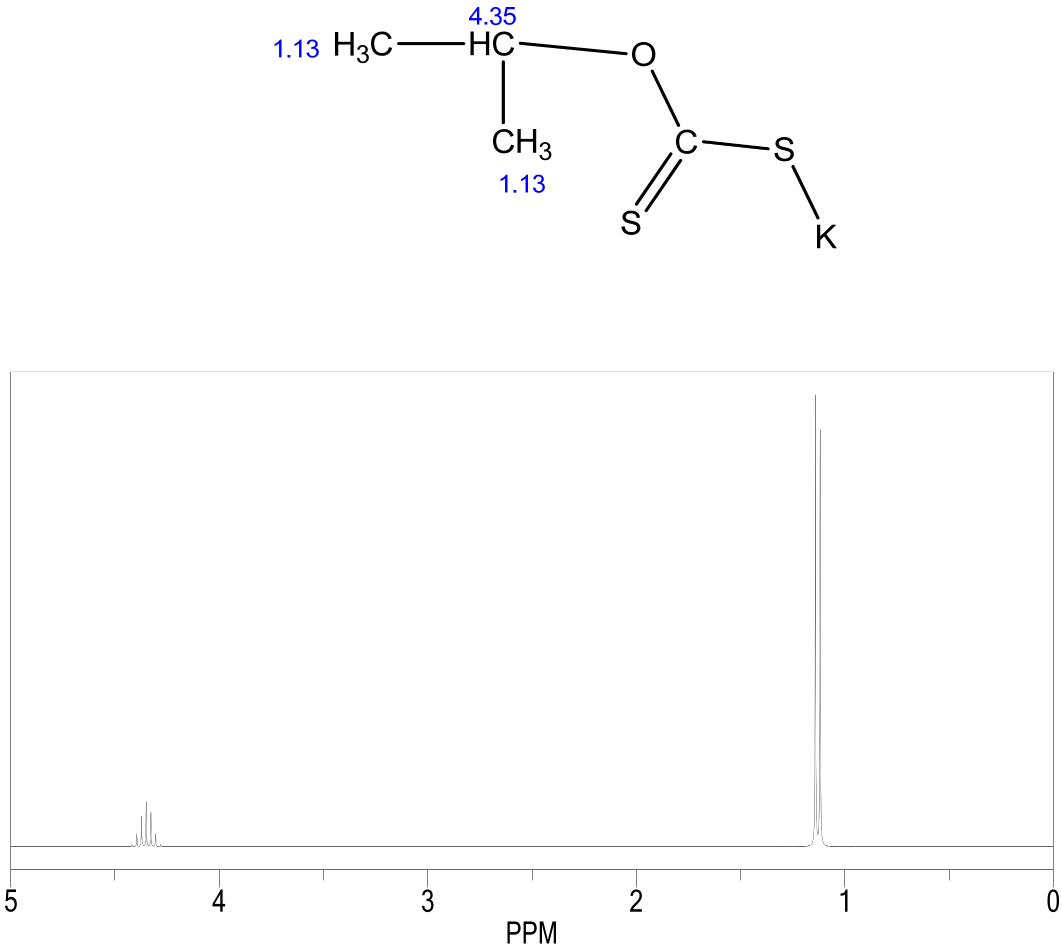



**Figure 4. IMR spectra of the potassium 0-iso-propyl xanthogenate protons.**

The 4.35 ppm. multiplet is presented by 7 lines (some of them not being well defined), considering the interaction with the $6^{th}$ proton of $CH_3$ and $CH_2$ following the schema (2Σ6 · ½ + 1).

The display of protons is more reduced in the potassium 0-third-butyl xanthogenate than in the potassium isobutyl xanthogenate and the potassium n-butyl xanthogenate, thus the signal is received in a weaker field.

The display of the methyl group potassium isopropyl xanthogenate is much weaker than that of the potassium propyl xanthogenate and the signal is therefore propagated in a weaker field. With the help of the ChemBio 3D software, the lengths of the bonds of potassium butyl xanthogenate (butyl xanthogenic acid) and the compounds with Au, Ag, Cu and SbO were measured. In the Au and Ag compounds of the n-butyl xanthogenate, the length of the metal and sulphur bond was of 2.35 Å, in the Cu compound was of 2.190 Å and in the antimonyl compound of 2.419 Å.

The length of the bond between copper and tiolic sulphur was 2.190 Å, in the 0-third-butyl xanthogenate compounds with Au and Ag, while the length of the bond between metals and tiolic sulphur was 2.360 Å and in the 0-third-butyl xanthogenate with antimonyl compounds, the length of the bond is 2.420 Å and the length of the antimony and oxygen bond is equal to 1.154 Å.

The length of the bond between sulphur and Au in the isobutyl xanthogenate compounds is 2.360 Å. It is interesting to observe that the length of the bond between carbon and carbonyl sulphur in potassium isobutyl xanthogenate is 1.356 Å, in potassium 0-third-butyl xanthogenate the length of the metal and tiolic sulphur was 1.576 Å and in the potassium n-butyl xanthogenate the length of the bond between carbon and sulphur was 1.584 Å.

The lengths of the bonds in n-butyl xanthogenic acid is characterised by the following data: O(4)-C(5) -1.356 Å; C(5)-S(6)-1.582 Å; C(5)-S(7)-1.820 Å; S(7)-H(8)-1.345 Å.

The lengths of the bonds in isobutyl xanthogenic acid were O(5)-C(6) -1.356 Å; C(6)-S(8)-1.582 Å; C(6)-S(7)-1.820 Å; S(7)-H(18)-1.345 Å. Practically, the lengths of the bonds are equal.

It is known that the solubility product for the copper butyl xanthogenate is Lp $3.1 \cdot 10^{-21}$, for the silver butyl xanthogenate is Lp $4.2 \cdot 10^{-20}$, for the silver isobutyl xanthogenate Lp $1.6 \cdot 10^{-20}$ and for the gold xanthogenate is Lp $2.0 \cdot 10^{-34}$. Therefore, the different activity of butyl xanthogenate isomers is related to the differences of the dipoles, of Van-der-Waals interaction and their steric energy compared to the same indicators established for the potassium n-butyl xanthogenate.

The lengths of the bonds of the carbon atom with each sulphur atom are not equal, due to the delocation of electrons, not allowing for them to be considered equivalent. The use of potassium isobutyl xanthogenate makes it possible to obtain superior quality concentrates without the reduction of metals extraction, an important issue for the practice of minerals flotation.

The 0-third-butyl xanthogenate, the technological and flotation characteristics of which are not known yet and still need further research, therefore being highly interesting.

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Scientific Reviewers:
Prof. PhD. Eng. Romulus Sarbu

# USING A FIXED BASE IN THE PIT AT THE JUNCTION RAMP UNDERGROUND TOPOGRAPHIC ELEMENTS

**FILIP LARISA OFELIA*** 
**DIMA NICOLAE****

**Abstract:** *Underground mining surveying activity underground requires the existence of a reference system materialized by a point and a direction whose elements, direction and orientation point coordinates are relative to the reference surface. Topographic base groundwater is reported in reference system elements and methods used to determine because they are of great importance. Moreover, achieving projected mining, mining lifting executed, control objectives and ground stability at the surface, evaluation of production and position in space geometry of the deposit is held against possible complex activities of the topographic elements connected to the reference system.*

In order to achieve superior performance in terminal stages of topographic features is proposed a method using a base surface measured near the ramp pit or underground shaft.

The method can be formulated as follows: in underground at a horizon reference system is embodied in the free zone through the point $F_1$ and direction $F_1F_2$ of the shaft (Fig. 1). It translates into the well pad reference system materialized through the point $A$ and direction $AB$ . This is possible if the angles $\alpha$ are $\beta$ measured on $AB$ and point $A$ the direction $F_1B$ .

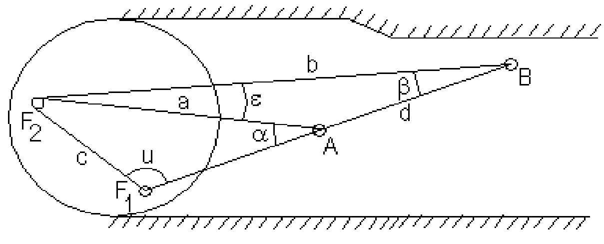


Fig. 1

* *Lecturer Ph.D. Eng, University of Petrosani*
** *Prof., Ph.D. Eng, University of Petrosani*

Reference system elements are the coordinates of the well pad $x_a$, $y_a$ the point $A$ and orientation $\theta_{AB}^5$ from direction $AB$.

Values are obtained by writing the elements:

$$x_A = x_1 + F_1A\cos\theta_{F_1A} = x_1 + F_1A\cos(\theta_{12} + u)$$
$$y_A = y_1 + F_1A\sin\theta_{F_1A} = y_1 + F_1A\sin(\theta_{12} + u)$$
$$\theta_{AB} = \theta_{F_1B} = \theta_{12} + u$$

But:

$$F_1A = c\frac{\sin(u+\alpha)}{\sin\alpha}$$

Unknown angle relationship is obtained, as is the coordinate relations $x_a$, $y_a$.

Therefore the problem is solved if there is solution to determine the angle $u$.

In this case the triangle $AF_1F_2$ we write:

$$\sin u = \frac{a}{c}\sin\alpha$$

But the triangle $ABF_2$:

$$a = \frac{d}{\sin\varepsilon}\sin\beta$$

Or:

$$a = \frac{d}{\sin(\alpha-\beta)}\sin\beta$$

And consequently:

$$\sin u = \frac{d}{c}\frac{1}{ctg\beta - ctg\alpha}$$

We note:

$$N = k(ctg\beta - ctg\alpha)$$

Where:

$$k = \frac{c}{d} = \frac{F_1F_2}{AB}$$

And then:

$$u = \arcsin\frac{1}{N}$$

To analyze the accuracy of differentiating the relation:

$$\sin u = \frac{1}{N}$$

And we get:

$$\cos u du = -\frac{1}{N^2}dN$$

Or:

$$\cos udu = -\sin^2 udN$$

And:

$$du = \frac{-\sin^2 u}{\cos du} dN$$

Applying the law of propagation of errors in measured quantities directly obtain functions:

$$m_u \pm tgu\sqrt{\left[\left(\frac{m_c}{c}\right)^2 + \left(\frac{m_d}{d}\right)^2\right]\rho^2 + \left(\frac{c}{d}\right)^2 \cdot \sin^2 u\left(\frac{1}{\sin^4 \alpha} + \frac{1}{\sin^4 \beta}\right)m_0^2}$$

Where:

- $m_c$, $m_d$ are the mean square errors of measurement of the sides $c$ and $d$;
- $m_0$ is the mean square error of measurement of angles $\alpha$ and $\beta$.

The relationship obtained can be simplified by introducing the relative error of measurement of distances:

$$f = \frac{m_c}{c} = \frac{m_d}{d}$$

So:

$$m_u = \pm tgu\sqrt{2f^2\rho^2 + \left(\frac{c}{d}\right)^2\left(\frac{1}{\sin^4 \alpha} + \frac{1}{\sin^4 \beta}\right)\sin^2 um_0^2}$$

Respectively:

$$m_u = \pm\sqrt{2tg^2uf^2\rho^2 + \left[\left(\frac{a^2}{cd}\right)^2 \frac{1}{\cos^2 u} + \left(\frac{b^2}{cd}\right)^2 \frac{1}{\cos^2 u}\right]m_0^2}$$

Minimum error $m_u$ exists when: $tgu \to 0$ and $\cos u \to 1$

And calculate the relationship:

$$m_u = \pm\frac{m_0}{c}\rho\sqrt{\left(\frac{a^2}{d}\right)^2 + \left(\frac{b^2}{d}\right)^2}$$

If $a^2 < d$ than $\frac{a^2}{d} < 1$

And may be some positioning achievable in the well pad (fig. 2):

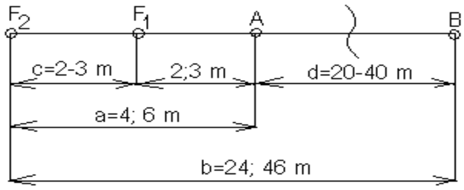


Fig. 2

As such:

$\left(\frac{a^2}{d}\right)^2$ the value is small and neglect and consequently for $d \approx b$

$$m_u = \frac{d}{c} m_0$$

The method of the triangle connecting junction: $m_\gamma = \pm m_0 \sqrt{2}$

And consequently: $m_u < m_\alpha (m_\beta)$

Method can be applied with high accuracy every materialization points $A$ şi $B$, it follows that $d > a^2$ and while the angles $\alpha$ and $\beta$ tend towards zero, and $u$ by $200^g$.

The method presented is superior in quality methods known in the sense that the measured sizes are available and relatively few.

Also embodied in the platform shaft direction orientation is obtained with high precision and creates underground guarantor of topographic base properly directed.

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Scientific Reviewers:
Assoc. Prof. PhD. Eng. Ioel Veres

# ÜBERSICHT ÜBER DAS GALILEO-SYSTEM

**KLAUS FISSGUS***
**RAREŞ MUNTEANU***

**Abstract:** *Europe is moving closer to the launch of its satellite navigation system Galileo. This will lead to a fully civilian controlled global satellite navigation system, with much improved navigation services and a certified positioning service. It will be fully compliant with ICAO's requirements for satellite navigation systems. The overall benefits include redundancy and integrity to meet the safety requirements of civil aviation and help the full introduction of satellite navigation for all phases of flight. Whilst the battle with GPS is likely to be bitter, in the end these two systems will benefit each other and massively extend the role of satellite navigation.*

**Key words:** *Galileo, GPS, European Satellite Navigation System, Positioning, Time service.*

## 1. GRUNDLAGEN

Das Galileo Navigationssystem wird wie GPS ein globales Satellitennavigationssystem sein. Das grundsätzliche Funktionsprinzip ist das gleiche und das System soll sogar mit GPS kompatibel sein. Zumindest mit der im Aufbau befindlichen weiterentwickleten Version von GPS. Im Unterschied zum GPS-System wird es jedoch nicht vom Militär sondern von zivilen Stellen betrieben kontrolliert. Es wird eine Reihe von Diensten mit garantierter Verfügbarkeit beim Galileo-System geben und ganz sicher ist auch, dass die bisher erhältlichen GPS-Empfänger nicht "einfach so" Galileo-kompatibel sein werden. Bei manchen neuen wird sich Galileo per Firmware-Update verwenden lassen, andere, ältere werden nie Galileo-kompatibel werden.

Sobald die ersten vier Satelliten des Systems für die Validierungsphase im Orbit zur Verfügung stehen, werden die Galileo-Dienste die teilweise auch mit GLONASS und GPS Daten kombiniert werden können stufenweise zur Verfügung gestellt werden.

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* *Lecturer Eng., Ph.D. at the University of Petroşani, kfissgus@yahoo.de, rares73@yahoo.de*

**Bild 1. Galileo-Satellit auf Soyuz-Rakete**

## 2. DIENSTE DES GALILEO-SYSTEMS

Es sind folgende fünf Dienste geplant:

### 2.1. Allgemeiner Dienst (Open Service; OS)

Dieser Dienst, der kostenlos über die frei zugänglichen Signale zur Verfügung steht, wird über eine Positions- und Zeitgenauigkeit verfügen, die in der Leistung ähnlich wie andere Satellitennavigationssysteme (GPS, GLONASS) sein wird. Man kann heute von einer zu erwartenden Genauigkeit von etwa 4 Metern ausgehen.

### 2.2. Sicherer-Dienst (Safety-of-Life Service; SoL)

Dieser Dienst ist für überlebenswichtige Aufgaben gedacht (z.B. Flugverkehr) und gegenüber dem offenen Dienst darin erweitert, dass es rechtzeitige Warnungen (wenige Sekunden) im Falle von Genauigkeitseinschränkungen oder Ausfall von Satelliten gegeben werden. Es ist geplant für diesen Service die Verfügbarkeit zu garantieren.

### 2.3. Kommerzieller Dienst (Commercial Service; CS)

Im kommerziellen Dienst stehen zusätzliche zwei Signale zur Verfügung, die einerseits den Datendurchsatz erhöhen, andererseits die Genauigkeit erhöhen. Diese Signale werden verschlüsselt und gegen Gebühren genutzt werden können. Auch hier ist eine Verfügbarkeitsgarantie geplant. Die Genauigkeit soll bis 10 cm betragen.

### 2.4. Regulierter Dienst; Regierungsdienst (Public Regulated Service; PRS)

Dieser zugangsbeschränkte Dienst wird ausschliesslich für Benutzerkreise zur Verfügung stehen, die bei der Wahrnehmung von hoheitlichen Aufgaben beteiligt sind (Polizei, Küstenwache, Geheimdienste, Militär). Sowohl Genauigkeit als auch Zuverlässigkeit dieser

Dienste soll besonders hoch sein. Zwei Signale mit verschlüsselten Codes werden zur Verfügung stehen.

### 2.5. Such- und Rettungsservice (Search and Rescue; SAR)

Galileo wird weltweite Such- und Rettungsmassnahmen dadurch unterstützen, dass es in das bestehende Netzwerk COSPAS-SARSAT und MEOSAR (Medium Earth Orbit Search and Rescue System) eingebunden wird. Die Satelliten des Galileo-Systems werden in der Lage sein, die Signale von Notsendern auf Schiffen, Flugzeugen und Personen zu empfangen und an die Nationalen Rettungszentren weiterzuleiten. Dadurch erhält eine Rettungsleitstelle genaue Informationen über den Ort des Notfalls. Zu jeder Zeit wird mindestens ein Galileo-Satellit das Signal empfangen können und erlaubt so eine Alarmierung in nahezu Echtzeit. Ausserdem wird es erstmals in bestimmten Fällen möglich sein, eine Antwort zum Notsender zurückzusenden.

**Bild 2. Galileo-Satellit im Orbit**

## 3. DIE DIENSTE IM EINZELNEN

Sehr viel genaues über diese Dienste ist noch nicht bekannt. Vieles wird sich sicherlich noch über die Nachfrage und die zu erwartenden Kosten definieren.

### 3.1. Allgemeiner Dienst (Open Service; OS)

Der allgemeine Dienst von Galileo ist für Anwendungen des Massenmarktes gedacht und damit eine direkte Konkurrenz oder auch Ergänzung zu GPS. Dieser Dienst wird zum modernisierten GPS-System (GPS III; ab 2010) so kompatibel sein, dass Empfänger die Daten beider Systeme verwenden können, denn beide System setzen das gleiche Datenformat (BOC1.1) ein. Galileo wird im Dienst OS Zeit- und Positionssignale liefern, die für den Benutzer kostenlos sind. Es werden jedoch für die Hersteller Lizenzgebühren fällig, womit anzunehmen ist, dass Galileo/GPS-Empfänger teuerer sein werden als reine GPS-Empfänger. Für diesen frei zugänglichen Dienst stehen bis zu drei Signalfrequenzen zur Verfügung, jedoch werden die kostengünstigsten Empfänger wohl nur eines dieser Signale nutzen und eine entsprechend eingeschränkte Genauigkeit liefern. Zum Standard werden sich aber wohl bald

Zweifrequenzempfänger entwickeln, die eine Korrektur der Ionosphäreneinflüsse erlauben. Gegenüber dem jetzigen GPS-System wird bei günstigen Empfängern in erster Linie eine Verbesserung der Abdeckung erreicht werden, da mit der Kombination von GPS und Galileo-Satelliten zu jeder Zeit mindestens 15 Satelliten verfügbar sein sollten. Dies wird besonders in Städten und bergigen Gegenden Vorteile bringen. Zweifrequenzempfänger werden eine höhere Genauigkeit liefern (ca. 4 m). Der frei zugängliche Dienst wird jedoch keine Integritätsinformationen des Systems oder Garantien irgendeiner Art beinhalten.

Es ist sogar so, dass nach langem Streit der Europäer mit den Amerikanern für Galileo nicht das störungsunempfindlichere Datenformat BOC1.5 eingesetzt wird, sondern BOC1.1. Grund war die Angst der Amerikaner, dass sonst das frei verfügbare Galileo-Signal in Krisenfällen nicht gestört werden kann. Zumindest nicht ohne ihr geplantes neue M-Signal, das ebenfalls BOC1.5 nutzt nicht auch zu stören. Dieser Kompromiss auf BOC1.1, erlaubt zwar maximale Kompatibilität zwischen Galileo und GPS, lässt aber alle Versprechungen und Ankündigungen mit Galileo ein verlässlicheres (weil nicht durch die US-Armee beeinflussbares) System zu haben relativ schwach dastehen. Lediglich der nur Staatsstellen zugängliche PRS-Dienst von Galileo ist störsicher.

### 3.2. Sicherer-Dienst (Safety-of-Life Service; SoL)

Der SoL-Dienst wird zertifiziert sein und die nötige Genauigkeit wird durch die Verwendung von Zweifrequenzempfängern erreicht. Unter diesen Voraussetzungen wird die spätere „Galileo Betriebsgesellschaft“ die Verfügbarkeit dieses Dienstes garantieren. Um diese Zuverlässigkeit zu erreichen wird der Dienst im Bereich der für die Flugnavigation reservierten Frequenzbereiche (L1: 1559 - 1591 und E5: 1164 - 1215 MHz ) integriert sein.

Dieser Dienst soll die Sicherheit speziell dann erhöhen, wenn keine entsprechende Infrastruktur am Boden vorhanden ist (z.B. ILS für Landeanflug). Innerhalb dieses Dienstes findet auch das EGNOS seinen Platz, das dann wie WAAS der unabhängigen Überwachung des Galileo (und GPS) dient. Ein weltweit verfügbarer solcher Dienst kann sicherlich die Effizienz und Sicherheit von Luftfahrt- und Schifffahrtsunternehmen steigern.

### 3.3. Kommerzieller Dienst (Commercial Service; CS)

Der kommerzielle Dienst zielt auf Anwendungen, die eine höhere Genauigkeit benötigen als der offene Dienst bietet. Dieser zusätzliche Nutzen wird durch Zahlung von Gebühren geboten. Im kommerziellen Dienst werden gegenüber dem offenen Dienst nochmals zwei zusätzliche Signale im E6-Bereich (1260-1300 MHz) zur Verfügung stehen. Dieses Signalpaar wird verschlüsselt sein, der Zugang wird über die Empfänger kontrolliert. Somit wäre sowohl eine Abrechnung nach Zeit als auch eine Art Abonnement möglich.

Im kommerziellen Modus wird Datenübertragung (Systemdaten, nicht jedoch Kommunikation) möglich sein und bei anderen Signalen auftretende Zweideutigkeiten bei Differentialanwendungen werden so gelöst werden können. Die entsprechenden Dienste sollen über Service-Provider zur Verfügung gestellt werden, die das Recht zur Verwendung der Signale vom Galileo-Betreiber kaufen. Es ist anzunehmen, dass vor allem für Vermessungsaufgaben dieser Dienst von Bedeutung sein könnte, falls das Kosten-Nutzen-Verhältnis sich rechnet.

### 3.4. Öffentlicher regulierter Dienst (Public Regulated Service; PRS)

Zusätzlich zu den für die Öffentlichkeit prinzipiell zugänglichen Diensten wird es noch einen besonders robusten und streng zugangskontrollierten Service für von den Regierungen authorisierte Anwendungen geben. Dieser regulierte Dienst wird für Polizei, Küstenwache und Zollbehörden aber auch Militärs zur Verfügung stehen. Der Zugang zu diesem verschlüsselten Dienst wird jedoch von zivilen Institutionen kontrolliert. Ein Zugang basierend auf einer Region oder Benutzergruppe wird durch in Europa gültige Sicherheitsrichtlinien gewährt.
Der öffentlich regulierte Dienst wird zu jedem Zeitpunkt und unter allen Umständen, auch in Krisenzeiten verfügbar sein. Das verschlüsselte Signal wird gegen Störung und Verfälschung gesichert sein und entspricht somit in etwa dem bestehenden militärischen GPS-Signal.

### 3.5. Such- und Rettungsservice (Search and Rescue; SAR)

Der Such- und Rettungsservice soll Europas Beitrag zum internationalen kooperativen Bestreben nach Rettungs- und Suchdiensten sein. Jeder Satellit wird einen Transponder enthalten, der Notsignale von Benutzern zu den Rettungsleitstellen (Rescue Coordination Center; RCC) weiterleitet, die dann die Rettungsaktion einleiten. Gleichzeitig kann das System dem Nutzer ein Rücksignal senden, das anzeigt, dass sein Notruf eingegangen und Hilfe auf dem Weg ist. Letztere Funktion ist eine Neuerung gegenüber dem bestehenden System, dass keine Rückmeldung an den Benutzer erlaubt.

Weitere Verbesserungen gegenüber dem heutigen COSPAS-SARSAT System aus bestehend aus vier niedrigfliegenden und drei geostationären Satelliten sind ein Nahezu-Echtzeitempfang des Notsignals überall auf der Erde (bisher ist die durchschnittliche Wartezeit eine Stunde); Genaue Lokalisierung des Notrufs (wenige Meter anstatt der momentan spezifizierten 5 km); Empfang des Signals durch mehrere Satelliten um Abschattungen durch das Gelände unter ungünstigen Umständen zu vermeiden.

Der Dienst wird in Abstimmung mit dem bestehenden COSPAS-SARSAT-System definiert und der Aufbau und Betrieb werden durch die IMO (International Maritime Organisation; Internationale Seeschifffahrts-Organisation) und ICAO (International Civil Aviation Organization; Internationale Zivile Luftfahrt-Organisation) geleitet.

**Bild 3. Galileo Ground Control Segment (GCS) in Oberpfaffenhofen**

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Scientific Reviewers:
Prof. PhD. Eng. Nicolae Dima

# MINIMUM COST ROUTE SOLVED WITH ARCGIS SOFTWARE

**ULAR ROXANA CLAUDIA*[*]**
**HERBEI MIHAI VALENTIN[**]**

**Abstract:** In order to find out the easiest way to reach from a point (town) source to another point (town) destination depending on the field features we shall take into account to use the field and so how hard is the move on this depending on what is on it and on its slope (the bigest is the slope the hardest is the move). The source and destination points will be taken from the offert shapefiles.

**Key words:** minimum cost, raster, distance, GIS, ArcGIS

## 1. INTRODUCTION

The inlet data in order to make this application were as follows:

- The field use categories - Landuse (Corine Land Cover 2000, CLC) that covers the studied area.
- The source and destination points, which in case of this application are made from towns: Recaș and Lugoj from Timis County.
- DEM – the digital elevation model generated for the studied area by using the software Global Mapper

The methodology is as follows:

## 2. CONVERSION OF CLC LAYERS INTO RASTER

For this it is used **ArcToolbox** - **Conversion Tools** - *To Raster* - F*eatures to raster*. The command is repeated for each trapeze.

Cassette *Features to raster* is completed as follows:

*Input: L_34_079, L_34_080, L_34_091, L_34_092*

*Field: CODE __00*

*Output raster: The place where it will be saved the created raster and its name (”conv2raster79”, ”conv2raster80 ”, ”conv2raster91”, ”conv2raster92”)*

*Output cell size: 20*

* *Assistant, Ph.D. Eng. University of Petrosani – Faculty of Mine*
** *Lect. Ph. D. Eng., U.S.A.M.V.B. Timişoara, Faculty of Agronomy*

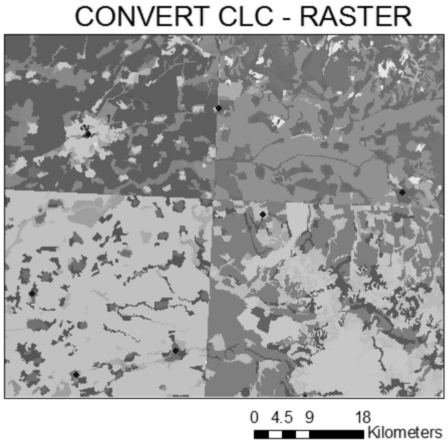



**Fig. 1 Raster map of the studied area**

## 3. RASTER RECLASSIFICATION DEPENDING ON ITS DIFFICULTY

It is classified each raster with information regarding the use category of the field (landuse) depending on the difficulty move of it.

An example classification would be almost on inverse order of its value.

The obtained raster for each trapeze will be classified by using **ArcToolbox** – **Spatial Analyst Tool** – *Reclass - Reclassify*.

The dialog cassette *Reclassify* will be completed as follows:

*Input raster: the ratser obtained into previous stage (”conv2raster79”, ”conv2raster80 ”, ”conv2raster91”, ”conv2raster92”)*

*Reclass Field: VALUE*

*Reclassification: The classification will be made as follows: for urban areas (112) it will be introduced the value 10, and the further values will be from 10 to 10.*

*Output raster: The place where it will be saved the created raster and its name (”Reclass79”, ” Reclass80 ”, ” Reclass91”, ” Reclass92”*

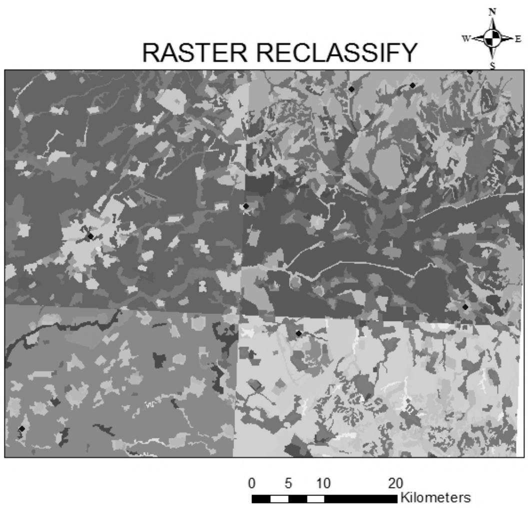



**Fig. 2 Raster Map of the reclassified studied area**

## 4. MAKING THE DIGITAL ELEVATION MODEL DEM OF THE STUDIED AREA BY USING THE GLOBAL MAPPER SOFTWARE

The Global Mapper is more than an instrument for visualization, capable to display tha most used sets of sata type raster, elevation or vector. It converts, edits, prints, creates some GPS tracks and allows to be used the GIS sets of data.

The data files may be loaded as layers, for example a digital elevation model – DEM may be loaded together with a topographical map in order to create a 3D representation with lights and shadows of the map.

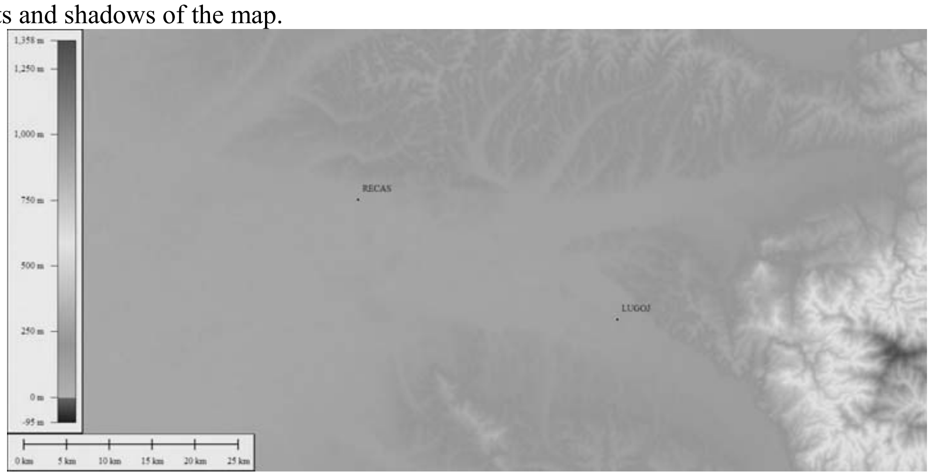



**Fig. 3 The digital elevation model made with Global Mapper software**

This DEM was imported then into ArcGIS.

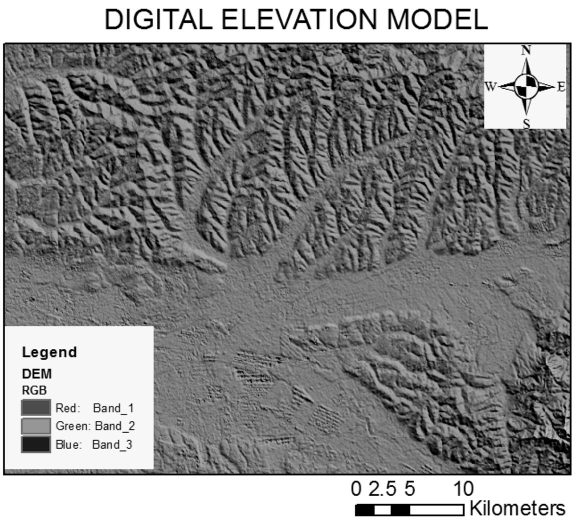



**Fig. 4 The digital elevation model imported into ArcGIS**

## 5. THE GENERATION OF THE SLOPES MAP FOR THE STUDIED AREA BY USING THE DEM MODEL

This operation will be made from **ArcToolbox** – **Spatial Analyst Tool**– *Surface-Slope*.

The dialogue cassette *Slope* will be completed as follows:
*Input raster: DEM*
*Output raster: The place where it will be saved the created raster and its name (Slope)*
*Output Measurement: Degree (the slope will be in degrees)*
*Z factor: 1*

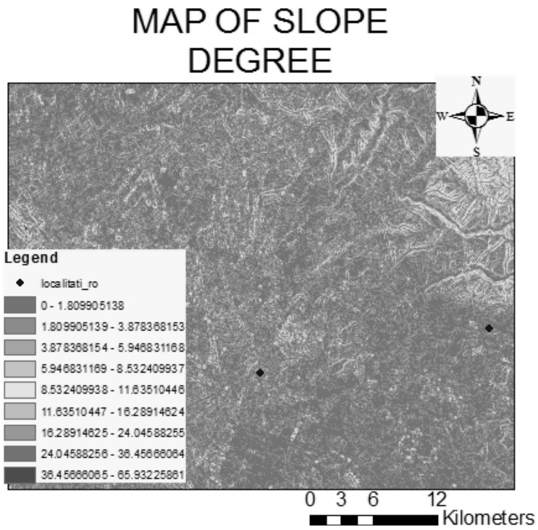



**Fig. 5 Slopes map (degrees)**

In order that the slope to be expressed in percents, it is used the command *Slope*. To input it will be selected the slope previously generated “Slope” , and to Output measurement it will be selected “Percent Rise”, and the result will be saved under the name of “SlopeProcent”.

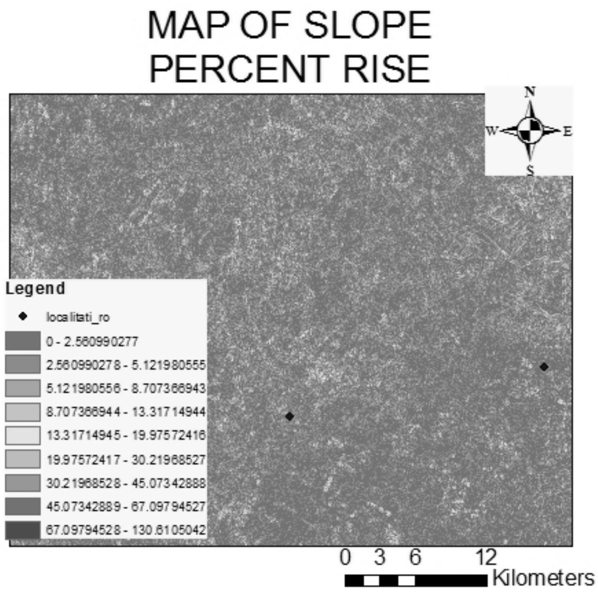



**Fig. 6 The slopes map (percents)**

### 6. CREATING A COST RASTER WHERE THE CELL VALUE SHOULD BE EQUAL WITH THE AMOUNT BETWEEN THE SLOPE AND THE LANDUSE RECLASSIFICATION, REPRESENTING THE COST OF MOVE THROUGH EACH CELL

This operation will be made from **ArcToolbox** – **Spatial Analyst Tool**– *Math- Plus*, for each reclassified raster, so we shall repeat it 4 times.

*The dialogue cassette Plus will be completed as follows:*

*Input raster 1: SlopeProcent (raster model of the slope in percents)*

*Input raster 2: Reclass Raster (reclass79, reclass80, reclass91, reclass92)*

*Output raster: we shall create 4 raster images (COST RASTER) for each trapeze (COST79, COST80, COST91, COST92)*

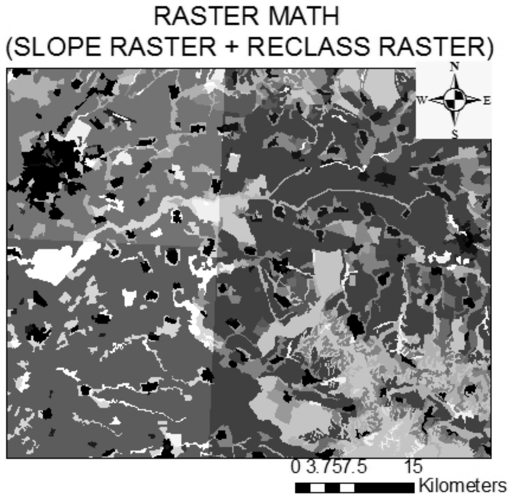



**Fig. 7 COST Raster**

### 7. OBTAINING A RASTER WITH COST OF MOVE FROM THE SOURCE POINT (TOWN) TO ANY OTHER DESTINATION POINT (TOWN)

In order to obtain a raster with cost of move from the source point to anz other destination point we make as follows: **ArcToolbox** – **Spatial Analyst Tool** – *Distance – Cost Distance,* for each CostRaster previously created, so, repeating this command 4 times.

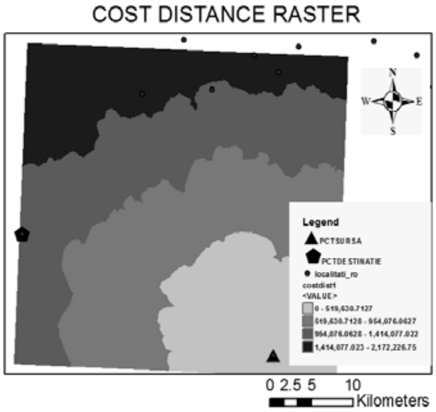
The dialogue cassette *Cost Distance* will be completed as follows:

*Input raster or feature destination data: it will be introduced the source point (town).*

*Input cost raster: it will be introduced the raster previously generated correspondent to the trapeze where it is the source point (eg.: COST80)*

*Output distance raster: The place where it will be saved the created raster and its name (eg.: costdist1)*

*Output backlink raster: backlink is the raster that shows the direction of movement for obtaining the minimum cost of move (eg.: back1)*



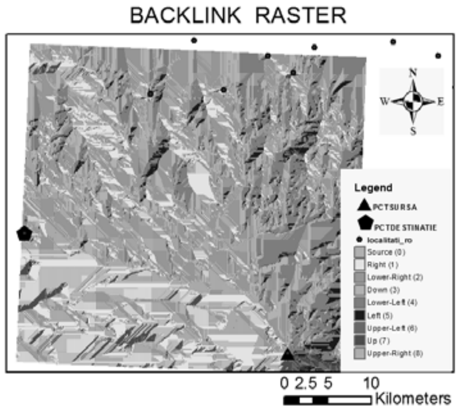




**Fig. 8 COST Distance Raster** **Fig. 9 Map for movement direction**

**8. DETERMINING THE MINIMUM ROAD FROM THE SOURCE TO THE DESTINATION**

In order to determine the minimum road from the source point (town) to the destination point (town) we shall make as follows: **ArcToolbox** – **Spatial Analyst Tool** – *Distance – Cost Path*.

*Cost Path* Cassette will be completed as follows:

*Input raster or feature destination data: it will be chosen the destination point*

*Input cost distance raster: it will be completed the costdist ratser previously created (eg.: costdist1 )*

*Input cost backlink raster: back1*

*Output raster: The place where will be saved the created raster and its name (DrumMIN)*

DrumMIN ratser (Cost path) will be a raster with the cell value of 1 for the source and respectively for the destination and 3 for the road.

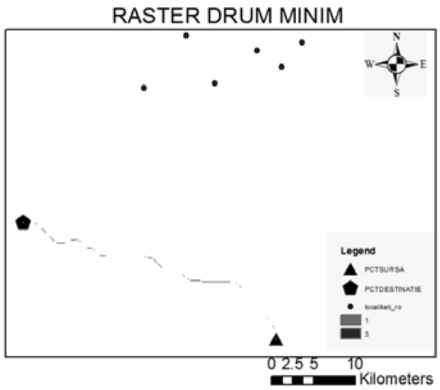



**Fig. 10 Minimum road between 2 town**

## 9. CONVENTION IN .SHP

By using the function **ArcToolbox** – **Conversion Tools –** *From Raster – Raster to Polyline* we may convert the obtained raster into .shp, by choosing to the input "*DrumMIN*" previously resulted and the resulted shp will be "DrumSHP" (RoadSHP).

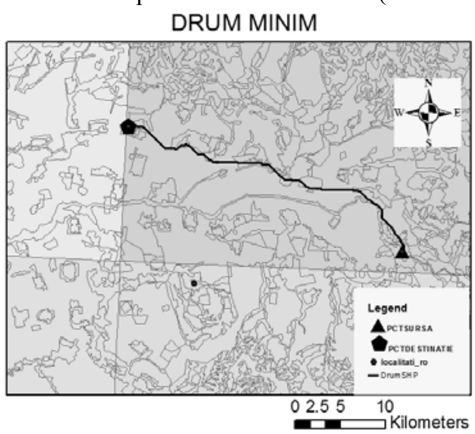



**Fig. 11 The minimum road between 2 towns overlapped to CLC**

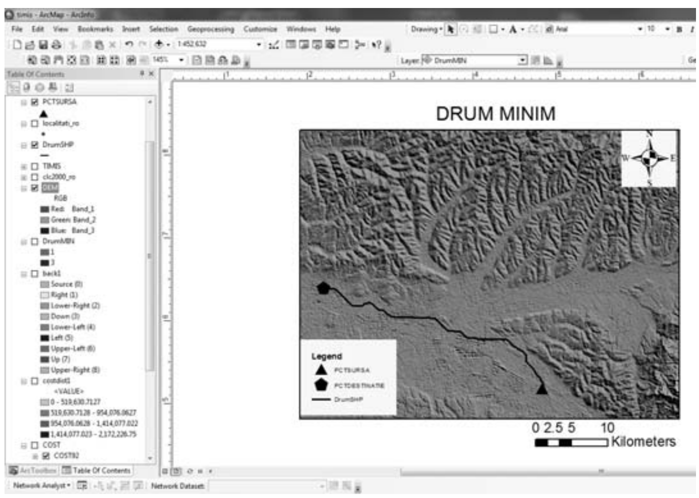



**Fig. 12 The minimum road between 2 towns overlapped to DEM**

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# AIR LEAKAGES RATE THROUGH SEALED SPACES

**CIOCLEA DORU*
LUPU CONSTANTIN*
TOTH ION*
GHERGHE ION***

**Abstract:** *The underground safety during coal mining can be influenced by several factors, among which some of the most important ones are air leakages through goafs. This air leakage is influenced at its turn by three factors: geo mechanical, technological and ventilation factors.The coal massif under mining is subjected to stresses that lead to strains nearby the gallery. Subsequently, there shall occur a deformation, break, factoring and fissuring of the coal and of the surrounding rocks. The mining of thick layers shall give birth to aerodynamic connection both through the goaf of the mined panel and between the goafs related to the two adjacent panels. These connections shall trigger air leakages in an uncontrolled manner. There also may occur aerodynamic connections between successive raises, thus occurring diagonal connections. All these aspects increase the instability of the air flow at the working face. Subsequently, any change of strengths along diagonal connections or on other mine structures in relation to the concerned mine working shall give air leakage through goafs.*

**Key words:** *Air leakages, goaf, ventilation*

## 1. FAVORING FACTORS THAT INFLUENCE THE AIR LEAKAGES REGIME THROUGH SEALED SPACES

Air leakages through sealed spaces or through goafs can lead to excessive oxidation of high reactivity coals, a phenomenon that can lead to auto-ignition of the coal mass and in the end to endogenous fire [2; 5].

Air leakages through sealed spaces or through goafs are influenced by three types of favoring factors: geo mechanical, technological and ventilation factors.

Of the three categories of favoring factors, the ventilation factors are considered to have the highest weight regarding the air leakages through goafs.

The following factors that belong to the ventilation category are considered to have a major impact concerning air leakages: the ventilation type used in two successive or adjacent coal-faces that are in exploitation and the same time, the depression in two successive or adjacent coal-faces that are in exploitation and the same time, respectively the pressure loss at

* *INCD-INSEMEX, Petroşani, România, doru.cioclea@insemex.ro, constantin.lupu@insemex.ro,, ion.toth@insemex.ro, ion.gherghe@insemex.ro*

coal-face level, but the determinant one is the depression in two successive or adjacent coal-faces that are in exploitation and the same time.

## 2. IDENTIFICATION OF THE AIR LEAKAGES REGIME THROUGH SEALED SPACES, WHICH OCCUR BETWEEN DIFFERENT WORK PLACES

In the past 15 years in the Jiul Valley coal field a new method in several variants has been applied, namely the *undermined coal bed exploitation method* [7; 9]. This method has practically become the main exploitation method which, besides its obvious advantages, also presents an increase of the risk factors already existing underground. The instability of the ventilation system is the predominant risk factor [1; 3; 4; 8; 10].

Once with the implementation of the undermined coal bed exploitation method it was necessary to transplant this method to the opening and preparation works performed for classical exploitation methods.

The average height of the sublevel is 10 m and it comprises the front coal-face with a height of 2,5 m, the difference of 7,5 m being constituted of the undermined coal bed.

### 2.1 Air leakages regime between the preparation works and the coal-face.

In the case of application of this method for the thick and high inclination layers, the layer shall be divided in sublevels vertically and the preparation works (outline) of the coal-face are performed at each sublevel. In order to maintain the continuity in exploitation, the preparation works for the following sublevel are performed simultaneously with the exploitation of the sublevel being in service. The blasting technology is used for digging of the directional preparation galleries on the floor and under the roof, which leads to the appearance of a fissuring zone that can facilitate the creation of aerodynamic connections between the diggings mine work and the goaf of the sublevel being in service, which is located at a superior level.

Figure 1 shows in principle the undermined coal bed exploitation method in the situation in which a preparation gallery is being dug at the next sublevel. In Figure 2 it is presented the intersection of the fissuring – crushing zones that arise on the preparation galleries alignment which belong to two successive sublevels. The air leakage between active mine workings model is presented in Figure 3.

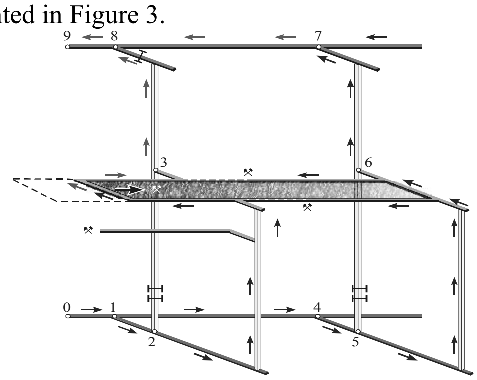


Figure 1: Ventilation network specific to the undermined coal bed method

*Source: Cioclea D.: Possibilities of quantitative qualitative assessment of air leakages in sealed spaces in order to ensure occupational health and safety in activities that take place in potentially explosive and/or toxic environments. INSEMEX Study, 2011*

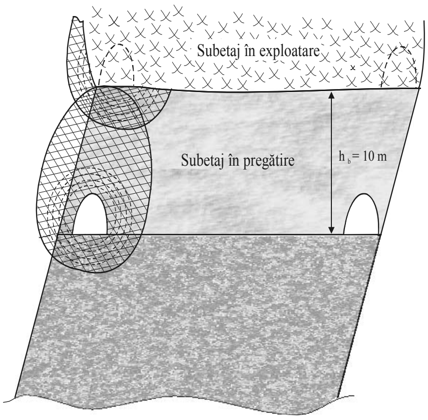


Figure 2: *Intersection of the fissuring zones around directional galleries belonging to two successive sublevels.*
*Source: Cioclea D.: Possibilities of quantitative qualitative assessment of air leakages in sealed spaces in order to ensure occupational health and safety in activities that take place in potentially explosive and/or toxic environments. INSEMEX Study, 2011.*

The lost flow [6] through short-circuiting $Q_{sc}$ is given by:

$$Q_{SC} = Q_{ref} + Q_p - Q_e \ (m^3/min) \quad (1)$$

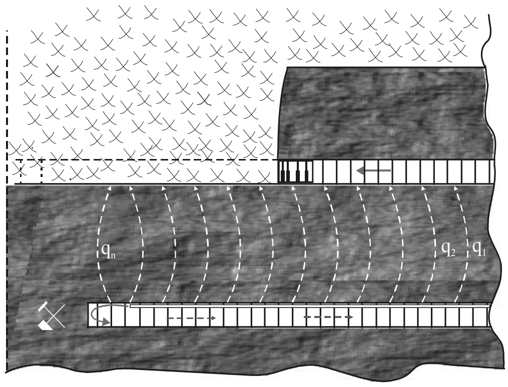


Figure 3: *The air leakages in the fissuring zone*
*Source: Cioclea D.: Possibilities of quantitative qualitative assessment of air leakages in sealed spaces in order to ensure occupational health and safety in activities that take place in potentially explosive and/or toxic environments. INSEMEX Study, 2011.*

Where:

$Q_{ref}$ - The flow measured at the exit of the ventilation tower when delivering under pressure, $m^3$/min;

$Q_p$ - lost flow on the length of the tower through non-tightness, $m^3$/min;

$Q_e$ - the flow measured at the exit of the mine working, $m^3$/min.

But:

$$Q_p = Q_a - Q_{ref} \ (m^3/min) \quad (2)$$

where:

$Q_a$ - suction flow in the ventilation tower, $m^3$/min.

Then:

$$Q_{SC} = Q_a - Q_e \ (m^3/min) \tag{3}$$

On the other side the exploited coal-face is ventilated under the general depression of the mine which carries on the coal-face a depression $H_a$.

Due to previously mentioned short-circuiting over the coal-face is circulated a flow $Q_{ta}$

$$Q_{ta} = Q_a + Q_{SC} \ (m^3/min) \tag{4}$$

where:

$Q_a$ – the circulated flow on the coal-face circuit, $m^3$/min.

The flow coming from short-circuiting comprises the sum of the short-circuiting flows, from each aerodynamic route:

$$Q_{SC} = \sum_{i=1}^{n} q_i \ (m^3/min) \tag{5}$$

But:

$$Q_{sc}^2 = \frac{H_f}{R_f} \ (m^3/min) \tag{6}$$

where:

$H_f$ - total depression applied on the alignment of the fissuring zone (Pa);

$R_f$ - aerodynamic resistance of the fissuring zone, (N $s^2/m^8$).

$$H_f = H_p + H_a \ (Pa) \tag{7}$$

Therefore:

$$Q_{SC} = \sqrt{\frac{H_p + H_a}{R_f}} = \sum_{i=1}^{n} q_i = Q_a - Q_e \tag{8}$$

Following completion of the aerodynamic connections through the fissured rock-mass, the canonical diagram is modified presenting diagonal connections – Figure 4

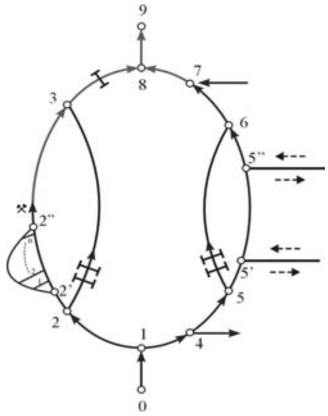


Figure 4: Canonical diagram which also includes parallel connections from the fissuring zone.

*Source: Cioclea D.: Possibilities of quantitative qualitative assessment of air leakages in sealed spaces in order to ensure occupational health and safety in activities that take place in potentially explosive and/or toxic environments. INSEMEX Study, 2011.*

**2.2 Air leakages regime behind the coal-face line**

The fresh air current possesses high enough kinetic energy so that it doesn't follow entirely the line of the working-front but enters the goaf in the form of lines of flow Figure 5.

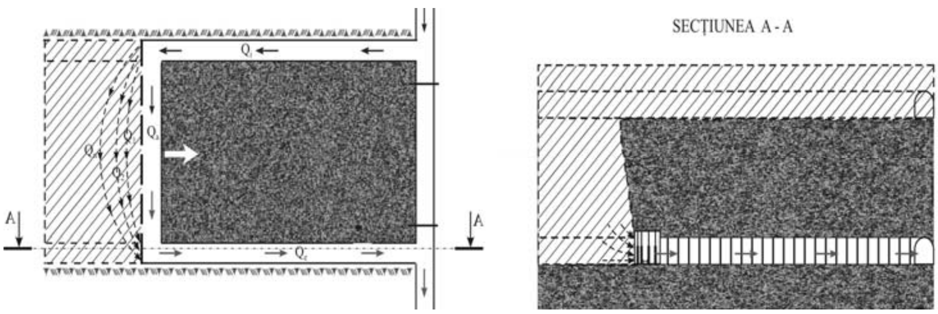


Figure 5: *Air leakages through goafs.*

*Source: Cioclea D.: Possibilities of quantitative qualitative assessment of air leakages in sealed spaces in order to ensure occupational health and safety in activities that take place in potentially explosive and/or toxic environments. INSEMEX Study, 2011*

The particularities presented in this case consist in the fact that the lines of flow are not disposed horizontally, but in space. In this case we will have an entering flow which generally is less or approximately equal to the evacuation flow. But at the line of the coal-face the flow is divided into the primary flow, which is circulated in the working front, and also into a series of flows which are circulated in the goaf and which meet with the flow at the intersection of the working front with the ventilation gallery 10.

So we can write:

$$Q_i \le Q_e \qquad (9)$$

$$Q = Q_a + Q_p \ (m^3/min)$$

Where:

$Q_p$ – total flow loss in the goaf

$$Q_p = Q_1 + Q_2 + ... + Q_n \quad (m^3/min) \tag{10}$$

But the depression at the coal-face level is:

$$h = R_t \cdot Q_i^2 \tag{11}$$

Where:

h –the depression created at the coal-face level ($P_a$);

$R_t$ – total aerodynamic resistance of the flow routes (N $s^2/m^8$);

$Q^2{}_i$ – the circulated flow through the coal-face and the one lost behind the coal-face, ($m^3$/min);

But:

$$\frac{1}{\sqrt{R_t}} = \frac{1}{\sqrt{R_a}} + \frac{1}{\sqrt{R_p}} \tag{12}$$

Where:

$R_a$ and $R_p$ - aerodynamic resistances of the coal-face respectively of the routes on which the lost flows are circulated (N $s^2/m^8$).

It can be observed from the figures that the routes of the flows $Q_1$...$Q_n$ represent parallel connections with the flow $Q_a$.

In this case the total resistance $R_p$ has the following form:

$$\frac{1}{\sqrt{R_p}} = \frac{1}{\sqrt{R_1}} + \frac{1}{\sqrt{R_2}} + ... + \frac{1}{\sqrt{R_n}} = \sum_{i=1}^{P_n} \frac{1}{\sqrt{R_i}} \tag{13}$$

Where:

$R_p$ – total resistance of the flowing routes through goafs.

In this case we have:

$$Q^2 = \frac{h}{R_z} = h\sum_{i=1}^{n} \frac{1}{R_i} \tag{14}$$

On the canonical diagram in Figure 6, this would mean the existence of 1 ÷ n aerodynamic connections that are parallel with the coal-face.

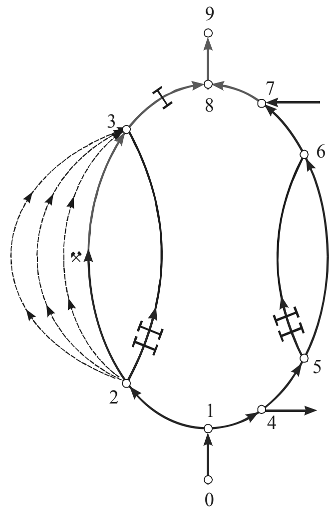


Figure 6: Canonical diagram which includes the parallel connections related to the air leakages through goafs.

*Source: Cioclea D.: Possibilities of quantitative qualitative assessment of air leakages in sealed spaces in order to ensure occupational health and safety in activities that take place in potentially explosive and/or toxic environments. INSEMEX Study, 2011.*

**2.3 Air leakages regime on the height of the sublevel**

Because of the phenomena that take place at the rock-mass – coal-face complex and that arise during the coal digging of the preparation works and after starting the actual coal exploitation, there occur a series of fissures on the alignment of the fresh air and polluted air galleries. These fissures are disposed on the entire perimeter of the gallery up to a distance of:

$$D = (2 \div 5) \cdot d \;\; (m) \tag{15}$$

Where:

D – distance in the rock mass up to where coal fissures can be found, (m)
d – diameter of the mining work executed in coal, (m).

These aerodynamic connections are distributed throughout the length on the direction of the coal-face and they make connection between alignment of the fresh air directional gallery through existent fissures in the undermined coal bed, up to the goaf level related to the superior sublevel, at this level it crosses the goaf on the whole width of the sublevel and it enters in the ventilation gallery through existent fissure at the level of undermined coal bed nearby Figure7.

From Figure 6 there can be observed that there exists an air circulation that is parallel with the coal-face on the alignment of several air current lines parallel with the working front $q_1 \ldots q_n$

$$Q_{SC} = q_1 + q_2 + \ldots + q_0 \tag{16}$$

Where:

$Q_{sc}$ – total short-circuiting flow ($m^3$/min)
$q_1 \div q_n$ – short-circuiting flows on each route ($m^3$/min).
But the equation can also be written:

$$h = r_{SC} \cdot Q_{SC}^2 \quad (Pa) \tag{17}$$

Where:

$r_{sc}$ – total resistance of the short-circuiting routes ($N\ s^2/m^8$);

where:

$$\frac{1}{\sqrt{r_{SC}}} = \frac{1}{\sqrt{r_1}} + \frac{1}{\sqrt{r_2}} + \ldots + \frac{1}{\sqrt{r_n}} = \sum_{i=1}^{n} \frac{1}{\sqrt{r_i}} \tag{18}$$

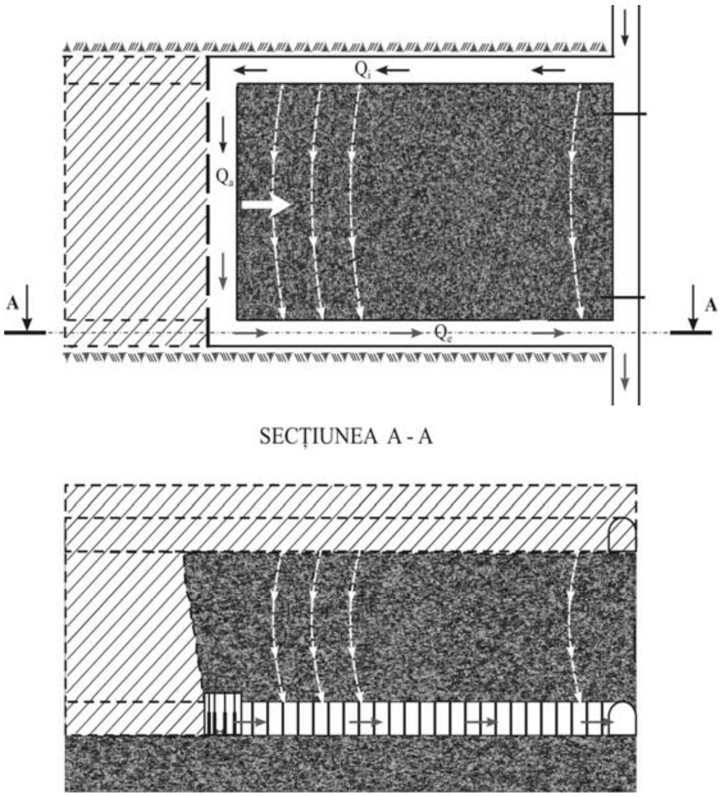


Figure7. Air leakages that take place over the coal-bed

*Source: Cioclea D.: Possibilities of quantitative qualitative assessment of air leakages in sealed spaces in order to ensure occupational health and safety in activities that take place in potentially explosive and/or toxic environments. INSEMEX Study, 2011*

### 3. CONCLUSIONS

**-** The state of safety in underground mining is influenced by several factors, among which are air leakages through goafs. Air leakages through goafs are influenced by three categories of favoring factors: geo mechanical, technological and ventilation factors. From these three categories of factors, the ventilation factors are considered to have the highest weight in terms of air leakages through goafs. From the ventilation factors category the determinant one is the depression in two successive or adjacent coal-faces that are in exploitation and the same time.

**-** The undermined coal bed exploitation method applied to thick layers with high inclination involves the division of the layers in sublevels. Air short-circuiting occur between the preparation work which is located at the inferior sublevel and the coal face that is located at a higher level because of the fissuring zones that result after blasting, located on the alignment of the preparation works at two consecutive sublevels, one of them in exploitation and the other now shaping and which intersect.

**-** In case of the exploitation of the thick and high inclination layers with the execution of the preparation works, on the layer occur aerodynamic connections between successive raises which leads to the appearance of diagonal connections. These give a high instability rate of the air flow at the working-front level. Therefore, any modification of the resistances on the diagonal connections or of the other mine workings related to the coal-face lead to air leakages through goafs.

**-** Fresh air current possesses high enough kinetic energy so that it doesn't follow entirely the line of the working-front but enters the goaf in the form of lines of flow. This is due to the specific form of the goaf related to undermined coal-beds which extends vertically behind the front line much above their support.

**-** Because of the phenomena that take place at the rock-mass – coal-face complex and that arise during the coal digging of the preparation works and after starting the actual coal exploitation, there occur a series of fissures on the alignment of the fresh air and polluted air galleries, through which aerodynamic connections with the superior exploited sublevel are realized. These aerodynamic connections are distributed throughout the length on the direction of the coal-face and they make connection between alignment of the fresh air directional gallery through existent fissures in the undermined coal bed nearby and the goaf related to the superior sublevel.

**-** The air leakages through goafs lead to instability or to the decrease of the air flow and which lead implicitly to the increase of gas concentration at the coal-face level. These also lead to the reactivation, respectively to the occurrence of new spontaneous combustion phenomena.

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Scientific Reviewers:
Assoc. Prof. PhD. Eng. Roland Moraru

# STATIC AND DYNAMIC RESPONSE LOAD COMPUTATION OWN AN UNDERGROUND CONSTRUCTION

**RITZIU WILLIAM FLAVY**[*]

**Abstract:** *It's a real railway tunnel, with 26.17 m of rock above, in the length of 128 m at an altitude of 1000 m in the Carpathians Mountain. The computation model is represented by bidirectional finite elements, considering a plain deformation. Lateral and under the tunnel we considered 5 tunnel diameters of the rock of the mountain. Above the tunnel I took just 26.17 m. So, our model is 63*56 m. Based on the model above, the computer program SAP2000-V14, gave the static and self-dynamic response of the nodal displacement and unit efforts. The output is for the entire model or most representative points of interest of the model. Not the absolute values are important but the relationships between the values are more significant. The output contains a number of nodal displacements, unit efforts, diagrams. The maximum displacement is on the vertical direction in the amount of 5.3 cm because of self weight of the tunnel and 0.02 cm because of the convoy (train). More consideration of the output of the program for the static considerations in the conclusions of the article. For the self dynamic response, there were determined 11 modes of vibrations, with a participation of 95 % of the modal mass. See the diagrams. So, the output determined that for the specified T: T1=0.407 s, modal mass is y=0.65973 a vertical translation, a rigid behavior. T2=0.326 s, modal mass is x=0.83512, an horizontal translation, T3=0.282 s, is a torsion.*

## 1. DESCRIPTION OF THE STRUCTURE STUDIED AND NEW TECHNOLOGY TO ACHIEVE CROSS-SECTION OF TUNNEL

- Studied tunnel is at an altitude of 1000 m, has 128 m length, and ground coverage of 26.17 m.
- To achieve a maximum speed of the train of 100 km / h, it was found that the descending slab solution of 0.6 m, this is allowed due to the low side pushing, then made a response to seismicity study of all construction - surrounding solid rock.
- Cross section is classic horseshoe shape; the soffit is concrete and has a protective moloane.

Complex technical expertise revealed physico-mechanical properties of land, concrete and reinforcement as in normal parameters.

### 1.1. Existing cross-section

The calculation:

[*] *Assoc. Prof. student Ph.D. Eng., City University of New York, williriz@yahoo.com*

• The calculation is made of two-dimensional finite element deformation state plan (Mestat 1997, Fierbinteanu 1989).

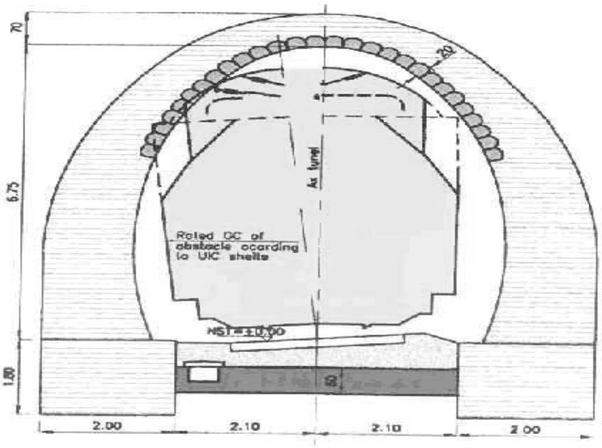
• The calculation was considered an area of 26.17 m above and the rest around 5 tunnel diameters

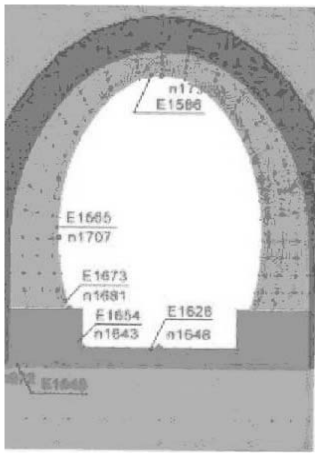
• Generated by the model size (63x56m) ensure the elimination of the consequences of disturbances created by the cinematic shape.

• Therefore the vertical sides of rigid links were placed horizontally and vertically elastic links.

• To increase the accuracy of the model has increased the number of vertical and horizontal elements resulting in 1866 nodes and 3613 degrees of freedom (equations).

• Vibration characteristics are determined by the modulus of elasticity (kN/m$^2$), Poisson ratio and specific gravity down concrete tunnel (B150), moloane concrete foundation (B75).




Detail: n = node
E = element

Table 1 The mechanical characteristics of materials

| Material | Modulus of elasticity (kN/m²) | Poisson coefficient | Density (kN/m³) |
|---|---|---|---|
| Earth = Waterproofing | $E_{static}$ =3,03 x $10^5$ <br> $E_{dynamic}$ =2,42 x $10^5$ | $\mu_{static}$ =0,22 <br> $\mu_{dynamic}$ =0,22 | 20,50 |
| Concrete tunnel B150 | 230 x $10^5$ | 0,22 | 24,00 |
| Moloane | 230 x $10^5$ | 0,22 | 24,00 |
| Concrete foundation B75 | 155 x $10^5$ | 0,22 | 24,00 |

4. Calculation of the static loads calculation to take into consideration static loads: curb weight + tare weight of the tunnel ground forces concentrated in the slab by convoy at a rate of 20% combination of the three.

5. Consider its dynamic response of the masses used to calculate the amount of static loads.

6. Calculation of the seismic action was considered:

a) Design spectrum as

b) As accelerograms

6a. Spectral loading cargo in three situations under P100 - 2006: the horizontal direction, vertical and both directions

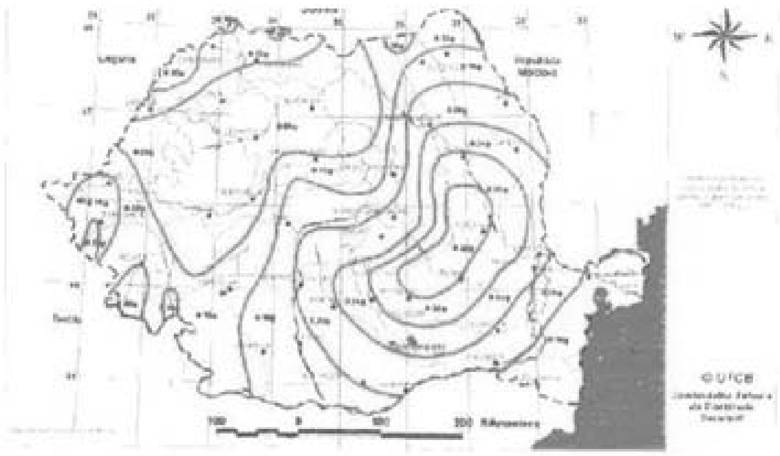


**Fig.5 zoning of the territory of Romania in terms of peak values of ground acceleration for earthquakes with design $a_g$ average recurrence interval IMR = 100 years [P100-2006]**


**Fig.6 Zoning of the territory of Romania in terms of control period (corner) of the response spectrum T_c [P100-2006]**

According to norm P100-2006, the structure is so framed that $T_c$ = 1.0 s and $a_g$=0,28g.

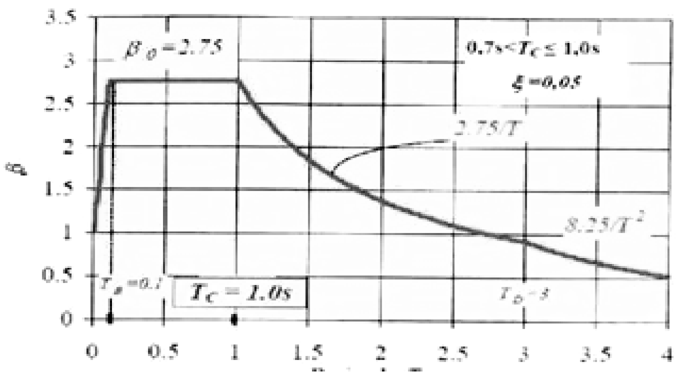



**Fig. 7 Elastic response spectrum normalized [P100-2006]**

**Period I**

To determine the behavior factor q value, normative data were used P100-2006 Table 1 - The structure regularity account and Table 1 - Comparison "q" factor values and paragraph (5-b) structure with only 2 walls ($a_u/a_2$ = 1,0). A value was chosen as q = 3.

**II. Output data**

**7. OUTPUT DATA FOR STATIC**

Output data are presented and interpreted for: (i) static load, (ii) its dynamic response;

Mechanical measurements representations - captured in SAP software 2000-V14 - are either nodal displacement are consistent efforts, in some case both whole and in detail the model for the tunnel and immediately adjacent area.

Displacement values are presented and unified efforts in all areas of interest:

(I) node key corresponding to the tunnel soffit, (ii) node in the middle slab, (iii) node vault birth, (iv) the end node of the foundation, (v) from node to free the land from the axis of symmetry model, (vi) various other areas that might be interesting for different loads.

Comments are made with values obtained but noted that not only quantitative, absolute values, are of interest, especially as qualitative relationships between them.

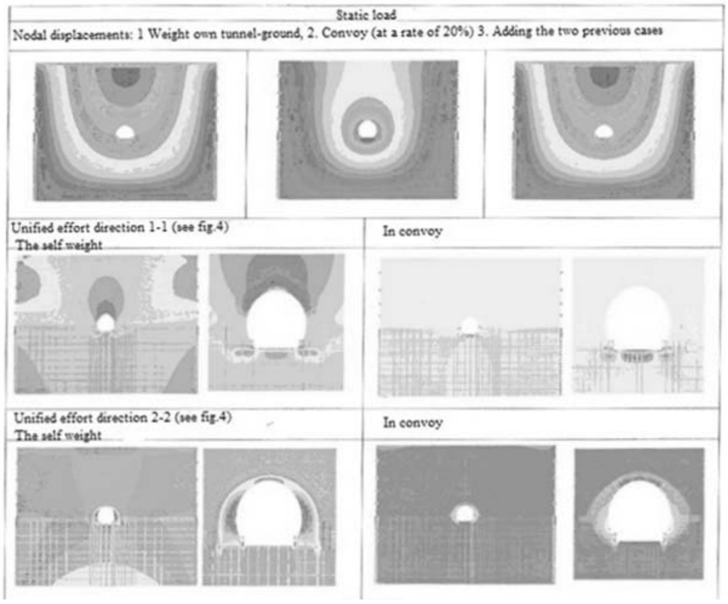
**7.1. Comments on static loading**

It is found that values of any size coming from symmetrical loads are also symmetric; it may be that in terms of geometry, materials and loads, the model is correctly done.

Is the maximum vertical direction, amounting to 5.3 cm the effect of their weight and 0.02 cm the effect of 20% of the conveyor. Horizontal displacement, amounting to 0.73 cm (for weight) 14% of the vertical displacement.

The efforts of both S11 and S12 unit had maximum values in the tunnel elements. For the maximum loading weight convoy are in different areas of the tunnel, while the convoy loaded with the maximum weight (S11 and S12) are in the slab.

Efforts in the direction of maximum in sections 1-1 are different - the middle slab to load its own weight and the upper slab for convoy. However, as a whole the model S11 forts are in the slab for both types of loads. Maximum effort for 1-1 Convoy is 11% of maximum effort 1-1 SOFT own weight. The distance between the prices is high or the radial corner. Convoy intake is different from the two levels, namely represents almost 3% at the maximum distance between walls is about 12% and the upper radial.




**8. DYNAMIC RESPONSE**

Were determined 11 modes of vibration and their participation was obtained for 95% of the modal mass. If we only own 10 ways modal mass is approaching 90%.

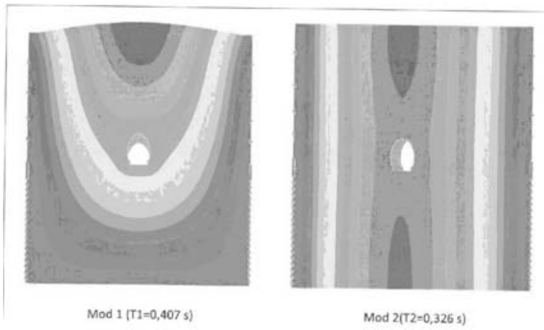



**Fig. 8. Own forms of vibration**

**9. COMMENTS ON ITS DYNAMIC RESPONSE**

Fundamental mode (T1 = 0.407 s) situated between the structure with rigid behavior. Vector type of vibration is vertical translation.

Module two (T2 = 0.326 s) is a horizontal vibration which causes the modal mass ratio of 84%. Its period 2 value is 20% lower than the fundamental period while the proportion in which the modal mass is driven higher by 27%.

Module three (T3 = 0.282) is the torsion, the value of its period is 31% lower than the fundamental mode.

Period 5 reaches half way between fundamental.

Eigenvectors are found in the representations that are quite orderly assembly movement and a drive assembly.

Based on these observations will be decided how to load the structure with the design spectrum.

**Table 6 Periods and modal masses**

| Mod | Period - (S) | Modal mass - x | Modal mass - y |
|---|---|---|---|
| 1 | 0,407 | | 0,65973 Vertical translation |
| 2 | 0,326 | 0,83512 Horizontal translation | |
| 3 | 0,282 | Torsion | |
| 4 | 0,217 | | 0,08343 |
| 5 | 0,200 | 0,00034 | |
| 6 | 0,172 | | 0,06342 |
| 7 | 0,127 | | 0,07860 |
| 8 | 0,115 | 0,3661 | |
| 9 | 0,104 | 0,05948 | |
| 10 | 0,066 | | 0,08244 |
| 11 | 0,053 | 0,05186 | |
| Sum of modal masses | | 0,98343 | 0,96762 |

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Scientific Reviewers:
Prof. PhD. Eng. Constantin Semen

# A METHODOLOGY FOR THE OPTIMIZATION OF THE THERMAL INSULATION DIMENSIONS

IONESCU ŞTEFANIA*

## 1. INTRODUCTION

Generally, either it is the case of a new building construction or of an old, existing building retrofitting, the thicketness of the thermal insulation is imposed (mainly based on the designer experience) and that it is verified if the correct thermal requirements are satisfied. From economic reasons, it is important to know requirements of a good thermal insulation. Currently the only way to find this "minimal thickness" is by the consecutive try-out method, namely to make reiterative calculation mainly for the corrected specific thermal resistance ($R'$ ) and the overall factor of thermal resistance (G), buts this supposes a laborious work.

Anyway, if for these calculations is applied a suitable methodology, than the supplementary work is reduced considerably.

## 2. THE OPTIMIZATION METHODOLOGY

The necessary reiterative calculation required to optimize the thermal insulating layer thickness (by the numerical analogy of the thermal fields for the analyzed thermal bridges) is reasonable reduced if there are respected the following:

- to detect and to use the parts of the building with similar characteristics (rooms or apartments or identical functional units or floors etc.) and to use the symmetry how many times it is possible;
- to impose an initial thickness of the thermal insulation as close as possible to the final solution for the optimal thickness; in this way the number of trials are significantly reduced, but is necessary some practice for this performance.

For instance in the case of structures with masonry walls or a structure with masonry walls hardened with reinforced convert straps and "column type" insertions, in order to have a value of $R' = 1{,}4\ m^2\ {}^0C/W$ for the overall thermal resistance of the external wall, it is necessary to provide in the current field (the pure sections) a thermal resistance of circa 1,8 time higher,

* Lecturer PhD.Eng., Engineering Faculty in Braila, University "Dunarea de Jos" of Galati, Calea Calarasilor 29, 810017, Braila, ROMANIA

so R $\approx$ 1,8 x 1,4=2,5 $m^2$ $^0C/W$, which give a good starting value for the thermal insulation thickness;

- an adequate approach of the numerical model: in order to avoid the frequent geometry and limit conditions changes for each variant of thickness, it is easier to modify the value of the thermal conductivity factor $\lambda$ of the thermal insulating material in a manner that simulate the thickness (this procedure will affect the results regarding the thermal flux with an average less than 3%, but the values of the minimal temperature on the internal surface diverges with circ. 0,0…2,5 $^0C$; for this reason the method is recommended only for the estimation of linear and punctual heat transfer factors $\psi$ and $\chi$ );

- to connect more thermal bridges in a single field and to estimate one $\psi$ factor that describes globally these bridges;

- according to C 107-Prescription, the thermal flux is estimated with the commutation relation: $\Phi = \sum\Phi_i = \sum(\alpha_i \times l_i \times \Delta T_i)$That is a simple procedure, but laborious, especially in the case of large buildings that have many types of thermal bridges. Therefore it is important to know

- that the modern versions of the computation soft can supply directly the flux values $\Phi_i$ in the network nodal points or on the elements; some numerical programs gives directly the amount of these values, therefore

- the flux that get through the interest sections (the internal surfaces of the analysed envelope part);

- to organize the computation of the factors $\psi$ , $\chi$ and the amounts $\sum(\psi_i l_i)$, $\sum(\chi_i)$, etc. using a tabular computing program as EXCEL or something similar.

## 3. COMPUTING EXAMPLE

In the ages of 1989-1990 was designed and constructed in Constanta city a building, very close to the sea, and it is intended mainly for teaching and training activities in the naval field (Fig.1) The building structure consists in monolith reinforced concrete frames and the external (non- loadbearing) walls are made of hollow ceramic building blocks masonry.

The building was designedaccording the older standards (effectual in that period) that gives less importance to the problems related to the heat transfer and energy comsumption in building service. In the conditions, according to the original project, the thermal insulation consists in a layer of 3 cm polystyrene placed on the internal surface of the wall. Without any checking, it is obvious that this constructive solution contradicts the current standards because:

- the thickness of the thermal insulation is unsatisfactory;
- the position of the thermal insulating layer on the internal face of the element is not recommended for new buildings.
- The thermal bridges (at the contour beams and columns, the window opening boundaries, etc.)
- The thermal bridges (at the contour beams and columns, the window opening boundaries etc.) are not corrected.

**Fig. 1.** Naval improvement center – front towards the sea [4]

**Fig. 2.** Naval improvement center – front towards the main road [4]

Fig.3 The studied building. The position of the analyzed room [4]

The expertise of the building was in a research contract. The hygrothermal estimation made for the entire building, according to the new technical standards (C107- prescription etc.) were very laborious. The paper presents just the case of a room situated at the first floor, at the corner of the building with the long external wall situated at the north and the floor slab exposed (partly) to the outdoor air action (Fig.1,2). The position is considered the most unfavorable considering the hygrothermal loads.

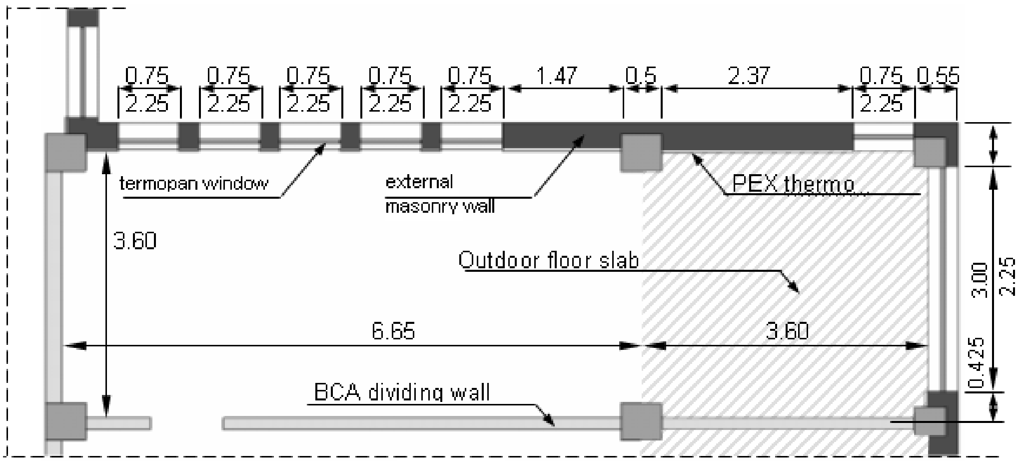


Fig.4 The analyzed room plane

As in other rooms disposed with the face to the sea, in this room emerged, from the beginning of the building service, surface condensing phenomenon (and possible condensing inside enclosing elements), on the internal surface of the external columns (without thermal protection), at the windows cills and seldom on top of the clay plates floor finishing on the surface where the floor slab is submitted to the outdoor air action (Fig.2)

**Fig. 5** Condensation at the corner pole

**Fig.6.**Condensation at the inferior edge of the window

**Fig. 7.** Condensation on the floor made of sandstone [19]

Because the thermal bridges are not similar to those presented in the (modest) data bases of the C 107- Prescription, for a correct estimation it was necessary to use numerical models and a computation soft capable to solve plane thermal fields problems.

For the assessment of the optimal thickness of the supplementary thermal insulation layer of polystyrene, disposed on the external face of the wall, the following path was traversed (see the results in tab.1).

**Iteration 1-** a supplementary thermal insulation layer with a constant thickness of 6 cm is assumed for the walls and for floor slab that is submitted to the outdoor air action. The total thicknessof the thermal insulating layer becomes 9 cm: 3 cm inside (the old insulation) + 6 cm outside (the new insulation). The values of $\psi$ are presented in tab. 1, column 1, and those of $\sum(\psi \cdot l)$ in tab 1, column 5. The corrected heat transfer factors and corrected thermal resistances are centralized in tab.2.

The values of the corrected thermal resistances of the walls satisfy the requirements imposed by C107- Prescription ($R' > R'_{min} = 1.4\ m^2{}^oC/W$); but the analogous requirement for the floor slab ($R' > R'_{min} = 4.5\ m^2\ {}^oC/W$) is not satisfied.

**Iteration 2-** the supplementary thermal insulating layer of the wall is reduced to 5 cm and the thermal insulating layer of the floor slab is increased to 17cm. The total thickness of the thermal insulating layer becomes 3+5 =9 cm: 3 cm (for the walls) and 3+17=20 cm (for the floor slab).The values of $\psi$ are presented in tab 1, column 2, and those of $\sum(\psi \cdot l)$ in tab 1, column 6. The corrected heat transfer factors and corrected thermal resistances are centralized in tab 3.

T he thermal resistance of the walls is adequate but for the floor slab do not satisfies the condition $R' > R'_{min}$ .

**Iteration 3-** the supplementary thermal insulation of the wall is reduced to 4 cm and the thermal insulating layer of the floor slab is increased to 27 cm. The total thickness of the thermal insulating layer of the walls becomes 3+4=7 cm, and for the floor slab becomes 3+27=30 cm. The values of $\psi$ are presented in tab 1, column 3 and those of $\sum(\psi \cdot l)$ in table 1, column 7. The corrected heat transfer factors and corrected thermal resistances are centralized in table 4.

**Table 1** ψ factors and ∑(ψl) – terms

| Detail | ψ | | | l | ψ.l | | |
|---|---|---|---|---|---|---|---|
| Bridge | Bridge | Bridge | Bridge | Bridge | Bridge | Bridge | Bridge |
| **Wall 35** | | | | | | | |
| Bridge A1 | 0.1784 | 0.1509 | 0.1523 | 2.25 | 0.4015 | 0.3396 | 0.3427 |
| Bridge A2 | -0.2022 | -0.2152 | -0.1596 | 1.25 | -0.2527 | -0.2691 | -0.1995 |
| Bridge B | 0.4506 | 0.4430 | 0.4434 | 9.00 | 4.0551 | 3.9867 | 3.9909 |
| Bridge C | 0.2351 | 0.2238 | 0.2661 | 2.25 | 0.5289 | 0.5036 | 0.5987 |
| Bridge D | 0.0677 | 0.0809 | 0.1534 | 3.50 | 0.2371 | 0.2831 | 0.5368 |
| Bridge K1 | 0.2800 | 0.2831 | 0.3002 | 3.75 | 1.0498 | 1.0618 | 1.1257 |
| Bridge K2 | 0.0371 | 0.0461 | 0.1061 | 2.90 | 0.1076 | 0.1336 | 0.3078 |
| Bridge L1 | 0.2457 | 0.2482 | 0.2911 | 3.75 | 0.9214 | 0.9308 | 1.0917 |
| Bridge L2 | 0.0783 | 0.0933 | 0.1734 | 2.90 | 0.2272 | 0.2706 | 0.5029 |
| ∑(ψ.l) | | | | | **7.2760** | **7.2408** | **8.2976** |
| **Wall 37.8** | | | | | | | |
| Bridge D | 0.0566 | 0.0689 | 0.1385 | 3.50 | 0.1980 | 0.2413 | 0.4847 |
| Bridge E1 | 0.9349 | 0.9273 | 0.9439 | 2.25 | 2.1036 | 2.0864 | 2.1239 |
| Bridge E2 | 0.2703 | 0.2920 | 0.4155 | 1.25 | 0.3379 | 0.3649 | 0.5194 |
| Bridge F1 | 0.3585 | 0.3552 | 0.3683 | 2.25 | 0.8065 | 0.7993 | 0.8287 |
| Bridge F2 | 0.0338 | 0.0731 | 0.1411 | 1.25 | 0.0422 | 0.0914 | 0.1764 |
| Bridge H1 | 0.2474 | 0.2047 | 0.2025 | 3.75 | 0.9277 | 0.7677 | 0.7592 |
| Bridge H2 | 0.0492 | -0.0044 | 0.0287 | 3.45 | 0.1696 | -0.0153 | 0.0989 |
| Bridge I1 | 0.3667 | 0.3734 | 0.4207 | 3.75 | 1.3753 | 1.4004 | 1.5777 |
| Bridge I2 | 0.1318 | 0.1540 | 0.2411 | 3.45 | 0.4548 | 0.5312 | 0.8320 |
| ∑(ψ.l) | | | | | **6.4156** | **6.2673** | **7.4008** |
| **Floor** | | | | | | | |
| Bridge G1 | -0.0660 | 0.0412 | -0.0043 | 3.00 | -0.1979 | 0.1236 | -0.0128 |
| Bridge G2 | -0.0755 | 0.0334 | -0.0121 | 0.60 | -0.0453 | 0.0200 | -0.0072 |
| Bridge H1 | 0.3178 | 0.2505 | 0.1926 | 3.75 | 1.1917 | 0.9395 | 0.7222 |
| Bridge H2 | 0.2827 | 0.2024 | 0.1408 | 3.45 | 0.9752 | 0.6984 | 0.4859 |
| Bridge J | 0.1272 | 0.0165 | -0.0516 | 3.60 | 0.4581 | 0.0593 | -0.1859 |
| ∑(ψ.l) | | | | | **2.3818** | **1.8408** | **1.0021** |

**Table 2**

| Linear thermal resistance | Corrected heat loose factor | Corrected thermal resistance |
|---|---|---|
| **Wall 35** | | |
| 2.795 | 0.6943 | 1.5402 |
| **Wall 37.8** | | |
| 2.842 | 0.6147 | 1.6269 |
| **Floor** | | |
| 2.309 | 0.6169 | 1.6209 |

**Table 3**

| Linear thermal resistance | Corrected heat loose factor | Corrected thermal resistance |
|---|---|---|
| **Wall 35** | | |
| 2.568 | 0.6795 | 1.4716 |
| **Wall 37.8** | | |
| 2.615 | 0.6392 | 1.5646 |
| **Floor** | | |
| 4.809 | 0.3500 | 2.8572 |

**Table 4**

| Linear thermal resistance | Corrected heat loose factor | Corrected thermal resistance |
|---|---|---|
| **Wall 35** | | |
| 2.568 | 0.7219 | 1.3853 |
| **Wall 37.8** | | |
| 2.615 | 0.6856 | 1.4586 |
| **Floor** | | |
| 7.081 | 0.2185 | 4.5758 |

The thermal mean resistance (balanced by the areas) of the two wall types are:

$$R'_{med} = \frac{\sum A_i}{\sum \frac{A_i}{R'_i}} = \frac{14.75 + 17.73}{\frac{14.75}{1.3853} + \frac{17.73}{1.4586}} = \frac{32.48}{22.8} = 1.425 \text{ m}^2\text{K/W} > 1.4 \text{ m}^2\,{}^{o}\text{C/W}$$

Also for the floor slab the condition R' = 4.58 $m^2$ ºC/W > $R'_{min}$ = 4.5 $m^2$ ºC/W is satisfied. However, the thickness of 30 cm for the thermal insulation that must be placed under the floor slab is exaggerated. Therefore, it is legitimate to have some doubt about the value of minimal corrected thermal resistance proposed by C107-prescription for the slab submitted to the outdoor air action.

## 4. CONCLUSIONS

In conclusion it was possible to optimize the thickness of the supplementary thermal insulating layer using just three steps of iteration. In this case, to optimize means to find the minimum thickness of thermal insulation that satisfies the condition $R' > R'_{min}$.

Generally, with a good "guess" of the initial thermal insulation thickness, we can find the solution with a reduced number of essays (1…3 steps).Following the recommendation regarding how to simplify the analyze of different variants, presented above, the process of finding the optimal thermal insulation thickness becomes accessible with a moderate supplementary labor, either in the case of a new building construction or in the case of an old building retrofitting.

It is obvious for the final solution it is necessary to verify the fulfillment of all the other requirements imposed by C107- Prescription (the minimal temperatures on the indoor surface, the thermal stability, the vapor condensation risqué etc.)

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Scientific Reviewers:
Prof. PhD. Eng. Mircea Georgescu

# STUDY OF THE COMMON CHARACTERISTICS REGARDING THE TYPES OF PROTECTION FOR ELECTRICAL APPARATUS DESIGNED FOR USE IN EXPLOSIVE GASEOUS ATMOSPHERES

**MOLDOVAN LUCIAN[*]**
**DARIE MARIUS[*]**
**BURIAN SORIN[*]**
**IONESCU JEANA[*]**
**FRIEDMANN MARTIN[*]**
**MAGYARI MIHAI[*]**

**Abstract:** *This paper presents a comparison between the types of protection for electrical apparatus by comparing some common characteristics that are important for maintaining the integrity of explosion protection.*

**Cuvinte cheie** *type of protection, comparaison*

## 1. INTRODUCTION

Generally speaking, designing and manufacturing of electrical apparatus benefits lately of special advantages, offered by the appearance of new components (integrated) and technologies, which makes the time that passes from enouncing the idea until physical achievement of the apparatus to be relatively short, and the process involved by that to be a monotonous one.

But, when the problem of adapting this apparatus to the particularities of use them in atmospheres with explosion hazard, the above mentioned process is considerably slowed, not by the missing of consecrated components for such processes, but especially by the leak of experience and knowledge regarding the standard requirements, referring to construction and using of electrical apparatus in areas with hazard of explosive atmosphere.

This state of fact is negatively more emphatic because, lately, the groups of standards from this field in the world, Europe and Romania have a peculiar dynamic caused especially by the homogenization and generalization process opened and maintained by IEC.

Considering the above mentioned, this paper proposes to help the designers and manufacturers of electric apparatus designed to be used in areas with hazard of explosive atmosphere by displaying a comparative study regarding definitive aspects for apliable types of protection.

[*] *PhD.Eng., INCD-INSEMEX, str. Gen. V. Milea, nr. 32-34, Petroşani, jud. Hunedoara*

## 2. CLASSIFICATION OF EXPLOSIVE ATMOSPHERES. HAZARD OF EXPLOSION

In order to speak about an explosion three factors must exist at the same time and in the same space. These factors form the triangle of explosion hazard (fig. 1**Error! Reference source not found.**).

Presence of flammable substances in form of gases, vapors, mists;

Presence of oxidant substance, air or oxygen, as support for violent combustion (explosion);

Presence of ignition source in form of sparks and hot surfaces.\

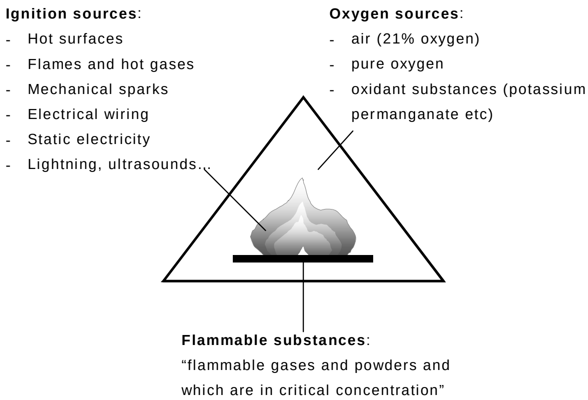


**Figure 1.** Ignition triangle

## 3. TYPES OF PROTECTION – SHORT DESCRIPTION

The type of protection represents a technical solution by which at least one of the factors represented in the ignition triangle is removed or limited below the critical values.

*Flameproof enclosure*

Represents a type of protection that permits to have an explosion inside equipment, but which by the characteristic elements for this type of protection (flameproof joints) makes that explosion not to be transmitted to the explosive atmosphere that surrounds the enclosure. Generally, it is used for power apparatus, but can also be used for other kinds of apparatus.

*Increased safety*

A type of protection which consists in applying some supplementary measures to avoid producing electric arcs, sparks, or excessive temperatures on any part of electrical apparatus (internal or external). These phenomena are not produced even in normal operation.

*Non-incendive*

Represents a type of protection which is based on the other types of protection principles, but it contains less rigorous prescriptions than those contained in the standards for types of protection eligible in zone 1. This type of protection is only eligible for zone 2.

*Intrinsic safety*

Represents a type of protection by which electrical parameters are safely limited so than the ignition source to be limited to a non hazardous value. This is also a consecrated type of protection for “low currents” applications.

*Encapsulation*

It is a type of protection by which the small kind apparatus is separated from hazardous atmosphere by moulding / enclosing in compound.

*Pressurization*

It's a type of protection by which the apparatus (often) in normal construction is placed inside an enclosure in which a protective gas is circulated so as in the inner space the explosive gas concentration is much lower than the lower explosive limit (LEL). Pressurization remains the only available solution for high frame sizes apparatus.

## 4. COMPARATIVE STUDY FOR THE TYPES OF PROTECTION

*Age*

The types of protection showed up like technical punctual solutions to protect the electrical equipment for use in surface or underground areas which involves the occurrence of explosive atmospheres.

The oldest types of protection are flameproof enclosure "d", which appeared at the end of the 19$^{th}$ century, oil immersion "o", sand filling "q", pressurization "p" and intrinsic safety "i" which appeared around 1930, their use and standards occurrence for them being noticed even from the first half of the 20$^{th}$ century.

Then after the second half of the past century started to be use the types of protection increased safety "e" (standardized in 1969) and encapsulation "m" (standardized in 1988).

At the end of the 20$^{th}$ century the types of protection oil immersion (o) and sand (powder) filling (q) were less and less used and leave the place for a composite type of protection which has some "soften" requirements regarding the type of protection. This type of protection was called non-incendive (n) and has a few subtypes like nA, nL, nC, nR.

*Incidence on equipment*

Regarding the usage frequency, it is relatively hard to do a documented (objective) study especially because the information regarding this subject are disparate and the study of certified / tested articles in INSEMEX Petroşani offers a unilateral image of this issue.

Based on authors experience the following conclusions can be exposed:

- The type of protection flameproof enclosure (d) is one of the most used types of protection for electrical apparatus operating in areas with hazard of explosive atmosphere as well for the power part and low current part. The tendency remarked regarding the use of this type of protection it's a low decreasing one especially because the appearance and use of other types of protection.
- Increased safety (e), pressurization (p), non- incendive (nA and nL) shows an increasing tendency regarding the usage owned especially to the less rigorous requirements comparative with the type of protection flameproof enclosure "d" and intrinsic safety.
- Intrinsic safety (i) keeps and consolidates its position being the direct applicable solution for low currents apparatus and systems.
- Encapsulation (m) has a low incidence, but the tendency is to slowly increase.
- Oil immersion (o) and powder (sand) filling (q) are types of protection practically unused.

*Eligibility for hazardous zones*

All types of protection are eligible for Zone 1 (d, e, ia, ib, q, o, ma, mb, px, py), except the types of protection non-incendive (n), intrinsic safety – level of protection "ic", pressurization "pz" which are eligible only for Zone 2.

Zone 0 necessitates special considerations, and intrinsic safety – level of protection ia, and encapsulation level of protection ma are (for the moment) the only types of protection eligible to use in such areas.

*Requirements regarding mechanical protection*

The requirements regarding normal degree of protection of enclosures varies from minimum to medium as a function of the types of protection (Table 1).

**Table 1.** Degree of protection requirements related to the type of protection

| Type of protection (symbol) | Degree of protection |
|---|---|
| Intrinsic safety (i) | IP 20 |
| Pressurization (p) | IP 40 |
| Increased safety (e) | IP 44 (insulated conductive live parts)<br>IP 54 (bare conductive live parts)<br>IP 20 (rotating electrical machines installed in clean environments and regularly supervised by trained personnel) |
| Non-incendive | IP 54<br>IP 20 (rotating electrical machines installed in clean environments and regularly supervised by trained personnel) |

*Creepage distances and clearances*

For the comparative study of those distances the clearance was chosen having as reference the value imposed by the type of protection increased safety (e).

For accomplishing the comparison the downgrade of the regression line was used (fig.2).

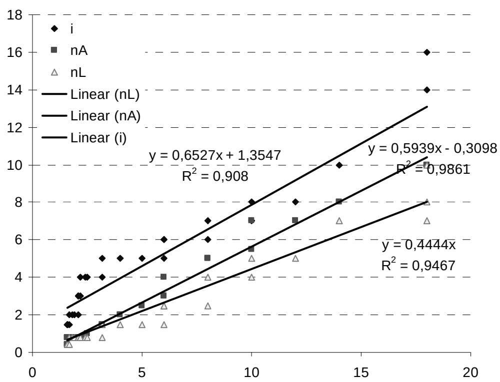


**Figure 2. Clearance (mm) at different voltages for the types of protection i, nA, nL function of the clearance (mm) imposed by the type of protection increased safety (e)**

Taking into account the above mentioned criteria it can say that the type of protection increased safety prescribes the largest clearances, being followed by the type of protection intrinsic safety, non-incendive nA and respectively nL, at approximately half values.

*Maximum voltage*

The maximum admitted voltage values for the types of protection are given in table 2.

**Table 2.** Maximum admitted voltage for different types of protection

| Type of protection (symbol) | Maximum voltage [kV] |
|---|---|
| Intrinsic safety (i) | 1,575 |
| Non-incendive (nL) | 15,6 |
| Encapsulation (m) | 11 |
| Pressurization (p) | 11 |
| Increased safety (e) | 11 |
| Flameproof enclosure (d) | - |
| Non-incendive (nA) | 15,6 |

*Technical protection solution*

Taking into account the protection strategy mentioned in the beginning of the paper four technical solution of protection can be stated, like this:

- segregation – separates the ignition source (apparatus) from the explosive atmosphere. The types of protection pressurization (p), encapsulation (m), oil immersion (o), powder filling (q) are based on this technical protection solution;
- eliminates the source of ignition. The types of protection increased safety (e) and non-incendive (nA) are based on this technical protection solution;
- limitates the energy of ignition source. The types of protection intrinsic safety (i) and non-incendive (nL) are based on this technical protection solution;
- limitates the deflagration expansion zone. The type of protection flameproof enclosure (d) is based on this technical protection solution.

## 5. CONCLUSIONS

This paper had the purpose to compare some common characteristics of the types of protection.

By the study made, some aspects that recommend various types of protection for one specific application (apparatus) were underlined.

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Prof. PhD. Eng. Mihai Pasculescu

# MAIN FACTORS WHICH INFLUENCE THE DESIGN CONCEPTS OF FLAMEPROOF ELECTRIC MOTORS ENCLOSURES, IN ORDER TO SUCCESSFULLY PASS THE TYPE TESTS IN EXPLOSIVE MIXTURES OF GASES, AND VAPORS WITH AIR

**MAGYARI MIHAI[*]**
**BURIAN SORIN[**]**
**FRIEDMANN MARTIN[***]**
**MOLDOVAN LUCIAN[****]**

**Abstract:** *The purpose of the paper is to perform a thorough study upon the major factors which influence the design concepts of flameproof electric motors enclosures designed to be used in potentially explosive mixtures of gases and vapors (especially of group II C), in order to successfully pass the non transmission test of an internal explosion. The researches conducted in the specialized Laboratory of INSEMEX Petrosani, on a very large number of flameproof motor samples have identified the pressure pilling phenomenon as the main responsible for the transmission of an internal explosion in the case of self ventilated electrical motors. The term pressure pilling, as used in this report, refers to the increase in pressure in a subdivided enclosure, above the pressures that would be likely to occur in the same compartment without subdividing. This pressure increase is a relative measure and may be considered abnormal compared to the pressure obtained in a constant volume combustion process with a precombustion gas pressure at or very near standard atmospheric pressure.*

**Key words:** *enclosure, flameproof, motor, pressure pilling*

## 1. INTRODUCTION

Even if the electric motors for environments with explosion hazard are designed and manufactured according to the same principles as any other electric machines, they have certain particularities related to the intended use. From here the proper type of protection derives, together with a schedule of limitations imposed to electric motors.

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[*] *Ph.D. Eng., senior scientific researcher II, INCD-INSEMEX Petrosani*
[**] *Eng, PhD. Candidate, senior scientific researcher II, INCD-INSEMEX Petrosani*
[***] *PhD. Eng., senior scientific researcher I, INCD-INSEMEX Petrosani*
[****] *PhD. Eng., senior scientific researcher II, INCD-INSEMEX Petrosani*

As well known, in the case of flameproof electric motors as well as in the case of most of technical equipment in general, design and manufacture surpassed long time ago the stage when manufacturers used to apply their own design concepts. In present, the design and manufacturing methods for the flameproof type of protection are fully determined by the provisions of standard SR EN 60079-1, according to which all new motors are constructed [1].

The electric motors with type of protection flameproof enclosure have to withstand the following type tests and verifications, in order to be certified having in view their placing on the market:

- reference pressure determination and overpressure test;
- test for non-transmission of an internal ignition.

The most important subassemblies of flameproof enclosure motors that endorse the type of protection are: stator casing, shields, rotor, fan and fan hood, terminal box, terminal box cover, as shown in Fig.1.

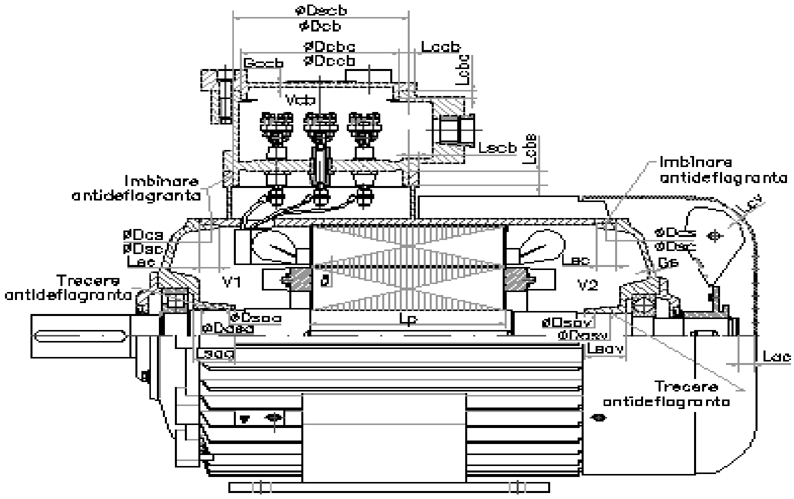


**Fig. 1 – Flameproof enclosure motor assembly**

## 2. MODERN RESEARCH METHODS FOR FLAMPEPROOF MOTOR ENCLOSURES

The research of a new type of flameproof enclosure of an electric motor, in order to determine its performances in explosive mixtures, consists, in the prototype stage, in the type test methods according to [2]. For a better knowledge of electric motors flameproof performances, the test methods should be previously studied for the purpose of adapting them to the specific conditions of actual prototypes of motors, provided for research. The flameproof performances are determined by mechanical characteristics, resistance to explosion and maximum safety experimental gap. These characteristics are determined, in their turn, by the kind of the provided explosive mixtures; enclosure's own geometrical structure; configuration of the enclosed equipment; flameproof joints dimensions; the place where ignition was initiated; nature of materials etc. These issues have to be practically studied on each motor enclosure provided with the enclosed apparatus.

The experimental test in explosive atmospheres is studied in the special test autoclaves that the specialized laboratory is equipped with, resistant to explosion pressure. Inside these autoclaves (explosion chambers), the explosive test atmosphere is obtained by introducing the specified explosive mixture according to [2], through a Gas Mixing Unit - GMU in the test chamber and controlling the test gas concentration through checking the oxygen concentration within the resulting mixture, by means of an oxygen analyzer. After obtaining the required explosive mixture, through the MESG (Maximum Experimental Safety Gap) device the mixture is verified again [3]. The mechanical action on test enclosures can be determined by direct exposure of motor enclosure to the resulting overpressure of an explosion and measurement of permanent distortions resulted. A more complicated problem is to determine the maximum experimental safety gap, since MESG depends upon the enclosure's geometrical features and the location of the explosion ignition source(s). The MESG for a specified test mixture can be determined according to the methods in [3], but in this case it won't reflect the influence of specific characteristics of the real motor enclosure anymore, therefore a preliminary study of the location of ignition sources having the maximum effect becomes also necessary.

In case of motor enclosures that contain a series of particularities that differentiate them from other types of enclosures, concerning the interior compartmentation that favors the pressure pilling phenomenon which cannot be avoided in great extent through constructive measures - due to the fact that always an air gap between stator and rotor will exist (of a low value so as to minimize electro-magnetic losses), each time when the explosion mixture is ignited from one of the rotating ends of the motor, the pressure recorded at the other rotating end will be highly amplified due to pre-compressing of the explosive mixture not ignited yet in the narrow gap between stator and rotor, by the pressure front resulted as consequence of igniting the explosive mixture at the opposite rotating end [2].

In case of these enclosures, this process leads to occurrence of certain so-called critical points (zones), namely at the shaft (rods) joints (passages) of a rotating electric machine that, because the nature of its structure has to have a gap of a much higher value compared to other gaps of joints, considering the fact that the shaft of the motor should be able to freely rotate, in safety; excluding any possibility of friction when operating at beneficiary - thing that could lead to hazardous overheating. This makes the joints (passages) favor the transmission (transfer) of an interior ignition, and a compromise solution has to be found in order to be able to achieve the two goals which are, on one hand avoiding transmitting an explosion to the outside and on the other hand avoiding mechanical friction between machine's shaft and its shield(s).

Figure 2 shows ignition devices placement within the explosive mixture, as well as locating the explosion pressure recording devices in different points within motor enclosure. The pressure is determined at the ignition end, at the opposite end and in any point where excessive pressure is likely to occur. In case of motor enclosures where the area under the base plate of motor's terminal box is of a particular interest - where, due to the opening in stator's casing for conductors passing from stator wiring towards the terminals-wall tube insulators assembly, a pre-compressing phenomenon occurs, responsible of much higher pressure than normally estimated.

The pressure piling (precompressing) premise appears when:

- either pressure values obtained during a series of tests differ from one another with a factor of $\geq 1{,}5$ , or
- the pressure rise time is less than 5 ms.

The test result is expressed by measuring and recording the explosion pressures, checking if the tested enclosure suffered any damage that could affect (impair) the type of protection [2].

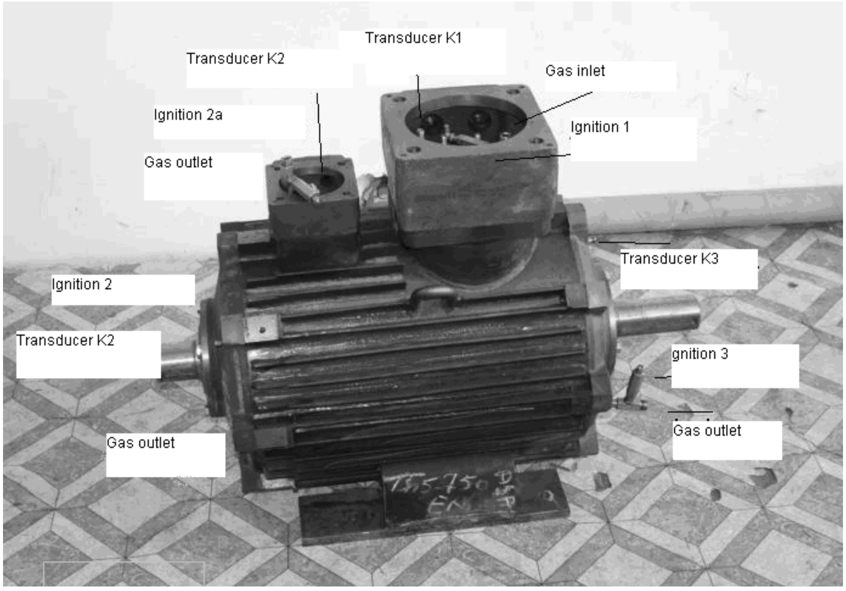


Fig.2 - Example of a flameproof motor test sample preparation for testing in explosive atmospheres

**2.1. Mechanical strength verification for motor enclosures**

The maximum pressure resulted from explosive mixtures combustion is determined by the mass of gases in reaction and combustion temperature. The pressure experimentally determined doesn't represent only the characteristic of the explosive mixture, but also a characteristic depending upon the yielded heat, geometrical shape and free cross section area of joints gaps.

In case of real electric equipment enclosures, in normal ambient pressure and temperature conditions, the resulted explosion pressure is lower, in general, due to energy losses through enclosure walls and under the effect of pressure discharge through the flameproof joints gaps.

Inside enclosure with interior compartments (as is the case of electric motors), overpressure peaks may also take place due to precompressing occurring in front of the ignition propagating wave. These pressure peaks induce sudden increases in the inner load that additionally strains enclosures strength.

The maximum explosion pressure and its variation curve represent the reference data when verifying the enclosure mechanical strength. Verification is carried out by exposing the enclosure to either static or dynamic overpressure with a safety factor of 1.5 times. The type test is carried out in laboratory with precompressed explosive mixtures, according to the following formula:

$$\frac{P_{ex1}}{P_{ex0}} = \frac{P_1}{P_0} \qquad (2.1)$$

where:

$P_{ex0}$ = explosion pressure of a mixture having its initial pressure equal to atmospheric pressure $P_0$.

$P_{ex1}$ = explosion pressure obtained when the mixture is initially precompressed at pressure $P_1$.

For current verifications on individual testing in factory, at manufacturer's premises, flameproof enclosures are submitted to static overpressure at a value specified in the EC Type Examination Certificate.

The enclosure is considered to have withstood the hydrostatic overpressure test if:

- none of the measured deformations overpass 1/300 mm on any side of the joint;
- none of the joint gaps has increased with more than 0.05 mm compared to reference measurement carried out in the hydrostatic pre-verification.

In this way validation of enclosures mechanical performances is firmly ensured in individual testing of each enclosure in the factory.

### 2.2 Determination of flameproof character

According to the provided test methods, the flameproof character is determined by the maximum experimental safety gap on the path where a deflagration could propagate towards exterior.

The MESG, determined according to [3] may differ from the critical gap - which represents another natural characteristic and relates to a stationary ignition process when pressures are equal on both sides and propagation path length is sufficiently long.

In non-stationary processes, as for example explosions within flameproof enclosures, the flameproof character becomes depended upon the length of the propagation path. Since pressures differ from one another, a turbulent gas flow towards exterior occurs. By increasing the interior pressure, the critical dimension of the extinguishing gap decreases, and becomes a new characteristic of the non-stationary regime. Thus, for the stationary regime the critical lamination gap is characteristic, while for flameproof enclosures the maximum experimental safety gap or the maximum flameproof gap represents a characteristic.

Deflagration propagation in a non-stationary regime through a gap can take place even after extinguishing the combustion on the path, due to the high temperature of released gas, at supersonic velocities, under the effect of high differences in pressures. Simple lamination and cooling by direct heat abstraction on joints surfaces are undetermined because, at high velocities, the gas jet is greatly damped under the adiabatic transformation effect. This remark can be experimentally verified by determining the influence of path length on the flameproof character. It can be assumed that, along with the path length increase through a gap, the exhausted gas temperature decreases more and more under the effect of cooling down. Still, a very small critical length, between 5 and 10 mm, can be experimentally determined, for which the maximum safety gap is greater than the one for very big lengths. At sub-critical lengths and in a certain range of over-critical lengths the maximum flameproof gap decreases, even if cooling through direct heat abstraction on surfaces results as negligible. Thus the maximum flameproof gap results as determined by adiabatic transformation under effect of differences in pressure and temperature, that renders to an increased heat exchange for the critical length that produces a higher gas diffusion angle. On over-critic lengths, a higher heat exchange can be obtained on the surfaces of the joints, but the result on the maximum gap is insignificant since for lengths of joints above 45 mm this practically does not increase anymore.

Lengths of joints over 25 mm may be justified only when greater clearances have to be ensured for shaft parts or if incendive particles release have to be prevented. Small critical lengths cannot be used because of the adiabatic transformation instability under effect of exterior actions and due to the risk of incendive particles release. Adiabatic transformation is determined by the explosion pressure.

The flameproof character is determined by the explosion pressure not only through its effect on the transformation process, but also through mechanical effects it has on the flameproof joints. According to [3], MESG is determined under conditions of non-deformable flanges. For practical applications the flanges can be deformed under explosion effects, thus enlarging the gap during explosion. The method of verification for the flameproof performances provides direct exposure of each type of flameproof enclosure to the effects of an internal explosion in an ambient explosive mixture, with the very intent of verifying the effect of reversible deformations as well. The gap width is a variable function of the internal explosion pressure. Fully rigid joints may also exist, but generally for enclosures with significant surface areas exposed to pressure, deformations occur and the flameproof character cannot be determined only by simple dimensional measurements, without testing the actual enclosure type in explosive mixtures.

According to standardized provisions, verification of flameproof character is to be carried out in overactivated explosive mixtures related to ignition transmission, with a safety coefficient of approx. 1.5 times greater than the one for the gas/air mixture that the enclosure is designed for. These mixtures are called explosive mixtures for verification of non-transmission of an internal ignition and they are different from the ones used for the overpressure type test. The explosive mixtures for flameproof character allow MESG verification with a safety factor of 1.5 [2].

## 3. FACTORS INFLUENCING THE DESIGN PRESSURES OF MOTORS ENCLOSURES

### 3.1. Pressure piling (pressure build-up)

The term "pressure piling" as used in this report, refers to the increase in pressure in a compartmented enclosure, above the pressures that would occur in the same compartment without compartmentation. This pressure increase is a relative measure and may be considered abnormal compared to the pressure obtained in a constant volume combustion process with a precombustion gas pressure at or very near standard atmospheric pressure.

### 3.2 Factors affecting pressure piling

The causes of pressure piling are not yet fully understood, certainly not to the degree that geometry of enclosure, ignition sources and location, and combustible gas mixtures influences can be used to predict when pressure pilling would occur, what pressures will be obtained. We can however, from a qualitative point of view, identify the factors that influence pressure pilling and suggest a design approach.

The main pressure piling causes are the following:

#### 3.2.1 Geometry of the enclosure

The geometry of the enclosure has an important role only if the ratio between enclosure's length and cross section dimensions is significant. For this case, when ignition occurs at one end, the flame front can accelerate down the length of the enclosure, even progressing to detonation in extreme cases.

As regards design considerations, no test data is available which would allow definitive guidelines to be established for enclosure length to width (or height) ratios. In the absence of actual test data, it is suggested that the length, divided by the smallest cross-section dimension, not exceed four (4). For values of this ratio of four (4) or less, pressure pilling is not likely to occur, unless other contributing factors also present.

#### 3.2.2 Enclosure compartmentation

Compartmentation of the enclosure is one of the leading causes of pressure pilling. Pressure pilling most often occurs in the smaller compartment after ignition in the larger one. Small areas or passages connecting the two compartments enhance the possibility of pressure pilling. If there is a series of interconnected compartments, the pressure will have a tendency to increase as the flame propagates from compartment to compartment, reaching its maximum in the last one.

As regards design considerations – in order to avoid pressure pilling, the designer should eliminate compartmentation in enclosure if possible. If the enclosure must be compartmented, either by partitions or equipment arrangement, then the openings connecting the compartments should be large enough. If large interconnecting passages are not possible, then the designer should consider "complete" isolation so that the flame does not propagate out of the single compartment in which ignition occurs. This can be accomplished by observing the flame path requirements [2].

### 3.2.3 The type of the gas employed and concentration of the explosive mixture

Gases having a higher explosion potential (as is the case of hydrogen and acetylene) may induce higher explosion pressures and they show a greater tendency to produce pressure piling; also, a concentration near the stoichiometric concentration would lead to higher explosion pressure values.

As regards design considerations, tests have to be carried out to determine the explosion pressures, using explosive mixtures of a type and concentration that would lead to generating the maximum explosion pressure for the explosion Group had in view.

### 3.2.4 Ignition source

Powerful ignition sources will produce higher explosion pressures than normal (12V) spark ignition. Also, location of the ignition may influence the pressure. Central ignition in a regular enclosure appears to produce the highest pressures; whereas, end ignition in long slender enclosures appears to induce the highest pressures.

With reference to design considerations, attention should be given to reduce as much as possible the strength of the potential ignition source that could occur inside the designed enclosure. If the potential ignition source is strong, the phenomenon of pressure piling must be accepted and the enclosure has to be designed for higher explosion pressures.

### 3.2.5 Precompression the gas mixture

The phenomenon of precompression will normally occur in compartmented and interconnected enclosures. Ignition in one compartment, particularly if it is the larger of the two compartments, may cause above atmospheric pressures to occur in the other compartment before ignition occurs. Final pressures are directly related to the amount of precompression, regardless of what causes the precompression to occur.

Concerning the design considerations, in case compartmentation cannot be avoided, then precompression in the second compartment prior to ignition can be estimated conservatively as the final explosion pressure in the first chamber. This approach is very conservative and is based on the assumptions that:

1. there is no resistance to flow between the first compartment and the second compartment during burning in the first compartment;
2. ignition in the second compartment will occur after burning of the explosive mixture is complete in the first compartment;
3. the initial pressure in the second compartment is equal to the final pressure in the first compartment;
4. there is high resistance to flow from the second compartment to the first compartment during burning in the second compartment.

For these considerations, the initial pressure in the second compartment is:

$$p_i = \frac{p_a \cdot V_1}{(V_1 + V_2)} \qquad (3.1)$$

where:

$p_a$ = atmospheric pressure;
$V_1$ = volume of the first compartment;
$V_2$ = volume of the second compartment.

This equation has the role of indicating the pressure value in the worst case condition that can be generated through precompressing and it is too conservative for the usual design of enclosures. High pressures predicted for compartmentation of the enclosure should encourage apparatus designers to alter the design of the enclosure or test it to establish more realistic pressures.

**3.2.6 Flame front acceleration**

Flame front acceleration can be caused by several factors. These include flow-induced acceleration, turbulence and flame front instabilities. Acceleration of the gas flow may occur at the interconnecting passageway between compartments. This increases the energy release rate, which in turn may increase the flow rate and a positive feed back loop may occur. Flame front acceleration may also be produced by turbulence from obstructions in the flow or from flame front instabilities which can occur through gas concentration gradients, acoustic resonance (usually associated with venting) and from normal differences between the burned and unburned gas at the interface.

In respect of design considerations, the designer should reduce the likelihood of flame front acceleration by following the design considerations for compartmentation and by minimizing obstacles which can create flow turbulence. Clearly, the designer cannot eliminate necessary equipment inside the enclosure, nor can he always eliminate potential turbulence generators. He should concentrate primarily upon avoiding compartmentation of the enclosure by equipment placement and where compartmentation is unavoidable; he should avoid unnecessary obstacles or constrictions at passageways between compartments.

## 4. CONCLUSIONS

Applying these design solutions and recommendations, with respect to flameproof motors enclosures (and not only) by manufacturers of explosion protected apparatus having the type of protection flameproof enclosure, will result in an increased likelihood that these motors would successfully pass the type tests, particularly tough, specific to hydrogen and acetylene, even from the design project stage of motors, without needing further modifications of motor manufacturing plans every time these tests are not passed - this meaning increased times for finalizing the certification process, and implicitly increased certification costs, which represent an essential criterion in the present economical context where the indigenous manufacturers of explosion protected equipment are competing within the European market with renowned manufacturers from developed countries as Germany, France or Great Britain.

## REFERENCE

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Scientific Reviewers:
Prof. PhD. Eng. Mihai Pasculescu

# INNOVATIVE TEST METHODS FOR BELTS EMPLOYED IN THE BELT CONVEYORS OPERATING IN ENVIRONMENTS WITH POTENTIALLY EXPLOSIVE ATMOSPHERES

**PĂRĂIAN MIHAELA[*]**
**GHICIOI EMILIAN[**]**
**LUPU LEONARD[***]**
**PĂUN FLORIN ADRIAN[****]**
**JURCA ADRIAN[*****]**
**VĂTAVU NICULINA[*****]**
**MUNTEAN BERZAN FLORINA[*]**

## INTRODUCTION

In industrial plants within industry areas with potentially explosive atmospheres classified as "Ex Zones", equipment in special construction for potentially explosive atmospheres should be employed so as it cannot generate electric sparks and arcs, mechanical (impact and friction) sparks, static electricity, hot surfaces or any other energy sources that could ignite an explosion.

The requirements to be fulfilled by these equipment are provided in the ***Directive 94/9/EC Of The European Parliament And The Council Of 23 March 1994*** *On The Approximation Of The Laws Of The Member States Concerning Equipment And Protective Systems Intended For Use In Potentially Explosive Atmospheres* fully transposed into Romanian legislation as The Government Decision no. 752 of 14 May 2004 on setting out the conditions for placing on market the equipment and protective systems intended for use in potentially explosive atmospheres.

The essential health and safety requirements provided in Directive 94/9/EC known also as ATEX Directive were transposed in European Standards with prescriptions for manufacturing, testing and marking of equipment intended for use in potentially explosive

[*] *PhD. Eng., senior scientific researcher, I$^{st}$ degree, INCD-INSEMEX Petroşani, România*
[**] *Ph.D.Candidate, senior scientific researcher, INCD-INSEMEX Petroşani, România*
[***] *PhD. Candidate, senior scientific researcher, INCD-INSEMEX Petroşani, România*
[****] *Ph.D.Candidate, senior scientific researcher, III$^{rd}$ degree, INCD-INSEMEX Petroşani, România*
[*****] *PhD. Eng., senior scientific researcher, III$^{rd}$ degree, INCD-INSEMEX Petroşani, România*

atmospheres currently used within the Certification Body SECEEx in OEC-INSEMEX, for conformity assessment of equipment with the ATEX Directive.

Legislation, standards and norms in our country as well as the European ones in the explosion protection field underwent specific modifications and adaptations, in the sense of developing certification and testing requirements, for a continuous increase of Ex equipment safety at the level of the newest technical scientific achievements. Thus, the permanent development of test methods for conformity assessment becomes a necessity.

This way, designing testing and assessment methodologies at the level of the newest international achievements, as well as designing and manufacturing test stands, functional verifications, method experimenting and validation, all have contributions in increasing the efficiency level of the present system of testing and certification.

On the other hand, by drawing up new methods and procedures in accordance with the international principles and practices is ensured an accurate aligning of assessment for the characteristics of technical equipment intended for use in environments with potentially explosive atmospheres to the European practice in the field.

## 1. NEW CONCEPTS FOR IGNITION RISK ASSESSMENT AT CONVEYOR BELTS

Ignition risk assessment when using equipment and protective systems in environments endangered by flammable substances that may generate fires and explosions is particularly important in order to ensure workers safety and heath. According to the legislation in force, the responsibility for risk assessment and adopting proper protective measures to ensure an acceptable safety level is incumbent on equipment manufacturers and users.

The protection concepts have in view mainly using that equipment that can ensure protection by preventing intrinsic ignition risks, accompanied if case, by additional protective devices and specific maintenance/use measures, according to the intended use.

Having this in view, it is essential that the belt conveyors employed in environments with potentially explosive atmospheres and all its components, to be submitted to a well documented, official hazard analysis, where all possible ignition sources in the equipment to be correctly identified and listed, and the measures to be applied in order to prevent ignition sources from becoming efficient. Examples of these sorts of sources include hot surfaces, naked flames, hot liquids/gas, mechanically generated sparks, and aluminum-thermal reactions, self-ignition of powders, electric arcs and static electricity discharges.

Additional protective devices refer to detection of dangerous circumstances and automatic warning or switching off the conveyor. Upon case, as provided in SR EN 620, in order to decrease the hazards, the conveyors may be fitted with the following types of automatic devices for detection of abnormalities in operation, and mitigate risks:

- devices for belt decentration detection;
- devices for detection of conveyor, hoppers, chutes blocks/overloads;
- shaft rotation detectors;
- belt speed surveillance devices;
- thermal detectors;
- height and/or width detectors.

In order to study the risks generated by the belt itself, depending upon its intrinsic properties, the following hazards must be taken into consideration: static electricity, heating by friction between belt and driving drum, flammability and flame propagation.

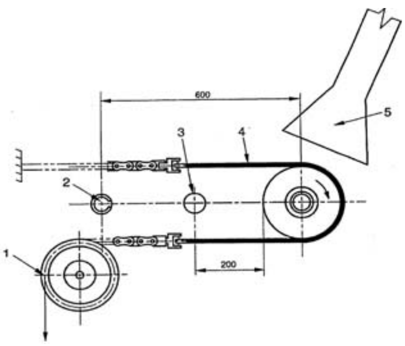
In order be able to answer the requests regarding belt safety parameters testing, within the LENE x EMEIP Laboratory, new test stands were produced, for friction on drum as well as for determination of the electrostatic field generated by a light conveyor belt in operation, according to the European standardized methods.

## 2. TEST STAND FOR DRUM FRICTION TEST OF CONVEYOR BELTS

The test method for determining the conveyor belt tendency to generate heat, flames or to glow when kept in stationary position at a predetermined tension, having the surface in contact all around a rotating steel drum is given in SR EN 1554:2002-*Conveyor belts - Drum friction testing.*

**Method principle**

A test piece of conveyor belt is wrapped half way around a rotating steel drum, as shown in figure 1, thus simulating a stalled belt. The test is carried out at specified tensions for a given time period, or until the belt breaks. The presence, or absence, of flame or glow is noted and reported and the maximum temperature of the drive drum is recorded. The test is conducted in still air or/and in moving air.



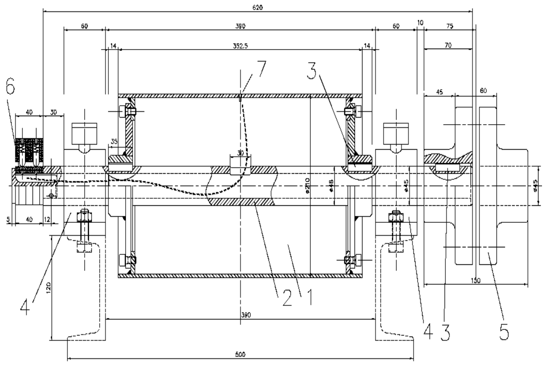

1 Guide pulley
2 Perforated air supply pipe
3 Anemometer
4 Test piece
5 Fume extraction hood

**Figure 1 - Schematic arrangement of test stand for drum friction testing of conveyor belts**

The test stand consists in the following parts:

1. **Steel drum** of external diameter (210±1)mm mounted on a horizontal axis and capable of being rotated at (200±5)rot/min.
2. **Belt tensioning system**, capable of applying the incremental tensions specified.
3. **Air flow system**, capable of achieving a (2.0±0.1) m/s velocity at a 200 mm distance from the horizontal steel drum surface, consisting in:
   - perforated pipe having 36 holes, each of a nominal diameter of 1.5 mm with an interval of 10 mm between them. The distance between the centre line of the perforated pipe and the steel drum is 600 mm;
   - air compressor;
   - anemometer, placed at 200 mm from the surface of the drum on the same horizontal plane as the perforated pipe and capable of measuring the velocity of the air current to an accuracy of ±5%.
4. **Extractor system**, capable of clear the noxes released during the test
5. **Drum temperature recording device**, comprising a mineral-insulated stainless steel sheathed thermocouple having a maximum outside diameter of 2 mm. The tip of the thermocouple is set not more than 0,5 mm below the surface of the drum, midway along its length, as shown in figure 2. Due to the rotation motion of the drum with its axis, the

thermocouple passing from the axis interior towards the exterior had been achieved by means of a collecting brushes system.



| | |
|---|---|
| 1. Cylindrical drum | 5. Elastic coupling |
| 2. Shaft | 6. Collector pieces |
| 3. Parallel wedge | 7. Special cork |
| 4. Supporting bearing | 8. Threaded bolt |
| | 9. Temperature sensor |

**Fig. 2 - Drum design diagram**

The test stand carried out in INSEMEX is shown in figure 3. Data collecting and processing from the thermocouple is achieved through a data acquisition board that transfers the data by means of software to a PC for further processing. This can be adjusted so at the temperature readings to be done in a time unit, thus resulting a diagram of temperature variation (figure 4).

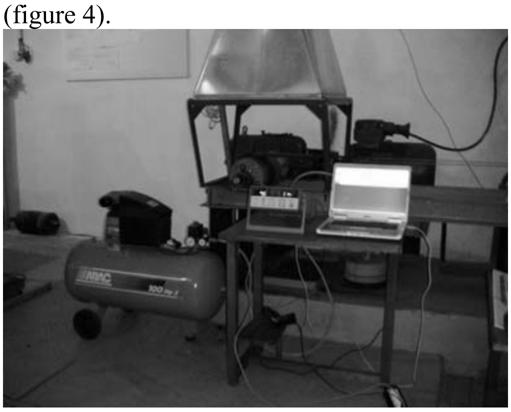


Fig. 3 - Test stand

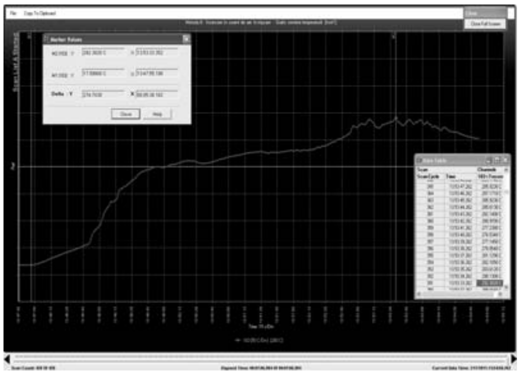


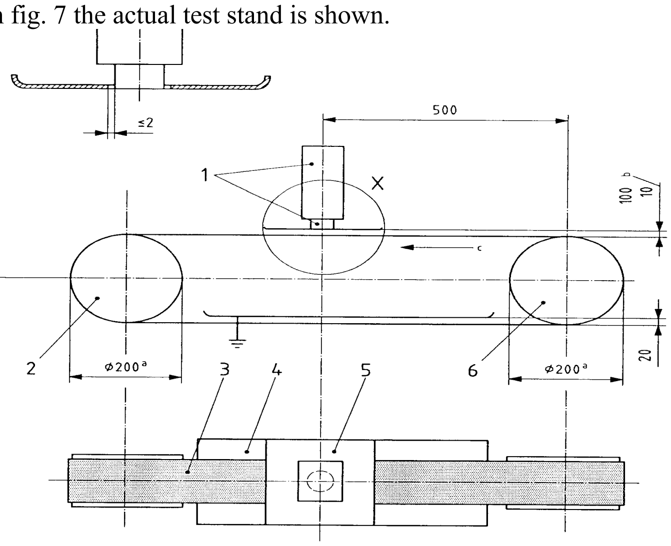
Fig. 4 - Test diagram

Periodically the contact terminals of the collecting brushes have to be checked to ensure there are no variations in the recorded temperature when the apparatus is switched on without a test sample.

## 3. TEST STAND FOR DETERMINATION OF THE ELECTROSTATIC FIELD GENERATED BY A RUNNING LIGHT CONVEYOR BELT

The test method, shown in *SR EN ISO 21179:2007-Light conveyor belts - Determination of the electrostatic field generated by a running light conveyor belt*, consists in displacement of an endless conveyor belt on two drums with a velocity of 5 m/s for 30 minutes, while the electrostatic field generated is measured.

The principle diagram of the stand is shown in figure 5. In figure 6 the test stand project is shown and in fig. 7 the actual test stand is shown.




Keyword

1-measuring device with electrode;
2-return mobile cylindrical roller;
3-test sample, (2500 ±50) mm ×(100 ±1)mm;
4-steel plate, earthed, 600mm×200mm
5 - steel plate, earthed, 200mm×200mm;
6 - driving fixed roller, cylindrical;

**Figure 3 -** Test arrangement of apparatus for measurement of surface potential generated by a running conveyor belt

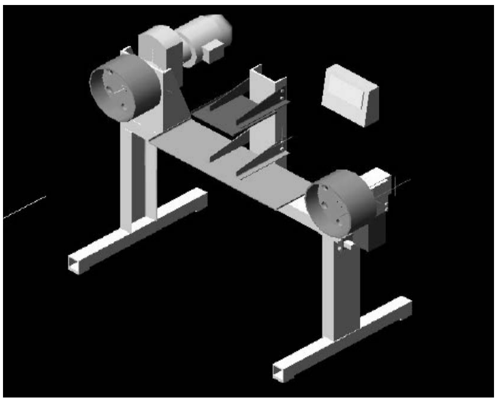
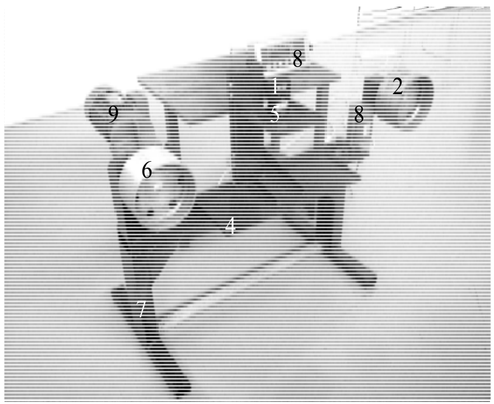


**Fig. 6 –** Test stand project




1-electrostatic field measuring/recording device;
2-return drum;
4-metallic plate, 600mm×200mm
5 - metallic plate, 200mm×200mm;
6 - driving drum;
7-metallic frame;
8-tensiometric cell and digital indicator;
9-motor gear

**Fig 7 -** The actual test stand

The test stand consists in the following parts:

- A pair of pulleys made of steel, diameter 200 mm or larger, rim width 120 mm. Surface evenness is given by a coarse non-covered surface, with maximum roughness $R_a$ = 1,6 µm, the final coating is made through chrome plating. The driving drum is cylindrical and fixed securely, the driven drum is mobile and convex, in order to be able to carry out the belt tensioning (h = 0,6 mm).
- belt driving device, able to ensure the belt sample velocity of 5 m/s, achieved with a motor-reducting gear SEW FAF27 DT80N2 type;
- belt tensioning device able to ensure a belt tension at the values given in table 1 below, achieved with a tensiometric cell TEDEA 1250 type an a weight digital indicator SC-1 type;

**Table 1 – Required values for the shaft load**

| $K_{1\%}$ (N/mm) [1)] | Shaft load F,(N) |
|---|---|
| ≤ 2,5 | 50 |
| > 2,5 ... 10 | 300 |
| > 10 ... 30 | 900 |
| > 30 | Mutually agreed upon |
| [1)] $K_{1\%}$ value shall be established according to SR EN ISO 21181 | |

- steel plate, sizes (200×200)mm, earthed, to correct the electromagnetic field distortion generated by the measuring electrode;
- steel plate, sizes (600×200)mm, earthed, to correct the electromagnetic field distortion generated by the return part of the sample;
- measuring device - the standard electrostatic field is measured with an output signal (electrostatic field measuring/recording device ACL 300B type);
- recording device.

## 4. CONCLUSIONS

The tests according to the above described methods will be carried out in accredited regime, having in view implementing within the quality assurance system of the accredited laboratory - LIEx.

Designing and developing the new test stands with performant apparatus of the newest generation as well as implementing the new test methods in the quality assurance system of LIEx laboratory of INSEMEX will ensure the premises of laboratory accreditation in conformity with the general requirements for testing and/or calibration, including sampling, provided in SR EN ISO/IEC 17025:2005-General requirements for the competence of testing and calibration laboratories.

The tests results in accredited regime are essential for product conformity assessment with the essential safety and health requirements stated in the applicable European Directives.

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Scientific Reviewers:
Prof. PhD. Eng. Ilie Onica

# DIMINISHING THE EXPLOSION RISK IN HARD COAL MINES FROM JIU VALLEY

**TOTH ION[*]**
**LUPU CONSTANTIN[*]**
**CIOCLEA DORU[*]**
**TOMESCU CRISTIAN[*]**
**CHIUZAN EMERIC[*]**
**MATEI ARONEL[**]**

**Abstract:** *Worldwide, the coal mining sectors displays a raising trend. Thus, coal demands coming from China, India and USA shall increase with 3 billion tons in the following 2 decades, reaching 9 billion tons per year. Coal mining comprises several risk factors, one of which being the explosion risk. An explosion is the result of time and space concurrency of: concentration of substances inside the explosion limits; oxygen in atmosphere; ignition source. Coal mines have firedamp (i.e. methane + coal dust), and for most of situations, the ignition source is endogenous fire (spontaneous combustion). This paper addresses the possible diminution of methane concentration in the underground atmosphere and the diminution of endogenous fires when using new technologies for preventing spontaneous combustions. There are reviewed the degassing methods used in the Romanian hard coal mines and the mining methods used in the Jiu Valley coal mines. Some are newly patented inventions or pending, all being developed by the experts of INCD-INSEMEX Petroşani.*

**Key words:** *risk, explosion, firedamp, combustion, prevention*

## 1. GENERAL ASPECTS

For the following 25 years, fossil fuels shall be the main source for power generation all around the world. Coal is a power generating raw material with low costs that is being used by both developed countries and by the developing countries. In spite of the fact that it represents the major polluting sources of the atmosphere ($CO_2$, $CH_4$, etc.) coal demands register ever higher rates. And this is due to a lack of an alternative less polluting power generating means.

[*] *INCD INSEMEX Petrosani, Romania,* insemex@insemex.ro
[**] *University of Petroşani, Romania,* aronelmatei@yahoo.com

In accordance with the new conditions, the coal demand has reduced in Romania and reached 3÷4 million tons/year of hard coal and 30÷32 million tons of lignite [5].

A highly performant management covered by the general process of industrial modernization of hard coal mining has included a series of measures for degassing and preventing of spontaneous combustion; consequently, there has been diminished one of the most important risk factors - ”the explosion”. [7].

## 2. EXPLOSIONS OCCURRED IN HARD COAL MINES

Generally, an explosion is a physico-chemical process that develops extremely rapid during which there is being burnt flammable substances or preparations; it is accompanied by a rapid transformation of the potential energy into mechanical work. The mechanical work represents the result of a sudden rise in the volume of gases emitted during explosion with an instantaneous rise of their pressure and temperature. Gas generation, with their sudden release, is specific to explosions and occur in all the three types of explosions: mechanical (physical), chemical and atomic. [6]

The explosions occurred in coal mines are chemical explosions.

An explosion shall occur when the following conditions are met simultaneously:

– the concentration of flammable substances in the atmosphere (comburant) situates within the UEL and LEL;

– the amount of explosive atmosphere has become hazardous at a certain moment; it is considered as hazardous, a compact explosive atmosphere of minimum 10 $dm^3$, located inside an enclosure, irrespective of its size;

– there exists an efficient ignition source (of sufficient high temperature and energy) to trigger the molecules for their further initiation and propagation of the rapid burning reaction.

Figure 1 shows the conditions necessary to be fulfilled to trigger an explosion.

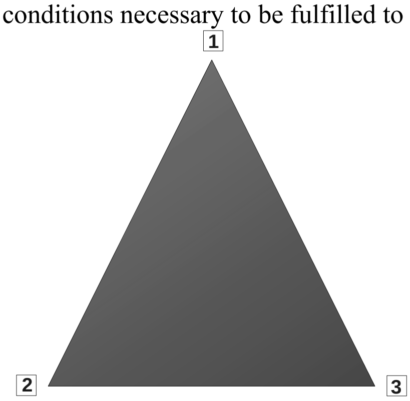


Figure 1: Explosion triangle

*Source: S. Simion, O. Baron, M. Basuc - Explosion risk, EUROPRINT Publishing House, Oradea, 2004*

Legend:

1 - fuel (gases, vapors, dusts / powders, mists)

2 - comburant (oxygen, oxidizing substances);

3 - initiation source (hot surface, flame, mechanical sparks, electric sparks, static electricity, etc.)

For the coal mines:

– Fuel is represented by ”firedamp” (a potentially explosive mixture of gases or any flammable gas that occurs naturally. The mine practice has several synonyms like ”mine gas” or ”methane”). [9]

– The comburant which is the oxygen in the mine atmosphere.

– The initiation source, which is coal self-ignition for most of the times (the superior stage of the spontaneous combustion).

In order to diminish the explosion hazard, measures have to be taken on one of the above said elements. As we cannot act upon the oxygen in the air, we have focused on changing the other conditions.

## 3. DEGASSING OF COAL BEDS

Methane ($CH_4$) is the main component of the mine gas (firedamp) which represents the result of the anaerobic transformations of the rests of plants during incarbonization.

The mine gas exists both in coals and in the surrounding rocks and it is made of methane (sometimes up to 100%), mixed with carbon dioxide (up to 5%), nitrogen (only some percentages), hydrogen and with homologous compounds of methane (1% ÷ 4%) and traces of carbon monoxides. The genesis of the mine gas can be connected to the biochemical transformation of the vegetation during incarbonization. [4]

Methane emitted into the underground atmosphere can accumulate under the following forms: profile, sheet, nest and methane wick. The profile involves an accumulation of methane in the section of the mine working along a width superior to 1/3 of the width of the mine working.

The sheet of methane involves an accumulation of methane in the section of the mine working along a width inferior to 1/3 of the width of the mine working and along a length superior than the width.

The nest of methane involves an accumulation in any pocket of the mine section, with a volume of 1 $m^3$ maximum.

Methane wicks are methane sheets with concentrations higher than 5%, width of 1 cm and length above 10 m. These wicks can propagate flame but cannot initiate explosion.

Coal bed degassing is an active means to diminish methane emissions in order to provide a safe mining of coal beds with a high output.

Degassing involves catching and draining of large amounts of methane from coal beds (main coal bed or the coal beds that cannot be mined), from sterile rocks or goafs and discharging to surface by sealed pipes (central degassing) or into a toxic air flow where it shall be diluted under the limit values stated by the norms (local degassing). [3]

Several qualitative and quantitative criteria are taken into consideration during the process for establishing the suitability of degassing of the rock massif from a coalfield with a high content of methane.

For the specific conditions of the Jiu Valley mines, these criteria are expressed by:

– methane dilution by ventilation means at the limit velocities required by the comfort and to avoid whirling the dust;

– methane concentrations at the crossing of the working with the head gallery and inside goafs and limitation of the coal output in relation to the maximum admitted concentration;

– preventing the occurrence of gaso-dynamic phenomena during coal mining in blind roads. [3]

Degassing can be accomplished in central or local system.

### 3.1 Central system degassing

Central system degassing is being applied at Lupeni, Paroşeni, Vulcan and Livezeni mines that belong to National Hard Coal Company in Petroşani, România. These mines have been equipped with these installations.

Central degassing stations are located at the surface of the mine and they include 4 groups of vacuum pumps for gas vacuuming. They have been produced in Poland and display the following characteristics:

- flow rate: $Q = 25\ m^3/min$;
- maximum vacuuming depression: $H = 4{,}000\ mm\ H_2O$;
- power of engines: $N = 75\ kW$;
- rotation: $n = 735$ rot/min.

Degassing is being accomplished by methane drainage from hole drills in underground and by methane drainage from goafs.

INSEMEX Petroşani has performed researchers in this field for several years; consequently, there have been developed basic degassing methods in relation to the:

- type of the mine workings;
- working method;
- width of coal bed;
- slant of coal beds.

Among the most known basic degassing methods, the most used one is the ”C” type basic method (Figure 2) - it is used during preparatory drivings that cross a thick coal bed, or a package of coal beds.

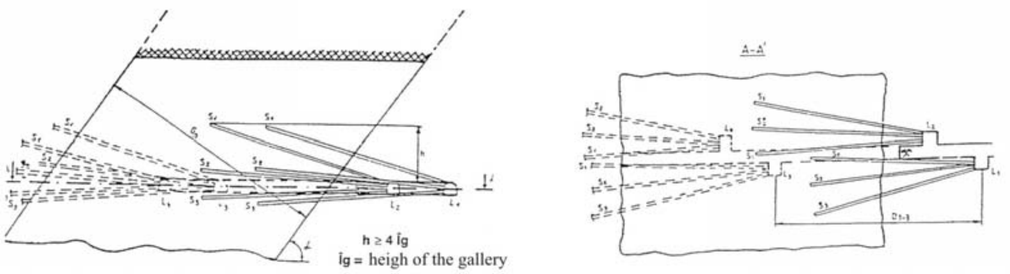


Figure 2: *Degassing of mine workings that cross thick beds*

*Source: Specification to specific rules of work safety for coal mines shale and tar sands, 1997, Ministry of Labour and Social Protection*

Figure 3 shows the percentage of methane that is being used as a result of drainage operations of the total amount of methane for the Jiu Valley mines which have implemented this method. [4]

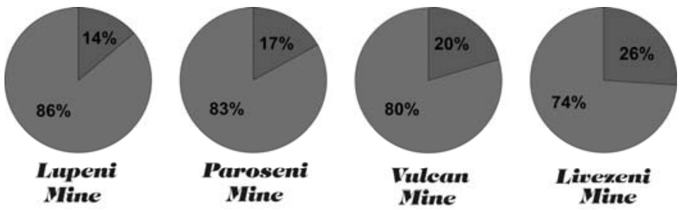


Figure 3: *Percentage of methane*

*Source: D. Surulescu - Studies and researches on the modernization of the National Hard Coal Company (CNH S.A.) together with the reorganization of the working process, doctoral thesis, University in Petroşani, 2007*

Legend:

red - percentage of $CH_4$ drained by degassing means
blue - percentage of $CH_4$ discharged by the ventilation system

**3.2 Local system degassing**

Methane can be locally drained in the following conditions:

– the amounts of gas determined by prognosis means can be drained by ejectors and then diluted to the concentrations stated by the legislation in force;

– it is not possible to provide on permanent basis concentrations higher than 20% vol. inside the drainage pipes;

– the prognosis of methane emissions, together with the gas emissions from underground workings don't support the suitability of central degassing operations. [3]

The local degassing installation is made of the following subassemblies (figure 4):

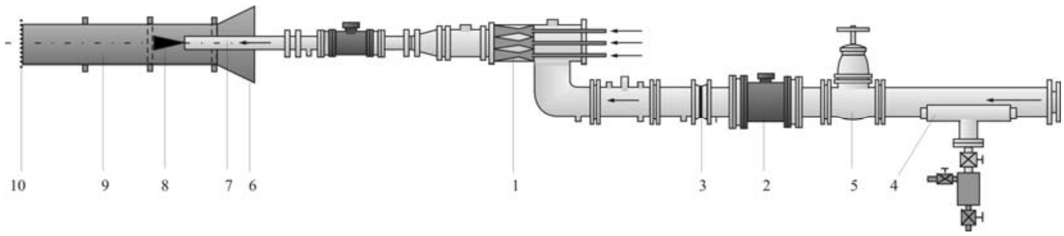


Figure 4: *The local degassing installation*

*Source: I. Matei, D. Cioclea, I. Toth, C. Gligor, N. Voinoiu, S.I. Purcaru - Preventing spontaneous combustions during coal undermining, AGORA Publishing House, 2003*

Legend:
1 - Degassing ejector
2 - Flame arrestor
3 - Royal - Duth device
4 - Water - detritus - gas separator
5 - Tap
6 - Section for supplementing the air flow rate in the dilution chamber
7 - Discharge section
8 - Gas deflector
9 - Gas dilution chamber
10 - Wire mesh to even the air flow rate

a) compressed-air degassing ejector

b) instruments for the measurement, protection and regulation of the specific parameters

c) gas mixing and diluting chamber.

The compressed-air degassing ejector is the basic element of the installation. It produces the power necessary for gas drainage.

## 4. PREVENTIVE METHODS OF SPONTANEOUS COMBUSTIONS WITH THE HELP OF INHIBITING TYPE CHEMICAL SUBSTANCES

By combining the results of the researches in the coal structure, the presence of catalyst-type microelements (V, Ni, Co, etc.) found in the composition of the Jiu Valley hard coals, the theories on coal self-oxidation and the self-oxidation mechanism, INSEMEX Petroşani - Romania has developed 2 new technologies for the prevention of spontaneous combustion based on the inhibiting characteristics of ”phosphate” substances. [1; 2]

**4.1 Engineering method for the treatment of the goafs by sprayed particles Apparatus for the production of sprayed particles**

During the mining with undermined bed in National Hard Coal Company in Petrosani mines, the prevention of endogenous fires is accomplished mainly with the help of very fine (micron – sized particles) derived from the inhibiting solution spread all through the goaf and at the working face, depending on the location of the installation and in compliance with the air flow. [1]

***4.1.1 Description of the installation***

The installation used to produce sprayed particles (figure 5) is made of a 200 l tank (1), an air-water spraying device (2) and the connection hoses (5) to the compressed air mains (3) at the working place and to the tank with the inhibiting substance. A tap (4) is mounted on the compressed air hose of the spraying device.

The special spraying device (figure 6) has been designed in order to attain a high level of selection regarding the size and the amount of air-sprayed particles.

The spraying device for spraying the inhibiting substance has got the following parameters:

- the working pressure: 3 – 4 atm;
- consumption of compressed air: 0,8 – 1,5 $m^3$/min;
- consumption of inhibiting solution: 1 – 4 l/min;
- output to transform the solution into air-sprayed particles: ≈ 80%.

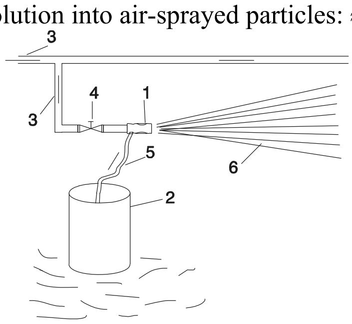


Figure 5: *The installation used to produce sprayed particles*

*Source: I. Matei, I. Toth, D. Cioclea, S.I. Purcaru, H. Vochițoiu - Spontaneous combustions in coal mines, PRINTEVEREST Publishing House - Deva, 2003*

Legend:

1 - mixing tank
2 - ejector
3 - compressed-air pipe
4 - tap
5 - connecting hose
6 - air-sprayed particles

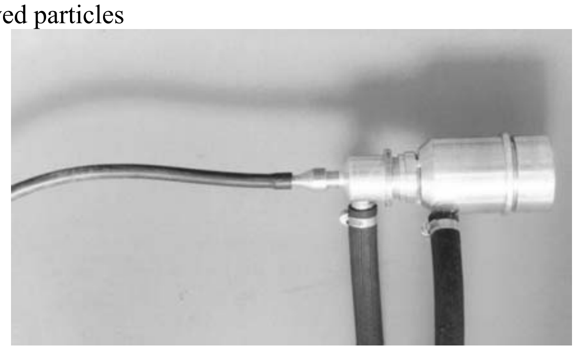

Figure 6: *The special spraying device*

*Source: I. Matei, I. Toth, D. Cioclea, S.I. Purcaru, H. Vochițoiu - Spontaneous combustions in coal mines, PRINTEVEREST Publishing House - Deva, 2003*

#### *4.1.2 Mounting and commissioning of the installation*

The inhibiting solution of 0.5 % inorganic inhibitor is put into the tank (1). Due to the phosphate high solubility, we can get an inhibiting final product in approx. 5 min after a manual stirring in the tank. Afterwards, a supply hose attached to the spraying is connected both to the compressed air mains and to the tank. The spraying device is placed in the cross drift or in front of goafs with high concentration of CO. The spraying device is equipped with a regulating means; accordingly one may regulate the size of the sprayed particles in such a manner that the very fine particles should be ≈ 90 % of the inhibiting solution. The amount of inhibiting solution in the tank ensures an autonomy of operation of around one hour.

#### *4.1.3 Treatment method with sprayed particles of inhibiting substance*

Due to the inhibiting characteristics displayed by the phosphate during the coal oxidation and self-ignition process, coal oxidation and self-ignition process, a suitable treatment with sprayed particles from the „phosphate” group shall diminish the risk of spontaneous combustions.

To treat adequately a goaf, this spraying device shall be located in the cross drift of the blasted pre-crushing raise. The sprayed device shall also be mounted in front of the holes in goafs where high concentrations of CO were previously detected (over 0,1 % vol).

The spraying device shall be placed at a height of 1 -1,5 m from the mine floor, being orientated towards the area that is to be treated with the help of sprayed particles and shall operate in every point for approximately one hour.

#### *4.1.4 Measures for labor protection*

Generally, the health approval delivered for the underground use of solutions state the specific measures for labor protection.

Additional to the PPE specific to the mining system (overalls, boots, helmet and gloves), there shall also be used plastic goggles.

During the production of the air-sprayed particles, the operators of the installation shall be outside the area of influence of these particles.

The amount of active substances necessary during a working shift shall be transported by the operators in sealed vessels (bags, metallic cans, etc.).

### 4.2 Method for the prevention of spontaneous combustion with chemical foam and inhibiting substances, locally applied with the help of ASC-3 type special installation

For the prevention of spontaneous combustions as well of underground fires, there is possible to treat goafs with chemical substances made of inhibiting substances + foaming agent + water.

The inhibitors used for the prevention of spontaneous combustions at coal deposits is made of inorganic inhibitor mixed with some foaming agent of the liquid foaming agent type. All these substances are being mixed with water and are injected into the goaf with the help of the installation shown in figure 7.

#### *4.2.1 Description of the installation used for the treatment of the goaf*

The installation shown in figure 7 is made of the following component parts:

– connection to the supply main for industrial or drinking water;
– line mixer;
– a 200 l vessel for mixing the solution;

– foam delivery pipe;

– apparatus for producing the ASC-3 chemical foam, made of an electric motor of 15kW, an air-driven motor and a SADU-type centrifugal pump.

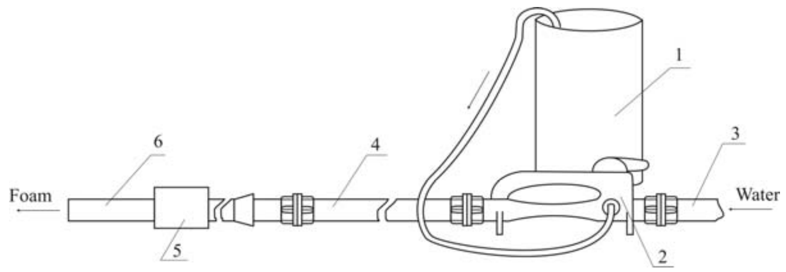


Figure 7: *Instalation used for the treatment of the goaf*

*Source: I. Matei, D. Cioclea, I. Toth, C. Gligor, N. Voinoiu, S.I. Purcaru - Preventing spontaneous combustions during coal undermining, AGORA Publishing House, 2003*

***4.2.2 Operation of installation***

Before commissioning, it is necessary that the mounting scheme shown in fig. 5 should be produced and then the whole installation be connected to the water main of the mine or to the mudding plant.

For being able to interconnect all the sub-assemblies, B and C connectors should be used (the ones also used by firemen), as well C-type hoses with a diameter of 50 mm.

After opening the supply valve, the incoming water reaches the line mixer and afterwards, it crosses a convergent–divergent ejecting nozzle; as a result, it sucks the mixture formed beforehand in the 100 l vessel in the suitable ratio between water and the mixture of chemical substance and foaming agent. Then, this mixture under pressure crosses the foam delivery pipe and here we can get a foam with an expansion rate of 10 by supplementing a great amount of air. Due to the fact that this mixture displays a low pressure when coming out of the foam delivery pipe, it can be thrown away over a distance of only 6-8 m away. Accordingly, an ASC-3 apparatus is necessary to be mounted in the goaf for the foam transportation along metallic pipe; this apparatus sucks in a powerful manner the foam from the delivery pipe and throws it with high pressure along the pipe located in the goaf.

***4.2.3 Treatment of goaf***

This installation is located on the working sublevel (for strongly inclined coal beds) or at the working panel (for low inclined coal beds and horizontal beds) on one of the preparatory galleries.

The mixture is injected through bore holes drilled either from directional galleries towards the upper part of the coal bed next to the goaf or towards the goaf that relates to the upper sublevel. Also, this mixture can be injected into holes drilled along the line of the working and directed towards the upper part of the undermined bed. Additionally, the mixture can be injected into the piping layed down on the floor of the mine working and lost in the goaf. This method shall be applied discontinuously.

If a continuous application is desired, then the mixture (inhibitor + foaming agent + water) shall be prepared at surface by using a part of installation shown in figure 7. The mudding station located at surface together with the related piping shall be used to inject the mixture into goafs.

**4.3 Implementation of the inhibiting-type means to prevent spontaneous combustion**

The methods said at 4.1 and 4.2 were tested at Lupeni mine; afterwards, this method has been extended to all the mines that belong to the National Hard Coal Company in Petroşani, i.e. at Uricani, Lupeni, Paroşeni, Vulcan, Livezeni, Petrila and Lonea mines (in accordance with figure 8.).

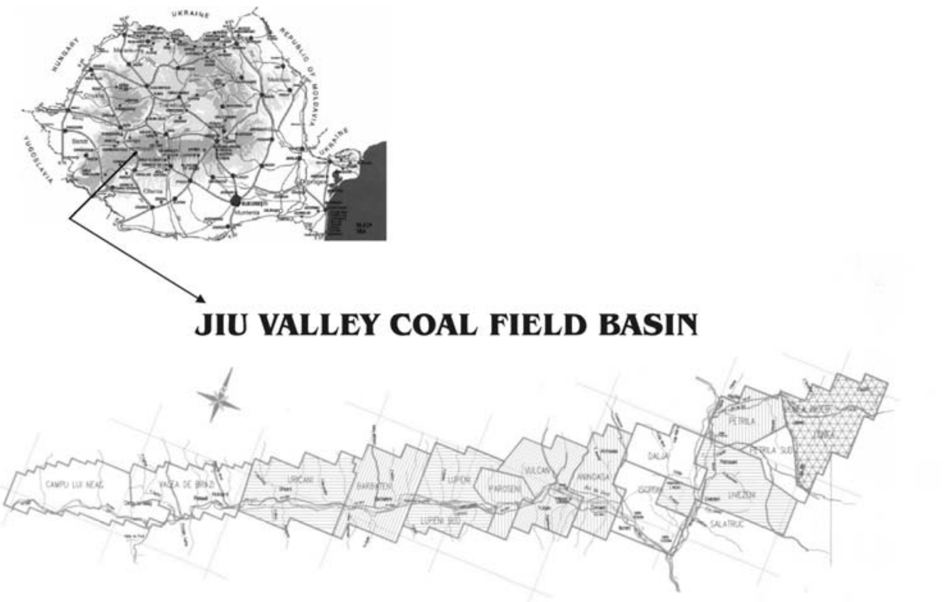


Figure 8: *Implementation of the inhibiting-type means to prevent spontaneous combustion*
*Source: I. Matei, D. Cioclea, I. Toth, C. Gligor, N. Voinoiu, S.I. Purcaru - Preventing spontaneous combustions during coal undermining, AGORA Publishing House, 2003*

Consequently, in 2010, the number of spontaneous combustions in the mines of National Hard Coal Company in Petrosani diminished with 5 and self-heating didn't turned into fire after the implementation of the above-said methods.

## 5. CONCLUSIONS

– Worldwide, coal shall play an important long-term part in providing the energetic balance.

– Coal demand shall increase with 3 billion tons in the following 20 years.

– Modernization of hard coal mining in Romania has also considered the diminution of one of the major risks - explosion.

– Diminution of the explosion risk has been performed by acting upon the combustive conditions: the potential explosive atmosphere and the ignition source from the explosion triangle.

– The diminution of the potential explosive hazard due to firedamp has been performed by implementing suitable methods of the degassing methods in the Jiu Valley coal mines.

– The diminution of spontaneous combustion has been accomplished by the implementation of the inhibitors based engineering methods.

– The implementation of this set of preventive measures has diminished the explosion risks; consequently in 2007 we had only 5 active fires in underground and no major explosive-type accidents have been recorded in the last 3 years.

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Scientific Reviewers:
Prof. PhD. Eng. Ilie Onica

# MODELING AND SIMULATING A VIRTUAL MONITORING AND AUTOMATED CONTROL PANEL FOR THE DEGASING PROCESS - CASE STUDY - THE LIVEZENI MINE

**STARK ADRIAN***

**Abstract:** *This paper shows a virtual way of monitoring methane emissions and degassing control, applied for the Livezeni mine. The system monitors the methane concentrations recorded by the transducers, and based on these values it automatically decides what actions are needed in that situation. This has been achieved using the LabView graphical programming environment.*

**Keywords:** *software, monitoring, gas, concentration, mine*

## 1. PARAMETERS

The first step in modeling and simulating a system is having a detailed knowledge of the phenomenon and its parameters. In order to achieve this, the following documents, from the Livezeni mine, were used:

- the degassing program;
- the ventilation plan;
- the location-plan of the gas transducers.

At the time when the above stated data was collected, the Livezeni mine had two panels that were being mined, panel 4 and panel 6, both in layer III. Throughout the mine there were 20 methane transducers, each with preset alarming and pre-alarming levels. The exact location of the transducers is shown on the virtual panel (fig. 1): 7 in panel 4, 3 in panel 6 and the other 10 in different parts of the mine. The ventilation of the mine was done with two fans and the central degassing process by a degassing station endowed with 4 vacuum pumps.

Knowing the process parameters and the possibilities offered by the LabVIEW environment, the next step was to create the virtual panel.

The limits in which the modeling and simulation had to be done were set by the physical lack of any transducer, be it gas or flow transducer. In such a case there is no way to know, for example, what the influence of opening or closing a ventilation door would be on the entire ventilation circuit, and, from the degassing point of view, there was no way to know if the degassing

* *Student Ph. D. Eng. at University of Petroşani*

measures, in a certain point of the mine, were or were not effective. Also, the option of generating values of the methane levels recorded by a certain transducer, based upon a mathematically determined function, was not valid, since the data recorded by transducers within the mine is recorded only graphically. Another set-back due to the lack of transducers is that the implemented system is independent of time, which means, for example, that it doesn't intensify the degassing process even if the methane levels do not drop after a certain period of time.

## 2. VIRTUAL PANEL

Based upon the above given specifications, the virtual panel is divided in 6 areas limited by contours on blue background (fig. 1). These contain (in an order from top to bottom, and left to right):


**Fig. 1.** Virtual panel

1 - the methane transducers from panel 4, layer 3, block VI. Each of the 7 transducers has a control that allows for the methane concentration to be changed, and an LED which changes color from green, to yellow, to red, depending on the reached methane level.

2 - the methane transducers from panel 6, layer 3, block VI. Each of the 3 transducers has the same role as those from panel 4, that have been described above.

3 – in this area there are two indicators, the first one shows the opening percentage of the ventilation door from panel 4, and the second, an LED, that shows if panel 4 is connected to electricity (green color) or not (red color).

4 – indicates the number of pumps working at a certain moment in the centralized degassing process. This number is 3 at the most, the 4th pump being a backup pump in case another breaks down.

5 – this area matches the one at point 3 and it is dedicated to panel 6;

6 – all methane transducers that belong to neither one of the two coal-faces. There are 10 such transducers, each having a control that allows the manual change of the methane concentration, and an LED that changes color from green, to yellow, to red, depending on the level reached by the methane concentration. Some of the transducers (8 of them) have an extra LED that shows if the area were the transducer is placed is connected to electricity (green color) or not (red color). All these LED are outlined on a grey background.

The pre-alarming and alarming levels have been set based upon the documents obtained from the Livezeni mine.

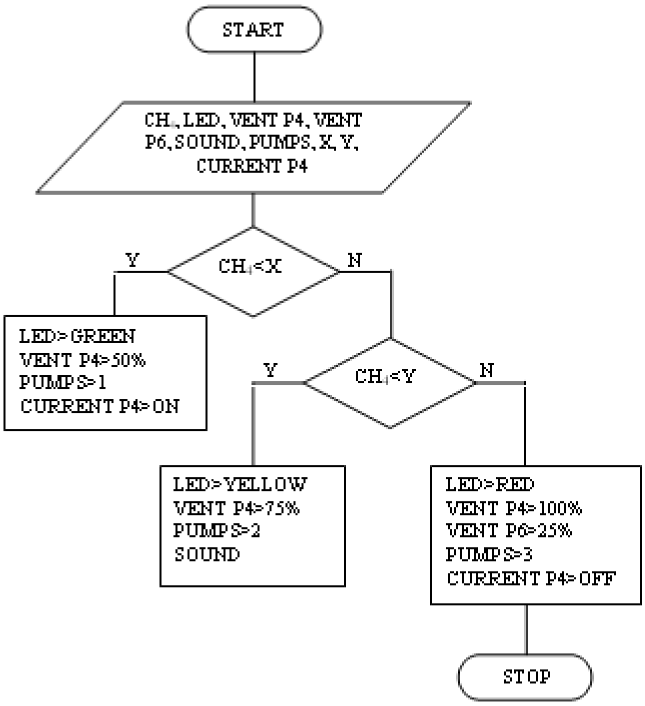


**Fig. 2.** Flow chart – transducer panel 4

## 3. FLOW GRAPHS

The virtual panel is based on 4 flow graphs, one for each situation in which a transducer is used.

### 3.1. Flow graph – transducer panel 4

This flow chart makes two tests. The first one compares the detected methane level with the pre-alarming level (labeled X) and the second compares the detected methane level with the alarming level (labeled Y).

If the measured value is smaller than the pre-alarming level: the LED has the color green, the ventilation door on panel 4 is 50% opened, one pump is working and the current is "on" in the coal-face.

If the measured value is between the pre-alarming and alarming levels: the LED has the color yellow, the ventilation door on panel 4 is 75% opened, 2 pumps are working, the current is "on" in the coal-face and a warning sound is played.

If the measured value is bigger or equal with the alarming level: the LED has the color red, the ventilation door on panel 4 is 100% opened, the ventilation door on panel 6 is 25% opened, 3 pumps are working and the current is cut in the coal-face.

### 3.2. Flow graph – transducer panel 6

The flow graph is similar to the one shown above (subchapter 3.2.), the only difference is that panel 4 has to be replaced by panel 6, and vice-versa, throughout the flow graph.

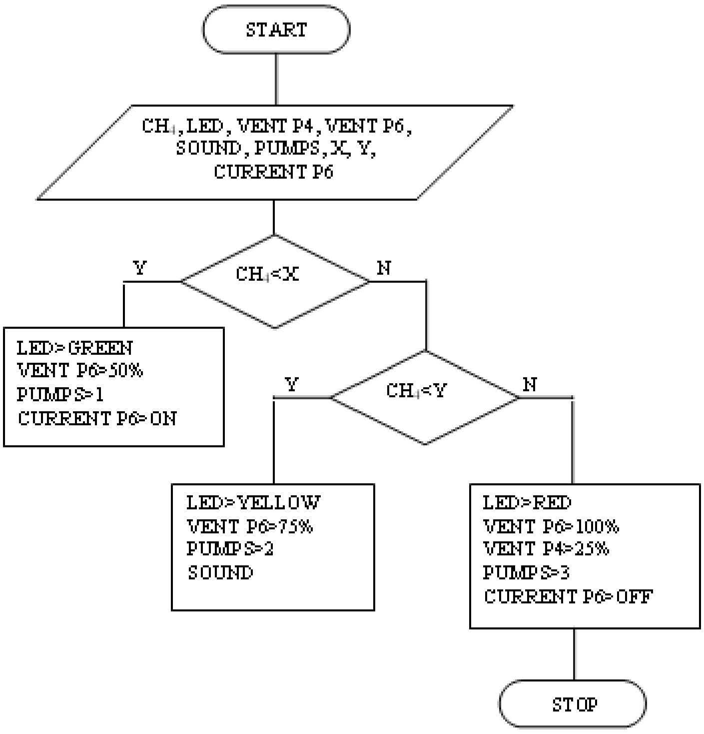


**Fig. 3.** Flow chart – transducer panel 6

### 3.3. Flow graph – transducer with acoustical warning and current cut-off

This flow chart makes two tests. The first one compares the detected methane level with the pre-alarming level (labeled X) and the second compares the detected methane level with the alarming level (labeled Y).

If the measured value is smaller than the pre-alarming level: the LED has the color green and the current is "on" in the coal-face.

If the measured value is between the pre-alarming and alarming levels: the LED has the color yellow and a warning sound is played.

If the measured value is bigger or equal with the alarming level: the LED has the color red and the current is cut in the coal-face.

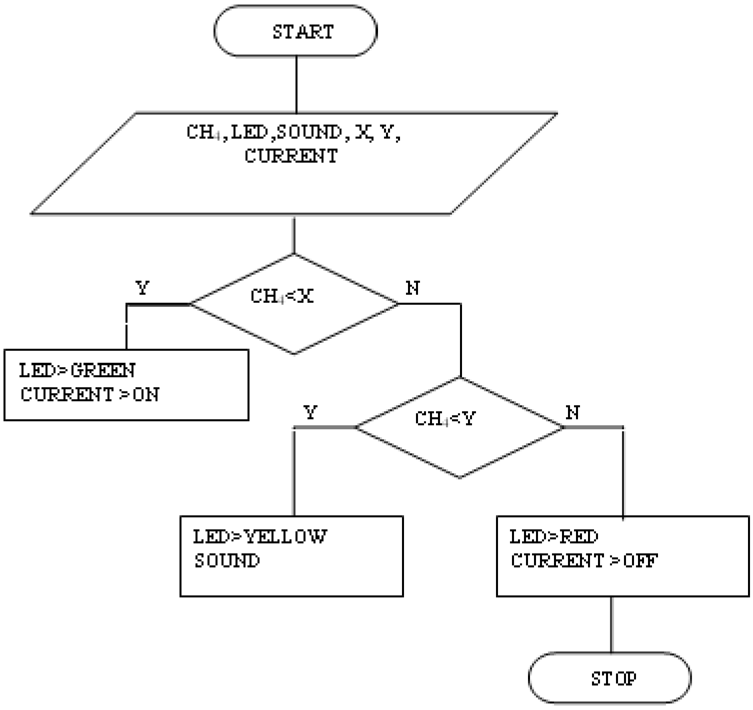


**Fig. 4.** Flow graph – transducer with acoustical warning and current cut-off

**3.4. Flow graph – transducer with acoustical warning**

This flow chart makes two tests. The first one compares the detected methane level with the pre-alarming level (labeled X) and the second compares the detected methane level with the alarming level (labeled Y).

If the measured value is smaller than the pre-alarming level: the LED has the color green.

If the measured value is between the pre-alarming and alarming levels: the LED has the color yellow and a warning sound is played.

If the measured value is bigger or equal with the alarming level: the LED has the color red.

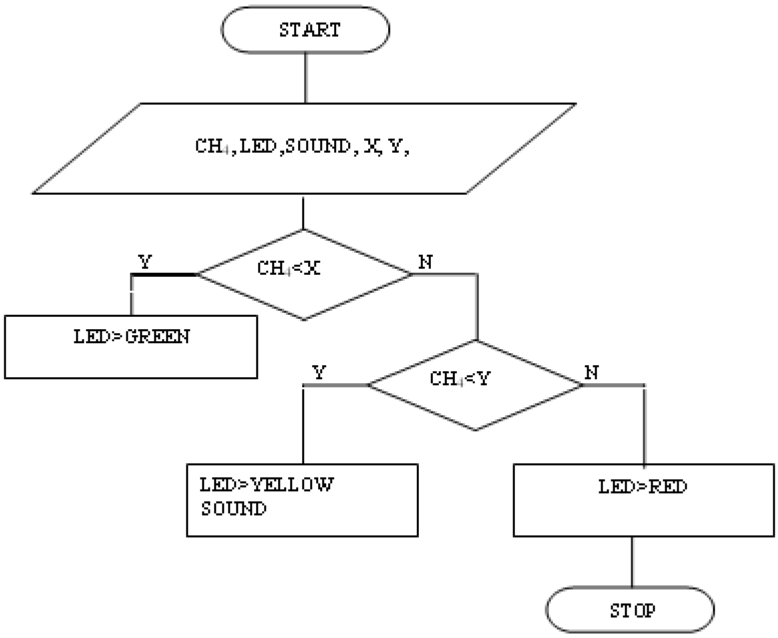


**Fig. 5.** Flow graph – transducer with acoustical warning

## 4. CONCLUSIONS

This paper shows a way to improve degassing systems in the Jiu Valley. The use of a virtual environment for this is welcomed because it comes very close to the real system, facing its designers with the problems they would have to solve in reality. The only limitation in this case was the lack of methane and flow transducers that lead to certain restrains.

The presented solution is very efficient cost wise, requiring only a programming environment, in this case LabVIEW.

Also the paper opens a new perspective regarding the possibility of implementing intelligent monitoring and control systems that offer system evolution predictability functions based upon comparisons with data bases and predefined models.

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Scientific Reviewers:
Prof. PhD. Eng. Eugen Cozma

# DEVELOPING A FRAMEWORK FOR BEHAVIOURAL CHANGE TOWARDS OCCUPATIONAL SAFETY ENFORCEMENT IN ROMANIAN COLLIERIES

**ROLAND MORARU***

**Abstract:** *Organisational culture has been defined as a complex framework of national, organizational and professional attitudes and values within which groups and individuals function. Unsafe behaviours play a major role in many of the accidents that are still occurring in the Romanian mining industry. Based on a thorough literature review, this paper aims to provide a practical framework for the process of identifying behavioural issues and taking effective action to address them. A framework for the development and maturation of organizational safety culture was formulated. The safety culture model proposed can be employed to enforce the safety climate within the Romanian collieries.*

**Key words:** *colliery, behaviour, safety culture, framework, safety maturity model.*

## 1. AIM AND SCOPE

Human factors and behaviours are widely recognised as having an important effect on accident causation and accident prevention. To contribute to the overall reduction of workplace accidents, workplace safety has been studied from different points of view [1], [21]. Despite the key role played by organizational culture in determining an organization's success or failure, there is no apparent consensus on how to describe the culture of an organization [12]. Brigges [2] argues that there are several important differences between "*culture*" as commonly used by anthropologists and "*culture*" as applied to organizations by management consultants. He noted that "*like many who borrow concepts from other fields, organizational writers have over-simplified matters to such an extent that their concept has lost much of its connection to the usages that are current in the field to which it belongs*". This paper aims to provide a practical framework for the process of identifying behavioural issues and taking effective action to address them for the collieries operating in the Romanian collieries.

## 2. LITERATURE REVIEW

In developing the work, we have reviewed the available literature and then developed a model to assist the user through the process of identifying behavioural issues, developing action plans, implementing corrective actions, and evaluating the effectiveness. Where there are

* *Assoc. Prof. PhD. Eng. at the University of Petroşani*

uncertainties or gaps in the available research, the author has exercised his judgement to lead the reader from one part of the process to the next. It should be noted that the paper has been written with a focus on the Romanian mining industry. This has led us to make assumptions about the current level of safety development that are considered to be valid for the collieries but may not be valid for other industries. According to Hofstede [14], organizational culture is considered the top-management business. Schein [20] defines organizational culture as "*a pattern of basic assumptions – invented, discovered, or developed by a given group as it learns to cope with its problems of external adaptation and internal integration*".

According to Reason [18], the definition of organizational culture most closely captures its essence: "*shared values (what is important) and beliefs (how things work) that interact with a company's people, organizational structures and control systems to produce behavioural norms*". Cooper (2000) defines corporate culture as "*to reflect shared behaviours, beliefs, attitudes and values regarding organizational goals, functions and procedures*". The concept of safety culture is often presented separately from an organization's other characteristics, such as the work schedule, technology, business strategy and financial decision-making [19].

Lee and Harrison [15] reveal that basically, any safety management system is a social system, wholly reliant upon the employees who operate it. Geller [11] put forward a model that has distinguished three dynamic and interactive factors: person; behaviour; and environment. The beliefs and values that refer specifically to health and safety form the subset of organisational culture referred to as safety culture [4]. Important early work on safety culture includes also studies assessing the shared perceptions guiding appropriate and adaptive safety related behaviour, and a later study by Cox and Cox [7] studying the attitudes that employees share in relation to safety.

## 3. BEHAVIOUR, SAFETY CLIMATE AND SAFETY CULTURE

Over the past twenty years, wide interest in the role of behaviours has led to the development of numerous safety climate tools and behavioural modification programmes. However, experience with these programmes has been variable with some companies reporting good success whilst other companies using the same programmes have not been successful. The paper is aimed primarily at the Romanian coal mining industry and is based on the assumption that the industry has already reached a fairly well developed position on safety management, as shown by:

- there is a wide awareness of safety issues and the need to improve safety;
- safety is considered during the design and fabrication of equipment and facilities;
- safety management systems and procedures are in place;
- there have been large improvements in safety but performance has levelled in recent years.

However, the mining industry's safety performance has levelled out with little significant change being achieved during the past few years. A different approach is required to encourage further improvement. This next step involves taking action to ensure that the behaviours of people at all levels within the organisation are consistent with an improving safety culture, see Figure 1.

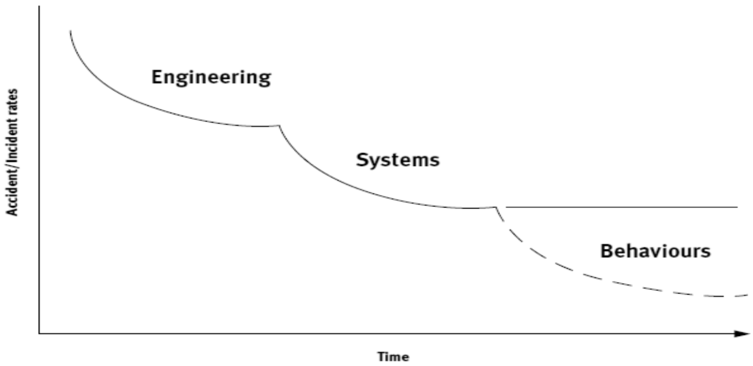


**Figure 1: Behaviour-based safety impact. A generic view**

Unsafe behaviours play a major role in many of the accidents that are still occurring in the coal mining industry. Behavioural issues are important, because behaviour turns systems and procedures into reality. It is not enough for an organisation to have good systems, because performance is determined by how organisations actually "*live*" or "*act out*" their systems [10].

Safety culture has been described as the collective values and attitudes of the people in the organisation; "*it is the way we do things around here*" [17]. Safety climate is the surface features of the safety culture reflected in employees' attitudes and perceptions [9]. These elements have been combined in the model shown in figure 2.

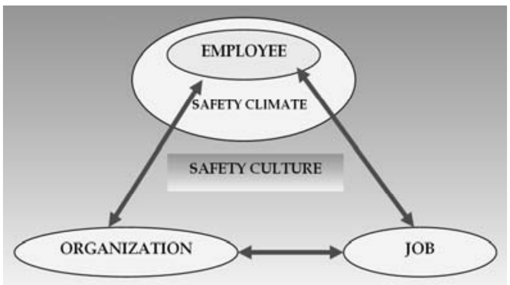


**Figure 2: Human and organisational aspects of safety**

An important implication of the interactions shown in figure 2 is that whilst the unsafe behaviour of an individual is often the final act in an accident sequence, their behaviour will have been influenced by the job, environment and the organization within which they work.

Managers and supervisors change the behaviour of others by their own action (or inaction). They can increase behaviour (positive or negative reinforcement) or can reduce behaviour (punishment or extinction). The view that safety can be improved by solely focussing on the behaviours of frontline staff is therefore mistaken. Behaviour modification is unlikely to be successful unless the job environment and organisational factors are also considered. This will require behaviour changes at all levels of the organisation, not just at the workplace. It became apparent that the same terms had different meanings, depending on professional background and experience. For example, the term "*behaviour*" can mean all non-technical aspects of safety or it can be limited to refer only to the safety behaviour of frontline employees. Confusion over the meaning of these terms is a major barrier to making information about the behavioural aspects of safety accessible [13].

**4. A SAFETY CULTURE MODEL FOR BEHAVIOURAL AND CULTURE IMPROVEMENT PROCESS**

The framework developed in this paper is based around the principle that good business processes can also be used to improve safety. The familiar Total Quality Management (TQM) business improvement process model is widely used to ensure quality and continuous improvement [6], [16]. This model has four steps or stages: 1) Assess; 2) Plan; 3) Do; 4) Monitor. The model is represented in figure 3 and it shows that organisations first asses s their current situation, then develop intervention plans, implement and monitor the progress of the interventions. The cycle is then repeated by re-assessing the actual situation against that desired. The TQM model can be directly applied to safety.

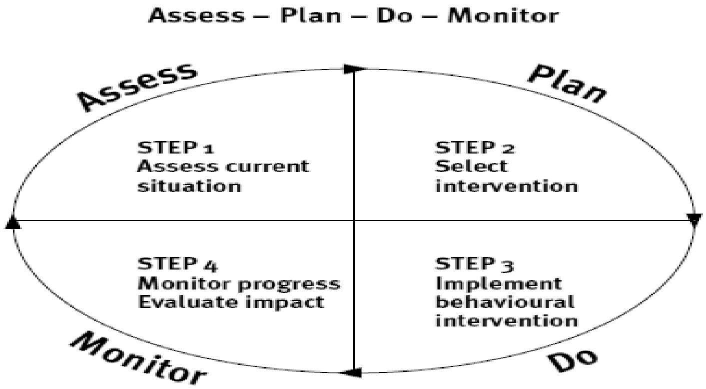


**Figure 3: TQM Continuous improvement model**

A review of behaviour modification programmes has shown that good programmes that have worked at one location can fail at another. The review identified factors that increased or decreased the likelihood of success. These factors can be linked to the existing culture of the organisation [3]. It is important to develop a model that would bridge these gaps and which could assist companies to identify which tools were appropriate for their current situation. The stages in developing such a model are described below. The safety culture maturity model provides a framework to assist in the selection and implementation of appropriate behavioural interventions. The safety culture maturity model presented in this paper refers to the maturity of the organisational behaviours, NOT the maturity of the safety management systems. The five stages of the safety culture maturity model are shown below in figure 4 [5].

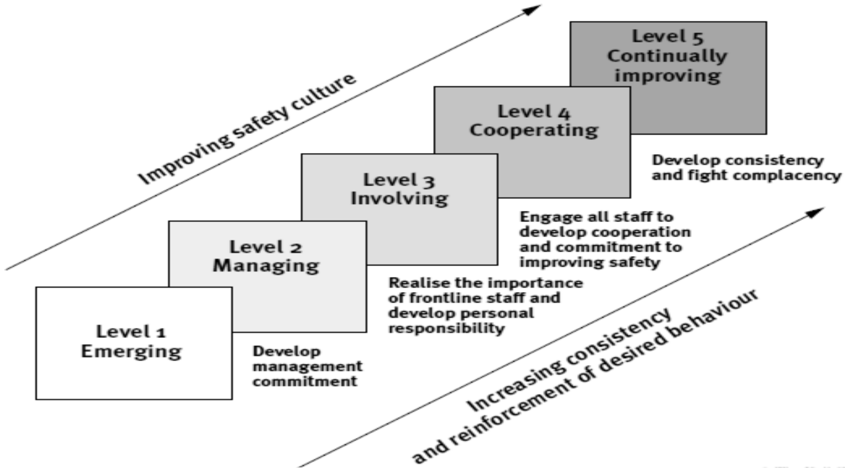


**Figure 4: Behaviour-based Safety Culture Maturity Model (BSCMM)**

Each level of the safety maturity model consists of ten elements as described below:

i. **Management commitment and visibility;**
ii. **Trust**, including trust between management and employees and between colleagues;
iii. **Communication**, refers to the style (e.g. two way) and effectiveness of communication;
iv. **Participation**, which is the extent to which front line staff are involved in decisions;
v. **Productivity versus safety;**
vi. **Learning organisation**: refers to the ability of an organisation to learn from mistakes;
vii. **Safety resources**, including safety staff and the time employees can spend on safety;
viii. **Shared perceptions** about safety, refers to the extent all employees have a shared vision;
ix. **Industrial relations and job satisfaction;**
x. **Training**, includes the value placed on training, the type and resources available.

In figure 4 above, the stages are shown as overlapping. Establishing where a company or installation is in terms of its safety culture maturity is an important issue for selecting appropriate behaviour modification programmes and implementing them effectively. A programme that is appropriate for one mining company or site may not be suitable for another at a higher or lower level of maturity. The BSCMM and the TQM models have been combined to produce a safety culture improvement process. The process is illustrated in figure 5. This model shows how the TQM process can be used to progress from one level of maturity to the next by: 1) assessing their current level of maturity, 2) developing a plan to move to the next level, 3) implementing the plan, 4) monitoring the implementation and 5) re-assessing the level of maturity to evaluate success and identify further actions.

The model can be used to help identify when it is appropriate to use the different types of behavioural tools that have been developed. In the ‘assess’ phase, diagnostic tools such as safety climate surveys, structured interviews and workshops can be used to assess the current level of safety maturity.

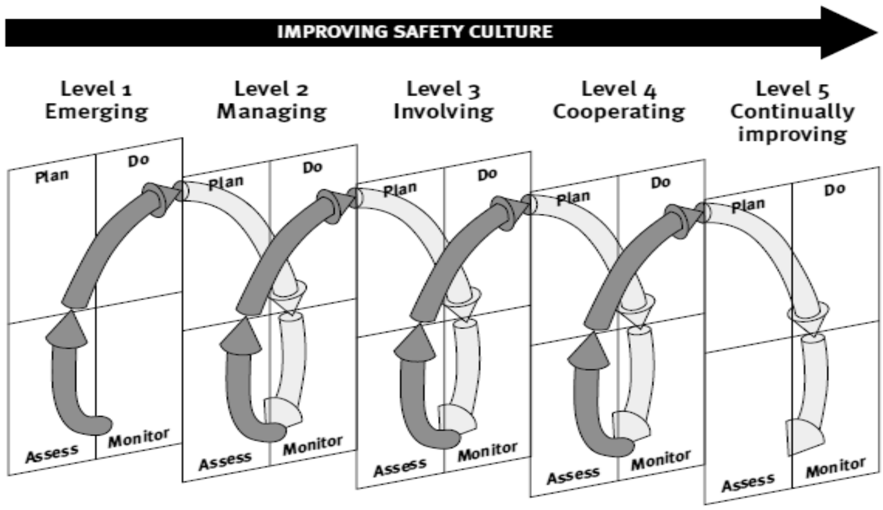


**Figure 5: Safety culture improvement process**

By focussing on what is most appropriate, the framework can help reduce the number of initiatives and increase the effectiveness of existing programmes. If the framework indicates that an existing behavioural intervention is inappropriate, the BSCMM can also be used to help communicate why it is being replaced with another programme that is more appropriate for current level of maturity.

## 5. CLOSURE

It must be emphasised that behavioural approaches should not be seen as the panacea for all safety problems. Behaviour modification is not an alternative to sound safety management policies, systems and procedures. However, when these are well established and functioning effectively, behaviour modification can play an important role in achieving further improvements in safety performance.

The main conclusions of this work can be expressed as it follows downwards:

- Behaviour modification is not an alternative to a rigorously applied conventional safety management system. Sound engineering and systems should be in place before attempting to use behaviour modification programmes to further improve performance.
- Research evidence and practical experience show that significant improvements in safety performance can be achieved by implementing appropriate behaviour interventions.
- Behaviour modification is unlikely to be successful unless the job environment and organisational factors are also considered. This will require behaviour change at all levels of the organisation, not just at the workplace.
- There is also evidence that appropriate behaviour interventions can improve other aspects of performance as well as safety.
- Good intervention tools which work at one location may fail at another location.
- The suitability of a behaviour intervention tool is influenced by the existing maturity of the organisation.

A Safety Culture Maturity Model has been developed to provide a framework to assist companies establish their current level of maturity and identify the appropriate actions required to move to the next level of maturity. The key steps in using behavioural interventions to improve (safety) performance are 1) assessing the current level of safety culture maturity, 2) planning an appropriate intervention, 3) implementing the programme effectively, 4) monitoring performance, and 5) returning to the start of process to re-assess the level of safety culture maturity. The BSCMM is particularly useful for large multi-site mining companies, as they can locate different interventions within a single framework. The framework can be used to identify different interventions that are appropriate for sites at different levels of maturity.

The safety culture maturity model, presented in the paper, should not be seen as a new initiative. It is a framework to assist the development of a strategy and plans to address behavioural issues, and to help the selection of appropriate interventions. Use of the model should help to avoid the introduction or continuation of unnecessary initiatives in the Romanian mining industry.

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Scientific Reviewers:
Prof. PhD. Eng. Romulus Sarbu

# KEY ELEMENTS OF HEALTH AND SAFETY OBSERVATION AND FEEDBACK PROGRAMMES

**ROLAND IOSIF MORARU***
**GABRIEL BUJOR BĂBUŢ***
**LUCIAN IONEL CIOCA****

**Abstract:** *Promoting safe behaviour at work is a critical part of the management of health and safety, because behaviour turns systems and procedures into reality. This paper aims to provide the reader with a basic understanding of theory underpinning strategies to promote safe behaviour, the key elements of programmes to promote safe behaviour which are currently in use, how to use behavioural strategies to promote a wider range of critical health and safety behaviours and how to integrate behavioural strategies into a health and safety management system.*

**Keywords:** *safe behaviour, health and safety, feedback programme, management system*

## 1. INTRODUCTION

Behaviour is a critical aspect of all activities conducted within every organisation. Therefore, the behaviour of all staff has a dramatic impact on health and safety. Behaviour modification techniques can be used to promote the effective use of risk control strategies and to analyse the at risk behaviours to ensure that the risk is minimised. There is strong research evidence that behaviour modification is effective in changing a range of behaviours within organisational settings. Within a safety context, the research shows that behavioural safety programmes can alter frontline employees' behaviour, reduce accident rates and improve the safety climate. It is widely accepted that human behaviour is a contributory factor in approximately 80 % of accidents [9]. This statistic has lead to confusion about how to improve health and safety at work, as many people have concluded that further improvements in safety will occur by changing the employees in some way to make them "safer" or to make them adhere to safety rules and procedures. Perceiving the problem as "within the employee" limits the identification of effective solutions. Behavioural change is not brought about by changing the person, but by changing their environment.

* *Assoc. Prof., Ph. D at the University of Petroşani, roland_moraru@yahoo.com, gabriel_babut@yahoo.com*
** *Prof. Eng., Ph. D. at the „Lucian Blaga" University of Sibiu, lucian.cioca@ulbsibiu.ro*

## 2. LITERATURE REVIEW

Promoting safe behaviour at work is a critical part of the management of health and safety, because behaviour turns systems and procedures into reality [1], [3]. Good systems on their own do not ensure successful health and safety management; the level of success is determined by how organisations „live" their systems [11]. There is strong research evidence that behaviour modification techniques are effective in promoting desired health and safety behaviours, provided they are implemented thoroughly, with continued support from management [5]. The core element of behaviour modification is the ABC model of behaviour, Antecedents (A) Behaviour (B) and Consequences (C). The ABC model specifies that behaviour is triggered by a set of antecedents (something which precedes behaviour and is causally linked to the behaviour) and followed by consequences (outcome of the behaviour for the individual) that increase or decrease the likelihood that the behaviour will be repeated [2].

Recent research, suggests that organisations should select behavioural safety programmes which match their level of cultural maturity because a mismatch is one reason why behavioural safety programmes fail. It is therefore important for organisations to establish that they are ready to implement a behavioural safety programme and to identify any potential problems they may encounter [13]. Although not all behavioural safety programmes include goal-setting, research evidence indicates that goal setting increases the amount of behavioural change [14]. A comprehensive review of behaviour modification research studies demonstrated the effectiveness of the technique [6], [7]. The review only included studies with a sound methodology, to ensure that the results presented were based on robust research principles. The author identified 88 studies that met the methodological criteria. This review clearly demonstrated that behaviour modification can be successfully used to change a range of behaviours. This also indicates that behaviour modification can be used to modify behaviours that enhance health and safety management in general, and not just the behaviour of frontline staff [8].

## 3. FOCUS ON BEHAVIOURAL SAFETY PROGRAMMES

Health and safety behaviour observation and feedback programmes promote desired behaviour, by introducing positive reinforcement for behaving safely. The positive reinforcement is provided through positive feedback [12]. Figure 1 below provides a generic overview of behavioural safety programmes. The elements listed are not present in all programmes, but they were contained in the majority of programmes.

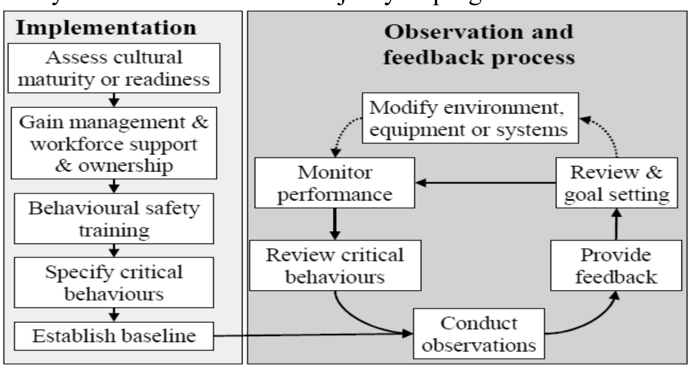


**Figure 1.** Overview of a behavioural safety programme

**3.1 Implementation**

The effectiveness of behavioural safety observation and feedback programmes is dependent upon effective implementation. Figure 1 outlines the main stages in the implementation of a behavioural safety programme. These stages are discussed bellow:

- ***Assess Cultural Maturity or Readiness***

The first stage in the implementation is the assessment of an organisations readiness to implement a behavioural safety programme. The term cultural maturity refers to the important safety culture elements (e.g. management commitment, trust, communication) that determine an organisation's readiness to implement a behavioural safety programme. By identifying potential barriers before implementing the programme, an organisation will be able to manage these problems more effectively [10]. For example, if a reorganisation is likely to occur during the implementation of the programme, then the programme could be delayed until after the reorganisation. There are a number of ways of assessing cultural maturity, for example, conducting a safety climate survey or holding workforce workshops [4].

- ***Management and Workforce Support***

Management and workforce ownership and support for the behavioural safety process is vital for the success of the programme. An effective way of gaining support and ownership is to involve employees in the programme. For individuals to be involved they must feel that their views and opinions are important and that they can make a difference. Therefore, employees must be able to influence the selection of the type programme and how it is going to be implemented. A particularly important group to involve are first line supervisors as they can either facilitate or prevent observations being conducted. In addition to involving employees in the selection of the programme, they also need to be directly involved in managing the programme. It is not possible for all employees to be involved in running the programme therefore individuals who are going to be involved need to be selected. Providers differed in their approach to the management of the process, with some providers using a single fulltime co-ordination and others opting for a steering group. Steering groups were more common and tended to be created by asking for volunteers. The selection of the steering group is critical, as it needs to contain respected staff members and be representative of the entire workforce. The majority of behavioural safety programmes require frontline staff to conduct behavioural safety observations on their colleagues. These individuals are usually referred to as observers. In most instances, employees are asked to volunteer to become observers, but sometimes the entire workforce is trained or specific groups (safety representatives or supervisors) are selected to participate.

- ***Behavioural Safety Training***

Irrespective of the whether a single co-ordinator or a steering group manage the programme, training in behavioural safety techniques will be required. This training is likely to include input on the psychology underpinning behavioural safety, how to identify critical safety behaviours and how to provide feedback, either face-to-face or to a group. The number of individuals trained and the depth of the training will depend on the specific programme. Some programmes train all staff, whereas others train a minority of employees. In addition to steering group training, observers require training in how to conduct observations and how to record the information. The depth and level of training varies between providers. Some of the providers assess the quality of the observations by comparing their own observation of the situation with the trainee's observation. The majority of providers give the organisation materials and instruction in how to train observers internally.

- ***Specifying Critical Safety Behaviours***

The majority of behavioural safety programmes develop a list of critical safety behaviours to be included on a checklist that is completed by observers. A range of techniques can be used to identify critical health and safety behaviours to include on the checklist. All the providers interviewed identified critical behaviours through the analysis of previous accident reports. Near-miss or dangerous occurrence reports are an important source of critical safety behaviours, as they may describe behaviours that nearly caused an injury. Relying solely on accident reports has the limitation that infrequent but critical health and safety behaviours may be excluded. Accident analysis only identifies behaviours that have led to an injury, thus excluding critical health behaviours with consequences that have not yet manifested themselves (e.g. exposure to asbestos) and behaviours that due to chance have not yet caused a recordable injury. In addition, the quality and level of detail provided by accident reports may not facilitate the identification of all the critical behaviours.

➢ ***Establishing a Baseline***

The final element in the implementation phase is establishing a baseline. This involves conducting initial observations to establish the current level of safe behaviours for the critical behaviours identified. Not all programmes establish a baseline. A baseline is useful as it allows feedback on the programme's success in changing behaviour.

**3.2 Observation and feedback process**

Once the implementation phase has been completed the observation and feedback loop starts. This is a continuous loop of observation, feedback, goal setting and review.

➢ ***Observations***

The first stage in the process is conducting observations. In general, peers conduct observations, but in some programmes they are conducted by superiors. The proprietary programmes vary in their approach to conducting observations and in how the safe behaviour is measured. In general, the observer is given a checklist with a list of behaviours and the observer has to indicate if the individual is safe, unsafe or the behaviour was not observed. It is critical that the behaviours are clearly described to enable the observer to judge whether someone is behaving safely or unsafely. In situations where it is difficult for others to observe the behaviour, self-observations can be used. This approach is particularly useful with peripatetic and lone workers or management behaviours. The specific format of the self-observation will depend on the frequency with which the behaviours are performed. For behaviours that are performed frequently e.g. adopting correct posture when using a VDU, the individual can be randomly prompted to conduct an observation, through a pager, email, telephone or a radio. When the individual prompted indicates whether or not the specific behaviours are safe or unsafe. For less frequent behaviours such as conducting safety audits, individuals are prompted to recall the frequency with which critical behaviours were performed. Clearly self-report methods rely on trust.

➢ ***Feedback***

Positive feedback is one of the most important elements in the process, as this is the positive consequence that is introduced to reinforce safe behaviour. There are two main types of feedback, summative and formative. Summative feedback provides the individual with information on their performance, e.g. *„Excellent work Paul"*. Formative feedback provides information on how they can improve their performance, e.g. „*The next time you conduct a risk assessment, try involving your team, as they are likely to have more knowledge of the practicalities of the job*". Formative feedback needs to be delivered by someone who is perceived as credible and knowledgeable by the individual receiving the feedback. Summative feedback can be given in public or in private, but formative should only be given in private or it may be perceived as a punishment. Three factors influence the impact of feedback; these are:

- **timing:** feedback should be timed so that it is useful and meaningful to the person receiving the feedback;
- **focus:** the feedback should be specific and focus on the desired behaviour

- **fit:** the feedback should fit with the expectations of the person receiving the feedback. Behavioural safety programmes vary in the type of feedback given. Some programmes provide feedback to the individual at the time; others provide feedback to the group. Table 1 summarises the types of feedback provided.

*Table 1.* **Types of feedback**

| Mode | Type | |
|---|---|---|
| | **Summative** | **Formative** |
| **Face-to-face** | Observer praises the person they observed for behaving safely | The observer highlights ways in which the observes could change their behaviour |
| **Graphical** | The percentage of behaviours which were observed as safe are displayed publicly | It is not appropriate to provide formative feedback graphically |

Giving feedback, especially formative feedback requires skill and expertise, therefore observers require a significant amount of training and coaching to master these skills.

➢ ***Goal Setting and Review***

Once the observations and feedback process is operating effectively, behavioural improvement goals are participatively set with the target group. Although not all behavioural safety programmes include goal-setting, research evidence indicates that goal setting increases the amount of behavioural change. It is important to set realistic, achievable goals otherwise people will become demotivated.

➢ ***Modify Environment***

The observation and feedback process may identify unsafe conditions or barriers (antecedents) to individuals behaving safely. Improvements to the environment or systems may be required in order to improve employees’ behaviour. This information is collected and actions are taken to make improvements. Prompt feedback to staff about status of unsafe conditions highlighted by the system is vital for sustained commitment to the programme.

➢ ***Monitor Performance***

The change in performance is tracked over time, to assess the impact of the programme on the critical safety behaviours. The change in the percentage of observations where behaviour is safe indicates the effectiveness of the process. If there is no change or limited improvement in a specific behaviour over time, it is important to investigate this behaviour in more detail to identify whether any barriers to behaving safely exist. For example, managers may be reinforcing productivity at the expense of safe behaviour, or poor plant design may make safe behaviour difficult to achieve in practice.

➢ ***Review List of Critical Behaviours***

The list of critical behaviours is revised periodically and new behaviours added and existing behaviours replaced. A critical behaviour can be removed from the list and replaced with a new behaviour, when it has reached „habit strength”, i.e. it is consistently observed as safe. Once the goals are achieved then another round of participative target setting is conducted. In general, participative target setting sessions are held at regular intervals (e.g. quarterly).

## 4. DISCUSSION AND CONCLUSION

Behaviour modification programmes have become popular in the safety domain, as there is evidence that a proportion of accidents are caused by unsafe behaviour. Whilst a focus on changing unsafe behaviour into safe behaviour is appropriate, this should not deflect attention from analysing why people behave unsafely. To focus solely on changing individual behaviour without considering necessary changes to how people are organised, managed, motivated, rewarded and their physical work environment, tools and equipment can result in treating the symptom only, without addressing the root causes of unsafe behaviour.

Current behavioural safety observation and feedback programmes only target a limited proportion of critical health and safety behaviours. Health and safety can be dramatically improved, if behaviour modification is used to promote even a proportion of the remaining critical health and safety behaviours. Currently behavioural safety interventions are often separate from other aspects of the health and safety management system. This lack of integration is likely to limit the effectiveness of the intervention. The effectiveness of the programme in changing behaviour is evaluated by comparing results with the baseline measure to establish the degree of behavioural change. The effectiveness of the programme in improving the safety climate is measured by repeating the safety climate survey to identify the degree of change in employee perceptions.

Designing an observation and feedback programme targeted at managers, professional and technical staff presents a number of difficulties. For example, the relatively low number of managers within an organisation means that there is less opportunity to observe managers displaying these behaviours. Therefore, even if managers are meeting with subordinates frequently to discuss safety issues they may not be observed. It can also be difficult to observe managers' behaviour as they can be conducted behind closed doors. It is unlikely that a random observation programme would be able to collect meaningful data on this behaviour and therefore it is unlikely to work. This suggests that a self-observation of the critical behaviours would be more effective. Consultation with the target group of managers is required before introducing a self-observation and feedback programme. The consultation needs to explain the rationale behind observation and feedback, the theory underpinning behaviour modification and how the information collected will be used. Managers will also require training in how to conduct the observations and record their data.

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Prof. PhD. Eng. Nicolae Afrim-Bancila

# INDIKATOREN FÜR DIE BEURTEILUNG DER NACHHALTIGKEIT

**RAREŞ MUNTEANU*, KLAUS FISSGUS***

**Abstract:** *The sustainable developmentie needs coherence. Any strategy needs a concept and also indicators for quantising the results and the processes. According to the Agenda 21, a system of appropriate indicators must be conceived in order to ensure the process of sustainable development and to sustain the ecological pillar. These indicators can and must be used also in the process of rehabilitation of the Jiu Valley mining area.*

**Key words:** *indicators, mining, sustainable development, development concept, land reclamation*

## 1. NACHHALTIGKEITSINDIKATOREN

Die Agenda 21 enthält die Aufforderung, entsprechende Indikatoren für nachhaltige Entwicklung zu bilden. In diesem Zusammenhang wird unter einem Indikator ein quantitatives oder qualitatives Maß verstanden, dass gemessen oder beschrieben und über die Zeit beobachtet werden kann und welches darüber hinaus fähig ist, den gegenwärtigen Status und oder geänderte Richtungen aufzuzeigen. Idealerweise werden zusammenfassende Indikatoren benötigt, welche es innerhalb eines Referenzsystems mit relevanten Kriterien ermöglichen, eine einfache, ganzheitliche Beurteilung der Nachhaltigkeit durchzuführen.

## 2. ANFORDERUNGEN AN INDIKATOREN FÜR DIE ROHSTOFFGEWINNUNG

Es gibt eine Vielzahl an Initiativen, die sich mit der Entwicklung von Indikatoren befassen. Dabei variiert die Zahl der vorgeschlagenen Indikatoren jedoch sehr stark; auch unter dem Aspekt, dass die Indikatoren beispielsweise auch die Weiterverarbeitung und Nutzung der Produkte widerspiegeln sollen. Diese Studie beschränkt sich jedoch auf den Betrachtungsrahmen „Bergwerk“. Hieraus resultieren auch andere Anforderungen an die Indikatoren:

- Möglichst übergreifend einsetzbar trotz Berücksichtigung der verschiedenen Rohstoffgruppen und Bergbauarten - Möglichst vergleichbar innerhalb der einzelnen

* *Lecturer PhD, University of Petrosani, rares73@yahoo.de, kfissgus@yahoo.de*

Rohstoffgruppen - Möglichst auf den gesamten Lebenszyklus eines Bergwerkes anwendbar - Ermittelbar, messbar, quantifizierbar sowie verifizierbar

- National und international verwendbar
- Aktuell und über die Zeit verfolg- und nachvollziehbar
- Handhabbar, d.h. eine möglichst geringe Zahl von ökonomischen, ökologischen und sozialen Indikatoren
- Als politisches Entscheidungsinstrument zur Beurteilung von Projekten und Sektoren

Neben diesen Anforderungen ist bei der Entwicklung der Indikatoren auf folgende weitere Aspekte Wert gelegt worden: Die drei Säulen Ökologie, Ökonomie und Soziales sollen gleichberechtigt und ausgewogen berücksichtigt werden. Die Indikatoren sollen die wesentlichen Effekte der Industrie auf Betriebs-, Unternehmens- und Sektorebene betrachten. Daher sind die verschiedenen Auswirkungen identifiziert und entsprechende Indikatoren abgeleitet worden. Weiter sollen Indikatoren entwickelt werden, die von der Industrie ergriffene Maßnahmen behandeln. Bislang verwendete Indikatoren oder Kennzahlen beziehen sich größtenteils auf Prozesse, die ausschließlich bestimmten technischen oder ökonomischen Randbedingungen unterliegen. Diese Randbedingungen sind aufgrund der anthropogen geschaffenen Systeme, die mittels Indikatoren zu charakterisieren und bewerten sind, zahlenmäßig relativ einfach zu erfassen. Zumeist handelt es sich um industrielle Fertigungsverfahren bzw. Betriebe, die weitestgehend unabhängig von natürlichen Einflussfaktoren betrieben und gestaltet werden. Es müssen also mit den bereits vorhandenen Kennzahlen standardisierte Aggregate, Produktionsverfahren und Verfahrensabläufe beschrieben werden. Diese unterscheiden sich nur durch die Art der eingesetzten Technik, jedoch sind die Arten der Inputs (Energie, Arbeitskraft, Kapital) und Outputs, (Produkte, Abfälle, Emissionen) ähnlich oder zumindest prinzipiell gleichartig. Zudem lassen sich bei industriellen Fertigungsprozessen relativ leicht funktionelle Einheiten identifizieren, also Endprodukte des jeweiligen Betriebes, die gewisse Standards erfüllen müssen bezüglich Qualität, Zusammensetzung, Form, Masse etc. Solcherlei Standards ermöglichen eine Vergleichbarkeit verschiedenster Produktionsprozesse.

## 3. INDIKATOREN FÜR DIE ÖKOLOGISCHE SÄULE

„Die Definition und Auswahl von Umweltleistungsindikatoren ist immer noch in einem frühen Stadium [...]“ [PollPrevHandBook 1998] Tatsächlich sind Indikatoren, welche die Auswirkungen anthropogener Handlungen auf die Umwelt messbar und beurteilbar machen wollen, je nach zugrunde gelegtem Ansatz sehr verschieden und oftmals auf bestimmte Probleme ausgerichtet. Dies gilt insbesondere im Hinblick auf die Rohstoffwirtschaft. Ein Indikator kann definiert werden als „etwas, das eine Einsicht in eine Fragestellung größerer Bedeutung gibt oder eine Entwicklung oder ein Phänomen sichtbar macht, das nicht sofort erkennbar ist“. In der ökologischen Säule gilt es mit Hilfe entsprechender Indikatoren, die Umweltqualität und ihre Veränderung aufgrund der temporären Einwirkung der Rohstoffwirtschaft abzubilden. Welche Bestandteile oder Eigenschaften die Qualität der Umwelt ausmachen, wird jedoch auf internationaler Ebene noch unterschiedlich bewertet. Zumeist werden jedoch als von der Rohstoffwirtschaft beeinflusste Umweltmedien Boden, Luft und Wasser genannt. Als weitere durch die Rohstoffgewinnung beeinflusste ökologische Belange werden beispielsweise Biodiversität, Beeinträchtigung der menschlichen Gesundheit, Veränderung des Landschaftbildes, Eutrophierung, Versauerung (Acid Mine Drainage), Klimawandel, Degradierung und Reduzierung natürlicher Ressourcen (biotische wie abiotische) genannt.

Grundsätzlich gilt jedoch: Ziel des Konzeptes der nachhaltigen Entwicklung in Bezug auf die natürliche Umwelt ist es,

- einen verantwortungsvollen Umgang mit den natürlichen Ressourcen und der Umwelt zu fördern und bereits vorliegende Schäden zu sanieren,
- Abfälle, Emissionen und Umwelteinwirkungen entlang der gesamten Versorgungskette zu minimieren,
- umsichtig und vorsichtig zu handeln, wenn Auswirkungen ungewiss oder unbekannt sind,
- innerhalb der Grenzen des vorliegenden Ökosystems zu wirtschaften und (hinsichtlich seiner Anfälligkeit, Schutzwürdigkeit, Seltenheit, Wichtigkeit o.ä.) kritisches natürliches Kapital zu schützen.

Im Rahmen dieser Studie, die ein rohstoffübergreifendes und international anwendbares Bewertungssystem bereitstellt, werden 10 Indikatoren zur Beurteilung der ökologischen Auswirkungen der Rohstoffwirtschaft vorgeschlagen (Tabelle 1).

**Tabelle 1: Übersicht über die vorgeschlagenen Indikatoren für die ökologische Säule**

| Nr. | Indikator | Einheit |
|---|---|---|
| 1 | Flächeninanspruchnahme | $\left[\frac{a \cdot km^2}{t}\right]$ |
| 2 | Wasserinanspruchnahme | $\left[\frac{m^3}{t}\right]$ |
| 3 | Anteil rezyklierten Wassers | $[\%]$ |
| 4 | Energieinanspruchnahme | $\left[\frac{kWh}{t}\right]$ |
| 5 | Emissionen in die Atmosphäre – Klimarelevant | $\left[\frac{t_{CO_2-Äquivalent}}{a}\right]$ |
| 6 | Emissionen in die Atmosphäre – Nicht Klimarelevant | $\left[\frac{t}{a}\right]$ |
| 7 | Emissionen in der Boden – gewichtet | $[-]$ |
| 8 | Emissionen in Grund- und Oberflächenwasser – gewichtet | $[-]$ |
| 9 | Freiwillige Investitionen in ökologische Projekte | $[\%]$ |
| 10 | Rückstellungen für Sanierung, Wiederherstellung und Ausgleichsmaßnahmen | $\left[\frac{€}{km^2}\right]$ |

Die in der Rohstoffwirtschaft nötige Inanspruchnahme der Ressourcen Fläche, Wasser und Energie (Input-Größen) wird durch die ersten vier Indikatoren abgebildet. Da sie den Einsatz dieser Ressourcen zur Produktion der Rohstoffe widerspiegeln, sind sie – mit Ausnahme des Indikators „Anteil rezyklierten Wassers" –, je nach Phase innerhalb des Lebenszyklus eines Betriebes, unterschiedlich zu erheben. Traditionell werden diese aufzuwendenden Ressourcen (Input-Größen) auf die produzierte Einheit oder auf die Masse der Produkte bezogen, um so den spezifischen Verbrauch ermitteln zu können. Der Lebenszyklus eines Rohstoffbetriebes, von der Exploration, über die Vorbetriebsphase und die Betriebsphase bis zur Nachbetriebsphase, zeichnet sich jedoch dadurch aus, dass nicht in jeder Phase eine produzierte, funktionelle Einheit ausgemacht werden kann, auf die man den Input-Größen beziehen kann. Die funktionelle Einheit, das Wertmineral/-metall, wird erst in der Betriebsphase kontinuierlich „produziert". Explorations-, Vorbetriebs- und Nachbetriebsphase sind dem eigentlichen Produktions- und Gewinnungsprozess vor- respektive nachgelagerte Prozesse. Im Rahmen dieser Studie werden grundsätzlich die Inputs jedoch immer auf Masseneinheiten bezogen dargestellt, wobei die funktionelle Bezugseinheit der Explorationsphase die Masse an Reserven ist, für die Vorbetriebsphase die geplante Masse an produziertem Wertstoff gewählt wird und in der Betriebs- und Nachbetriebsphase die tatsächlich produzierte, kumulierte Wertstoffmasse erhoben wird. Um die Abhängigkeit der Rohstoffwirtschaft von den vorliegenden natürlichen Randbedingungen zu berücksichtigen, werden die Input-Größen in der Vorbetriebs-, Betriebs- und Nachbetriebsphase zudem auf den Anreicherungsgrad und in der Betriebs- und Nachbetriebsphase zusätzlich auf das in der Aufbereitung erreichte Ausbringen bezogen. Diese beiden Faktoren, der Anreicherungsgrad und das Ausbringen, sind im Verlauf der Erarbeitung dieser Studie als für die Rohstoffwirtschaft relevante und zu berücksichtigende Parameter erkannt worden. Das Ausbringen bezeichnet die Effizienz der primären Aufbereitungsprozesse. Insofern werden mit diesem Faktor die oben angesprochenen Forderungen nach einem verantwortungsvollen Umgang mit den natürlichen Ressourcen und die Minimierung von Abfällen angesprochen. Beide Forderungen greifen auf zwei Ebenen. Einerseits gilt es Lagerstätten und deren Wertstoffinhalt möglichst effizient und vollständig zu nutzen. Dies führt zu der Forderung, dass geförderte Rohstoffe so aufzubereiten sind, dass der Wertstoffinhalt möglichst vollständig gewonnen wird. Es lässt sich somit die Forderung nach bestmöglichen Aufbereitungsverfahren ableiten, die die einmal in Anspruch genommene Lagerstätte optimal nutzen. Die andere Ebene, auf der die Forderung nach verantwortungsvollem Umgang mit den natürlichen Ressourcen und die Minimierung von Abfällen angewendet werden kann, bezieht sich auf die für die Gewinnung und Aufbereitung der Rohstoffe nötigen Inputs an Ressourcen, also Fläche, Wasser und Energie. Die Nutzung dieser drei Ressourcen bei der Rohstoffgewinnung und Aufbereitung ist nötig und unbestreitbar. Jedoch muss im Sinne einer nachhaltigen Entwicklung möglichst effizient mit diesen gewirtschaftet werden. Beide genannten Aspekte werden durch den Faktor Ausbringen erfasst und beschrieben. Der ebenfalls berücksichtigte Anreicherungsgrad erfasst die Randbedingungen, die der Bergbau bei Erschließung einer Lagerstätte vorfindet. Gerade im Metallerzbergbau sind die Gehalte der Wertstoffe im Gestein sehr niedrig, so dass entsprechend mehr Fläche, Energie und Wasser für Gewinnung und Aufbereitung in Anspruch genommen werden wird, als dies bei Massenrohstoffen wie bei Kies und Sand der Fall ist. Um solche geringhaltigen Rohstoffe auf dem Weltmarkt verkaufen zu können, sind Anreicherungsprozesse notwendig, die ein Konzentrat mit mittleren bis hohen Wertstoffgehalten liefern. Die hierfür nötigen Anlagen werden zusätzlich Fläche, Wasser und Energie benötigen, und dies umso mehr, je höherhaltig das produzierte Produkt respektive je größer der Unterschied (das Verhältnis) zwischen Wertstoffgehalt im Produkt und Wertstoffgehalt im Erz ist. Die Anreicherung kann als Vorleistung der Rohstoffwirtschaft angesehen werden, die bestrebt ist, möglichst hochwertige Produkte (beispielsweise Konzentrate mit hohem Wertstoffgehalt) an die weiterverarbeitende Industrie zu liefern. Tendenziell lässt sich durchaus feststellen, dass je hochwertiger das gelieferte Produkt, umso weniger Fläche, Energie und Wasser müssen in der nachfolgenden Verarbeitung eingesetzt werden. Der Faktor Anreicherungsgrad berücksichtigt dies. Die Indikatoren 5 bis 8 erfassen die Emissionen in die Umweltmedien Boden, Wasser und Luft. Sie werden teilweise mit Gewichtungsfaktoren versehen und als Summenparameter verschiedener Stoffe gebildet. Die Auswahl der zu betrachtenden Stoffe beruht auf den in Wissenschaft und (Umwelt-)Politik als umweltrelevant identifizierten Stoffkatalogen. Mit den Indikatoren Nr. 9 und 10 werden Maßnahmen der Betriebe, Unternehmen und Sektoren erfasst, die Eingriffe in die Umwelt durch Sanierungs-, Rehabilitierungs- oder Ausgleichsmaßnahmen zu kompensieren.

## 4. KONZEPT FÜR EINE NACHHALTIGE ENTWICKLUNG IM SCHILTAL

Die Probleme des Schiltaler Reviers sind typisch nicht nur für dieses Gebiet. Überall in der Welt, wo es Bergbauindustrie gibt, sind ähnliche Situationen anzutreffen. Am Anfang entwickelt sich die Bergbauregion stark und schnell. Die Bevölkerung steigt sehr schnell. Später, wenn die Reserven sinken, werden einige oder alle Gruben geschlossen und ökonomische und soziale Probleme erscheinen: die Arbeitslosigkeitsquote steigt, die Ökonomie der Region hat Schwierigkeiten, denn alle Geschäfte sind mehr oder weniger von der Bergbautätigkeit abhängig und deswegen folgt soziale Unruhe. Einige Regionen bieten bessere Bedingungen als andere an, um alternative Wirtschaftstätigkeiten zu entwickeln. Es gibt viele Faktoren, die Einfluss auf die allgemeine Situation haben:

- die Ökonomie des Landes und der Region
- die Entfernung von anderen wichtigen Städten und Regionen
- die Infrastruktur (Straßennetzwerk, Eisenbahnnetzwerk usw.)
- Alternativen für Investoren
- die Ausbildung der Arbeitskräfte.

In Europa hat die Kohlenindustrie eine komplexe und komplizierte Situation. Ein Ergebnis der Bemühungen diese Industrie rentabel zu machen ist, dass viele Gruben geschlossen und saniert wurden. Das heißt, dass viele Regionen ähnliche Bedürfnisse wie das Schiltal haben. Heutzutage bietet die Globalisierung der Weltwirtschaft den Investoren sehr schnell Gelegenheiten, Profit weltweit zu suchen. Das heißt, dass die europäischen Länder im Wettbewerb mit Ländern von anderen Kontinenten stehen; Länder, wo die Arbeitskraft billiger ist (zum Beispiel in Asien).

In Rumänien ist das Schiltal nicht einmalig, weil andere Regionen Rumäniens gleichartige soziale und wirtschaftliche Bedingungen haben. Das bedeutet, dass eine originelle und erfolgreiche Lösung gefunden werden muss.

Eine erfolgreiche zukünftige Entwicklung des Schiltals braucht Kohärenz. Dafür wird ein Konzept benötigt. Die Idee der Entwicklungskonzepte ist in Deutschland zuerst entwickelt und verwendet worden. ***Um das Konzept für nachhaltige Entwicklung zu gründen, braucht mann auch die richtige Indikatoren für die ökologische Säule zu verwenden.***

Die Sanierung und Wiedernutzbarmachung der ehemaligen Bergbauflächen benötigen eine umfassende Analyse der allgemeinen Bedingungen nach der Schließung und des Potenzials auf nationaler, regionaler und lokaler Ebene. Solche Entwicklungskonzepte sollen von Menschen, Geschäftsleuten und Behörden erkannt, verstanden und akzeptiert werden und müssen die Vorteile und die Eigenschaften der Region, z.B. des Schiltals berücksichtigen.

Ein erfolgreiches Konzept für das Schiltal könnte sein: Das Schiltal wird als eine Verwaltungseinheit betrachtet, der Wiederaufbauprozess wird einheitlich geführt und unter diesen Bedingungen werden Tradition und Neues mit originellen Lösungen für eine nachhaltige Entwicklung verbunden**.**

Die wichtigsten Voraussetzungen, sind:

- eine saubere städtische Umwelt
- alle gerichtlichen Punkte in Verbindung mit dem Besitz des Bodens sind zu klären
- attraktive Gebäude für Wohnung und Arbeit
- gute Schulen für die Kinder
- Möglichkeiten zur Freizeitgestaltung
- Möglichkeiten für Kultur
- Möglichkeiten, um schnell andere Bestimmungsorte zu erreichen
- eine entsprechende Infrastruktur.

Gleichzeitig muss der Entwicklungsplan die lokalen Hauptwerte herausstreichen:

- eine sehr schöne Landschaft und heutzutage, nach der Schließung mehrerer Umwelt verschmutzender Betriebe oder nach der Modernisierung von anderen auch ein sauberes, ökologisches Umfeld;
- die Menschen, einschließlich des guten Zusammenlebens, von Rumänen und Angehörigen anderer Nationalitäten, die aus dem ehemaligen Habsburger Reich stammen – als gutes europäisches Modell

- die Ausbildung – viele Personen sind gut ausgebildet und das auch, weil es in der Hauptstadt des Schiltals, Petrosani, eine Universität gibt, wo die Studenten im technischen und ökonomischen Bereich vorbereitet werden
- die Universität bietet die Gelegenheit neue, moderne, umweltfreundliche Technologien zu entwickeln, allein oder in Zusammenarbeit mit Firmen und/oder mit lokalen Forschungsinstituten
- Möglichkeiten für Kultur, Erholung

Sehr wichtig ist aber die Sanierung – Zuerst muss das Problem der Sanierung erledigt werden. Das bedeutet nicht nur Ökonomie, sondern zuerst Ökologie, denn ohne eine saubere Umwelt sind alle weiteren Taten umsonst. Saubere Luft, Land und Wasser sind eine „sine qua non" Kondition für erfolgreiche Investitionen. Die ganze Bergbautätigkeit (Förderung, Aufbereitung, Transport) hatte bisher eine sehr negative Auswirkung auf die Umwelt.

Sanierung bedeutet auch Vorbereitung und Nutzbarmachung von Flächen, die früher von der menschlichen Tätigkeit beeinflusst wurden. Dafür wird empfohlen, eine umweltspezialisierte Firma zu gründen. Sanierung kann auch ein Geschäft werden und die Nationale Steinkohlegesellschaft, die Universität von Petrosani, sowie die Planungsfirmen INSEMEX und ICPM haben die nötigen Fachleute. Letztlich sind einige Privatfirmen mit guten Fachleuten gegründet worden, leider sind sie noch klein, aber haben Potential für die Zukunft. Viele Flächen, die der Bergbauindustrie gehörten, waren private Grundstücke. Deswegen müssen auch gerichtliche Punkte, wie Eigentum und Erbe geklärt werden. Gleichzeitig ist es unerlässlich, eine entsprechende Infrastruktur anzubieten, denn die ganze Wirtschaftstätigkeit ist davon abhängig. Die hohe Qualität von Verkehrswegen, Straßen, Wasser, Kanalisation, Strom, Internet, Telefon (entweder mobil oder klassisch) sind die Voraussetzungen einer erfolgreichen Entwicklung. Natürlich sind dafür Baufirmen nötig. Das Ziel der Regionalentwicklung ist, ein besseres Leben für die Menschen anzubieten. Dafür braucht man auch ein schönes städtisches Umfeld, mit modernen (entweder neuen oder sanierten) Gebäuden und Freizeitmöglichkeiten, denn die Menschen müssen sich wohl fühlen. Es wird empfohlen, dass alle diese Maßnahmen im Rahmen eines koordinierten Regionalplans zusammengefasst werden. In Bezug auf die Flächen, muss beachtet werden, dass einige Grundstücke früher privat waren (bevor die Kohleförderung anfing). Dies ist jetzt zu klären.

Die Fortführung der Tätigkeit in der Bergbauindustrie auf neuer Basis. Die Tätigkeit muss modern, umweltfreundlich und wirtschaftlich werden; der Staat wird nicht mehr die Bergbauindustrie mit Geld unterstützen. Rentabel können energetische Komplexe sein, z.B. das 2004 gegründete integrierte Projekt Paroseni, das das Kraftwerk Paroseni, die Gruben von Paroseni und Vulcan und die Aufbereitungsanlage von Coroiesti umfasst. Weiter kann ein energetisches Zentrum auf Basis von Kohle gegründet werden, möglicherweise auch in Zusammenarbeit mit dem Braunkohlerevier Gorj.

Verwertung des Abraums – Der Bergbau bietet weitere Möglichkeiten z.B.: durch neue Technologien die nützlichen Elemente aus den Halden zu verwerten, die durch die traditionellen Technologien nicht verwertet worden sind.

## 5. SCHLUSSFOLGERUNGEN

Die nachhaltige Entwicklung ist ein sehr wichtiges Thema. Um eine nachhaltige Entwicklung zu erreichen, braucht man einen Konzept, un Kohärenz zu erlangen, aber auch ein Beurteilungssystem. Der Bergbau im Schiltal ist in eine schwierige Lage, aber es gibt Möglichkeiten für die Region zukünftlich sich zu entwickeln, und die Nachhaltigkeitsindikatoren wurden sehr nützlich für den Entwicklungsprozess.

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# APPLICATIONS POTENTIELLES AU GÉNIE CIVIL DES DEUX GRANDES APPROCHES CONCEPTUELLES DE L'ANALYSE DES RISQUES

**BĂBUȚ GABRIEL BUJOR*** 
**MORARU ROLAND IOSIF*** 
**BĂBUȚ MONICA CRINELA****

**Abstract:** *The civil engineering workings have certain specific features which do require particular risk management methods. The aim of this paper is to present two major risk analysis conceptual approaches, namely: the MADS approach (systems malfunction analysis methodology) and the Cindynics approach. The authors are introducing the basic principles and are highlighting, as far as possible, their applicability in the field of civil engineering.*

**Key words:** *risk analysis, conceptual approach, MADS, Cindynics, civil engineering*

## 1. INTRODUCTION

L'ingénieur caractérise le risque comme une entité à deux dimensions: probabilité d'une part (les accidents surviennent plus ou moins souvent) et gravité d'autre part (ils ont des conséquences plus ou moins importantes) [5]. C'est en ces termes simples, bien que parfois interprétés avec ambiguïté, que se pose la problématique de gestion des risques dans tous les domaines industriels et dans le domaine du génie civil en particulier. Mais, cette simplicité de dénomination ne doit pas cacher la multiplicité et la difficulté des efforts à accomplir pour identifier et évaluer les risques ainsi que pour les réduire ou les rendre acceptables.

Les ouvrages du génie sont en interaction avec le milieu naturel toujours insaisissable dans sa complexité ou son évolution dans le temps. Ce sont des ouvrages souvent passifs dont le rôle est de résister à la force de gravitation terrestre ou à des forces extérieures comme la poussée des eaux ou des terrains, le vent, les séismes, etc. Par ailleurs, les utilisateurs de ces ouvrages sont souvent des collectivités de personnes (par exemple, un pont, un immeuble ou un tunnel), qui constituent également le principal champ d'exposition aux risques induits par l'existence de ces ouvrages.

* *Assoc. Prof., Ph.D at the University of Petroşani, gabriel_babut@yahoo.com, roland_moraru@yahoo.com*
** *PhD-Student.Eng. at the University of Petroşani, babut_crina@yahoo.com*

La conception des ouvrages, leur réalisation mais aussi leur exploitation sont les phases de la vie d'un ouvrage de génie civil pendant lesquelles les acteurs sont différents, les personnes ou les biens exposés sont différents et les risques engendrés également. Des négligences dans l'une de ces phases peut avoir des conséquences dans une autre alors que les acteurs, les utilisateurs ou les personnes exposés ont changé. Cela rend difficile la gestion globale des risques dans le domaine du génie civil.

## 2. LES PRINCIPES FONDATEURS DE LA MADS ET DES CINDYNIQUES

Dans la plupart des pays industrialisés, l'évaluation globale des risques est pratiquée sur la base d'outils et de méthodes maintenant éprouvées parmi lesquelles on peut citer par exemple: l'AMDEC (Analyse des modes de défaillance, de leurs effets et de leur criticité), les arbres de défaillance, les arbres d'événements, la méthode HAZOP (dans l'industrie chimique), etc. Ces outils et méthodes sont pour l'essentiel issus du domaine de la sûreté de fonctionnement qui s'est développée principalement dans l'industrie nucléaire, l'industrie aéronautique et l'industrie chimique [5], [6].

En ce qui concerne le contexte conceptuel à la gestion globale des risques, deux écoles s'y côtoient: la méthodologie d'analyse des dysfonctionnements dans les systèmes (MADS) et les Cindyniques. Elles ont vocation à fonder prochainement ce qu'on pourra appeler une ou des sciences du risque.

### 2.1 La méthodologie d'analyse des dysfonctionnements dans les systèmes

D'origine bordelaise (Université de Bordeaux I, voir notamment [1], [8]), les auteurs de cette approche appellent Science du Danger le corps de connaissances qui a pour objet d'appréhender des événements non souhaités. Appréhender consiste à :

- représenter les systèmes d'où sont issus (systèmes sources) et sur lesquels (systèmes cibles) s'appliquent les événements non souhaités;
- mettre en relation les systèmes source et cible afin de modéliser le processus de danger;
- identifier, évaluer, maîtriser, gérer et manager les événements non souhaités dans des systèmes complexes et variés, a priori (prévention) et a posteriori (retour d'expérience).

Les événements non souhaités (ou ENS) sont les dysfonctionnements susceptibles de provoquer des effets non souhaités sur l'individu, la population, l'écosystème et l'installation. Ils sont issus de, et s'appliquent à: la structure, l'activité, l'évolution des systèmes naturels et artificiels. Cette définition explicite deux catégories d'événements non souhaités: ceux attribués au système source mais aussi aux effets que ces derniers provoquent sur le système cible.

Le processus de danger est le modèle de référence que l'on constitue en représentant de façon générale les systèmes source et cible. Cette phase permet l'acquisition des connaissances sur les systèmes source et cible:

- représentant les processus de danger; il s'agit de processus cognitifs, relationnels, technologiques ou biologiques.
- modélisant le processus de danger; il s'agit de relier les processus sources de danger aux processus susceptibles d'être affectés au niveau de la cible du danger.

Cette représentation est immergée dans un champ de danger, tapissé de processus qui peuvent influencer l'état du système source, des processus sources du danger, du flux mais aussi du système cible. Il existe trois types de flux de danger: les flux de matière, d'énergie et d'information.

La méthode générale de connaissance et d'action (par exemple avec la méthode MOSAR, Méthode Organisée et Systémique d'Analyse de Risques) consiste à identifier, analyser, maîtriser, gérer et manager des événements non souhaités:

- l'identification des ENS consiste à les localiser au niveau du processus de danger (recherche de l'origine des flux de danger, recherche des effets créateurs ou amplificateurs des flux, recherche des effets provoqués sur le système cible) ;
- l'analyse des ENS consiste à effectuer une analyse de risque à l'aide d'outils identifiés (probabilité, gravité). Les échelles d'évaluation peuvent être quantitatives ou qualitatives.

Sur le plan conceptuel, le modèle processus de danger permet de classifier les techniques du danger par la notion de point de vue. Comme le montre le tableau 1, le point de vue dépend du type de système cible que l'on cherche à protéger des effets d'un système source.

*Tableau 1.* **Notion de point de vue**

| **Système source** | **Système cible** | **Points de vue** |
|---|---|---|
| Installation | Installation | Sûreté de fonctionnement, sécurité des biens |
| Installation | Opérateur | Ergonomie, sécurité du travail, conditions de travail |
| Opérateur | Installation | Fiabilité humaine, malveillance interne |
| Installation | Population | Hygiène et santé publique, hygiène et sécurité de l'environnement, génie sanitaire |
| Population | Installation | Malveillance externe |
| Installation | Ecosystème | Hygiène et sécurité de l'environnement, écologie appliquée, génie sanitaire |
| Ecosystème | Installation | Risques naturels, étude de site, urbanisme |

Le processus de danger est aussi un modèle fédérateur des connaissances et des pratiques des techniques du danger. À titre d'exemple, on peut expliciter la sécurité du travail comme dans le tableau 2.

*Tableau 2.* **La sécurité du travail vue par l'approche MADS**

| **Sécurité du travail** | |
|---|---|
| Définition et objectifs | Aptitude du système de production à fonctionner sans porter atteinte à son environnement |
| ENS | Dysfonctionnement de l'installation<br>Accident ou maladie professionnelle des opérateurs |
| Problématique | Centrée sur l'installation, technico-juridique et normative.<br>Approche traditionnelle; obligation de moyens<br>Approche systémique; obligation de résultat |
| Méthodes | MOSAR, Etude de sécurité |
| Origine des outils | Droit, norme, règles de l'art, ingénierie, mathématiques, informatique |
| Mots clés | Installation, risque, danger, réglementation, normalisation, obligation de résultat |

Une implication intéressante du modèle systémique est la suivante : tout système peut être découpé en trois sous-systèmes: un sous-système opérant, un sous-système d'information et un sous-système de pilotage.

### 2.2 Les Cindyniques

Du grec Kindunos, qui veut dire danger, est venu le nom de cette école dont la naissance remonte à 1987 [4]. Elle est actuellement supportée et développée par l'Institut Européen des Cindyniques. Les principaux concepts cindyniques reposent sur la représentation à 5 dimensions qu'on appelle *l'hyperespace du danger* [2] :

- la dimension des faits de mémoire de l'histoire et des statistiques (axe statistique). C'est ce que l'on stocke dans des banques de données.
- la dimension des représentations et modèles élaborés à partir des faits (axe épistémique). C'est la banque de connaissances qui sert d'appui aux calculs.
- la dimension des objectifs (axe théologique). Il s'agit pour chacun des réseaux impliqués dans la situation d'expliciter sa stratégie.
- la dimension des normes, lois, règles, standards et codes de déontologie, obligatoires ou de libre adhésion, contrôlés a priori ou non, etc … (axe déontologique).
- la dimension des systèmes de valeurs (axe axiologique).

Dans les situations cindyniques, le danger résulte d'une part des déficits dans chacune de ces dimensions (déficits systémiques cindynogènes, tableau 3), des disjonctions, c'est-à-dire des contradictions entre les dimensions, mais aussi des dissonances entre deux ou plusieurs réseaux d'acteurs évoluant dans la même situation. Par ailleurs, un certain nombre de principes ont été dégagés depuis la création des Cindyniques. Ces principes sous-tendent l'émergence des dissonances, des disjonctions et des déficits. Il s'agit:

- du principe de relativité qui pose que la perception du danger est relative à la situation et à l'acteur qui la perçoit;
- du principe de conventionalité qui signifie que les mesures du risque sont subordonnées à des conventions entre les acteurs;
- du principe des finalités contradictoires des acteurs ;
- du principe d'ambiguïté selon lequel il est dans la nature des choses qu'un certain flou enveloppe les 5 dimensions; le travail de prévention consiste ainsi à s'attaquer à ces ambiguïtés;
- du principe de transformation qui signifie que les accidents et catastrophes sont une transformation brutale du contenu des 5 dimensions;
- du principe de crise qui pose que la crise est une désorganisation des réseaux d'acteurs pris dans la situation;
- du principe de nocivité selon laquelle toute action sur la situation qui a des effets réducteurs de danger a aussi des effets créateurs de danger.

*Tableau 3.* **Les déficits systémiques cindynogènes (DSC) empiriques d'après [3]**

| Code | Type de deficit |
|---|---|
| **DSC 1** | Culture d'infaillibilité |
| **DSC 2** | Culture de simplisme |
| **DSC 3** | Culture de non-communication |
| **DSC 4** | Culture nombriliste |
| **DSC 5** | Subordination des fonctions de gestion du risque aux fonctions de production ou à d'autres fonctions de gestion créatrices derisques |
| **DSC 6** | Dilution des responsabilités |
| **DSC 7** | Absence d'un système de retour d'expérience |
| **DSC 8** | Absence d'une méthode cindynique dans l'organisation |
| **DSC 9** | Absence d'un programme de formation aux cindyniques adapté |
| **DSC 10** | Absence de planification des situations de crise |

Les quatre premiers DSC inclut dans le tableau 3 sont de nature culturelle, les deux suivants sont des déficits organisationnels et les quatre derniers sont des déficits managériaux. Les Cindyniques évoluent et s'enrichissent actuellement de nouveaux champs d'application (la cindyno-thérapie par exemple), mais aussi de nouveaux concepts (la cindynamique par exemple).

## 3. CHAMPS D'APPLICATION AU GÉNIE CIVIL

### 3.1 MADS en pratique

La mise en œuvre pratique de MADS a été formalisée dans une méthode appelée MOSAR, méthode d'analyse des risques participative. Elle peut être mise en œuvre selon une approche déterministe ou, quand c'est possible, une approche probabiliste. En pratique, MOSAR se décline en deux modules, le module dit module A qui sert à mener une analyse macroscopique (approche globale sur l'installation destinée à rechercher les risques de proximité), et le module B qui vise à analyser finement l'installation concernée en détaillant les risques à l'aide des outils plus classiques de la sûreté de fonctionnement. Le déroulement complet de la démarche consiste ainsi à parcourir les étapes suivantes. D'une part, pour l'approche macroscopique: 1) identification des sources de dangers; 2) identification des scénarios de risques; 3) évaluation des scénarios de risques; 4) négociation des objectifs et hiérarchisation des scénarios; 5) définition des moyens de prévention et leur qualification. Puis pour l'approche microscopique, consiste en: 1) identification des risques de fonctionnement ; 2) évaluation des risques à partir d'arbres; 3) négociation des objectifs précis de prévention; 4) affinement des moyens de prévention; 5) gestion des risques. On pourra retrouver les détails de la méthode dans diverses publications dont [7].

### 3.2 Les cindyniques en pratique

Il est souvent reproché à l'approche cindynique sa difficulté d'utilisation en pratique. Faute de disposer d'un cas concret pouvant réfuter ce reproche, nous expliciterons ici comment une telle approche permet de préparer une évaluation globale des risques dans le cas d'un tunnel routier. Il convient tout d'abord de fixer les réseaux (ou groupes) d'acteurs auxquels on s'intéresse. Dans la problématique des tunnels, la liste des acteurs est longue et nous nous limiterons aux trois groupes d'acteurs suivants :

- le maître d'ouvrage (la société d'exploitation, en règle générale) ;
- le maître d'œuvre (le constructeur) ;
- les utilisateurs (véhicules personnels, routiers, etc…).

On peut projeter chacun de ces groupes dans les 5 dimensions de l'espace du danger et obtenir ainsi, sous forme synthétique, les tableaux 4 à 6.

*Tableau 4.* **Le maître d'ouvrage dans l'espace du danger**

| **Acteurs** | **Par exemple une société d'autoroute CNADNR** |
|---|---|
| Faits | • accès aux données centralisées du ministère. |
| Modèles | • outils de représentations et modèles propres. |
| Objectifs | • faire des bénéfices financiers en réalisant et exploitant des tunnels sur des sections de voies concédées du réseau national. |
| Règles | • comme le ministère. |
| Valeurs | • primauté de la vie humaine;<br>• souci de l'amélioration de la sécurité et du respect environnemental;<br>• souci de satisfaire les usagers;<br>• importance de la rentabilité financière de l'ouvrage. |

Dès lors, on peut envisager d'énoncer quelques déficits, disjonctions et dissonances possibles chez et entre les acteurs. En ce qui concerne les déficits, on peut par exemple déplorer un manque de connaissances et de données, chez l'Etat et ses services, notamment en matière d'incendie en tunnels.

*Tableau 5.* **Le maître d'œuvre dans l'espace du danger**

| **Acteurs** | **Entreprise de BTP - Génie Civil** |
|---|---|
| Faits | - accès aux données centralisées du ministère. |
| Modèles | - outils de représentations et modèles propres à la construction de tunnels. |
| Objectifs | - faire des bénéfices. |
| Règles | - toutes les règles et normes constructives dans le domaine des tunnels;<br>- le droit du travail. |
| Valeurs | - primauté de la vie humaine; rentabilité financière de la construction. |

*Tableau 6.* **Les utilisateurs dans l'espace du danger**

| **Acteurs** | **Utilisateurs par exemple les véhicules personnels** |
|---|---|
| Faits | - une carte routière;<br>- la visibilité du trafic, signalisation; informations sur le trafic;<br>- une connaissance a priori d'accidents antérieurs dans les tunnels. |
| Modèles | - une certaine idée de la conduite automobile. |
| Objectifs | - gagner du temps; se déplacer. |
| Règles | - code de la route. |
| Valeurs | - la liberté de mouvement; la primauté de la vie humaine. |

Dans la dimension des règles, on peut signaler une inadaptation ou une insuffisance des réglementations particulières (pour chaque tunnel) concernant les conditions d'utilisation des ouvrages. En particulier en ce qui concerne la réglementation des poids lourds (manque d'une inter-distance unique, valable dans tous les tunnels, absence d'un volet sur le comportement à tenir à l'intérieur des tunnels dans les formations obligatoires initiales et continues des conducteurs de poids lourds). Il y a aussi des insuffisances dans la réglementation du transport des matières dangereuses (absence d'évaluations comparatives de risque entre l'itinéraire empruntant le tunnel et les itinéraires alternatifs), ou le contrôle de la vitesse des véhicules.

De même, en matière de disposition constructive, la réglementation n'est pas toujours suffisante. Chez les maîtres d'ouvrages, on peut signaler également une non mise en conformité des ouvrages en gestion, avec la réglementation. Ainsi, que dans certains tunnels, doivent être installés ou complétés des systèmes de ventilation et de désenfumage, de gestion technique centralisée, de détection automatique d'incidents, de lutte contre l'incendie et de fermeture automatique des accès. Dans d'autres, doivent être réalisés des travaux lourds de construction d'abri et d'issues de secours. En ce qui concerne les dissonances, on peut en signaler relatives aux règles, par exemple entre les ministères chargés des transports de deux pays reliés par un tunnel, qui se manifeste par un manque de référentiel en matière de génie civil et d'équipement des tunnels, de coordination de l'exploitation, de contrôle de la sécurité, de recherche et de sécurité des véhicules (cf. diagnostic établi par le comité d'évaluation au niveau national). Par ailleurs, on peut aussi identifier des disjonctions, par exemple la disjonction entre finalités et règles chez les conducteurs automobiles (gagner du temps - respecter les limites de vitesses).

## 4. CONCLUSION

Les deux approches MADS et Cindyniques apportent des concepts intéressants qui facilitent l'appréhension des problèmes de sécurité ou plus généralement des dangers dans une organisation.

L'approche MADS tente de fédérer les pratiques plus anciennes du management de la sécurité (par intégration des outils et méthodes de l'analyse de sécurité). Elle a été fondée sur l'expérience de ses protagonistes acquises sur le terrain dans l'évaluation des risques. Associée à MOSAR (Méthode Organisée Systémique d'Analyse des Risques), elle fournit un langage mais aussi des outils opérationnels pour l'analyse des risques.

Les Cindyniques, c'est d'abord une approche théorique, basée sur un langage nouveau dont les applications pratiques ne font qu'apparaître. Cette approche est plus générale, plus englobante et plus facile à mettre en œuvre dans les systèmes non technologiques. Par ailleurs, le vocabulaire qu'elle utilise même s'il est plus difficile d'accès me paraît plus cohérent, plus naturel en quelque sorte. Les notions de „flux ou de champs de danger" par exemple, reprises du vocabulaire de la systémique, ne sont pas très parlantes, alors que le concept de déficits systémiques cindynogènes (les déficits qui, dans les systèmes, engendrent des dangers) par exemple, l'est davantage. Il reste encore à l'école des Cindyniques à convaincre de son sens pratique. Ce reproche essentiel lancé à son encontre est en train de tomber.

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Scientific Reviewers:
Prof. PhD. Eng. Mircea Georgescu

# ROMANIAN TELLURIUM OCCURENCES CASE STUDY – PODUL IONULUI WASTE DUMP

**BUIA GRIGORE**[*]
**LORINȚ CSABA**[**]
**IGNA LAURENȚIU**[***]

**Abstract:** *The beginning of the third millennium, under the sign of the new information age, is dependent on new mineral resources. Among these, tellurium holds a leading position due to its properties and uses in modern technologies. In Romania, tellurium is present as a minor element; it appears in sulfosalts associated with neogene volcanic rocks or alongside gold-silver tellurides, as well as a native mineral. It is also widespread in waste dumps and tailing ponds of former mining works, from where it can be easily recovered.*

**Keywords:** *tellurium, grade, resources, reserves, waste dumps, recovery, rehabilitation/environment reintegration.*

## 1. INTRODUCTION

As noted in the previous articles „Li, Te, Se, Nb-Ta - XXI CENTURY METALS?" and „XXI CENTURY METALS - Li, Te, Se, Nb-Ta - NATIONAL SITUATION", the beginning of the third millennium, under the sign of the new information age, is dependent on new mineral resources.

Among these tellurium is at the top due to its properties and uses in modern technologies. However, these generate an increasing demand on the market for this metal, which is a challenge for the mining industry. In Romania, the occurrences of tellurium are known especially in the so-called "Golden quadrilateral", where it is associated with a variety of minerals, mostly tellurides.

With this new approach, the authors aim to highlight one of the occurrences in the national potential, through a case study on the Podul Ionului waste dump.

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[*] *Professor Ph.D. eng., at University of Petrosani, Faculty of Mining, Management, Environmental Engineering and Geology Department, Universitatii street, No. 20, 332006, Petrosani, Romania; grigbuia@upet.ro*
[**] *Assistant Professor Ph.D. eng., at University of Petrosani, Faculty of Mining, Management, Environmental Engineering and Geology Department, Universitatii street, No. 20, 332006, Petrosani, Romania; csabigeo@upet.ro*
[***] *Eng. geologist, at S.C. Deva Gold S.A., Certeju de Sus; laur.igna.333@gmail.com*

## 2. TELLURIUM – GENERAL FACTS, HISTORY, ROUNDUP

Tellurium (*Tellus lat.-fruit of the earth*) was found in Romania in 1782 by Austrian scientist *Franz-Joseph Müller von Reichenstein*. Tellurium is relatively rare (0.0018 ppm. clarke) and is usually found in combination with other elements (gold, silver), forming tellurides. Tellurium also appears as an isomorphic substitute of lead, hence its presence in galena. Tellurium, like selenium, forms exclusively in magmatic deposits belonging to the hydrothermal phase.

Precisely because of its rarity, pure tellurium is very expensive. By estimation, the minimum exploitable grade in gold-silver tellurides is about 15 ppm. [7].

Tellurium is a silver-coloured semi-metal with hexagonal crystal structure. It is considered to be of relatively low toxicity, but prolonged exposure to tellurium is to be avoided, in particular to prevent inhalation exposure. Among the many uses of tellurium, the following can be mentioned: the energy industry (thermoelectric devices), steel processing, glass and plastics colouring, metal alloys (due to its ductility), semiconductor and solar panels manufacturing, etc. [5].

## 3. TELLURIUM OCCURRENCES - THE NATIONAL SITUATION

Tellurium is present as a minor element in galena, chalcopyrite and pyrite associated with Laramic and Neogene deposits particularly in: Baita Bihor, Coranda, Ilba, Cavnic-Bold, etc, where the mean grade is between 40-120 ppm. . [7]

Tellurium also appears in sulfosalts associated with Neogene volcanic rocks in Baiut (As, Cd, Ga, Tl ± Se, Ge, Te, Co, Ni, Cr, Ti) [1], and Varatec (As, Cd, Bi , Te, Co, Ni, V, Ti, W) (Borcos M., 1984) [10] in the Gutai Mountains and also in Tibles Mountains(Cd, Mn, Ti, F, Te) [9], where it can be recovered along with other elements.

At Sacarâmb, alongside gold-silver tellurides, tellurium was highlighted in sulfosalts (As, As, Bi, St, Te, Co, Ni). [4].

In its mineral form, this element was found in Romania at Sacarâmb, Cordura, Musariu Nou, Fata Baii and Vâlcoi, as follows:

***At Sacarâmb*** in the Metaliferi Mountains, in the Brad-Sacarâmb Neogene Vulcanics area, the Barza-Sacarâmb Sarmatian series, along with Au and Ag, Pb and Zn together in hydrothermal deposits of Miocene age. The host rock is made up of quartz-andesite with hornblende and biotite presenting propylitic, potassic(adularia) and argilic alteration, in NE and NW oriented vein deposits and forming a network in the middle of the central volcanic unit. The chemical composition is Au, Ag, Te ± Pb, Zn, Cu and secondary Cd, Ga, In, As, Sb, Bi, Se, Sn, Co, Ni, and the mineralogical one: pyrite, mispickel(arsenopyrite), sphalerite, galena, chalcopyrite + nagyagite ($Pb_5A$ (Te, Sb)$_4$ $S_{5\text{-}8}$), krennerite (Au, Ag)$Te_2$), sylvanite (Au, Ag $Te_4$), altaite (PbTe), frohbergite ($FeTe_2$),hessite ($Ag_2Te$), petzite ($Ag_3AuTe_2$), tellurium, tetrahedrite, boulangerite, jamesonite, stibnite, native arsenic differentiated distributed in vein groups, specified association dominating the inferior parts of the vein groups. [8].

***At Cordurea*** in the Metaliferi Mountains, in the Brad-Săcărâmb Neogene Vulcanics area, in a complex Neogene volcanic andesite structure, in Cretaceous sedimentary formations, from a Mesozoic alkaline rock complex. The host rock consists of Sarmatian-Pannonian quartz-andesite with hornblende and biotite presenting propylitic, argilic, sericitic, potassic(adularia) and silicic alteration. The deposit appears as veins with Au, Ag ± Pb, Zn, Cu, Te, Cd, Sb, Hg, Ti, Mn, As of hydrothermal origin. In terms of mineralogy, the deposit contains pyrite, tetrahedrite, bornite bournonite, chalcopyrite, galena, nagyagite ($Pb_5A$ (Te, Sb)$_4$ $S_{5\text{-}8}$), hessite, gold, marcasite, realgar, cinnabar (Berbeleac I. , 1984) [10].

***At Musariu Nou*** in the Metaliferi Mountains, in the Brad-Sacarâmb Neogene Vulcanics area in a Neogene andesitic subvulcanic body. Host rock consists of Badenian-Sarmatian andesite – quartz-andesite presenting propylitic, chloritic, potassic(adularia), sericitic, argilic and silicic alteration; sandstone, marl, etc. The deposit is also veins with impregnations. The following elements can be distinguished : Au, Ag ± Pb, Zn, Cu, As, Cd, Mn, Ti, Se, Te, Tl, Sn, Ga, Co, Ni, V ± Bi, Sb, Mo, Cr, B in minerals such as pyrite, mispickel, chalcopyrite, sphalerite, tetrahedrite, galena, frohbergite ($FeTe_2$), weisite, sylvanite (Au, Ag $Te_4$), nagyagite ($Pb_5A$ (Te, Sb)$_4$ $S_{5\text{-}8}$), krennerite( (Au, Ag)$Te_2$), calaverite ($AuTe_2$), montbrayt ($(Au,Sb)_2Te_3$),tellurium, petzite ($Ag_3AuTe_2$), hessite ($Ag_2Te$), empressite (AgTe), altaite (PbTe), etc. in specific Gold-telluride associations (Borcos M., 1984) [10].

***At Fata Baii*** in the Metaliferi Mountains, in the Zlatna-Stanija volcanic area, in hydrothermal veins with nagyagite ($Pb_5A$ (Te, Sb)$_4$ $S_{5\text{-}8}$) and tellurium.

***At Vâlcoi*** in the Metaliferi Mountains, in the Rosia Montana-Bucium-Baia de Aries volcanic area, stationed in Cretaceous sedimentary formations, in hydrothermal veins with Au, Ag ± Te, Pb, Zn, Cu (Borcos M., 1984) [10].

## 4. CASE STUDY – PODUL IONULUI WASTE DUMP

Podul Ionului waste dump consists of sterile material derived from the execution of mining, geological research and the opening workings of the Stanija mining field (Fig. 1.). Base slope on the left side of the dump is strongly eroded by a stream over a length of about 65 m (Fig. 2.).


*Fig.1. Target location*

*Fig.2. Podul Ionului waste dump*

For this reason, floods have displaced a volume of approx. 500 $m^3$ of deposited dump material. Aside from this, the dump does not show signs of instability of the direct foundation or dump material.

### 4.1. Podul Ionului waste dump rock composition

Concerning the chemical composition of rocks stationed in the area of interest, there are two sets of data available, data that was taken from previous analysis and current analysis data. To determine the chemical composition of rocks and verify the results presented above, especially the desire to record the presence of tellurium, new samples were taken from different points of the dump and tested by modern spectrophotometry. The results show the following situation:

Tab. 1. Results obtained by spectrophotometric analysis of samples from Podul Ionului dump

| Component | Grade | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Sample 1 | | Sample 2 | | Sample 3 | | Sample 4 | |
| | [%] | ppm. | [%] | ppm. | [%] | ppm. | [%] | ppm. |
| $Al_2O_3$ | 12,4769 | 124769 | 17,2707 | 172707 | 17,3102 | 173102 | 16,8025 | 168025 |
| $As_2O_3$ | 0,0978 | 978 | 0,1155 | 1155 | 0 | 0 | 0,1589 | 1589 |
| BaO | 0,4368 | 4368 | 0 | 0 | 0,3580 | 3580 | 0 | 0 |
| CaO | 11,8995 | 118995 | 0,6352 | 6352 | 6,6248 | 66248 | 6,1148 | 61148 |
| $Cr_2O_3$ | 1,8341 | 18341 | 0,5393 | 5393 | 0,4745 | 4745 | 0,2753 | 2753 |
| CuO | 0,0918 | 918 | 0,1262 | 1262 | 0,3275 | 3275 | 0,0788 | 788 |
| $Fe_2O_3$ | 24,4007 | 244007 | 21,5020 | 215020 | 16,5993 | 165993 | 25,6962 | 256962 |
| $GeO_2$ | 0,0469 | 469 | 0,0612 | 612 | 0 | 0 | 0,0355 | 355 |
| HgO | 0,0650 | 650 | 0,0647 | 647 | 0 | 0 | | 0 |
| $K_2O$ | 2,6440 | 26440 | 7,2227 | 72227 | 6,0225 | 60225 | 6,6595 | 66595 |
| MgO | 2,7112 | 27112 | 0,9250 | 9250 | 0,8921 | 8921 | 0,9795 | 9795 |
| MnO | 0,5511 | 5511 | 0,1474 | 1474 | 1,2263 | 12263 | 1,2594 | 12594 |
| $Na_2O$ | 0,2257 | 2257 | 0 | 0 | 0 | 0 | | 0 |
| NiO | 0,0705 | 705 | 0,0718 | 718 | 0,0679 | 679 | 0,0671 | 671 |
| $P_2O_5$ | 0,4908 | 4908 | 0,7304 | 7304 | 0,2010 | 2010 | 0,3536 | 3536 |
| $SiO_2$ | 38,3731 | 383731 | 43,7802 | 437802 | 45,0815 | 450815 | 37,7449 | 377449 |
| $SO_3$ | 0,1437 | 1437 | 2,7646 | 27646 | 0,7622 | 7622 | 0,5308 | 5308 |
| SrO | 0,2102 | 2102 | 0,0440 | 440 | 0,0311 | 311 | 0,0224 | 224 |
| **$TeO_2$** | **0,0322** | **322** | **0** | **0** | **0,0040** | **40** | **0,0925** | **925** |
| $TiO_2$ | 2,6357 | 26357 | 2,3309 | 23309 | 2,5889 | 25889 | 2,3482 | 23482 |
| $V_2O_5$ | 0,1002 | 1002 | 0,1927 | 1927 | 0,1119 | 1119 | 0,0934 | 934 |
| ZnO | 0,0793 | 793 | 0 | 0 | 0 | 0 | 0 | 0 |
| $CeO_2$ | 0 | 0 | 0,3093 | 3093 | 0 | 0 | 0 | 0 |
| $Rb_2O$ | 0 | 0 | 0,2225 | 2225 | 0,0559 | 559 | 0,0699 | 699 |
| $ReO_2$ | 0 | 0 | 0,0680 | 680 | 0,5060 | 5060 | 0,5303 | 5303 |
| $SeO_2$ | 0 | 0 | 0,0323 | 323 | 0,0170 | 170 | 0 | 0 |
| $ThO_2$ | 0 | 0 | 0,0279 | 279 | 0 | 0 | 0 | 0 |
| $ZrO_2$ | 0 | 0 | 0,1404 | 1404 | 0 | 0 | 0 | 0 |
| $Ga_2O_3$ | 0 | 0 | 0 | 0 | 0,0139 | 139 | 0,0257 | 257 |
| $Nb_2O_5$ | 0 | 0 | 0 | 0 | 0,0263 | 263 | 0 | 0 |
| PbO | 0 | 0 | 0 | 0 | 0,3579 | 3579 | 0 | 0 |
| $Ta_2O_5$ | 0 | 0 | 0 | 0 | 0,0968 | 968 | 0 | 0 |
| **Total** | **99,6172** | 996172 | **99,3249** | 993249 | **99,7575** | 997575 | **99,9392** | 999392 |

Analysis results revealed the presence of tellurium in three of the four samples tested, at concentrations of 322 ppm, 40 ppm, 925 ppm, respectively, which confirms the existence of this element in rocks from the Podul Ionului dump. More than the mere presence of this metal, it is worth presenting the high concentration (322 ppm., 40 ppm. and 25 ppm.) in which it appears compared to the minimum exploitable grade in gold-silver telluride of about 15 ppm. [7].

This is just one example of the existence of tellurium and other valuable elements in mining waste dumps, through which the authors try to emphasize the importance of thorough investigation, with modern means, of other waste dumps, tailing dams, etc. Thus, it is possible to highlight some important reserves of elements with a high demand on the metal stock market.

Also, after judicious exploitation of these perimeters, is created a favourable premise for their environmental reintegration, being aware that most of them are in poor condition in relation to environmental factors.

## 5. CONCLUSIONS

The beginning of the third millennium, under the sign of the new information age, is dependent on new mineral resources of which tellurium occupies a leading position due to its properties and uses in modern technologies, especially in obtaining electricity from sunlight. Analyses revealed the presence of tellurium in three of the four samples tested, confirming the existence of this element in rocks from the Podul Ionului dump.

This case study underlines the importance of thorough investigation, with modern tools and equipment, of other similar perimeters, by whose exploiting, in the current world situation, Romania could be a leading provider of tellurium from ores and concentrates, especially from mining waste quartered in dumps and tailing dams associated with old mining works.

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Scientific Reviewers:
Prof. PhD. Eng. Vlad Codrea

# ENVIRONMENTAL AIR QUALITY IN JIU VALLEY

**FLOAREA DANCI**[*]

**Abstract:** *Regardless of their nature, the emissions of pollutants influence the environment and generate thermodynamic processes that lead to rebalancing and change of the original status of the environment. An eloquent Earth scale system example is the rising of green house gas concentration and it's consequences- the global warming. Ignoring these processes lead to the aggravation of the situation regarding the natural balance. The lack of legislative mesures, the lack of a good ecological education and awareness regarding the present situation, will lead to a continuous degradation of the environment. Studying the complex processes that lead to breaking the natural balance represents the starting point in limiting these processes and establishing good efficient plans for conservation and environmental protection.*

## 1. SOURCES OF ATMOSPHERIC POLLUTION IN VALEA JIULUI

The main sources of atmospheric pollution in Valea Jiului with chemical gas and solids are:

- Power plants;
- Auto transportation;
- Ventilation units of mining facilities;
- Technological processes like industrial painting, foundries, industrial welding.

The atmospheric pollutants resulting form mining activities are:

- gas emissions from the ventilation units of the mining shafts;
- atmospheric polluting elements from the power plants;
- dust- from the industrial ventilation units;
- dust- generated by the surface minning processes.

Due to the processes involved, mine shafts generate toxic gas which is expelled straight in the atmosphere using large ventilation units.

## 2. COLLECTING AND ANALYZING AIR SAMPLES

The collecting was made according to STAS 10813/76. This method referes to aspiration of 15÷40 l/s or 0,45÷1.200 $m^3$/30' of air through filters with an average pore size of 0,8÷0,85 μ, and weighing of the powder left on the filters. The intake interval was

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* *student PhD. Eng – University Petrosani*

30' for each sample. For this type of intake the maximum addmited concentration value provided by STAS 12.574/87 is 0,5 g/m$^3$ air/30'.

In order to determinate accurately the pollution degree in the area, there were two mesurements at an interval of 30' on the suspendable powders. The final result was obtained by calculating the arithmetic average of the two intermediate results. The sampling locations were: dumps, ventilation units from the mining facilities, ash pond, S.E. Paroseni.

In every situation the analisys revealed that the results did not exceed the sanitation value of 17 g/m$^3$/month.

For each of the polluting sources, the collecting of polluting powder was made by the direction of the wind.

In order to determine as precise as possible the impact of these polluting sources, measurements were made at every active ventilation unit from Jiu Valley. The results from 2010 are shown in the tables below.

2010 - EM LUPENI *Table 1*

| Determined parameter | U.M. | CMA | Process | | | |
|---|---|---|---|---|---|---|
| | | | Transport flux | Mechanical shop | Power plant | Gas station |
| $SO_2$ | µg/m$^3$ | 0,40 | 2,3 | 2,01 | 2,9 | 2,2 |
| $NO_x$ | µg/m$^3$ | 0,50 | 0,4 | 0,4 | 0,6 | 0,8 |
| CO | µg/m$^3$ | 0,50 | 0,4 | 0,8 | 0,4 | 0,2 |
| $CH_4$ la un debit de 2.6 m$^3$ | % | - | - | - | - | 61 |

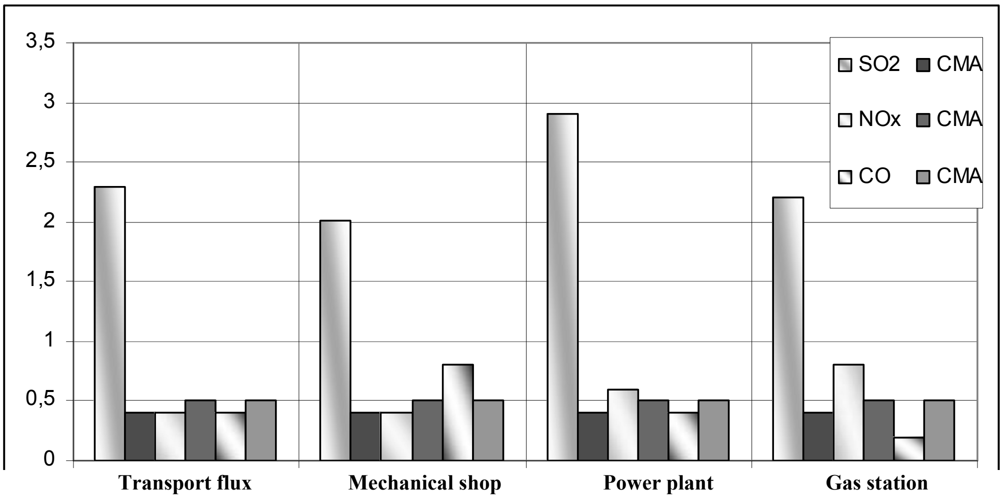


*Fig. 1*

2010 - E.M. LONEA *Table 2*

| Determined parameter | U.M. | CMA | Process | | | |
|---|---|---|---|---|---|---|
| | | | Transport flux | Inside transport | Mechanical shop | Power plant |
| $SO_2$ | µg/m$^3$ | 0,40 | 2,3 | 3,2 | 2,1 | 2,4 |
| $NO_x$ | µg/m$^3$ | 0,50 | 0,4 | 0,1 | 0,3 | 0,1 |
| CO | µg/m$^3$ | 0,50 | 0,2 | 0,5 | 0,4 | 0,5 |

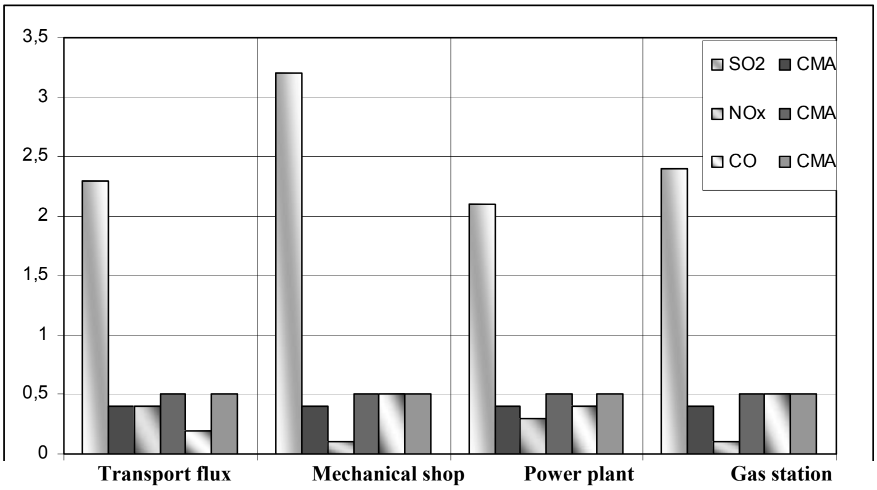


*Fig. 2*

2010 - EM PETRILA *Table 3*

| Determined parameter | U.M. | CMA | Process | | | |
|---|---|---|---|---|---|---|
| | | | Transport flux | Inside transport | Mechanical shop | Power plant |
| $SO_2$ | µg/m$^3$ | 0,40 | 1,6 | 3,0 | 2,3 | 3,5 |
| $NO_x$ | µg/m$^3$ | 0,50 | 0,3 | 0,5 | 0,2 | 0,3 |
| CO | µg/m$^3$ | 0,50 | 0,7 | 0,3 | 0,3 | 0,9 |

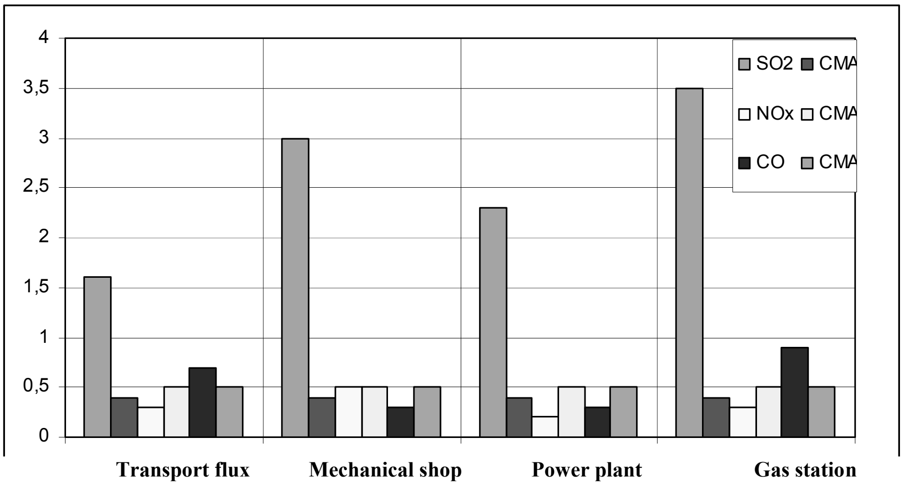


*Fig.3*

2010 - EM LIVEZENI *Table 4*

| Determined parameter | U.M. | CMA | Process | | | |
|---|---|---|---|---|---|---|
| | | | Transport flux | Inside transport | Mechanical shop | Power plant |
| $SO_2$ | $\mu g/m^3$ | 0,40 | 2,0 | 3,8 | 3,2 | 3,3 |
| $NO_x$ | $\mu g/m^3$ | 0,50 | 0,1 | 0,2 | 0,2 | 0,4 |
| CO | $\mu g/m^3$ | 0,50 | 0,4 | 0,9 | 0,7 | 0,8 |

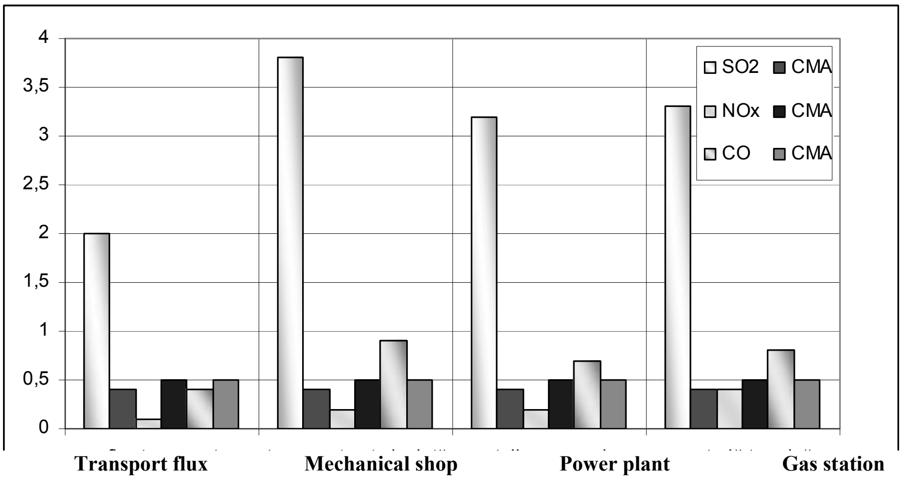


*Fig. 4*

2010 - EM VULCAN *Table 5*

| Determined parameter | U.M. | CMA | Process | | | |
|---|---|---|---|---|---|---|
| | | | Transport flux | Inside transport | Mechanical shop | Power plant |
| $SO_2$ | $\mu g/m^3$ | 0,40 | 1,5 | 1,8 | 1,3 | 1.4 |
| $NO_x$ | $\mu g/m^3$ | 0,50 | 0,2 | 0,5 | 0,4 | 0,3 |
| CO | $\mu g/m^3$ | 0,50 | 0,5 | 0,9 | 0,6 | 0,5 |

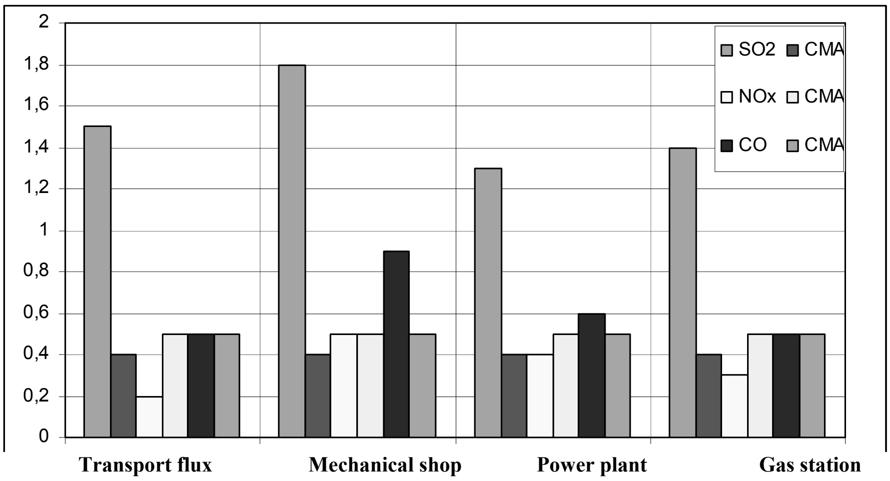


*Fig. 5*

2010 - EM PAROSENI *Table 6*

| Determined parameter | U.M. | CMA | Process | | | |
|---|---|---|---|---|---|---|
| | | | Transport flux | Inside transport | Mechanical shop | Power plant |
| $SO_2$ | μg/m$^3$ | 0,40 | 2,8 | 1,8 | 1,9 | 2,8 |
| $NO_x$ | μg/m$^3$ | 0,50 | 0,5 | 0,7 | 0,4 | 0,5 |
| CO | μg/m$^3$ | 0,50 | 0,9 | 1,3 | 0,6 | 0,9 |

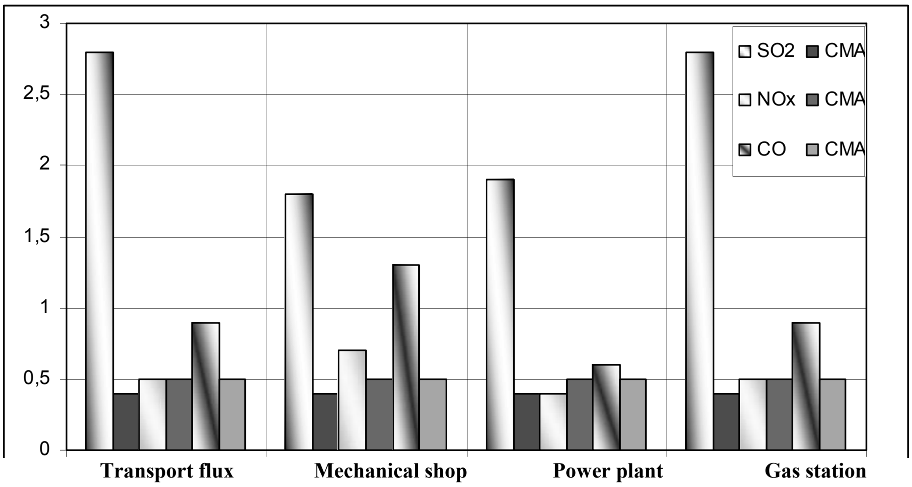


*Fig. 6*

2010 - EM URICANI *Table 7*

| Determined parameter | U.M. | CMA | Process | | | |
|---|---|---|---|---|---|---|
| | | | Transport flux | Inside transport | Mechanical shop | Power plant |
| $SO_2$ | μg/m$^3$ | 0,40 | 1,8 | 2,8 | 1,9 | 3,2 |
| $NO_x$ | μg/m$^3$ | 0,50 | 0,7 | 0,5 | 0,7 | 0,3 |
| CO | μg/m$^3$ | 0,50 | 1,3 | 0,9 | 0,5 | 0,4 |

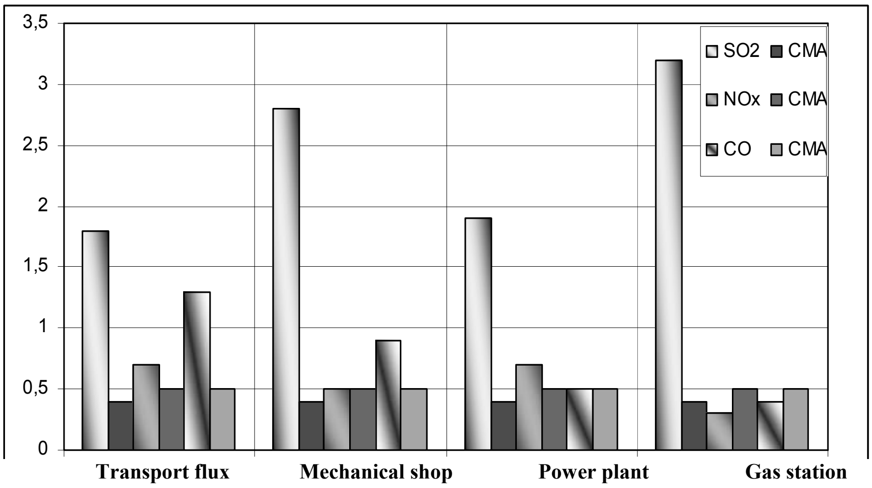


*Fig. 7*

2010 – EPCVJ *Table 8*

| Determined parameter | U.M. | CMA | Process | | | |
|---|---|---|---|---|---|---|
| | | | Transpoort flux | Inside transport | Mechanical shop | Power plant |
| $SO_2$ | µg/m[3] | 0,40 | 3,2 | 3,8 | 3,2 | 2,9 |
| $NO_x$ | µg/m[3] | 0,50 | 0,3 | 0,9 | 0,3 | 0,7 |
| CO | µg/m[3] | 0,50 | 0,4 | 0,9 | 0,4 | 0,7 |

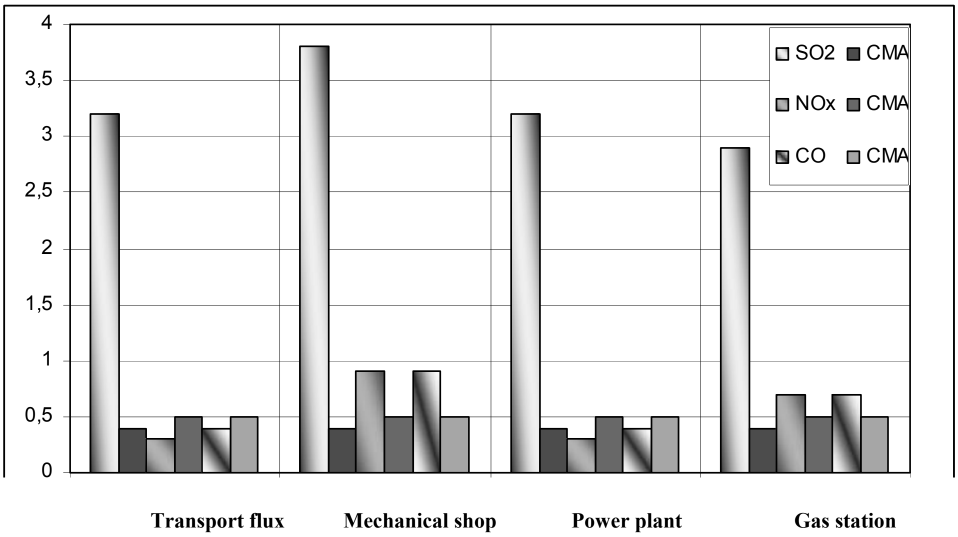


*Fig. 8*

There were measurements at a total of 13 ventilation units and there were discovered 6 types of gas, which, by their nature are either generated out of raw mining material as a result of displacement of rocks, either as a resul of other underground processes.

From the measurements given notice that all mining objectives are exceeded maximum permissible concentrations of SO2 values. All operations are conducted and concentrations exceed the maximum permitted NOx and CO.

The types of gas discovered at the exhaust parts of the ventilation units were:

**a) Carbon monoxide (CO) -** is a toxic odorless gas without taste or color. It's density is fairly the same as air's, therefore carbon monoxide is commonly found all around in nature. The carbon monoxide results mainly from the incomplete burn of fuel like oil, coal, gasoline or wood.

The carbon monoxide sources are:

- mobile sources: car/vehicles engines
- stationary sources: fuel burning installations and units, solid waste incinerators

The main causes for the presence of carbon monoxide within the mining shafts are:

- underground fires
- explosions of methane and coal dust
- operating with explosive substances
- operating different types of internal combustion engines

When inhaled, the carbon monoxide replaces oxygen in the blood stream and may affect vision, attention along with the mental and fizical capability. Also, inhalation of carbon monoxide may lead to more serious effects regarding the nervous system, cardiovascular or pulmonary elements. At a concentration of over 1 % it may provoke instant death.

According to the prevention guidelines 462/1993, there are no limit values for the carbon monoxide emission.

The carbon oxide resulted from the incomplete combustion of fuel, from industrial or exhaustion gas is particularly toxic because it blocks the hemoglobin-the oxygen carrier in the blood stream.

The carbon dioxide comes mostly from the combustion of fosile fuel. It's rising concentration in the atmosphere beyond normal values affects the ecological balance by increasing the greenhouse effect and climate changes..

**b) Sulfur dioxide ($SO_2$)**

The main sulfur dioxide pollution sources are stationary and mainly represented by installations that use oil or coal as fuel for a combustion process.

Underground, sulfur dioxide appears as a consequence of mine shafts fires, explosions, or controlled blasts. In coal mines appears along with methane leaks. It is deadly in a concentration of 0,05%.

**c) Nitrogen oxides ($NO_x$)**

Nitrogen oxides are equally produces by mobile and stationary sources. The main pollution source is the burning of coal, unrefined oil, gas, wood and domestic or industrial waste.

Underground, nitrogen oxides come from:

- reaction of large amounts of explosive substance;
- malfunction of Diesel engines.

Nitrogen oxides emissions affect the lungs, the heart and the respiratory system.

**d) Hydrogen sulfide ($H_2S$)**

The main causes of it's presence in the mines are:

- decomposing of organinc substances;
- deposits emissions;
- explosive processes.

Hydrogen sulfide as a result of coal process may lead to neurasthenic disease, involving asthenia, fatigue, headache, dizziness, anxiety, nervousness, daytime sleepiness.

**e) Hydrochloric acid (HCl)**

It's presence in the mine shafts is determined mainly by the presence of the salt (NaCl) in the deposit along with other sulfur compounds. When oxidized, these compounds form sulfuric acid which brings out the hydroclorhidric acid out of slat according to the reaction: $2NaCl + H_2SO_4 = 2HCl + Na_2SO_4$

**f) Methane gas ($CH_4$)**

Underground it goes along with coal deposits, also forming out of organic resides in the carbonization process.

Methane is one of the most dangerous and common gas in the mine shafts.

## 3. POLLUTION CAUSED BY PAROSENI POWER PLANT

As a result of coal burning, in the atmosphere is released a complex of organic and anorganic pollutants with a negative effect over the envoirment. In this situation the main pollution ellement is acid gas: $SO_2$; $NO_x$; CO; $CO_2$

Along with these, there are powders and volatile organic compounds (hydrocarbons- methane, aldehides and organic acides).

The concentration values of the polluting elements released by this power plant are shown in table 3.17.

The sulfur dioxide and the powders that come out of burning fuel are the main pollutants in the areas near power plants all over the world. Each is a part of a pollutant complex composed of $SO_2$, $H_2SO_4$ aerosol and $SO_2$ powders.

The last recommendation coming from the World Health Organisation regarding people's health protection rules are as follow:

*Table 9* Notes environmental factor air worthiness

| Liability note ($N_b$) | $SO_2$ | Frequency $F_i$ | $NO_x$ | Frequency $F_i$ | Suspendable powder | frequency $F_i$ |
|---|---|---|---|---|---|---|
| 10 | 0,0 - 0,2 | 1 | 0 - 0,009 | 1 | 0 - 0,023 | 1 |
| 9 | 0,2 - 0,35 | 2 | 0,009 - 0,1 | 3 | 0,23 - 0,1 | 0 |
| 8 | 0,35 - 0,5 | 1 | 0,1 - 0,2 | 3 | 0,1 – 0,2 | 4 |
| 7 | 0,5 - 0,6 | 1 | 0,2 -0,25 | 2 | 0,2 - 0,25 | 2 |
| 6 | 0,6 - 0,75 | 1 | 0,25 - 0,3 | 1 | 0,25 – 0,35 | 2 |
| 5 | 0,75 - 0,85 | 1 | 0,3 - 0,4 | 1 | 0,35 - 0,4 | 1 |
| 4 | 0,85 – 1,0 | 4 | 0,4 -0,45 | 1 | 0,4 - 0,45 | 2 |
| 3 | 1,0 - 1,7 | 2 | 0,45 - 0,5 | 0 | 0,45 - 0,5 | 0 |
| 2 | 1,7 - 1,85 | 1 | 0,5 - 0,6 | 0 | 0,5 - 0,65 | 1 |
| 1 | Peste 1,85 | 0 | Peste 0,6 | 0 | Peste 0,65 | 1 |
| **CMA** | | - | | - | | - |

- for 24 hours:
  - total acidity: 10 μg /m$^3$.
  - $SO_2$: 125 μg /m$^3$;
  - Suspended powders : 120 μg μg /m$^3$;
- For one year
  - $SO_2$: 50 μg /m$^3$;
  - Ash: 50 μg /m$^3$;

By comparison to these limit values the romanian standard stipulates for $SO_2$, as a singular pollutant a value of 750 μg /m$^3$ on short term (30 minutes) which is a larger number related to 500 μg /m$^3$ in 10 minutes.

Also, for the synergistically action of $SO_2$, with suspended powders the rule value is:

$$\frac{C_{SO_2}}{CMA_{SO_2}} + \frac{C_{praf}}{CMA_{praf}} \leq 1$$

where :

$C_{SO2}$ – sulfur dioxide concentration

$C_{praf}$ – dust/powder concentration

$CMA_{SO2}$ – sulfur dioxide maximum addminted value

$CMA_{praf}$ – powder/dust maximum addmited value

Considering the 24 hour values of the romanian standard (250 μg /m$^3$ $SO_2$ and 150 μg/m$^3$ dust/powder) we may conclude that by comparison with the World Health Organisation values there is less protection thus an underestimated risk.

Studies around the world show that powders resulting of burning coal contain a set of metal-like compounds with an highly toxic effect on peoples' health.

These powders also contaminate the other environmentall factors (water, vegetation, soil), finally affecting humans through drinkable water and food.

## 4. CONCLUSIONS

The processes and activities of coal exploitation in Valea Jiului have a local and temporarily effect and are most commonly related to:

- toxic gas and suspended solids pollution resulted from the underground eploitation and released through ventilating units, power plants, transportation flux, etc.
- Polluting emissions generated by working equipment and transport vehicles
- Volatile hydrocarbons resulting from handeling fuel
- Acoustic emissions, mobile or stationary produced by working equipment/instalations or transport vehicles
- Effects on vegetation by debilitare physiological and foliar necrosis device
- Training and acid rain impact on soil through acidification and destruction intensified their
- Intensifying greenhouse effect by emission of $CH_4$ in the atmosphere

Atmospheric pollution is present through the entire exploitation period, revealing a suspendable powder defilement, especially coal dust. During the dry period, with strong wind, solid dust particles are transported over great distances affecting communications and causing inconveniences for the population.

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# EVALUATION OF THE EXPOSURE TO EXTERNAL NATURALLY OCCURRING GAMMA-RADIATION IN PETROSANI, ROMANIA

**IONESCU CLEMENT[*]**
**SBIRNA LIANA SIMONA[**]**
**PROOROCU MARIAN[***]**
**MATEESCU MONICA[***]**
**MOLDOVAN CLEMENTINA[*]**
**SBIRNA SEBASTIAN[****]**

**Abstract:** *This paper aims to present the results of a study performed – by using gamma spectral analysis – on different soil samples collected from Petrosani – a Romanian city situated on the Jiu Valley, in a coal mining zone. The purpose of this research is to estimate the gamma dose rate in out-door air (at a height of 1 m above the ground), in order to compare the result thus obtained to the annual effective dose value which is recommended not to be exceeded for the population. By calculating the mean activity concentrations for the primordial decay chains (those of Uranium-238 and Thorium-232), as well as the mean activity concentration for the Potassium-40 radioisotope, one may evaluate the gamma dose rate received by the public in Petrosani, which is proved to be lower than the maximum admitted value, so the study leads to the conclusion that the inhabitants are not dangerously exposed to gamma radiation.*

**Key words:** *soil radioactivity, gamma spectroscopy, absorbed gamma dose rate*

[*] *Assoc. Prof. Ph.D. Eng. - University of Petrosani, 20 University Street, Petrosani, Romania, ionescu_c01@yahoo.com; c_moldovan01@yahoo.com*
[**] *University of Craiova, 107 I Cl. Bucuresti, Craiova, Romania, s.sbirna@gmail.com, monica.daniela.mateescu@gmail.com*
[***] *University of Agricultural Sciences and Veterinary Medicine, 3-5 Manastur Street, Cluj-Napoca, Romania, mproorocu@yahoo.com*
[****] *Craiova Regional Environment Protection Agency, 1 Petru Rares Street, Craiova, Romania, sebastian.sbirna@gmail.com*

## 1. INTRODUCTION

Investigating the soil radioactivity (as well as the soil radioactivity of other materials having similar composition to that of the earth crust) is essential to be performed, as it is known that acute full-body equivalent dose exceeding the maximum admitted value, which is 1 mSv/year (Al-Masri et al., 2006) might cause slight blood changes, syndrome of nausea, hair loss, hemorrhaging, *etc*. A dose of 5 Sv is considered to be approximately lethal for 50% of exposed population for an acute exposure to radiation, even under standard medical treatment, whereas a dose higher than 7.5 Sv, even with extraordinary treatment, such as bone-marrow transplants, will not prevent the death of the individual exposed (Selim et al., 2009).

Predominant part of the radioactivity of soil derives from the decay of the primordial radionuclide U-238, Th-232 and K-40 and the numerous decay products (also called "daughter products/nuclides") of the first two of them (which are therefore called "parents nuclides").

The artificial radionuclide Cs-137 is also present in the soil, as a result of nuclear weapons tests or nuclear accidents, but it generally does not significantly influence the absorbed dose rate (Selvasekarapandian et al., 2002).

The contribution of other nuclides to the activity of soil is negligible.

## 2. AREA DESCRIPTION

Petroşani is located in the Jiu Valley, which is the entrance to the Retezat National Park and provides access to the Vâlcan, Parâng and Retezat mountains. Being placed in one of the Hunedoara County depressions, Petrosani city lies on the lowest stage of relief in this region.

The territory of Petrosani, according to geo-technical divisions, is partitioned in four divisions:

The first division lies in the South of the city, on the old heap of barren rock leftover from the Mine of Petrila. The soil is composed by coal residue from the Petrila Preparation. The zone does not fit for construction.

The second division, the central area of Petrosani, located on the conference of the low terrace of the Jiu with the mountain slopes. The soil is composed of sandstone, rubble, and loam. The terrain is fit for building, but it asks for increased care with open excavations.

The third division lies in the upper meadow of Jiu in the Aeroport area. Silt deposits and loam and sand dust compose the soil. The terrain is fit for construction works and only foundations must be consolidated.

The fourth division, the Jiu Meadow, lies on West of the railway. The soil is composed of silt and gravel deposits and loam dust. The terrain is fit for construction, but the functional spaces below terrain level must receive special attention.

The main pollution sources are the coal residue heaps from the coal mines.

## 3. MATERIAL AND METHODS

For the soil sampling, a grid design (100 m x 100 m) was used as proposed by M. Carter and E. Gregorich (1998), in order to cover a surface of 12 ha, which exhibits an elevation of 10 m, situated in the central area of Petrosani, *i.e.* from the second division of the territory.

Twelve samples were collected in conformity with the recommendations of IAEA (Uchida and Tagami, 1999), as shown in Figure 1.

An FH 40 G digital survey meter for radiation monitoring was used in the sampling procedure.

By using a 12 cm diameter metal corer to the depth of 30 cm, a single core at each sampling site was taken and placed into a hermetic plastic bag.

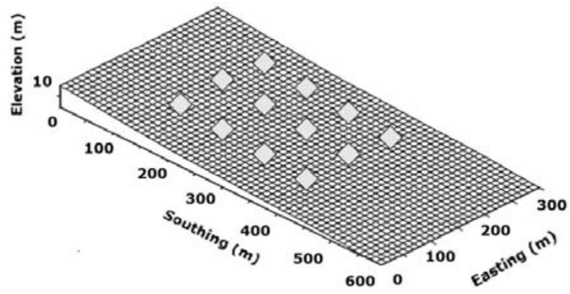


Figure 1. The grid design used for the soil sampling

In the laboratory, the samples were oven-dried at 105°C for 12-24 hours, mechanically powdered, sieved, weighed dry for the evaluation of the activity and stored in 250 ml containers, hermetically sealed, so that the overpressure produced inside would not result in the leakage of gas.

These samples were kept for a 40 days period, in order to ensure the secular equilibrium between the parent nuclides and their daughter products.

Then, all twelve samples were subjected to gamma-spectrometric analysis, performed on an HPGe Detector, Canberra Model BE 3820, using the associated software Genie 2000.

The system was calibrated both in energy response and counting efficiency, the IAEA recommendations (Misiak et al., 2011).

The density of the sample used for calibration was 1.3 g/cm$^3$, which was the same as the average of the soil samples analyzed (1.24 g/cm$^3$), with the counting time of 40,000 seconds for each sample.

### 4. RESULTS AND DISCUSSION

To estimate the activity concentrations of U-238 series, Th-232 series and K-40 natural isotope (as well as the one of the artificial isotope Cs-137) and, therefore, to evaluate the absorbed dose rate in air due to these radionuclide, the twelve samples were analyzed, Table 1 and Table 2 giving the results thus obtained.

Figure 2 presents the gamma spectrum for one of the samples.

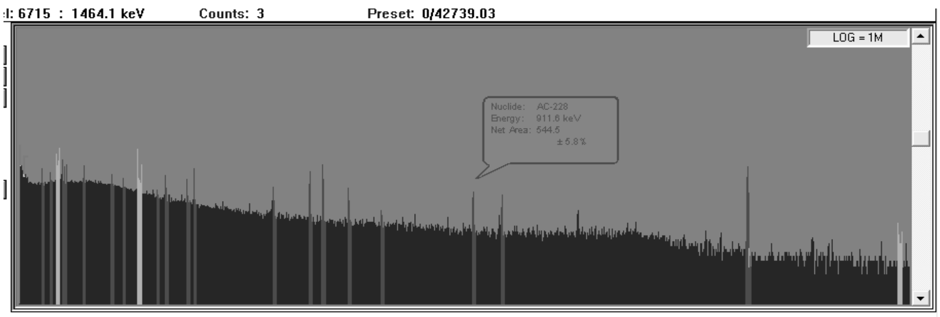


Figure 2. The gamma spectrum obtained for one of the twelve soil samples taken from Petrosani central area

**Table 1. The peaks observed in the spectrum: energy, area, region of interest (ROI) and the nuclides to which the peaks are attributable**

| Peak* | Energy (keV) | Peak area | ROI start-end | ROI centroid | Nuclide |
|---|---|---|---|---|---|
| F 1 | 47.23 | 754 | 210-217 | 214.00 | Pb-210 Th-232 |
| F 2 | 63.98 | 495 | 286-295 | 290.65 | Pb-212 Pb-212 |
| M 3 | 75.43 | 1993 | 338-358 | 343.39 | Pb-212 |
| m 4 | 77.68 | 2909 | 338-358 | 353.75 | Th-234 |
| F 5 | 87.73 | 946 | 394-404 | 399.83 | Ra-226 |
| F 6 | 90.44 | 520 | 407-417 | 412.28 | Pb-212 Pb-214 |
| F 7 | 93.50 | 868 | 421-431 | 426.30 | Pb-214 |
| F 8 | 129.61 | 271 | 586-597 | 592.19 | Pb-214 |
| F 9 | 186.38 | 685 | 845-858 | 852.41 | Bi-214 Cs-137 |
| F 10 | 209.46 | 284 | 953-965 | 959.08 | Bi-212 Ac-228 |
| M 11 | 238.90 | 3391 | 1086-1114 | 1093.49 | K-40 Bi-214 |
| m 12 | 241.88 | 779 | 1086-1114 | 1107.84 | |
| F 13 | 277.45 | 117 | 1266-1275 | 1270.31 | |
| F 14 | 295.42 | 881 | 1345-1360 | 1352.70 | |
| F 15 | 338.45 | 678 | 1543-1557 | 1550.06 | |
| F 16 | 352.00 | 1562 | 1605-1619 | 1612.38 | |
| F 17 | 510.91 | 987 | 2331-2351 | 2341.14 | |
| F 18 | 583.10 | 817 | 2661-2683 | 2672.70 | |
| F 19 | 609.21 | 1223 | 2782-2803 | 2792.46 | |
| F 20 | 661.58 | 612 | 3025-3042 | 3032.33 | |
| F 21 | 726.97 | 167 | 3325-3341 | 3333.14 | |
| F 22 | 910.95 | 544 | 4166-4187 | 4176.93 | |
| F 23 | 968.72 | 376 | 4434-4452 | 4442.09 | |
| F 24 | 1460.78 | 3313 | 6684-6715 | 6699.59 | |
| M 25 | 1764.24 | 203 | 8082-8108 | 8092.00 | |
| m 26 | 1765.56 | 145 | 8082-8108 | 8097.41 | |

*the peaks are numbered in order of increasing energy

**Table 2. The activities and activity uncertainties for all the observed peaks and the yields to be used in calculating the weighted activity for each nuclide**

| Nuclide | Nuclide ID confidence | Pk no | Energy (keV) | Yield (%) | Activity (Bq/kg) | Activity uncertainty (Bq/kg) |
|---|---|---|---|---|---|---|
| K-40 | 1.000 | 2420 121 - | 1460.75* | 10.67 | 3.47810E+002 | 2.18960E+001 |
| Cs-137 | 0.995 | 3 4 51119 | 661.66* | 85.21 | 6.40697E+000 | 4.28345E-001 |
| Pb-210 | 0.923 | - | 46.52* | 4.05 | 3.58156E+001 | 2.79142E+000 |
| Bi-212 | 0.777 | - | 727.18* | 6.65 | 2.32582E+001 | 4.28457E+000 |
| | | - | 1620.56 | 1.51 | | |
| Pb-212 | 0.971 | 25121416 9 | 74.81* | 10.50 | 3.35753E+001 | 2.22680E+000 |
| | | 22 2 7 - 9 | 77.11* | 17.60 | 3.02790E+001 | 1.90902E+000 |
| | | - | 87.30* | 7.90 | 2.28133E+001 | 1.98196E+000 |
| | | - | 238.63* | 43.60 | 2.35323E+001 | 2.10138E+000 |
| Bi-214 | 0.556 | | 609.31* | 44.80 | 1.56738E+001 | 1.07821E+000 |
| | | | 768.36 | 4.80 | | |
| | | | 1120.29 | 14.80 | | |
| | | | 1238.11 | 5.86 | | |
| | | | 1280.96 | 1.44 | | |
| | | | 1764.49* | 15.36 | 1.65241E+000 | 4.94911E+000 |
| Pb-214 | 0.997 | | 241.98* | 7.50 | 2.15496E+001 | 2.38475E+000 |
| | | | 295.21* | 18.50 | 1.67597E+001 | 1.73953E+000 |
| | | | 351.92* | 35.80 | 1.62521E+001 | 1.01378E+000 |
| Ra-226 | 0.988 | | 186.10* | 3.50 | 4.41687E+001 | 4.09386E+000 |
| Ac-228 | 0.998 | | 911.07* | 27.70 | 2.00237E+001 | 1.67647E+000 |
| Th-234 | 0.902 | | 63.29* | 4.50 | 2.18058E+001 | 4.85321E+000 |
| | | | 92.58* | 5.40 | 3.13953E+001 | 4.19629E+000 |
| U-235 | 0.580 | | 143.76 | 10.90 | | |
| | | | 163.33 | 5.00 | | |
| | | | 185.71* | 57.50 | 1.04200E+000 | 2.51528E-001 |

*peaks observed in the gamma spectrum

The method is a relative one: five and three daughter products were used, respectively, for the determination of U-238 and Th-232, to obtain accurate results, presented in Table 3.

Table 3. Weighted mean activities and weighted mean activity uncertainties

| Nuclide | Nuclide ID confidence | Weighted mean activity (Bq/kg) | Weighted mean activity uncertainty (Bq/kg) |
|---|---|---|---|
| K-40 | 1.000 | 3.478099E+002 | 2.189605E+001 |
| CS-137 | 0.995 | 6.406966E+000 | 4.283449E-001 |
| Pb-210 | 0.923 | 3.581559E+001 | 2.791416E+000 |
| BI-212 | 0.777 | 2.325823E+001 | 4.284573E+000 |
| PB-212 | 0.971 | 2.611474E+001 | 1.049107E+000 |
| BI-214 | 0.556 | 1.585128E+001 | 1.053614E+000 |
| PB-214 | 0.997 | 1.698643E+001 | 8.314550E-001 |
| RA-226♣ | 0.988 | 4.416871E+001 | 4.093859E+000 |
| Ac-228 | 0.998 | 2.002373E+001 | 1.676468E+000 |
| TH-234 | 0.902 | 2.708147E+001 | 1.179547E+000 |
| ? U-23 | 0.580 | 1.042002E+000 | 2.515284E-001 |

♣= nuclide is part of an undetermined solution

The activity concentration in the soil submitted to this study lie in the range 125.6 – 148.8 Bq/kg for the U-238 decay chain, 51.2 – 78.2 Bq/kg for the Th-232 decay chain and in the range 298 – 410 Bq/kg for K-40, with a mean of 142.9, 63.5 and 323.8 Bq/kg, respectively (for the presented sample the values are 139.9, 69.4 and 347.9 for U-238, Th-232 and K-40, respectively.

As far as U-235 is concerned, its situation is not quite obvious, since none of its daughter products appears in the gamma spectrum and the only peak that might be attributed to it is the one at 185.71 keV, which clearly interferes with the one emitted by Ra-226 at 186.1 keV. To separate the contribution of 235U and the one of 226Ra in the dual 185.71+186.1 keV peak, a sealed sample containing only 226Ra was prepared and the NPA (net peak area) ratios of the peaks 186.1/46.52, 186.1/609.31, 186.1/1764.49, 186.0/241.98,186.0/295.21 and 186.0/351.92 were determined. Then NPA of the 46.52, 609.31, 1764.49, 241.98, 295.21 and 351.92 keV peaks for the soil sample were measured and multiplied by turns with the corresponding one of the above ratios. These products all gave the probable value of the NPA 186.1 – contribution of 226Ra in the area of the complex peak for that sample (because the above NPA ratios do not strongly depend on the elemental composition of the sample). NPA 186.1 was computed as the weighted average of the four products and subtracted from the total peak area to obtain NPA 185.71 – contribution of 226Ra.

This procedure shows that the contribution of U-235 nuclide to the gamma spectrum is negligible comparatively to the one of Ra-226, so that it might be neglected in calculating the absorbed dose rate, as well as the man-made radionuclide Cs-137.

Consequently, for the absorbed dose rate, expressed in nGy/h, one should use the formula recommended by UNESCAR (Selvasekarapandian et al., 2002):

$D = 0.\ 427C_U + 0.662C_{Th} + 0.043C_K$

$C_U$, $C_{Th}$ and $C_K$ standing for the activity concentration of $^{238}U$ series, $^{232}Th$ series and $^{40}K$ in soil, respectively.

The dose rates obtained were in the range of 93.82 – 144.23 nGy/h, with a mean dose of 117.02 nGy/h (for the presented sample, the value is 120.63 nGy/h).

The effective dose rate outdoors, *E*, in units of mSv per year is calculated by the following formula: $E = DT\ F$

*D* being the calculated dose rate (in nGy/h), *T* is the number of exposure hours (in h/y) and *F* is the conversion factor (0.7 Sv/Gy).

Therefore, the value for the annual effective dose from external gamma radiation received by the inhabitants (obtained as an average for the twelve values) is 0.72 mSv/y, that is less than the value of 1 mSv/y, which is maximum allowed for the population (if only the presented sample would be taken into account, the value would be 0.74 mSv/y.

## 5. CONCLUSION

The study of soil radiation and the concentration activities of radionuclides in the environment of Petrosani – city situated in Central Romania, in Hunedoara County – have been carried out in order to establish reliable data on the background radiation level of the region.

Soil samples have been collected from Petrosani and analyzed regarding the radioactivity of primordial radionuclides, by gamma-ray spectrometry.

It is observed that the average activity of $^{238}U$ series, $^{232}Th$ series and $^{40}K$ isotope in soil samples is found to be 142.9, 63.5 and 323.8 Bq/kg, respectively, which contribute to a total gamma dose of 117.02 nGy/h, leading to an annual effective dose received by the population of 0.72 mSv/y, that does not represent any danger for the exposed public.

The method can be applied without correction for materials having similar elemental composition, such as most rocks and some building materials, and even for materials having different composition, using appropriate corrections.

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Prof. PhD. Eng. Aurora Stanci

# NOISE LEVELS ASSESSMENT ON ROMANIAN OIL DRILLING PLATFORMS IN THE BLACK SEA

**ROLAND MORARU***

**Abstract:** *The first Romanian drilling platform, Gloria, started his operation in 1975 in the Black Sea. Since then, the national legal and regulatory frameworks have dramatically changed, mostly after 2006 when the entire occupational health and safety legislation was harmonized with the European Directives. The need to comply with the new constraints concerning the noise control on the drilling and production platforms operated by the largest Romanian company in the field, required a systematic and coherent campaign of measurements, aimed primarily at noise levels assessment. Outlined in the paper, the data obtained by measurements have revealed that the highest number of noise sources which are exceeding maximum allowable limit are located on the Fixed Central Production Platform. The spectral analysis determinations are also highlighted, together with some of the technical and organizational measures for noise level reduction.*

**Key words:** *noise level, drilling platform, exposure, assessment, sonometer,*

## 1. INTRODUCTION

At 09 November 1975, the first Romanian drilling platform, which presently is a production platform, was launched in the Black Sea. In the years that followed, several other drilling platforms were built and launched, such as: Prometeus, Fortuna, Atlas, Jupiter and Saturn. Hundreds of drilling operations were done and in 07 Mai 1987 the marine oil field, which is presently operated by Petromar Constanţa, was intercepted.

It is well documented that it is not possible to separate the human from the technology factors [5]. The user needs to control the machine in order to make the process work and to minimise the negative occupational impacts on health and safety. As emphasized by recent work [1] in the field of occupational risk assessment and management in Romania there is plenty room for improvement. This is particularly true in the case of workers on the drilling platforms held by Romanian companies and one of the major concerns is the noise risk factor.

The need for noise level reduction, in the case of the workers on the Black Sea drilling platforms is required, first of all, from the inherent viewpoint of providing a safe and sound

* *Assoc. Prof. PhD. Eng. at the University of Petroşani*

environment, but also from the employers responsibility to provide adequate working conditions, with respect to the noise exposure, from the EU legislation point of view [2].

## 2. MEASUREMENT EQUIPMENT AND METHOD

The method applied for measurement and determination of the noise exposure level on the drilling platforms was the one established by the Romanian Standardization Association [9] in the national standard SR EN ISO 11202+AC: 1999, „*Noise emitted by machines and equipments – Acoustic pressure level measurement of the emission at the working place – In situ control method*". For noise level assessment, outside the working place (comfort conditions), it was employed the method given in the national standard STAS 6161 - „*Acoustics in constructions. Noise levels measurement in civil engineering. Control methods*" [8].

In the working environment, the daily exposure level of a worker is expressed in dB (A) and represents the average weight in time of the exposure levels, for the normal shift duration of 8 hours. This covers all the noise, including the noise having impulse character.

$$L_{E,z} = L_{Aech,T_e} + 10 \lg \frac{T_e}{T_0} \tag{1}$$

where:

$L_{Aech,T_e}$ represents the permanent equivalent acoustic level on the length of the working shift, $T_e$. It is defined as the acoustic level, in dB (a), of a constant noise which, acting continuously on the shift's length, induce a similar hearing effect as the variable noise effectively measured at the working place.

$T_e$ - the daily exposure time of employee , ($T_e$ can be higher or lower than 8 h);

$T_0$ = 8 h.

When the noise level changes during the working day, but it remains constant on certain time spans, the permanent equivalent noise level will be determined employing the relationship given bellow:

$$L_{ech,z} = 10 \lg \left[ \frac{1}{100} \sum f_i \cdot 10^{L_i/10} \right] \tag{2}$$

where: $L_i$ is the noise level on the time span $f_i$, ; $f_i$ is expressed as percentage of the working day duration.

In our case, the following portable apparatus were employed for the measurement and assessment of noise level exposure on the drilling platforms operating in the Black Sea:

- *sonometer 1/1- 1/3 octave Brüel&Kjaer type 2260 Investigator*, for noise level determination in the working environment and assessment of comfort conditions;
- *noise level dosimeters Brüel&Kjaer type 4442 and type 4445*, for noise level measurement in the working environment;
- *acoustic adjuster Brüel&Kjaer type 4231,* for apparatus calibration, before each measurement series.

## 3. RESULTS AND DISCUSSION

The noise level measurements were performed at the following working places and other locations on the drilling platforms:

- **Fixed Central Production Platform (FCPP):** Platform manager, Gas drying unit operator, Compressor machinist, Extraction operators stages I and II, Injection unit operators, Electrician dispatcher, Turbine engine mechanic, Maintenance electrician, AMC operators, Chief electric, Production dispatcher, Gas dispatcher, Automatist engineer, Radio station operator, Rest Cabins block C1-Social Group.

- **Utilities Social Group Platform (USGP3):**, Platform manager, Production engineer, Production foreman, Extraction operator, AMC operator, Electrician, Radio station operator, Social Group rest cabins.
- **Fixed Social Platform (PFS8 Gloria)**: Platform manager, Production engineer, Production foreman, Extraction operator, Injection operator, Machinist, Electric chief, Electrician, Mechanic chief, AMC operator, Corpsman, Resting rooms.
- **MIDIA oil terminal:** Chief of the shift**,** Gas reception – distribution operator, Module operator, Gasoline park operator, Operator 1 at the crude oil reception-supplying installation, Separators operator, AMC operator.

Kotus and Kostek [4] are proposing a new method of assessing noise-induced harmful effects on the human hearing system, based on determining the cumulative impact on hearing system produced by the excessive noise taking into consideration properties of the human hearing system. The utilization of the substitute sources system consisting of monopole sound sources is one of the methods of sound sources modelling in the industry. The knowledge of the actual acoustic pressure distribution around industrial sound sources is necessary for determination of the parameters of such models [7].

In our study, to obtain an objective and accurate analysis and interpretation of the measurement's results carried out regarding the noise levels on the Black Sea drilling platforms, certain observations were carried out

First of all, it was taken into consideration the specific character of the activities in this field of work and the kind of worker's exposure to noise, both workers exposed in the working environment and in outside it. The professional activity (working shift) on the sea platforms is in such a manner conceived, that every moment, any worker has to be aware of their own working task and the related specific hazard (fore, explosion, occupational risk factors, etc) [3].

Watchfulness is the overall signal word. The activities are conceived for a continuous monitoring and permanent control of machines and technical equipments, in order to prevent and/or mitigate any potential hazard.

The workers and any member of staff are in permanent contact with the technical dispatcher, which coordinates the entire production activity. Effectively, the production staff members is dispatched in such a manner that he is in continuous circulation, at various levels of the platform, during the 12 hours working shift. Consequently, with a view to their exposure at noise, the workers are submitted to this risk factor, both in production areas, with strong noise sources (such as, compressors, crude oil pumps, cooling pumping stations, separators, turbines, etc) and in less noisy areas (such as, energetic dispatching point, operator's cabins, rest rooms, etc).

From the point of view of noise exposure level, the activities carried out on the drilling platforms can be divided into three main categories, as it follows:

A. Monitoring, control and other activities, equipments in areas with noise levels comprised between 80 – 96 dB(A) (e.g. platform supervisor, mechanics, machinists, electricians, electro-mechanics, oil operators, gas operators, chemist operator, etc);
B. Monitoring and control activities, equipments in areas with noise levels comprised between *50-80 dB(A)* (e.g. dispatchers, administration staff, radio communication staff, etc);
C. Specific rest and recreational activities, after the working shift ending (e.g. rest cabins – noise levels comprised between 35 - 64 dB(A)).

In order to evaluate the daily noise exposure for the workers on these platforms, they were taken into account the measurement 's results, the specific activities performed in each particular working place and the exposure duration, both at work and after the shift comes to end. The following findings were emphasized:

- **Fixed Central Production Platform (FCPP):**
  - in every working place were measurements were performed, the daily noise exposure level exceeds the maximum allowable limit , with 3 – 6 dB(A);
  - noise levels in the "control rooms" located in the drilling platform's productive sections, Blocks A and B, levels 12.500 m, 18.500 m and 23.500 m, are exceeding the maximum allowable limits, according the Government Decision 601/2007 **(Leq in cabins > 75 dB(A))**.
- **Utility Social Group Platform USGP 3**
  - *TPD electrician* - the daily noise exposure level exceeds the maximum allowable limit , with **1 dB(A)**;
- **Utility Social Group Platform USGP 6**
  - *Platform manager* - the daily noise exposure level exceeds the maximum allowable limit , with **1 dB(A)**;
  - *Chief mechanic & AMC electro - mechanic* - the daily noise exposure level exceeds the maximum allowable limit , with **7 dB(A)**;
  - *Machinist* - the daily noise exposure level exceeds the maximum allowable limit , with **13 dB(A)**;
  - *Chief electric & electrician* - the daily noise exposure level exceeds with **5 dB(A)** the maximum allowable limit;
- **Fixed Social Platform GLORIA FSP 8**
  - *Platform manager* - the daily noise exposure level exceeds the maximum allowable limit , with **13 dB(A)**;
  - *Machinist* - the daily noise exposure level exceeds the maximum allowable limit , with **19 dB(A)**;
  - *Chief mechanic* - the daily noise exposure level exceeds the maximum allowable limit , with **14dB(A)**;
- **MIDIA OIL TERMINAL**
  - *Gas reception – distribution operator* - the daily noise exposure level exceeds with **10 dB(A)** the maximum allowable limit.

The results obtained through exposure evaluation allow the following interpretation:

i) Category *„A" – control and monitoring activities in the production installations ,* (gas drying operators, gas distribution, oil extraction, water injection – treatment) **– the daily noise exposure level do not exceed the maximum allowable limit.**

*ii)* Category „*B*" of workers, represented by *compressor machinists, AMC electro - mechanics, electricians, motor - operators,* namely the personnel providing the control, supervision, operation and maintenance in processing, transportation, treatment, compression, cooling, separation equipments - **the daily noise exposure level is exceeding the maximum allowable limit.**

## 4. SPECTRAL ANALYSIS FOR THE IDENTIFICATION OF SOURCES GENERATING UNACCEPTABLE NOISE LEVELS

The analysis and identification of harmful frequencies emitted by different noise sources on the drilling platforms have considered the hazardous range of frequency spectrum 20Hz – 20kHz and the recommended sound spectrum for the human ear. The limit recommended spectrum (noise curve – Cz) analyzed in wave band of 1/3 octave is mentioned in Romanian standards [8], [9] and the spectral analysis determinations on the drilling platforms took in consideration these limit values Cz.

For these measurements [6], the *Brüel&Kjaer type 2260 Investigator Sonometer* was employed, mounted with a filter set of 1/1-1/3 octave [10]. Spectral analysis determinations were performed at 23 existing sources, such as: high pressure compressor – exaust; low pressure compressor – engine; Buster pump – electromotor; Shulzer pump – exhaust; FTA oil transfer pump – electromotor; Diesel generator group; Caterpillar generator; mud pump; crude oil pump etc. As examples, in figures 1 and 2, respectively in tables 1 and 2 there are presented the results obtained and the curves plotted for two representative working places.

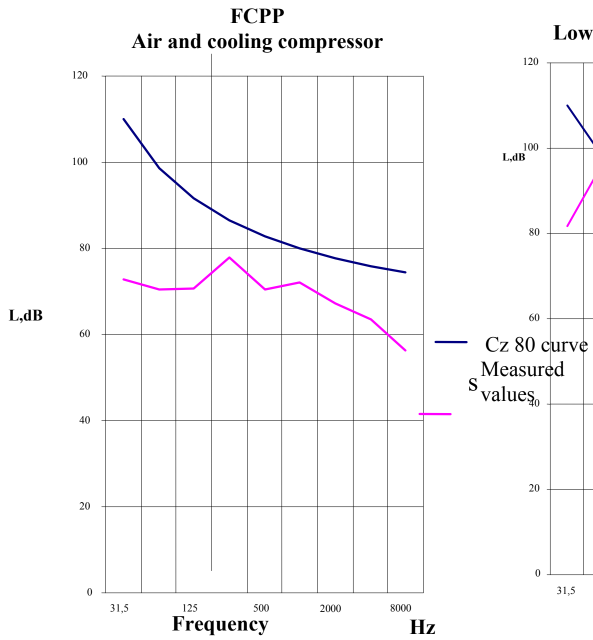


**Fig. 1. FCPP: Air and cooling compressor**

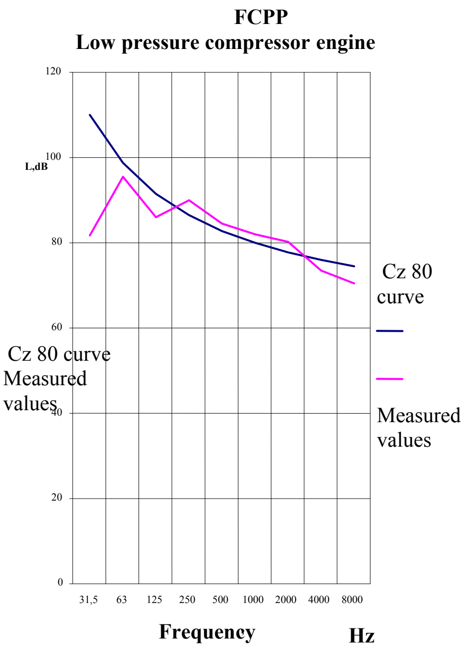


**Fig 2. FCPP: Low pressure compressor–engine**

**Table 1. Measurement results for the PFCP cold and air compressor**

| Frequency Hz | 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | $L_A$ = 75 dB(A) |
|---|---|---|---|---|---|---|---|---|---|
| Measured values | 72.8 | 70.5 | 70.6 | 77.8 | 70.4 | 72 | 67.2 | 63.5 | |

**Table 2. Measurement results for the PFCP low-pressure compressor - engine**

| Frequency Hz | 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | $L_A$ = 92 dB(A) |
|---|---|---|---|---|---|---|---|---|---|
| Measured values | 81.7 | 95.5 | 85.9 | 90.1 | 84.5 | 81.9 | 80.2 | 73.5 | |

In the results interpretation for the spectral analysis determination it was considered each measurement performed for each source on the drilling platform. Analyzing the results obtained through the measurements in 1/3 octave wave band, at production equipments level the following findings were emphasized:

- **Fixed Central Production Platform (FCPP)**

The noise sources generating Cz 80 noise curve exceeding are those located in the following locations: gas drying – compressing equipments (high and low pressure compressors), water injection – treatment installation (Sulzer pump and Buster pump) and stage II extraction equipment (FTA and DTA crude oil pumps). The existence of the refuge cabins, in the area of production equipments with high noise levels, determines the exceeding of the noise level inside these buildings, over the maximum allowable limit (Leq = 76 - 87).

Also, the operation of high level noise sources, such as the compressors, are affecting the comfort conditions inside the rest cabins (Leq = 40 - 46).

- **Utility Social Group Platform (USGP 6, USGP 7)**

The main noise generating sources, above the Cz 80 noise limit curve, affecting also the worker's exposure limits, are those located at the platform's lowest level 12.500 m, inside the Social and Utility Groups, namely the Donkey boilers and the Diesel generator groups. A major aspect is related to the absence of a sound – insulating cabin on these two platforms, which should protect against the extremely high noise level supported by the machinist (Leq>100 dB(A)).

## 5. CONCLUSIONS

Regarding the noise exposure in the work place, there were investigated and evaluated the activities which are assuming supervision and hourly monitoring (patrol activity), areas with fixed locations and rooms, requiring a special psycho – sensory concentration (dispatching points, command centers, AMC workshops, radio stations, etc) and command, intervention and maintenance activities, all of these carried out in areas with operating equipments.

The noise level measurements emphasized that the production platforms were the allowable limits are exceeded are FCPP, USGP 6, USGP 7, USGP 8, FSP GLORIA and Midia Oil Terminal.

The highest noise level and highest number of noise sources is the Fixed Central Production Platform (FGPP), considered the most important one. In fact, the entire oil and gas production is concentrated here, wherefrom the processed raw material is circulated, through the piping system, on shore to Midia Oil Terminal.

The spectral analysis determinations have also highlighted that, for all the five production platforms where the Cz 80 noise curve is exceeded, the determined curves are comprising the entire noise spectrum, both the low frequency one, and those of mean and high frequencies. Several noise level reduction measures were already implemented, with good results, as it concern the noise level exposure of workers on the production platforms in the Black Sea.

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Scientific Reviewers:
Prof. PhD. Eng. Romulus Sarbu

# SUBSTANTIATION CRITERIA FEASIBILITY OF SOLID HOUSEHOLD WASTE MANAGEMENT ALTERNATIVES

**STOICA (RĂDEANU) MIHAELA***

**Abstract:** *Studies performed during the second half of the twentieth century on the relations between the patterns and growth rates of socio-economic development, the speed, shape and extent of deterioration phenomena of natural capital in developing and developed countries have shown that socio-economic development has always been accompanied by environmental damage. Analysis of these reports has stressed the need to develop strategies and action programs to reduce long-term socio-economic impact and to adapt these systems to the changes that occur in the structure, quality and functionality of natural capital components.*

**Key words:** *natural capital, waste, management, alternatives, evaluation criteria, recycling, recovery, sustainable development*

## 1. INTRODUCTION

Waste management implies the management and systematic monitoring of precollection activities, the selection and the actual collection, transport, treatment, recovery, disposal and storage of waste. The following waste management elements are particularly important:

- establishing responsibilities for each specific waste management activity;
- creating and implementing an appropriate institutional and organizational framework;
- development and implementation of an efficient financial system.

The general objectives of waste management are, priority wise, the following:

- source reduction of generated waste quantities and of their level of harmfulness;
- selective collection of waste in order to recycle and recover the maximum possible quantity, both technically and economically;
- implementing diverse and specific waste treatment technologies that are, if possible, complementary;
- the use of appropriate landfills in order to ensure a minimum impact on the environment and on the population's health.

The means of achieving waste management objectives can be grouped into:

*Legal*

- rules, regulations,- local, national and international instructions, national and international standards;
- administrative devices and structures - (institutions, services)

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* *student PhD. Biologyst, Biology Faculty, Universiy of Bucuresti*

*Organizational tools*

- organizing (setting) waste management;
- providing the appropriate machinery, equipment and facilities for each waste management activity

*Financial resources received from*

- central and local authorities;
- waste generators;
- economic agents and institutions, in order to cover their own waste production.

The local authorities' choices in selecting the optimal integrated management system can be influenced by several technical, financial or political constraints.

However, the main features of an integrated management system are:

- setting policies;
- planning and evaluation activities performed by those who design the system, by users and by all the other parties involved;
- using studies in order to categorize waste and adjust the system for each type of waste that is generated;
- separation, collection, recovery of energy and materials and landfilling;
- establishing training programs for those working in the system;
- public information programs and eco-civic education;
- identification of financial mechanisms, costs and benefits;
- setting prices for services and creating economic incentives;
- proper management of public administration and operational units;
- incorporating private sector businesses, including the collectors, producers and entrepreneurs.

The main advantages of an integrated management system are:

- some problems can be solved more easily when they are connected with other aspects of the system than separately;
- integration allows resources to be used according to requirements;
- it allows participants from the public and private sectors to act from an appropriate position;
- some management practices are more costly than others, but integration provides the identification and selection of the least expensive solutions; some activities in waste management involve higher costs than benefits, others bring more revenue and therefore, the system works through compensation.

Studies on integrated waste management for cities, counties and regions have a key role in developing a sustainable waste management. Their main purpose is to identify waste streams and offer alternatives for their management. Furthermore, studies on integrated waste management must analyze and present the planning frame for the following:

*Compliance with waste policy and target fulfillment*: studies on integrated waste management are important instruments that contribute to the implementation of policies and targets set for waste management.

*Establishing sufficient and characteristic capacities for waste management*: studies on integrated waste management must provide information on waste streams and quantities that are to be collected, treated, recovered and / or removed. Moreover, it should contribute to providing alternatives for waste collection, treatment, recovery and / or disposal according to each type of waste.

*Technology control*: delineating waste streams ensures the identification of areas where technological measures are needed in order to eliminate or minimize certain types of waste.

*Describing economic and investment requirements*: studies on integrated waste management are a good starting point for determining the financial requirements to operate waste collection, recycling, treatment and disposal schemes.

On this basis, investments in waste recycling, treatment and disposal facilities can be determined.

The growing complexity of waste management issues and standards leads to increased requirements for recycling, treatment and / or disposal facilities. In many cases, this includes larger and more complex recycling, treatment and / or disposal facilities, implying the cooperation of several regional units for setting up and operating them.

The development of integrated waste management systems will have a beneficial impact on the socio-economic situation of the population, both locally and regionally, by:

• extending the waste collection area, thus contributing to raising living standards and the quality of life, especially in rural areas;

• increasing the volume of collected waste and diversifying the sanitation services, new jobs will appear, some in new areas, some of which require higher education degrees (compost producing facilities, for instance ), making career retraining possible;

• increasing the level of collaboration between the population and the service providers, thus leading to a continuous improvement of sanitation services;

• In general, by creating an appropriate infrastructure for integrated waste management, an appropriate level of environmental protection and human health will be ensured;

• monitoring improper closed landfills and rehabilitating the land affected by uncontrolled waste storage lead to health and environment related risk mitigation;

• contributing to the improvement of public hygiene and to the landscape exploitation, with direct impact on land and building values;

• increasing product value by using fewer resources ("productivity" increase);

• reducing the negative environmental impact per unit of used resource ("ecoefficiency" increase)

The extension of the selective collection of waste will lead to the following changes in the population’s social behavior:

• selective collection of household waste, household habits will change;

• urban and rural landscapes will be affected by the emergence of individual containers, and even more so by that of community recycling bins, colored differently according to a color code;

• vegetable waste composting will eventually change the way biodegradable waste is perceived, its status thus switching from not easily manageable waste to economically valuable raw material;

• good practices will cause changes in perception within the population, raising awareness on the problems caused by the metabolism of the socio-economic system.

In order to take an appropriate decision on waste management in a given region, the following steps must be taken into account:

**1.** Setting goals and targets.

**2.** Identifying alternatives for achieving the targets.

**3.** Establishing criteria for evaluating the alternatives.

**4.** Selecting the feasible alternatives for the region.

**5.** Evaluating the results and selecting the optimal alternative

## 2. PRINCIPLES OF THE ALTERNATIVE SELECTION PROCESS

According to the EU strategy, the waste management system hierarchy is based on minimization - reuse - recycling and, in the second phase, on disposal.

The initial hierarchy principle of waste management systems encourages option enforcement in the following prioritization order:

- Option 1 - prevention and minimization close to the source, as much as possible;
- Option 2 - where option 1 is not applicable, the waste must be reused directly or with little effort to alter the "quantity";
- Option 3 - waste materials should be recycled or reprocessed into a form that changes them into secondary sources of "raw materials";
- Option 4 – when recycling is not possible, the energy embedded in the waste should be recovered and used as "alternative energy", thus replacing the "nonrenewable energy" obtained from fossil fuels;
- Option 5 - when waste cannot be processed according to the options presented above, they must be eliminated by being stored in proper landfills.

Recently, a shift from 4 to 6 options took place, as shown below, in Figure no. 1.

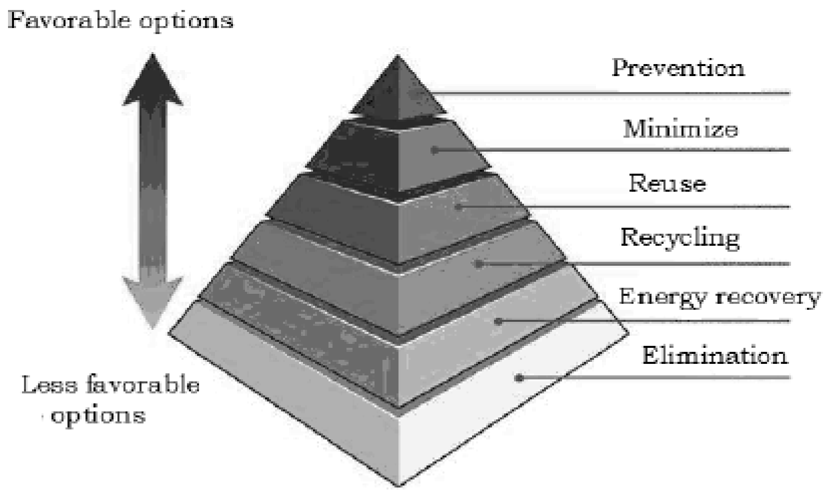


**Fig. 1 - The hierarchy concept of waste management systems**

The instruments defining an alternative to waste management have been identified as being divided into "technical tools" and "economic instruments". Technical tools are the specific technologies used for collecting, processing and disposal of the various types of waste that are generated. In the years to come, techniques and technologies for integrated waste management will undoubtedly have to be introduced in Romania, and implicitly, in the study area,. As the required know-how and experience to integrate these technologies locally and nationally have yet to be attained, a first stage of pilot stations must be implemented, in order to identify the optimal waste management methods. The pilot stations will be used to obtain real economic and technical parameters and operating experience, as well as to inform the population and get its consent.

The creation and implementation of an integrated waste management system must be supported by both economic and legal instruments integrated with other sectoral policies. Funding is made according to the laws in force, from the following sources:

- Environment Investment Fund, which will complete the subsidies from the state budget
- local budgets
- Public-Private Partnership
- Structural Funds
- banks / financiers of repayable loans
- private investors
- The National Research and Development Plan through National Programs (which private companies can access, particularly SMEs)
- Other specific research and development programs.

Waste management alternatives include a descending priority listing:

• prevention - through the use of "clean technologies" in waste generating activities;
• reducing quantities - by applying the best practices for each type of waste generating activity;
• recovery - through reuse, material recycling and energy recovery;
• disposal - incineration and storage.

Waste recovery has the following subsidiary objectives:

• developing the market for secondary raw materials and supporting the promotion of recycled product use;
• dephasing waste generation from economic growth and achieving an overall reduction of waste volume;
• promoting material recovery within the technical and economic limitations ensuring the population's good health and the environment's well being;
• promoting energy recovery in energy efficient facilities where material recovery is not feasible technically and economically the energy benefit resulting from incineration is positive and where the possibility of using the generated energy efficiently exists.

Waste composition and quantity vary depending on the development level of a country. Thus, it can be said that the economic and cultural development of a geographic area can also be quantified based on how the community manages to solve its waste problem.

The necessary steps to identify and assess alternatives for solid waste management are performed using the following working tools:

1. List of goals;
2. List of identified alternatives;
3. Multicriteria analysis;
4. Alternative ranking list;

The list of goals is a form that includes, in an easily identifiable and compressed way, the main objectives of the waste management derived from the local, regional and national environmental policies.

**Examples of objectives:**

1. solid waste recovery
2. Implementing selective waste collection systems
3. Reducing quantities of stored biodegradable waste
4. Reducing quantities of stored packaging waste, through recovery

*List of alternative identification* is a helpful tool in applying multi-criteria analysis. It includes information on technical and economic possibilities, as well as on the recovery potential of each area that is being considered for waste management alternative enforcing.

Four principles of alternative selection have been established:

- *availability and applicability of technology* - in order to define the alternative technology, it is necessary that the proposed technology be validated, approved and tested, and that it be available and applicable for the identified objective;

- *social-involvement and acceptance* - any waste management system and particularly the one linked to municipal solid waste (the largest share in the production of this type of waste is represented by individuals) must accept and wish that the alternative management be enforced. The current legal framework for implementation of these projects needs public consultation and agreement;

- *socio-economic development of-the area –industry and economic* development , the evolution of the population's income, changes in unemployment rates, changes in GDP, infrastructure development (coverage of transport infrastructure, road, rail, etc.);

- *specific factors of waste- management* - coverage of sanitation services, waste quantities and composition in the study area (kg /inhabitant / year).

**Table no. 1. Alternative example according to objective 2**

| Objective | Necessary investment | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|---|
| Implementation of separate waste collection systems | Collection equipment | Pre-sorting in community locations only | Individual pre-sorting only, on three streams | Individual pre-sorting on two streams, community pre-sorting on three streams and the setting up of special collection lines for paper and polyethylene |

**3. ALTERNATIVE EVALUATION CRITERIA**

**3.1 Evaluation criteria selection**

The multicriteria analysis is a grading scale of the identified alternatives, based on the agreed upon criteria. The evaluation criteria selection was done in order to meet the process's priorities.

Three main categories of criteria for assessing alternatives (table. 2) have been established:

- environmental benefits – this - criterion is important because of the need to recover, protect and preserve nature and biodiversity. A rich, healthy natural environment, as well as well-protected natural resources is vital for sustaining life in general and also for ensuring sustainable development. Other important issues are the need for the present and future compliance with legal obligations and integrating environmental criteria into the overall economic development project selection system.

- social benefits – this- criterion is relevant because any danger to human life, be it real or potential, is unacceptable. Public health must be protected. Improving living conditions, risk and discomfort reduction must have a high priority;

- Economic benefits – this- criterion is useful because it must provide associated benefits in addressing the problem. The highest priorities are assigned to the problems whose solutions involve small costs and great benefits.

These main categories of criteria were associated with three sub-criteria, and a weight (Table no. 5)

The selection of these criteria was based on the Delphi method, with the help of certified experts.

The economy depends on the natural capital's structure and functions. The way resources are used and the consumption speed are endangering the natural capital's carrying capacity. It is estimated that over the past 50 years, ecosystems have changed due to anthropogenic causes more than ever in history, mainly because of the growing demand for food, water, wood and fuel.

Thus, proper management of secondary products of the socio-economic system's metabolism supports prosperity, solidarity and security improvement within communities, a better quality of life for current and future generations.

**Table no. 2. Alternative evaluation criteria and sub-criteria**

| | |
|---|---|
| **40%** | **Environmental benefits** |
| | *Sub-criteria* |
| 1 | Environmental impact |
| 2 | Legal framework |
| 3 | Contribution to achieving waste management objectives |
| **20%** | **Social benefits** |
| | *Sub-criteria* |
| 1 | Contribution to lengthening life expectancy |
| 2 | Creating new jobs |
| 3 | Social acceptance |
| **40%** | **Economic benefits** |
| | *Sub-criteria* |
| 1 | Technology availability |
| 2 | Maximum efficiency enforcement potential upon system initiation |
| 3 | Additional business stimulation and the ability to interconnect with the other technologies operating in the area |

Waste generation and disposal cause the loss of natural resources and reduce the natural capital's ability to cope with the impact associated to the effects of waste disposal and raw material extraction and processing, as well as those associated to the manufacturing and distribution of new products.

Actual costs associated to raw material extraction are higher than what is paid for waste recovery treatment as, in most cases, the raw material is not an easily renewable resource. Such inefficient use of resources produces indirect economic and business related losses.

For a large number of waste treatment projects, it is necessary, according to regulations, to perform an environmental impact assessment (EIA), especially in the case of waste dumps, hazardous waste disposal facilities or certain types of waste treatment facilities, such as authorized landfills. In addition, numerous facilities, such as landfills and incinerators, require authorization for carrying out their activities; these authorizations (or permits) set risk and hazardous substances management and pollution control consitions.

The main elements of an environmental impact analysis are:

- emissions in the atmosphere, particularly greenhouse gas emissions (significant impact for incineration);
- sewage spills and soil contamination (significant impact for incineration and storage);

- impact on biodiversity (significant impact of large projects built near protected areas);
- impact on human health linked to air pollution and environmental contamination (significant for any waste treatment facility);
- noise and odor (significant impact for many treatment facilities);
- impact on landscape aesthetics (significant for incineration and storage);
- site fire and explosion risk management (significant for some special treatment facilities such as waste oil treatment facilities and incineration).

In urban areas, inconveniences can be recorded during the construction phase of the plant while the perturbations noticed during the operation phase, in addition to the previously mentioned ones, are mostly linked to the waste collection phase.

A qualitative approach to environmental impact can always be used in order to categorize types of potential environmental impacts in accordance with the type of damage they could produce or with their levels of hazardousness. For example, the major impact of a landfill could be soil and water contamination, while for incineration, the impact on air quality is much more significant.

Critical factors influencing the success of an investment in this sector are quite numerous, and include investment costs, dynamic costs of key inputs (energy, raw materials), the price of recovered products, repair costs or other environment related costs.

For each objective following alternative, grades (from 1 to 4) are given for each criterion, and then the alternatives' scores are computed.

The performance levels are the following:
a) Exceeds requirements 4 points
b) Meets requirements 3 points
c) Reasonably meets requirements 2 points
d) Meets minimum requirements 1 points
e) Does not meet requirements 0 points

Feasibility criteria can be assessed following these aspects:

*1. application conditions: legal and institutional support, , technical and material ground, human resources;*

*2. possibility of criteria monitoring and measurement.*

If a criterion does not meet one of the two aforementioned issues, they are considered to be not applicable.

**Table no. 3. Alternative evaluation criteria and subcriteria feasibility**

| Criteria | | Criteria Feasibility Analysis | |
|---|---|---|---|
| | | **The existence application conditions** | **Possibility of criteria monitoring and measurement** |
| **40%** | **Environmental benefits** | | |
| *Sub-criteria* | | | |
| 1 | Environmental impact | Decision 445/2009 on impact assessment of certain public and private projects on the environment | Performing impact studies is legally regulated and can be monitored and measured |
| 2 | Legal framework | Legal framework is defined | It can be monitored and |

| | | | |
|---|---|---|---|
| | | for each type of waste | measured |
| 3 | Contribution to following waste management objectives | Feasibility studies can determine an alternative's contribution to achieving objectives. | It can be monitored and measured |
| **20%** | **Social benefits** | | |
| *Sub-criteria* | | | |
| 1 | Contribution to lengthening life expectancy | This subcriterion has application conditions | It can be monitored and measured |
| 2 | Creating new jobs | This subcriterion has application conditions | It can be monitored and measured |
| 3 | Social acceptance | This subcriterion has application conditions | It can be monitored and measured |
| **40%** | **Economic benefits** | | |
| *Sub-criteria* | | | |
| 1 | Technology availability | This subcriterion has application conditions | It can be monitored and measured |
| 2 | Maximum efficiency enforcement potential upon system initiation | This subcriterion has application conditions | It can be monitored and measured |
| 3 | Additional business stimulation and the ability to interconnect with the other technologies operating in the area | This subcriterion has application conditions | It can be monitored and measured |

**Table no. 4. Example of multicriteria analysis – objective 2**

| **OBJECTIVE 2. Implementation of selective waste collection** | | **Investment objective: Collection equipment** | | |
|---|---|---|---|---|
| MULTICRITERIA ANALYSIS **Criteria/alternatives** | | **ALTERNATIVES** | | |
| | | **Alternative 1** | **Alternative 2** | **Alternative 3** |
| | | Pre-sorting in community locations only | Individual pre-sorting only, on three streams | Individual pre-sorting on two streams, community pre-sorting on three streams and the setting up of special collection lines for paper and polyethylene |
| Weight: 40% | Environmental benefits | Points | Points | Points |
| Sub-criteria | | | | |
| Environmental impact | | 3 | 3 | 3 |
| Legal framework | | 3 | 3 | 3 |
| Contribution to achieving waste management objectives | | 1 | 2 | 3 |
| Amount 1 | | 7 | 8 | 9 |

| **OBJECTIVE 2. Implementation of selective waste collection** | | **Investment objective: Collection equipment** | | |
|---|---|---|---|---|
| MULTICRITERIA ANALYSIS **Criteria/alternatives** | | **ALTERNATIVES** | | |
| | | **Alternative 1** | **Alternative 2** | **Alternative 3** |
| | | Pre-sorting in community locations only | Individual pre-sorting only, on three streams | Individual pre-sorting on two streams, community pre-sorting on three streams and the setting up of special collection lines for paper and polyethylene |
| Amount 1 x weight | | 2,8 | 3,2 | 3,6 |
| 20% | Social benefits | | | |
| Sub-criteria | | | | |
| Contribution to lengthening life expectancy | | 1 | 2 | 2 |
| Creating new jobs | | 0 | 2 | 3 |
| Social acceptance | | 3 | 2 | 2 |
| Amount 2 | | 4 | 6 | 7 |
| Amount 2 x weight | | 0,8 | 1,2 | 1,4 |
| 40% | Economic benefits | | | |
| Sub-criteria | | | | |
| Technology availability | | 4 | 4 | 4 |
| Maximum efficiency enforcement potential upon system initiation | | 4 | 3 | 3 |
| Additional business stimulation and the ability to interconnect with the other technologies operating in the area | | 2 | 3 | 3 |
| Amount 3 | | 10 | 10 | 10 |
| Amount 3 x weight | | 4 | 4 | 4 |
| **TOTAL AMOUNT** | | **7,6** | **8,4** | **9** |

**Table no. 5. Score interpretation is to be made as follows:**

| **Score** | **Evaluation - assessment** | **Decision** |
|---|---|---|
| *1 to 3 points* | ***VERY POOR*** | *The alternative cannot be taken into account* |
| *between 4 and 6 points* | ***POOR*** | *The alternative is not reliable* |
| *between 7 and 9 points* | ***NORMAL –WELL*** | *The alternative may be implemented after a feasibility study* |
| *more than 10 points* | ***VERY WELL*** | *The alternative is feasible* |

*The ranking list of the evaluated alternatives* is a document that includes the possible alternatives, ordered descendingly starting with the most reliable alternative (one that meets the highest score) to the least recommended alternative (the one with the lowest score).

**4. CONCLUSIONS**

The growing complexity of issues and standards in waste management leads to increased demands on recycling, treatment and / or disposal facilities. In many cases, this includes larger and more complex recycling, treatment and / or disposal facilities, thus requiring the cooperation between several regional units in order to set up and operate these facilities.

In the light of the new developments and directions in waste management objectives, new technologies should be taken into account. These technological options, that would lead to achieving objectives and targets, must be considered according to national and regional characteristics and should not be too complex, in order to facilitate implementation.

The following are necessary in order to achieve the strategy's objectives:

- regulatory instruments, economic instruments, statistical tools and other instruments.

For national and European waste management objectives it is necessary to involve the entire society, which is represented by: central government and local authorities, waste generators, professional associations and research institutes, civil society.

Based on the objectives and targets associated to the situation in the study area (especially in terms of existing possibilities and capabilities and of their development potential) alternatives must be found.

The aim of the new management system (integrated management) is "indefinitely preserving viability and efficient operation of dynamic socio-ecological systems or of sustainable co-development conditions.".

It is important to remember that sustainable development can only be brought into discussion when the mutual adaptation conditions of the development cycles of natural capital and socio-economic development are provided.

Conventional management practices, mainly sectoral and reductionist, provide a wide range of mechanisms that are applicable to holistic management. Development problems associated to the holistic approach are no longer restricted to the economic and social development, as this approach targets spatial and temporal relations, material, energy and information exchanges, information within and between socio ecological systems of a country, macro- region or at a global scale.

Basically, integrated waste management must be designed within the sustainable development limits of any socio-ecological system:

- maintaining structural and ¬ functional diversity of natural capital components;
- restricting gas, liquid or solid ¬ emissions of socio-economic system waste, based on the carrying capacity of natural capital components;
- ethical and moral norms on ¬ accessing and using resources and services produced by natural capital components in order to achieve the desired standard of living.

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Prof. PhD. Eng. Romulus Sarbu

# THE IMPACT UPON AIR OF POLLUTANTS FROM ROSIA COAL DEPOSIT

**TĂTAR ADINA MILENA*** 
**PĂSCULESCU DRAGOŞ**** 
**VAJAI GHEORGHE*****

**Abstract:** *This paper presents the activity realized as part of Rosia quarry, as main atmospheric pollution source, being identified all atmospheric emissions on the site. Determinations have been realized at dusts in suspension, depositing dusts, comparing them with limit admitted values. It can be realized a statistic regarding chronic, obstructive, lung illnesses from the Rovinari Hospital.*

**Key words:** *atmospheric emissions, processes, quarrying, mining, pollutants.*

## 1. GENERAL ASPECTS

Mining has a great influence on the environment, which can exceed, most of time, the one of the industrial branches, and in all mining processes, starting with extraction and continuing with preparation, metallurgy and thermal-energetic sector. The range of this influence is very large, containing positive influences, as the ones connected to the economic development of mining areas and the ones connected to the social and urban development, but also negative influences connected to the modification of the environment, with basic implication in ecosystems regarding agriculture and silviculture, hydrography, communication means, deallocated human sites, quality of inhabitant's life, as well as the fauna and flora from exploitation perimeters and from those limitrophe to these.

Rosia de Jiu quarry is part of Rovinari coal basin, being situated in the area of Farcasesti village, in the proximity of town Rovinari, at a distance of about 30 km south of Tg-Jiu municipality, residence of Gorj County.

The perimeter of the quarry being delimited this way:

-at north, a conventional line passing through localities Boncea, Prundurei, Moi;

- at East, a conventional line connecting localities Moi and Brostenita;

* *Ph.D. Student, Eng., "Traian Vuia" Scholar Group Tg. Jiu, Romania*
** *Lecturer, PhD., Eng., University of Petrosani, Romania*
*** *Ph.D. Student, Eng, SC Gavella Com SRL, Oradea, Romania*

- at South, a conventional line starting from Brostenita, passes North from Bohorelu and Matasari up to Timiseni;
- at West, a conventional line binding localities Timişeni and Rosia de Jiu.

The perimeter has two areas, namely:

- meadow area – situated on the right bank of Jiu river, next to localities Moi and Vladuleni, on the northern part and near localities Farcasesti and Roşia de Jiu, on south part;
- hilly area – situated South of Rosia de Jiu village, delimited between Valea Paraului and Valea Roşie.

## 2. AIR QUALITY MONITORING

Air pollution as environment factor, as a result of exploitation, transportation, storage and stockpiling activity, is manifested by:

- solid emission (dusts from quarry rock, stock-pile and transportation, coal powder from transportation and storage)
- gases emanation (methane, exhaust gases from transportation means).

From the point of view of immissions of depositing dusts and dusts in suspension from Roşia de Jiu, Quarry, are diffuse and represented by:

- coal transportation with conveyor belts (line source);
- loading set of cars and auto vehicles with coal (surface source);
- (pile) coal deposit (surface source).
- devices for depositing and taking over with bucket wheel

Significant sources of air pollution around Roşia Quarry are positioned in the area of coal deposit. The deposit is between Roşia Jiu village and Rovinari city (fig.1)

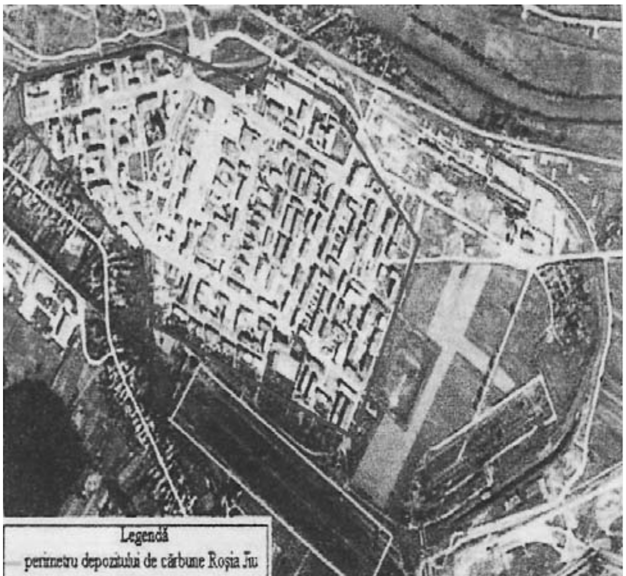


**Fig.1. Position of the Rosia Coal Deposit (Google Earth)**

The impact of an anthropic activity on the environment is determined by position, size and its location, the nature of the activity realised and its volume.

The deposit from Roşia quarry is realised from two lines of coal piles. The line of piles is positioned on the lateral to Farcăşeşti village, belonging to the company ENERGETIC COMPLEX ROVINARI, and the line of piles positioned to the centre of Rovinari, belonging to the NATIONAL SOCIETY OF LIGNITE OLTENIA- Subunit EMC- ROSIA QUARRY. Coal dust emissions, having the form of powder in suspension are wind involved to areas with inhabitants and close ecosystems. The evaluation realized for the deposit has been influenced by synergetic action of the pollutants emissions due to the steam power plant, namely dust emissions on chimneys, transportation issued dust, etc.

From the total capacity of coal deposit, that of 20% is operated by S.N.LO.-Tg-Jiu and 80% by S.C.TERMOELECTRICA S.A- Energetic complex Rovinari.

From the point of view of the size of site, it can be observed that coal deposit of SNLO-E.M.C. Roşia occupies a surface which is 9 times smaller than the surface of the coal deposit of S.C. TERMOELECTRICA S.A. Coal deposit of SNLO-E.M.C.

The type of activity is identical, meanwhile, from the point of view of capacity, it is obvious the fact that coal deposit of S.C. TERMOELECTRICA S.A., is bigger.

The effects of emission from the two companies are synergetic. Due to the aspects presented above, we consider that in global pollution index, the contribution of the activity realised by SNLO-E.M.C. Rosia, is smaller than the contribution of the Company S.C. TERMOELECTRICA S.A.- Energetic Complex Rovinari). From the analyses realised in the area E.M.C Rosia on dusts, it has been established the predominance of carbon in organic form or in organic compounds. There have been also determined quantities of silicon, iron, manganese, zinc, titanium. Roşia de Jiu Quarry is positioned in the influence area of the Rovinari steam power plant, the greatest zonal pollutant. Due to the circulation of the ash influenced by meteorological aspects (wind, precipitation, temperature), it cannot be established with exactness the contribution of Roşia de Jiu Quarry at air pollution. From the results of the measurements it can be stated that the limit values, admitted, are not respected. The coal deposit has a significant impact on the environment.

Everything mentioned can be gathered in an ensemble impact which is manifested by installing in the area of a specific microclimate with accentuated aridity, associated with the apparition of phenomenon, violent electrical discharges and torrential rains at the end of the spring and beginning of the summer.

The deposit has three main functions:

-Realize compatibility between the work regime of the quarry and the expedition regime by conveyor belt, in wagons and auto, variable depending on coal request.

-Storage of a coal quantity: pile A =56 thousand tons; pile B = 60 thousand tons.

-ensuring a coal quantity with sort of 0-200 mm and pile homogenization through different layers.

### 2.1. Monitoring the depositing dusts

For the quantification of depositing dusts in the surrounding air, have been realised measurements (APM Gorj source). A sample point has been positioned next to coal deposit E.M.C. Roşia – limit of functional area, being realised the monitoring of pollution with depositing dusts in the year 2010. The results of the realised analyses have been compared with values settled by STAS 12574-87. There can be observed high over takings of the admitted limit value in months June, August and September. The greatest exceeding of the admitted limit value is during September, 1,72 time and the smallest values in march, representing 65,52% from the maximum admitted concentration.

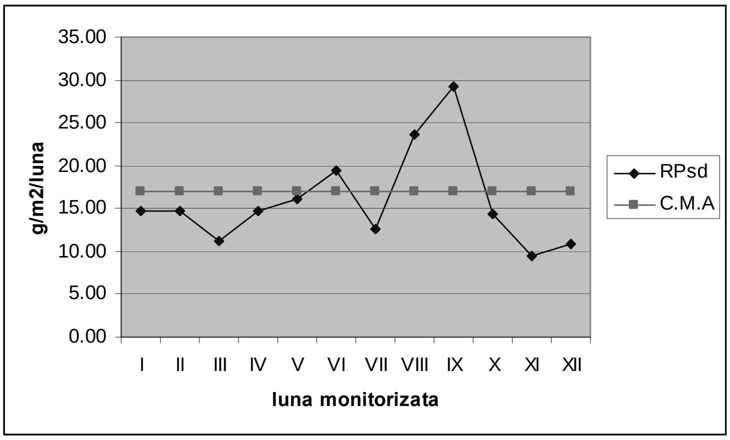


**Fig.2 Variation of depositing dusts concentration in the area of Roşia coal deposit in the year 2010**

**2.2. Monitoring dusts in suspension**

By measuring the immision of dusts in suspension, the sampling points have been positioned in locality Farcasesti, at a distance of 100m in the direction SV and NE, concerning the coal deposit.

Coordinates of sample points assay from surrounding air, are presented in Table 1.

**Table 1. Sample points assay from the surrounding air**

| **Test Code** | **Place N** | **Test E** | **$PM_{10}$** |
|---|---|---|---|
| RPsu1 | 44,89135 | 23,16016 | PM10. |
| RPsu2 | 44,89156 | 23,16812 | PM10 |
| Distance to deposit (m) | Direction to deposit | Mediation period | |
| 100 | SV | 24 ore | |
| 100 | NE | 24 ore | |

The results of the analyses have been compared with the values settled by the order no. 592/2002 (according to this, the maximum admitted concentration being of 50 µg /$m^3$), and the analyze method is according to STAS 10813/1976. The limit admitted values are not respected.

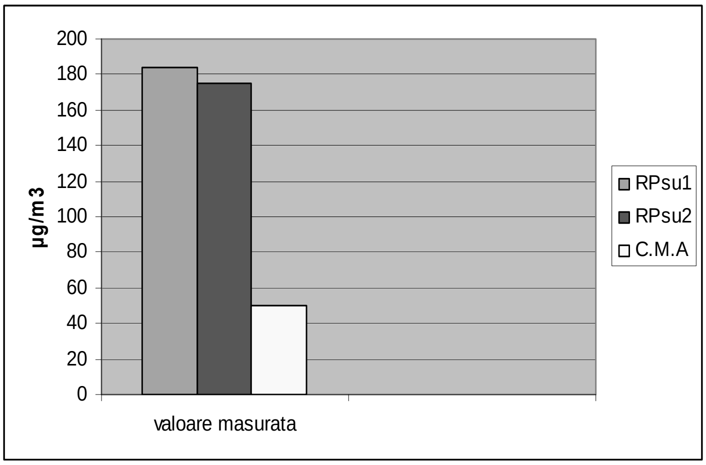


**Fig.3 Changes in concentrations of particulate matter in the coal storage area in June 2010 Rosia**

These have been exceeded by C.M.A 10,81 times in the RPsu1 and 10,30 times in RPsu2 for dusts in suspension.

The statistics regarding obstructive chronic pulmonary illnesses, in the evidence of Rovinari Hospital, in the year 2009, are presented in chart 3.

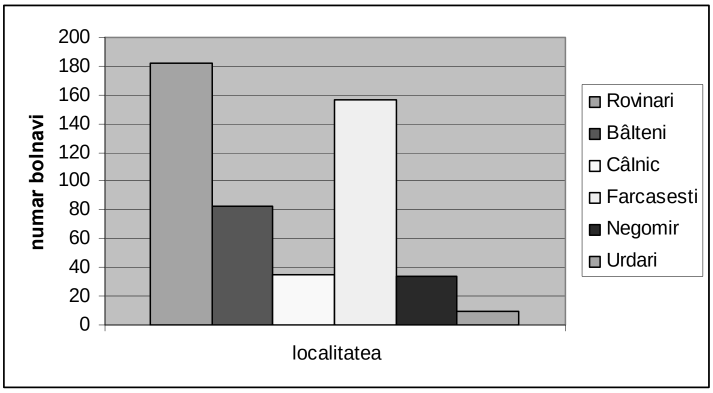


**Fig.4. Statistics on chronic obstructive pulmonary disease in hospital records in 2009 Rovinari**

It can be observed a great number of morbidity for the inhabitants in the areas found in the proximity of Roşia and Rogojelu coal quarries and deposits.

## 3. CONCLUSIONS

Mining has a great influence on the environment, containing positive influences and negative influences. Significant sources of air pollution around Roşia Quarry are positioned in the area of coal deposit.

From the analyses realized in the area E.M.C Rosia on dusts, it has been established the predominance of carbon in organic form or in organic compounds, silicon, iron, manganese, zinc, titaniu.

There can be observed very high exceeding of the limit values for dusts in suspension, namely to pollutant of depositing dusts. From information presented results that the coal deposit has a significant impact on the environment. A person living in a contaminated environment inhales and detains impurities from which a part being gathered in lungs and in the rest of the organism, contributing this way at his anatomic, physiologic and pathological modifications. In rapport with the intensity of air contamination, morbidity appears and also life shortening, in proportion with the population from contaminated areas. The proportion of retaining particles varies in rapport with dimensions and its concentration in the air and with the anatomic and functional characteristics of the lungs of persons exposed to contaminated air, the retention process being between 10% and 90% from the number of particles exiting in the air.

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# REINTRODUCING IN THE ECONOMIC CIRCUIT OF WASTE DUMPS FROM OLTENIA. CASE STUDY NEGOMIR VALLEY WASTE DUMP

**SMEU COSMIN ALIN***
**IACOB DUMITRU****
**VOIN VIOREL*****

**Abstract:** *Given that the tasks ahead for reuse degraded terrains by mining activities are very large and growing, especially in the mining basins of Oltenia, where open pit mining prevailed and which continues today, there must not be spared any effort to achieve high-quality work and achieve in this way, the maximum economic effect for reusing degraded lands in each variant. This paper presents an example of planning works necessary to be carried out in this purpose, possible to be implemented for waste deposits from Oltenia, namely Negomir Valley dump.*

**Key words:** *reintroducing in the economic circuit, waste dumps, Negomir Valley, stability of waste deposits, remodeling, refurbishing.*

## 1. INTRODUCTION

The problem of reintroducing the land affected by open pit mining operations must be followed since the design phase because it has a marked influence on the career limits, stripping ratio, and finally, the costs of extraction. Therefore, to determine the final contour of a open pit should be considered mandatory interdependence dimensions operating site up to date with the value of land expropriated, geometric parameters of open pits and agrochemical characteristics of the surrounding rocks and cover.

Among the many reasons that support the need for remodeling and rehabilitation of land affected by human activities include:

- eliminating the risk of slipping a positive relief, occurred in an area with outdoor storage of sterile dumps;
- eliminate the negative visual impact of areas with lunar aspect;
- the need for reintegration of degraded areas in the production and/or in the ecological circuit of the regions where they are, which leads to regenerate their economic potential;

* *Student Ph.D. Eng., SC Complexul Energetic Turceni SA, Cariera Jilt Nord*
** *Student Ph.D. Eng., SC Complexul Energetic Turceni SA*
*** *Prof. Ph. D. Eng. at University of Petrosani, Mining Faculty*

- improvement of environmental quality;
- reducing the slope and with it, reducing the intensity of the phenomena of erosion and accelerating vegetation installation process. [2]

One of the major external dumps from Oltenia is Negomir Valley, as the name suggests, a waste deposit located on a slope, along a valley, and was chosen for this case study because of features that are presented in the next paragraph.

## 2. WASTE DUMPS DESCRIPTION

Negomir Valley dump was designed to store a part of the sterile rocks generated from Pinoasa open pit. Negomir Valley is located south of Pinoasa open pit, Figure 1.

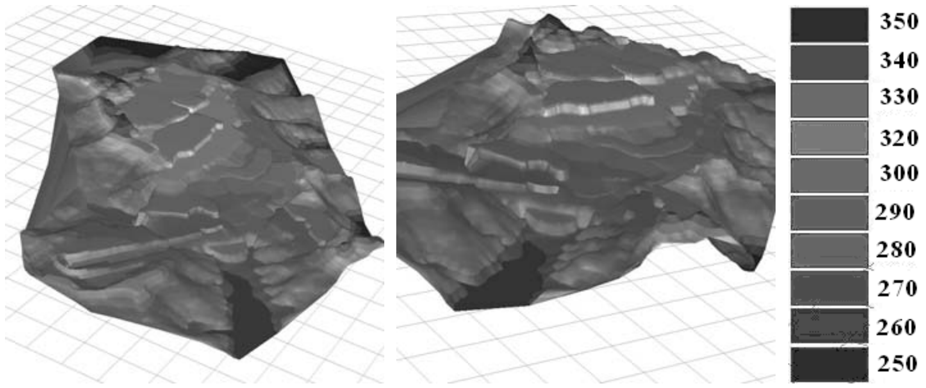
Location area is within the area of Oltenia Subcarpathians terrace, with a relief resulted from erosion. In areas of the depression microrelief water from precipitation accumulates as ponds which mostly are seasonal.

The storage of the sterile rocks in the waste dump is done on an unimproved base, without water drainage works.

Topsoil removal works were carried out sporadically and without continuity.

Negomir Valley dump has most favorable conditions of instability, fact which has imposed rethinking a new technology for depositing the sterile rocks, namely gradually lowering the depositing equipment and reducing the maximum height of the steps to 10-12 m and creating an appropriate gap between step I and step two of work. [6]

The final capacity of storage for Negomir Valley dump is 270 million $m^3$.




a b

**Figure 1. Negomir Valley waste dump, 3D model, elevation factor a – 1/2, b – 1/3**

The waste deposit is made in steps with heights of 15 m, slope angle of 26º/level, general slope angle 4º30 'and platforms width of 120 m.

The deposit is likely clay, geomechanics parameter values are:

$\gamma a$ = 19.5 to 20.2 $kN/m^3$;

c = 0.05 to 0.25 $daN/cm^2$;

$\varphi$ = 12-21º;

w = 23.5 to 33.2%.

The depositing activity is carried out with three machines type A2Rs 6500x90 both low and high gear in steps of 15m. [8]

### 3. DUMP STABILITY ANALYSIS

Since Negomir Valley dump is prone to instability phenomena, mainly due to lack of drainage works, and reporting of such events in the early stages changes in the originally designed geometry were assumed for the deposit, required before designing the rehabilitation works and reintroduction in the economic circuit, by performing a new stability analysis for the current geometry.

Any investigation of the steady state of a natural slope or artificial slope starts from the need to know the factors influencing stability, namely:

- geological and hydrogeological factors;
- natural mechanical factors and geomechanics;
- anthropogenic factors (technogenical);
- hydro meteorological and seismic factors;
- biotic factors. [3]

Slope stability analysis for the steps of waste dumps is carried out using the same methods as in the slope "in situ" under the assumptions of flat or curved slipping surfaces, for interior and exterior dumps built on horizontal surfaces, or polygonal surfaces, when dumps are located on the slopes with variable slopes, where connecting steps were not executed. Most often, checking waste dumps stability and for the steps system is done by assuming a circular slip surface, Figure 2 and the stability condition is expressed by the ratio of resisting moments or forces (resistance forces) and sliding moments or forces (active forces), moments of forces are calculated in relation to the center of the sliding surface. [5]

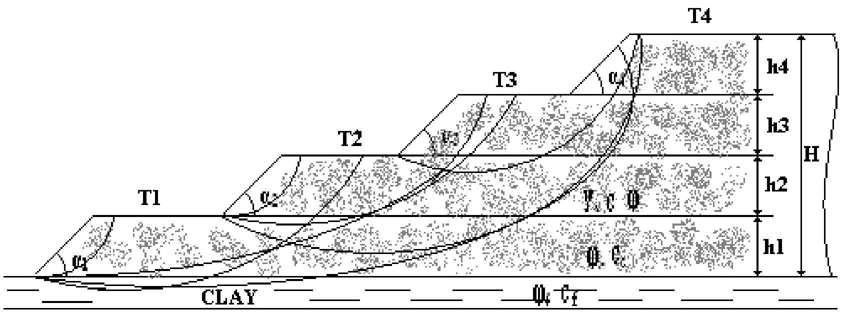



**Figure 2. Stability of a step and for the step system in case of a circular sliding surface**

For dumps located on slopes there are three assumptions for landslides occurrence.

In the first case of sliding surface, at the bottom, is formed in the contact area between the waste dump and base land and the sliding mass continues in the dump to its upper platform, with a roughly circular area, Figure 3a.

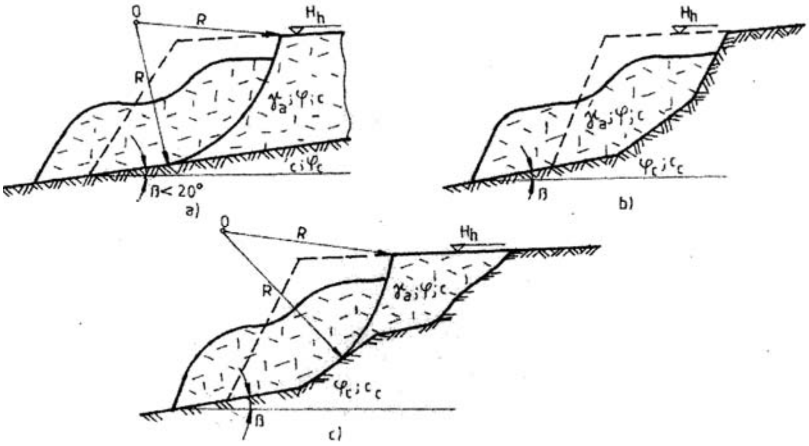



**Figure 3. Sliding surfaces for deposits built on variable slope terrains**

In the second case, the sliding surface can be formed entirely at the contact between the foundation and waste dump (in which case the entire waste dump slides) Figure 3b, or at the contact, at the bottom, of the dump in the support area, continued with an breaking circular area around the rock and is formed under the influence of the active forces (where slippage can be only partial) Figure 3c. [5]

Avoiding these phenomena is provided by scarification of the base land, the following changes the ratio of active and passive forces acting for and against production that slip, due to increasing resistance to shear in the contact rocks plane, or twinning steps using horizontal or backward tilt, the tangential components of the weight is canceled and eliminates the slide possibility of the waste dump on the direct foundation. [4]

Stability analysis for step systems of waste dumps is based on the same methods used for slope stability analysis of individual slopes, composed of rocks poorly cohesive, the most common methods are presented in the literature:

- vertical strips method (Swedish method or Fellenius);
- Janbu's method;
- Bishop's method;
- Goldstein method;
- Friction circle method;
- horizontal forces method (Maslov-Berer);
- dimensionless parameters method etc.

To perform the stability analysis were considered two longitudinal sections L1-L1 and L2-L2, materialized on the situation plane in Figure 4.

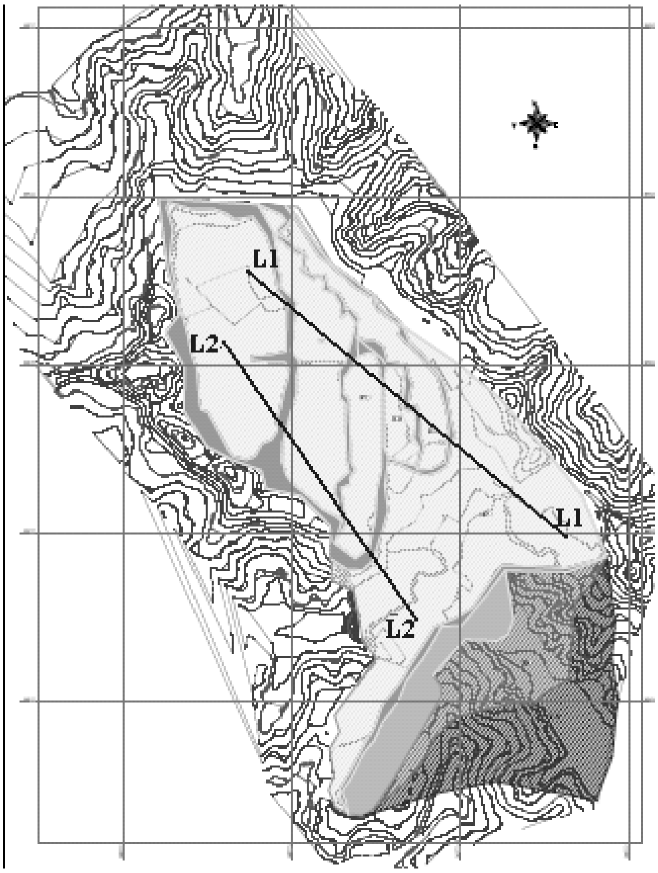



**Figure 4. Negomir Valley waste dump (situation plane)**

To analyze the stability of Negomir Valley waste dump 2 longitudinal section have been made (Figures 5 and 6) crossing the central areas of the dump, the physical and geomechanical characteristics considered in the stability analysis are presented in Table 1.

**Table 1. Physical and geomechanical characteristics**

| Rock type | Natural humidity | | |
|---|---|---|---|
| | Volumetric weight $\gamma_{nat}$, (kN/m$^3$) | Cohesion c, (kN/m$^2$) | Internal friction angle φ ($^o$) |
| Waste materials | 19,8 | 20,0 | 17 |
| Natural terrain | 19,6 | 23,1 | 20,5 |

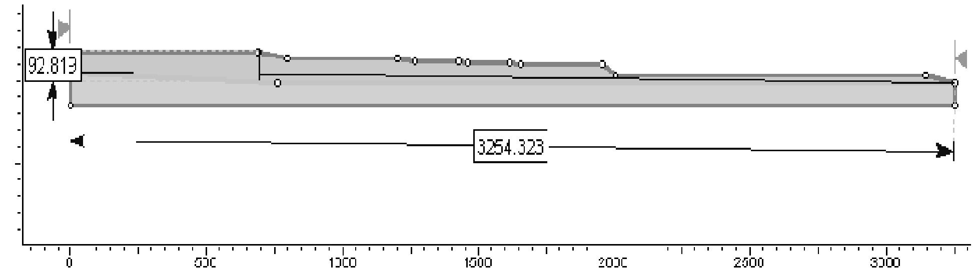



**Figure 5. Longitudinal section L1-L1**

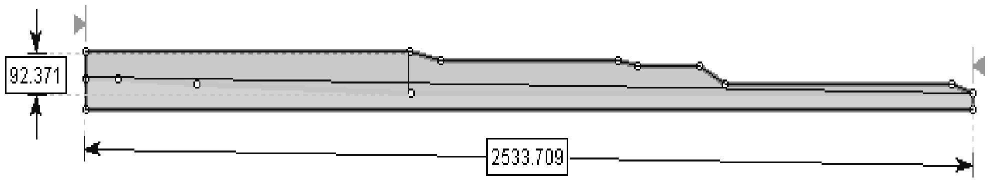



**Figure 6. Longitudinal section L2-L2**

By modeling the sections, L1-L1 and L2 -L2, and placing the models in the specialized software for stability analysis Slide, were obtained the results presented in Table 2.

**Table 2. Stability analysis results**

| Section | Height | Slope angle | Analysis method | | |
|---|---|---|---|---|---|
| | **H (m)** | **α (°)** | **Fellenius** | **Bishop** | **Janbu** |
| L1-L1 treapta 1 | 25,578 | 14 | 1,956 | 2,010 | 1,938 |
| L1-L1 treapta 2 | 30,959 | 32 | 2,180 | 2,510 | 2,142 |
| L1-L1 sistem trepte 3, 4, 5 | 24,844 | 3 | 5,914 | 7,299 | 6,018 |
| L1-L1 treapta 6 | 22,291 | 10 | 2,516 | 2,841 | 2,470 |
| | | | | | |
| L2-L2 treapta 1 | 23,238 | 20 | 1,404 | 1,470 | 1,382 |
| **L2-L2 treapta 2** | **41,203** | **29** | **1,070** | **1,204** | **1,065** |
| L2-L2 treapta 3 | 10,419 | 10 | 4,902 | 6,036 | 4,991 |
| L2-L2 treapta 4 | 23,970 | 13 | 2,646 | 3,133 | 2,638 |

Analyzing the stability coefficient values obtained by different methods of analysis can be said that the waste dump Negomir Valley has generally good stability (while the dump material is at natural humidity).

However it can be seen that for step 2 of L2-L2 longitudinal section (Figure 7), the stability coefficient is very close to the limit of balance.

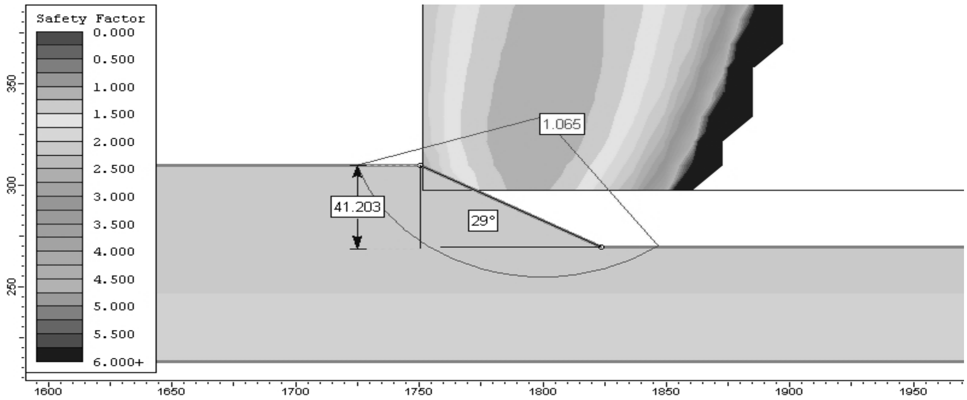



**Figure 7. Critical sliding surface for step 2 of L2-L2 section (after Janbu)**

In order to comply with regulations in force (which recommends a value of stability coefficient over 1.3) and to increase stability reserve can be considered two simple methods: using the scaling of Hoek, respectively building a support structure, in front of the second step, of larger rocks along the length of influence of the section.

Using the Hoek procedure, in conditions that do not change the height of steps (requires moving a large volume of material) it follows that the angle of slope of the step should be reduced from 29° to a value of 22º to obtain a value of stability coefficient of 1.3. By reducing the slope angle a much smaller volume of material should be moved that can be leveled on the lower level without affecting its stability.

The other method mentioned involves moving construction materials, and from this point of view is more expensive and requires a longer time for construction.

## 4. PROPOSALS FOR REINTRODUCING IN THE ECONOMIC CIRCUIT OF NEGOMIR VALLEY WASTE DUMP

The results obtained for the stability analysis performed on Negomir Valley dump, indicating its good stability, taking into account the recommendations on step 2 of section L2-L2, allows to identify and propose the optimal solution (in terms of economic and environmental protection and restoration) of improvement and return of the dump into the economic circuit.

In this domain of recovery of degraded lands there are many ways that can be followed: productive recovery, naturalistic recovery, recovery for recreational purposes, residential recovery etc. [2]

To reach a decision on best redevelopment option should take into account past experiences and results in this area, but must be taken into account the principles underlying ecological rehabilitation, in this case especially:

- the principle of natural autonomy;
- the principle of compliance with the population;
- the principle of economic efficiency. [3]

Given the above, for Negomir Valley waste dump, which is located in a valley, the best option is redevelopment by forest recultivation.

Reforestation works do not imply, in the early stages, circulation of heavy machinery, planting seedlings is a manual operation. And also avoids overloading of slopes, strain that would arise due to the deposit of an agricultural soil layer, with thickness up to 1 m of topsoil, which could have a negative influence on the stability of the deposit.

In the mentioned reforestation made on the exterior and interior waste dumps from Gârla open pit, which occupies an area of 125 hectares of pine plantation, Tismana external waste dump plantation that has aged 16 years and occupies an area of 32 hectares and 8 ha of guard channel slopes on the northern side of the pit area, forests at Rovinari - Peşteana and Rosia de Jiu, which occupies 40 hectares. [1]

These good results obtained previously, particularly with pine plantations, creates the conditions for reforestation of the external waste dump Negomir Valley with the same species (either pine or red pine) species that has a relatively high growth rate and contribute to increase the stability significantly in a short period of time.

Recultivation with pin is able to provide, initially, a reintegration of the dump in the landscape, and then, once mature, the plantation can be seen as a renewable resource available to local communities.

It intends to plant pins the whole planting area of about 197 ha of the dump, the number of seedlings per hectare is recommended between 6000 and 8000, based on planting schemes in rows, planting will be effective in pits with dimensions of 30x30x40 cm and soil at the root. [7]

The scheme envisaged planting 6000 seedlings per hectare (distance of 0.8-1 m between seedlings and 1.25 to 2.5 and even 3 m between rows, resulting in a total of 1.182 million seedlings.

With the remodeling work of step 2 of section L2-L2 influence length is not large and they can be made with bulldozers used in the work of capital leveling of the dump, and planting seedlings will work with their staff (possibly on a voluntary basis), then the costs of reforestation of Negomir Valley dump to reintroduce it in the economic cycle is just about the purchase of seedlings. The current average price of pine seedlings is 25 lei, resulting in a total cost of 29.55 million lei to reforestation of the dumps after scheme outlined above.

## 5. CONCLUSIONS

The recovery process of land affected by open pit mining of lignite in Oltenia - Romania is in progress, so that environmental restoration problems for the Romanian state are one of the key concerns.

Depending on the necessary production of lignite to achieve and concrete conditions that will perform the work of extraction, were planned for the next ten years to be reintroduced in the economic circle of surfaces, so as to significantly reduce the gap between the areas of degraded lands and those introduced into the economic circuit.

Negomir Valley waste dump was designed to store a part of the sterile rocks from Pinoasa open pit, location area is within the area of Oltenia Subcarpathians terrace, with a relief resulted of erosion, surrounded by wooded hills.

Stability analysis on Negomir Valley dump showed a good overall stability, allowing to start reforestation work to restore the dump in the economic circuit.

However there are necessary works, on a small scale, to remodel the slope of step 2 on of the section L2-L2 length of influence to increase the reserve of stability, up to a stability coefficient over 1.3, reducing the slope angle from 29º to 22º, while maintaining the current height.

We recommend lowering the depositing equipment and reduce the forward steps to a maximum height of 10-12 m and create a corresponding gap between stages I and stage two of work indenting reserve stability.

Given the configuration of the land (waste dump located on the slope with variable angles) and the principles of ecological restoration, the optimal variant is identified to be rehabilitation by reforestation.

Costs of reforestation of the dump (197 ha) are generated by the purchase of pine seedlings and amounts to an estimated value of 29.55 million lei.

The proposed variant can be applied to other waste dumps from Oltenia, placed in similar location conditions and for which the stability conditions are ensured, of course while respecting the fundamental principles of ecological rehabilitation.

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# UTILISER LES DECHETS COMPOSTES VERT DANS LA RECULTIVATION BIOLOGIQUES DES TERRAIN DEGRADEES DANS LA VALLEE DE JIU

**DUNCA EMILIA[*]**
**CIOLEA DANIELA IONELA[**]**

**Abstract:** *Analyzing the situation of land in the Jiu Valley, it was found that 16% of them fall into classes of poor quality and very poor. Improve its quality might be achieved by using green waste compost made from. Excessive mature compost in storage, leading to a very advanced its mineralization, which is to lose some of its beneficial effects soil. The best time for application of compost to land is degraded at the end of thermophilic phase, when the product is rich in organic substances present paper aims to study the possibility of obtaining green waste composting and use in biological recultivation of degraded land.*

**Key words:** *compost, green waste, degraded land, biological recultivation*

## 1. INTRODUCTION

La pollution atmosphérique due à la combustion de combustibles solides installations de chauffage ou de l'industrie, grâce à la contribution d'oxydes de soufre et d'azote, métaux lourds, le monoxyde de carbone et les particules de matière qui libère.

L'acidification est le processus par lequel la surface du sol est faible dans les bases et subir un changement continu, il, tout cela conduit à la dégradation des sols et des eaux ainsi que de contribuer à la détérioration des écosystèmes.

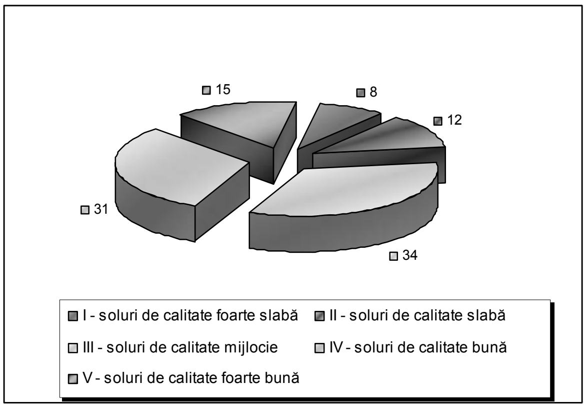


**Fig. 1.1 Répartition des classes fertilité des sols**

Analyser la situation dans les zones agricoles Vallée de Jiu, en fonction des classes de solvabilité, il

[*] [1] *Lecturer Eng. PhD., University of Petrosani, Mine Faculty*
[**] *Assist. Prof. Eng. PhD., University of Petrosani, Mine Faculty*

apparaît que la plupart des terrains se trouvent dans la classe III et IV (65%) et seulement 15% dans la classe V (I - très mauvaise qualité, V - les points forts aussi bien). Il y a une autre classe de sols anthropiques qui contribuent à la dégradation des écosystèmes qui les entourent à savoir les décharges et les étangs de cendres.

## 2. LA SITUATION DES DECHETS DANS LA VALLEE DE JIU

Déchets ménagers et similaires du commerce, d'industrie, est influencé non seulement par des changements dans la population, mais la couverture de développement aussi économique, la population et des revenus des services d'assainissement.

Basé sur le nombre d'habitants de la région et la quantité de déchets ménagers produits en 2011, il va calculer l'indice de la production de déchets ménagers en kg/habitant/an.

Déterminer le volume moyen quotidien de déchets municipaux générés dans une localité est la relation:

$$Q_{med} = N \cdot I_m \cdot 0{,}001, \text{ [tonnes/jour]} \quad (1)$$

où:

$Q_{med}$ - le volume moyen quotidien de déchets municipaux générés;

N - nombre d'habitants du village;

$I_m$ - indice moyen des déchets de production.

Indice moyen des déchets de production est déterminée par des mesures et des données statistiques et diffèrent d'une localité à l'autre.

Calculs mondial, estimations, etc. peuvent être prises: $I_m$ = 0,8 kg/habitant/jour en milieu urbain et 0,15 kg/habitant/jour dans les zones rurales.

Prévisions de l'évolution de la production de déchets ménagers sera déterminé en tenant compte des facteurs pertinents suivants: histoire, pessimiste et optimiste. (Figure 1.2.)

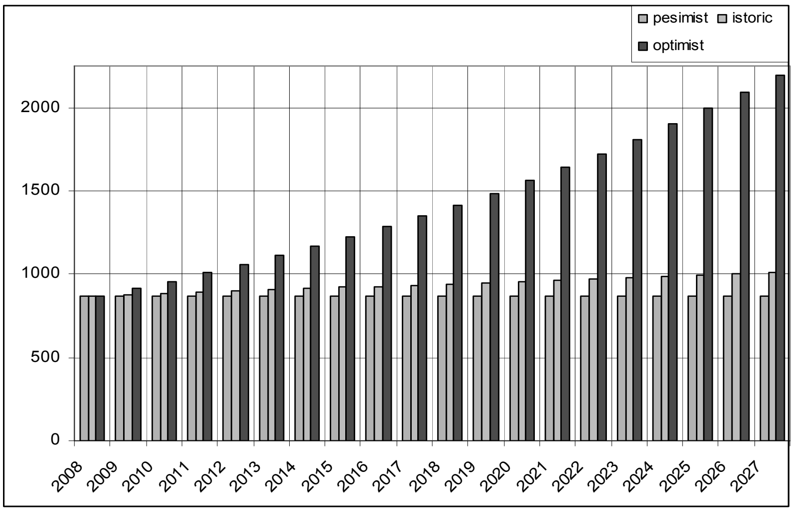


**Fig. 1.2. Indice Prévisions des déchets ménagers générés dans la Vallée de Jiu**

Plus facile de choisir des solutions techniques à mettre en œuvre seront:

- identifier les fractions de déchets provenant de déchets ménagers collectés dans le mélange;

- identifier pour cent de contenu biodégradable (%) et la quantité (en tonnes)
- pour aider à identifier le type de déchets du plus pour atteindre la cible.

La méthodologie pour le plan de mise en œuvre d'emballage des déchets calcul était basée sur la directive sur les emballages.

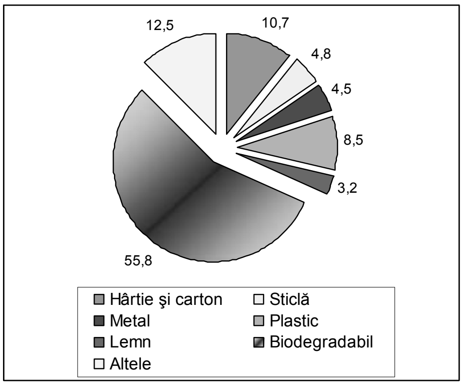


**Fig. 1.3. La composition des déchets**

### 3. CARACTERISTIQUES DE COMPOSTAGE

Le compostage des déchets organiques est composté de transformation d'engrais. L'avantage de mettre le produit est capitalisé avec des applications directes dans l'agriculture, les coûts d'énergie, exploitation, entretien, installation simple, des professionnels non spécialisés.

L'inconvénient du procédé de compostage nécessite un contrôle de la présence de substances inhibitrices du processus biologique de fermentation aérobie.

Les résidus organiques issus de l'agriculture, l'élevage, l'industrie et l'activité humaine, ce qui soulève de graves questions concernant l'entreposage, les processus de biodégradation qui se développent les microbes et les odeurs peut être convertis en bio fertilisants et les biocarburants.

Production de déchets organiques municipaux est un processus de croissance, qui développe en raison de la perte de matière organique du sol due à l'agriculture intensive et des conditions climatiques. Cela nécessite le développement de bio procédés de recyclage des déchets comme une alternative aux autres procédés de recyclage, comme par exemple, l'incinération ou l'enfouissement.

Un des processus biologiques à celle requise pour l'assainissement des déchets solides organiques est contrôlé décomposition aérobie appelé compostage.

Le compostage peut être fait à différents niveaux de l'activité humaine, d'où ils produisent leur propre compost jardinier, d'installations industrielles pour la récupération par le compostage.

Le compostage est généralement défini comme un processus de décomposition par oxydation biologique des déchets constituants organiques, pratiquement n'importe quel type, dans des conditions contrôlées. Depuis le compostage est un processus biologique de décomposition des matières organiques exige des conditions spéciales, en particulier, déterminé les valeurs optimales de température, d'humidité, l'aération, le pH et C/N, nécessaire pour assurer une activité biologique optimale dans les différentes étapes du processus.

La technologie de préparation du compost comporte deux étapes principales, à savoir:

• la préparation mécanique des matériaux pour le compostage,

• la fermentation des déchets.

Les déchets ménagers nécessitent une formation avant la fermentation. La préparation consiste à broyer et mélanger des déchets. La méthode pour les transformer en compost pour être aérobie, car il est plus rapide et éviter les odeurs désagréables.

Compostage phases consistent à:

- identifier le traitement des déchets biodégradables, en termes de nature et la quantité;
- de la détermination de la plateforme région et l'équipement nécessaire pour être utilisés;
- l'évaluation des conditions climatiques dans la zone (la zone humide, sec, très chaud);
- déchiquetage et l'élimination des matières compostées en tas le long de la plateforme;
- mélange continu du matériau (2-3 fois par semaine selon les conditions météorologiques);
- ajout de l'eau si nécessaire;
- évaluer le niveau de traitement et le calendrier de la transformation est achevé.

On a besoin du matériel suivant:

- déchiqueteuses (broyeur),
- chargeur,
- matériaux inorganiques séparateur;
- Shaker (Turner)
- atelier de maintenance des équipements
- su plateforme de béton bitumineux.

Appareils doivent être dimensionnés en fonction des besoins spécifiques du client.

### 3.1. Facteurs influençant le processus de fermentation

- ***L'oxygène***

La quantité d'air qui fournit l'oxygène nécessaire est la fermentation de 4,5 à 5 litres d'air pour 1 kg de matière sèche et par heure. Lorsque c'est possible, la quantité d'air de ventilation peut être augmentée par simple inversion de tas de compost (si les plates-formes de compostage extérieur), l'introduction d'air à travers des tuyaux perforés (pour le compostage en tas), l'introduction d'air froid ou chaud chambres de fermentation en continu le mélange des déchets avec l'aide d'équipements spéciaux.

- ***Eau***

Pourcentage d'humidité optimal est basé sur la quantité de matière organique disponible dans les déchets. Lorsque la teneur en matière organique est humidité < 50% devrait être de 45%. Lorsque la teneur en matière organique est l'humidité > 50% devrait être de 50 à 55%. Pour augmenter l'efficacité de la fermentation est nécessaire pour contrôler le processus. Compost doit être protégé de la pluie, parce que l'augmentation de l'humidité entraîne une augmentation dans les processus de fermentation anaérobie.

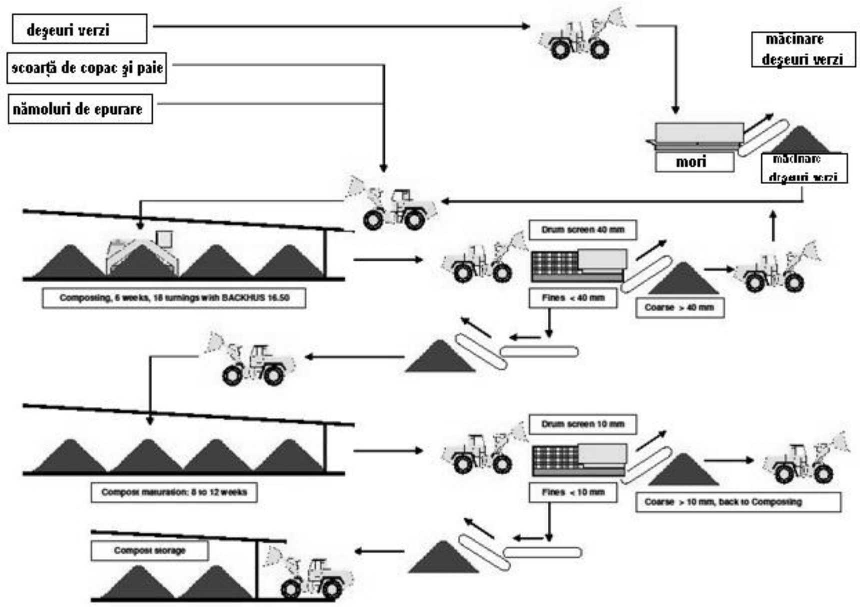


**Fig. 1.4 Technologie de traitement des déchets et le compostage des déchets vert**

▪ ***La composition des déchets***

Il est un facteur important dans le déclenchement du processus de fermentation. Si les déchets ménagers sont riches en matières fermentescibles et la température ambiante est élevée, un processus de feux de compostage se déroule rapidement et correctement. Si les résidus sont pauvres en matière organique, surtout en hiver, et la fermentation est retardée introduction d'air supplémentaire ne fera que nuire au processus de fermentation.

D'autres facteurs influençant le processus de fermentation sont:

- le degré d'homogénéisation du mélange,
- les déchets soumis à la fermentation granulométrie,
- Le règlement des terrains vagues en tas ou dans des récipients pour la fermentation,
- le ralentissement du taux d'augmentation de température.

Terrains vagues frais sont biologiquement actives et peuvent être utilisées que comme des lits chauds pour les cultures d'hiver ou de printemps ou des serres, mais les gaz malodorants. Pendant le processus de compostage vise à atteindre un des températures particulièrement élevées pour détruire les agents pathogènes et la production microbienne de la matière colloïdale spécifique.

Le compost peut être utilisé pour améliorer l'état des sols dégradés pour adultes biologiques seulement.

Le compost est considéré comme mature lorsque l'activité de micro-organismes est minimisée.

Détermination de la maturité du compost se fait par la détermination de la consommation d'$O_2$ (ou la production de $CO_2$) par des essais sur les plantes, en analysant la structure physique, etc.

Le compost est mieux utilisé dans recultivation biologiques à la fin de la phase thermophile, lorsque le produit est riche en matière organique. Échéance du dépôt excessif aboutit à une très avancé de sa minéralisation, qui fait partie des Saxons perd ses effets favorables sur le sol.

**3.1.1. Périodes de dormance du processus de fermentation.**

Correspond à la période de temps nécessaire pour atteindre les colonies de microorganismes dans le nouvel environnement créé. Cette phase débute près de l'entreposage des déchets et dure jusqu'au début de l'augmentation de la température dans la masse des déchets.

✓ *Phase de croissance*. Correspondant augmentation de la température de phase dépend en grande partie sur la composition des déchets, l'humidité et la présence d'air.

✓ *Phase thermophile*. Période correspondante de températures les plus élevées. Cette phase peut prendre plus ou moins en fonction de la quantité de matière organique et le degré d'isolation thermique. A ce stade, il peut agir plus efficacement sur la fermentation.

✓ *Phase de maturation*. Correspondant fermentation secondaire, lent, d'humidités favorables, que la transformation de composés organiques en humus sous l'action de microorganismes.

Le compost est mieux utilisé dans recultivation biologiques à la fin de la phase thermophile, lorsque le produit est riche en matière organique. Échéance du dépôt excessif aboutit à une très avancé de sa minéralisation, qui fait partie des Saxons perd ses effets favorables sur le sol.

Nous recommandons un temps maximum de 3 mois de stockage du compost à utiliser. Un élément très important qui caractérise l'état et la qualité du compost est le rapport carbone/azote. Ce rapport reflète les déchets de fermentation stade de développement.

Caractéristiques d'un bon compost pour l'agriculture:

- granulométrie: 90% de compost à travers un tamis à l'oeil passant tamis 35 mm,
- le pourcentage de carbone: > 50% déterminée en matière sèche,
- signaler carbone/azote: avoir entre 20 à 30 (à partir de déchets frais est acceptable 10-15).

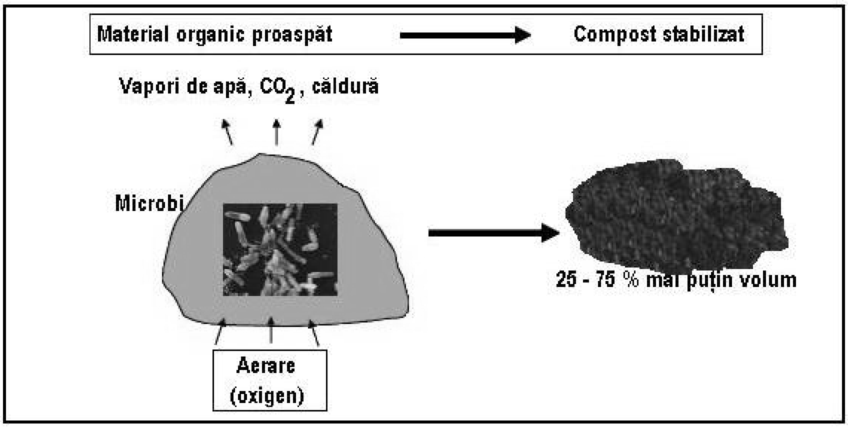


**Fig. 1.5 Les phases de fermentation et de compostage**

**3.1.2. Les méthodes d'utilisation du compost**

Après des études en laboratoire et sur le terrain peut être dit que le compost peut être utilisé lorsque les conditions suivantes:

- le dépistage, 90% du matériau doit passer à travers un tamis d'un maillage de 35 mm,

- le pourcentage d'équivalent carbone doit être supérieure à 5% en masse de matière sèche,
- le pourcentage d'équivalent azote à plus de 0,3% en masse de matière sèche,
- le rapport C/N (carbone/azote) pour se situer entre 10 à 20.

Conditions à remplir par le compost pour utilisation dans la remise en culture biologique sont:

- compost épandage doit être au dessus du sol,
- si les déchets sont frais et utilisé plus de 10 t / ha, doit quitter après cette diffusion, par les cultures semis (1-1,5 mois) pour compléter la fermentation et la maturation se déroulera,
- faut-il être utilisé de compost grossier préférence sur terre battue terre compactée et de compost bien sur la terre sablonneuse sec,
- compost contenant plus de 5% du calcium est utilisé de préférence sur les sols acides
- le compost peut être utilisé sur terre avec des sols pauvres en humus,
- la posologie recommandée varie de 20 à 100 t/ha en fonction de la qualité du sol et la nature des cultures à semer et peut conduire à une augmentation des rendements en moyenne d'environ 15%/an.

L'utilisation du compost est généralement rentable pour les utilisateurs d'un maximum de 200 km de l'usine pour produire du compost. Sur cette distance, les coûts de transport augmentent et il n'y a pas d'utilisation économique.

## 4. CONCLUSIONS

Dans une étude conclusions suivantes peuvent être tirées:

- identifier les types de déchets qui peuvent être utilisées comme engrais vert
- la quantité de déchets organiques dans le développement de la vallée de Jiu est en croissance,
- détermination de la plate-forme de zone et le matériel nécessaire pour être utilisé
- avant le traitement de compostage de déchets verts,
- les facteurs affectant le compostage des déchets doivent être soigneusement étudiés,
- le meilleur que vous pouvez utiliser le compost pour restaurer les terres dégradées.

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Scientific Reviewers:
Prof. PhD. Eng. Sanda Krausz

# STUDY ON THE REDUCTION OF EMISSIONS POWDERS - MINTIA THERMOELECTRICAL POWER

**CIOLEA DANIELA IONELA***
**CĂPĂȚÂNĂ CAMELIA****

**Abstract:** *The coal deposits as well as the slag and ashes deposits of these installations contribute at the atmosphere's pollution through the particles' shatter. The papers is one study on the reduction of powders emissions from Mintia thermoelectrical powers. The amount of slag and ash discharged from the plant in a year is about 1 million tonnes. To this end, use two warehouses located in major river bed on the right bank of the Mures River, an area of approx. 70 ha and another place called Valley-Tirnava Bejan at cca. 4 km of power plants, occupying an area of approx.130 ha. Environmental impact assessment of air pollutants is can be done by emissions inventory by emission modeling measurement of dispersion of air pollutants and air quality parameters.*

**Key words:** *reduction, emissions, powders, environment.*

## 1. INTRODUCTION

Thermal power stations Mintia - Deva is for a long time the third largest electricity producing unit in Romania. The size of installed capacity and high availability, security and operational continuity, Thermal mind is a source of basic electricity National Power System.

Throughout the period covered by the commissioning, Thermal mind has produced 9 ÷ 10% of the country's electricity and 18 ÷ 22% of the electricity produced by power plants using coal as raw material.

Thermal power stations Mintia – Deva is located in southeastern Transilvania, the Mures river, 7 km from the town of Deva and has an installed capacity of 1260 MW in six groups of condensation energy of 210 MW each, fed every 2 steam boilers of 330 t ab/ h, 13.72 MPa, 550$^{o}$C, each block being an independent unit.

The main fuel used is coal Jiu Valley (sorted energy coal and mixed coal), Preparation Lupeni Coroeşti, Petrila Livezeni with average calorific value of 3680 kcal / kg (15,407 kJ / kg) until a few years ago using and coal is imported from South Africa, Australia, Russia. Coal is transported by rail and sea. Auxiliary fuel, and start using them to stabilize the flame are gas and fuel oil.

* *Assist. Prof .Eng. PhD., University of Petrosani, Mine Faculty*
** *Lecturer Ph.D. Eng., University "Constantin Brancusi" of Tg. Jiu*

Electricity is supplied to the national power system voltage of 220 and 400 kV, with delivery options and outside the country, in line Sibiu - Arad - Szeged.

The plant was commissioned in three stages: 1969 ÷ 1971 - No energy groups. 1 ÷ 4; 1977 - No energy group. 5; 1980 - No energy group. 6. [1]

Each group has an output power of 210 MW.

Since 1984, delivers thermal and heat (heat) for approx. 25,000 apartments in Deva, with an installed capacity of outlets uncontrolled delivery of the turbines of 300 Gcal/h (6x50 Gcal/h).

After investigations we find that control plant performance / retention powders are affected by changes in the resistivity and adhesion (cohesion) fly ash, depending on the mineralogy of coal, as fuel and the amount of unburned carbon in fly ash. Influence the governance of the combustion ash size distribution and therefore the emission of dust.

To retain dust from flue gases are frequently used various devices such as electrostatic filters (ESP electrostatic), bag filters and wet scrubbers (scrubbers) and cyclones (the mechanical retention of dust).

No energy group. 1 is equipped with flue gas dedusting two horizontal dry type electrostatic 46/12/4 formula x 9/0, 350. Electro were upgraded in 1995, a modernized version. Constructive solution is in four fields with step of 350 mm. Fields are sectionalizate electro mechanical and electrical. The two sections of a field are powered by a single high voltage equipment.

No energy groups. 2, 3 and 4 are equipped with flue gas dedusting two horizontal dry type electrostatic 54/12/3 formula x 9/0,300. Were performed electro various modernization works, most recently in 1989-1990. Constructive solution in 3 fields with step of 300 mm.

Fields are sectionalizate electro mechanical and electrical. The two sections of a field are powered by a single high voltage equipment. No energy group. 5 is equipped with flue gas dedusting two horizontal dry type electrostatic 55/12/2 formula x 9 + 1 x 10 / 0.300.

Electro were upgraded in 1988-1989. Constructive solution in 3 fields with step of 300 mm. Fields are sectionalizate electro mechanical and electrical. The two sections of a field are powered by a single high voltage equipment. No energy group. 6 is equipped with flue gas dedusting two horizontal dry type electrostatic 56/12/3 formula x 9 / 0,300.

Electro were upgraded in 1991-1992. Constructive solution in 3 fields with step of 300 mm. Fields are sectionalizate electro mechanical and electrical. The two sections of a field are powered by a single high voltage equipment.[1]

## 2. EUROPEAN DIRECTIVES TRANSPOSED IN ROMANIAN LEGISLATION

The current legislation concerning the atmospheric noxes regime is accomplished through two environment directives belonging to the European Union which concern the big burning installations from the electric and thermal energy production sector:

- *The directive concerning the big burning centrals* ***(LCP, 2001/80/CE),*** *transposed in* HG no. 541/2003 (completed and modified by HG 322/2005) concerning the establishment of some measures for the limitation of some pollutants that come from big burning installations' emissions in the air. The transpose of the directive 2001/80/CE (LCP) into the national legislation is made in order for Romania to achieve some environment performances according to the European Union politic to improve air's quality;[2]
- *The directive concerning the prevention and control of the industrial pollution* ***(IPPC, 96/61/CE),*** transposed in Law no. 84/2006 for the approval of OUG no. 152/2005 concerning the integrated prevention and control of the pollution (abrogates and replaces OUG no. 34/2002). The directive 96/61/CE (IPPC) is the only directive focused on the industrial sector and it refers to the air as well as to the water and waste.[3]

### 3. THE REDUCTION OF EMISSIONS POWDERS - MINTIA THERMOELECTRICAL POWER

Another aspect of air and soil pollution with particulate matter, is the phenomenon of entrainment by air currents from the ashes fly ash and slag deposits in the period when some compartments are subject to cannot or is not in operation (fig. no.1).[4]

This phenomenon occurs especially during dry periods with low humidity and winds relatively strong. The winnow coal ash is more intense than coal ash due to grain and specific gravity much lower.

**Fig. no.1. The winnow ashes in wind conditions and low atmospheric humidity**

To avoid these phenomena, even at the design stage of cannot deposits were designed to stop winnow ways, first by covering the free surface and dried with a sodium silicate film.

This technical solution failed due to some major drawbacks: high costs of working materials, the mechanical strength of film and practically disappears after the first rain.

His appeal to other variants practically unfeasible such as topsoil or aggregate coverage of river that they have created other ecological imbalances in the area, since the required coverage area is about 60 hectares which would require a volume of about 100,000 cubic meters of river aggregate earth or vegetable.

Surface protection by grassing solution applied to deposits of lignite ash was not accepted because the chemical characteristics of coal ash from the ash differs significantly from the lignite or lignite power plants results obtained were not very convincing.

Since the time required to protect the deposit surface is very short, the order of 15 to 20 days in the summer of 2003 was experienced film method of emulsion bitumen, the Thermal Timisoara assimilated and adapted to the specific conditions Mintia power plant (fig. no.2).[4]

Given the emergency situation created by the very favorable weather conditions winnow to experienced phenomena in collaboration with a firm specializing in road construction and asphalt coatings, based on the results of the Thermal Timisoara, cationic bituminous emulsion coating of a surface about 3 hectares, situated right on the main air stream and scatter the ashes of the train depot. As seen in the image of fig. no.2, bituminous carpet completely eliminated winnow phenomenon that retain their physical - mechanical and in case of rain or bituminous carpet pedestrians.

**Fig.no.2. Bituminous carpet eliminates the appearance of gray winnow**

This film, thick 3-4 mm layer formed with a mass of ash asphalt plastic does not allow training by wind but by flooding ash hydroblend deposit with the fragment, leaving the bottom due to the higher specific weight hidroblend.[1]

From the technical solution has been a success, but the costs of such operations exceeded the financial possibilities of the society as such to appeal to the more affordable solution that is wet the surface dry, subject cannot work (fig. no.3).

This solution proved to be effective protection both technical and economic as water

**Fig. no.3. Wet the surface of deposit - effective solution to protect the winnow**

source was provided by circuits slag and ash disposal from stations hidroblend pump (fig. no.4), for wetting is affecting a circuit that recycled water was pumped from the warehouse.

Proper wetting was achieved through the practice of holes on a pipe special generator mounted on the perimetric storage.[4]

Expenses incurred pursuant to this solution were significantly lower than bituminous solution Skinning variant since the necessary materials consisted only of reusable pipelines, already in storage.

Wetting was carried out under constant supervision of operating personnel, applying the procedure only when the weather requires.

**Fig. no.4. Pipe with holes raw water wetting of the surface storage**

Note that Skinning, whatever it applied, it was necessary only for a maximum period of four months, because restarting the process of discharge into raised section of the storage. It has also been the main reason was dropped Skinning bitumen, very expensive.

If storage technology would remain in reserve in a year, Skinning bituminous emulsion would become competitive even financially.[1]

Basic protection against involvement ash dams by air currents was performed successfully by covering with topsoil and grassing (fig. no.5), the circuit they reentrance landscape of the area.

**Fig. no.6. Storage of clay - ash Mures**

**Fig. no.7. Storage of clay - ash Bejan**

He went on the perimeter dike no. 1 storage in topsoil and planted grass and shrubs essences weak solution in addition to favorable landscape effects, led to stabilization and deposit protection dam itself.

The amount of slag and ash discharged from the hydraulic plant in a year is 1 ÷ 1.3 million tons, fig. no.6 and no.7. To this end, use two clay deposits - ash, located one in the bed of the river Mures major on the right bank, an area of approx. 67 ha and another place called Bejan-Tarnava Valley, approx. 4 km from the power plants, occupying an area of approx. 80 ha. Slag and ash is captured and transported hydraulically in a mixture of approx. 10 parts water to 1 part solid.

At present, thermal power plant is equipped with the following [4]:

- a station with four pumps Bagger type having the characteristics: Q=1085 $m^3$/h and P=765 kPa, step I;
- a station with 4 pumps of type Bagger, which operates in series with the first, with characteristics: Q = 1085 $m^3$/h and P = 785 kPa, step II.

These two stations provide slag and ash disposal from energy groups 1, 2, 3, the total height H=160 m $H_2O$.

No energy groups. 4, 5, 6 are made also two stations operating in series:

- a station with three pumps Bagger type having the characteristics: Q=1085 $m^3$/h and P=765 kPa;

- a station with a pump having the characteristics: Q = 1085 $m^3$/h and P = 785 kPa;

- a station with three pumps Bagger type having the characteristics: Q=1085 $m^3$/h and P=765 kPa.

Stations are designed and built to run on two lines, the other two being the backup. Wash water pump circuits slag and ash are located in the engine room to share - 4.00 m. The hydraulic transport of the mixture is made by five metal pipes (wires Bagger). Hydraulic transport water from the slag and ash, after clearing the deposit of slag and ash, is captured by wells and recirculated through the recirculation Bagger two wires.

## 4. CONCLUSIONS

From theoretical and practical study found that:

- bituminous carpet completely removed from the warehouse winnow phenomenonthat retain their physical - mechanical and in case of rain or bituminous carpetpedestrians. From the technical solution has been a success, but the costs of suchoperations exceeded the financial possibilities of the society as such to appeal to themore affordable solution that is wet the surface dry, subject cannot work.

- moistening dry surface – this solution has proved effective protection both technicaland economical source of water as was provided by circuits slag and ash disposal in pumping stations for wetting is affecting hidroblend a circuit that was pumpe circulated water from the warehouse. Expenses incurred pursuant to this solutionwere significantly lower than bituminous solution Skinning variant since the necessary materials consisted only of reusable pipelines, already in storage.

## REFERENCES

**[1] Ciolea D.I.** - *Situația actuală pe plan mondial şi în România, privind reducerea noxelor atmosferice rezultate din arderea combustibililor solizi în C.E.T.*, Referat II teza de doctorat, Petroşani, 2005

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Scientific Reviewers:
Prof. PhD. Eng. Romulus Sarbu

# ASPECTS FOR AIR POLLUTANT EMISSIONS RESULTING FROM THE C.E.T. MINTIA DEVA

**CIOLEA DANIELA IONELA[*]**
**DUNCA EMILIA[**]**

**Abstract:** *This paper presents aspects of atmospheric emissions of pollutants - $SO_2$, $NO_x$, PM- from C.T.E. Mintia. The diagrams presented are easily observe the evolution of "the good" emissions since 1980-2010, but also fuel and electricity and heat directly related to emissions from 2007-2010.*

**Key words:** *emissions, pollutant, energie, mediu.*

## 1. INTRODUCTION

S.C. Electrocentrale Deva S.A. main activity is production of electricity and heat and is a co-generation plant with aconversion efficiency of approx. 32%. Cogeneration, the combined solution and simultaneous production of electricity and heat, the energy benefits, economic and environmental fall it presents is in the category 'clean' technologies for energy production. [1]

The reduction of the emissions from the big burning installations is accomplished through different methods, but mainly the measures considered are divided in two categories, respectively primary measures and secondary measurements.

## 2. EVALUATION OF EMISSIONS OF POLLUTANTS IN ATMOSPHERE

Main pollutants in the atmosphere emission values for 2010 are, fig.no. 1[4]:

***The emissions pollutans***

Evaluation of emissions of pollutants in atmosphere (fig.no.2) (concentration ofgaseous pollutants and particulate) is to stack on each channel and flue gas from boilers electro energy by:

- continuous measurement (on-line);
- drawings of samples and laboratory analysis;
- calculate the amount of pollutant (emission) discharged into the atmosphere: *"Methodology for assessing the operational emissions of $SO_2$, $NO_x$, dust and $CO_2$ from thermal and thermoelectric PE-1001/1994".*

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[*] *Assist. Prof. PhD. Eng., University of Petrosani*
[**] *Lecturer PhD. Eng., University of Petrosani*

Emissions of pollutants are influenced by the quality of fuels (coal oil, natural gas). The methodology is based on fuel consumption - *B*, fuel value - $H_i$ and emission factors - *e*:

$$E = B \cdot H_i \cdot e \quad \text{[Kg]} \qquad (1)$$

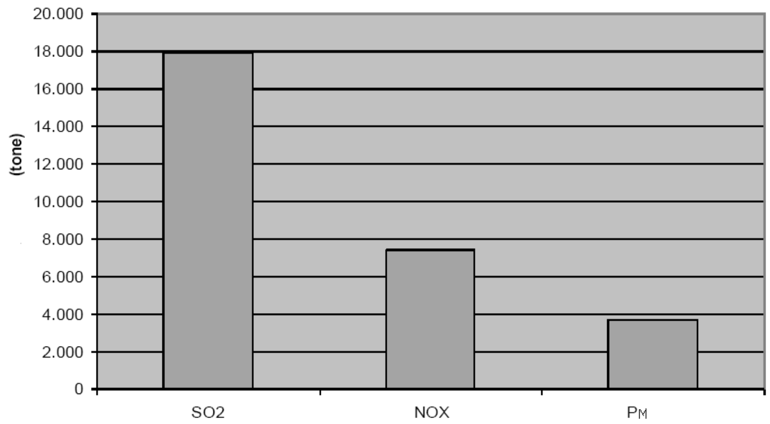


**Fig.no.1. Emissions of pollutants in atmosphere - 2010**

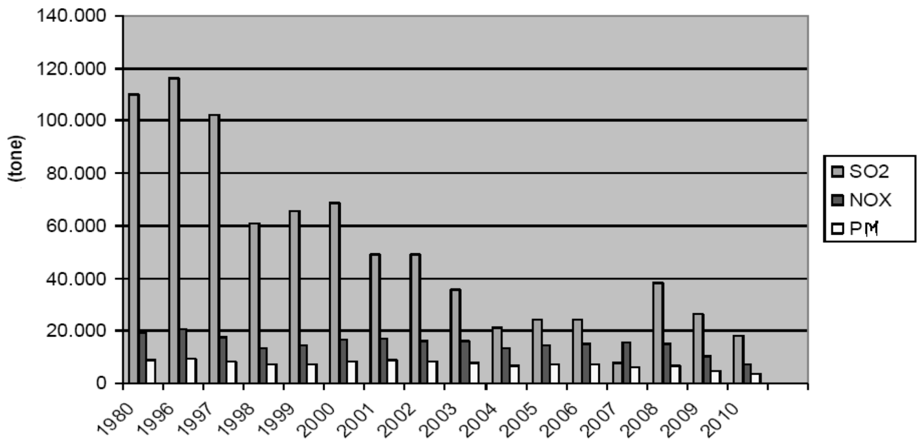


**Fig.no.2. Emissions of pollutants in atmosphere – 1980-2010**

The electricity and heat produced depending on fuel is presented in fig. no.3 [4]:

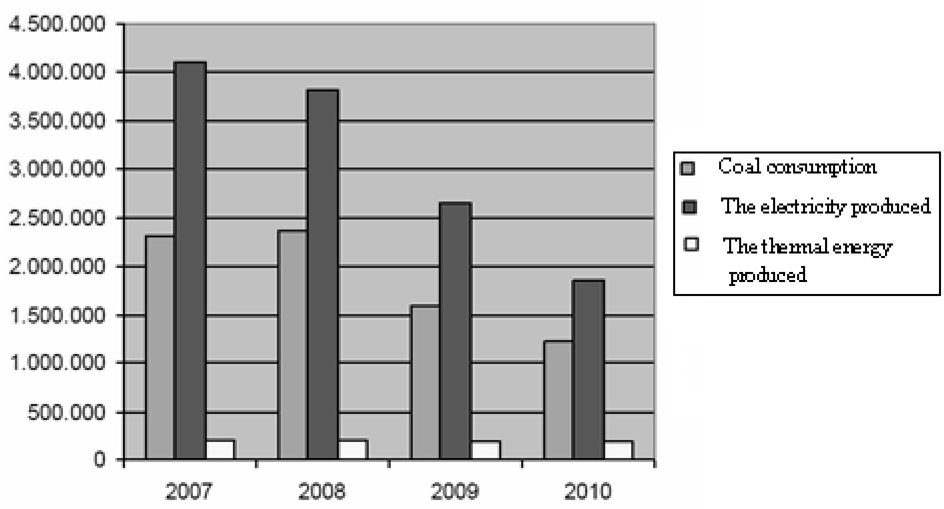


**Fig.no.3. The electricity and heat produced depending on fuel**

The emission situation polunate 2007-2010, is presented in fig.no.4 [4]:

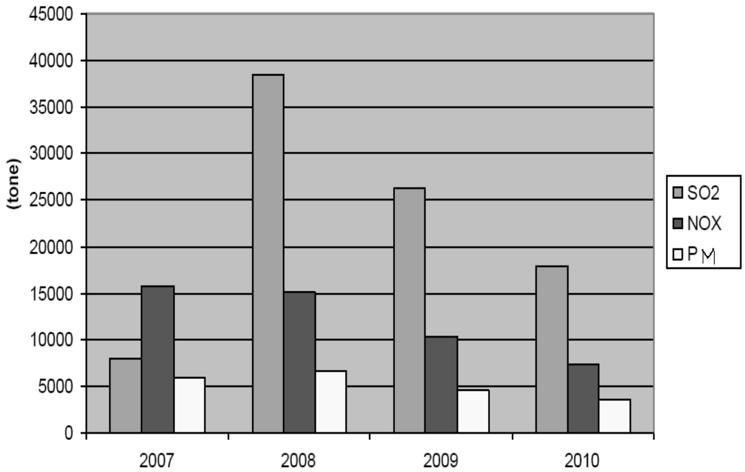


**Fig.no.4. The emission situation in 2007-2010**

Emissions monitoring is done through a continuous monitoring system and useexisting energy groups conditioning equipment and measuring gaseous components in the sample basket with sequential sampling gaseous concentrations to determined $SO_2$, $NO_x$ and particulates, independent measuring the relevant process operation parameters (% of $O_2$, temperature, pressure, humidity and flow of combustion gases to the chimney).

***The imissions pollutans***

The impact of pollutants on air quality generated annually is determined by mathematical modeling of the concentrations associated fields and values of threshold limit values, which are the criteria for assessing air quality. Simulation of pollutant dispersion in the atmosphere is leading by mathematical modeling of pollutant emissions, taking account of aerological and meteorological data.

***Ambient air quality***

Impact assessment of the influence sensitive receptor is compared with threshold limit values and values under national law (*Law no.655/2001, STAS 12574/1987*) and the European Union, transposed into national law by *MO nr.592/2002*-approval of the Norms on the limit values, threshold values and criteria and evaluation methodsof sulfur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter ($PM_{10}$ and $PM_{2,5}$), lead, benzene, carbon monoxide and ozone in ambient air. Mathematical models have better results when used for immediate estimates of timeintervals (annual).[4]

## 3. THE EMISSION/IMISSION LIMIT VALUES FOR LARGE COMBUSTION PLANTS

The emission limit values for large combustion plants is presented in tabel no.1[2]:

**Tabel no.1. The emission limit values for large combustion plants**

| The fuel type | Emission | P [MW] | VLE [mg/m$^3$] |
|---|---|---|---|
| **Solid fuel** **$O_2$ of reference: 6%** | $SO_2$ | $50 \leq P < 100$ | 2000 |
| | | $100 \leq P < 500$ | Linear decrease from 2000 to 400 |
| | | $P \geq 500$ | 400 |
| | $NO_2$ | $50 \leq P < 500$ | 600 |
| | | $P \geq 500$ | 200 |
| | PM | $P < 500$ | 100 |
| | | $P \geq 500$ | 50 |

In tabel no.2 is presented the imission limit values for large combustion plants.[3]

**Tabel no.2. The imission limit values**

| **Substance pollutant** | **MAC [μg/m$^3_N$]** | | |
|---|---|---|---|
| | **Average short-term** | | **Long-term average annual** |
| | **1 h** | **The daily** | |
| **$SO_2$** | 350 | 125 | 20 |
| **$NO_2$** | 200 | - | 40<br>30 |
| **$PM_{10}$** | - | 50 | 40 to protect human health<br>20 for plant health protection |

## 4. CONCLUSIONS

➢ Big burning installations on solid fuels, as the one at C.T.E. Mintia Deva, which makes the object of these papers, contribute considerably to the atmospheric noxes emissions ($SO_2$, $NO_x$, CO, $CO_2$), flying ashes (dust in suspension-aerosols, sedimentable dust) and smut, needing their complying to the best available techniques (BAT) demands.

➢ Through the air dispersion of $SO_2$ and $NO_x$ and from the atmospheric oxidation of these highly watersoluble gases, appreciable quantities of hard acids appear (sulfuric and nitric acid) which produce a certain degree of acid precipitations (rain and fog), which fall on the soil as *acid rains* and determine negative effects on all of the natural and artificial environment's factors. The $CO_2$ emissions lead to the atmosphere's warming and produces *the greenhouse effect*.

**5. REFERENCES**

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Scientific Reviewers:
Prof. PhD. Eng. Romulus Sarbu

# AGROCHEMICAL STUDY OF INNER DUMP MATERIAL TISMANA II

**EPURE GHEORGHE-DORU***

**Abstract:** *The study was prepared agrochemical a whole works the delineation of homogeneous plots against soil type, crop and fertilization treatments, the average soil sampling in each plot so defined agrochemical, perform laboratory analysis and representation agrochemical. Based on that, on cartograms, land surfaces with similar agrochemical characteristics differentiated the application of fertilizers and amendments. This study was conducted on material from landfill to achieve ecological reconstruction of the deposit of tailings Tismana II.*

**Key words:** *deposit of tailings, ecological reconstruction, soil,*

## 1. INTRODUCTION

L'étude est basée utilisation des produits agrochimiques d'engrais et d'amendements pour assurer la réalisation des rendements élevés et la qualité, le maximum d'efficacité économique, l'augmentation progressive ou maintenir le haut niveau de fertilité des sols et des eaux souterraines. Il enregistre aussi le statut et les tendances de changement de qualité du sol sous l'influence de son utilisation d'engrais et d'amendements, restauration de la couverture du sol et l'impact de l'industrialisation sur l'environnement

## 2. L' ETUDE AGROCHIMIQUE

Voici les recommandations pour l'analyse de l'agrochimie à l'aide d'engrais et d'amendements tel que requis par les plantes cultivées et l'offre en éléments nutritifs du sol.

L'étude couvre les phases suivantes du travail de l'agrochimie préparé:

A. La phase préparatoire.
B. Phase de terrain.
C. Laboratoire de phase.
D. Phase de bureau.
E. La phase finale.

**A. La phase préparatoire**

Cette phase comprenait les éléments suivants:

* *student PhD. Eng. - University of Petrosani - Mining Faculty*

- contactez l'unité réceptrice (E.M. Rovinari);
- préparation de la base topographique pour l'étude de l'agrochimie;
- matériel de préparation des terres pour l'échantillonnage des sols agrochimiques.

**B. Phase de terrain**

Il était composé des éléments suivants:

- présentation à l'unité de réception, la préparation du plan de travail, la reconnaissance de la terre;
- bonne collecte des échantillons de sol agrochimiques;
- d'orientation et de champ de contrôle.

Le plan de travail préparé automne suivant:

- la surface du périmètre;
- nombre d'échantillons de sol prélevés.

Dans le domaine de 30 hectares de décharge intérieurs Tismana II ont été recueillies en moyenne 121 agrochimique échantillons de sol.

Zone de traçage récolte a été de 0,25 ÷ 0,30 ha, plan d'envergure et la profondeur d'échantillonnage 1:2000 a été de 0 à 20 cm.

**C. Laboratoire de phase**

Cette phase a été réalisée dans le sol en laboratoire et agrochimiques Bureau des études et comprend tous les tests de laboratoire Gorj opérations réelles à l'arrivée au laboratoire et le rapport de l'enseignement secteur de l'analyse cartographique.

Les échantillons ont été enregistrés en leur donnant le nombre de laboratoires en conformité avec le système de numérotation adopté par le laboratoire de l'OSPA Gorj.

Dans cette phase ont été réalisées par analyse de plusieurs séries, grandes et petites.

➢ ***Analyse des grandes séries***

Indicateurs pour la gamme complète des échantillons de produits agrochimiques ont été représentés par:

- pH en suspension aqueuse pH $H_2O$ - a conduit à un sol ratio: l'eau 1:2,5, potentiomètre avec un couple d'électrodes de verre au calomel;
- teneur en phosphore mobile - Egner-Riehm déterminée par la méthode - Domingue, l'extrait d'acétate d'ammonium - lactate à pH 3,7 (P-AL);
- mobiles teneur en potassium - déterminé dans la solution d'extraction comme le phosphore mobile, à savoir K-AL.

➢ ***Analyse des petites séries***

Des indicateurs supplémentaires pour les petites séries d'échantillons de produits agrochimiques sont les suivants: 10% des échantillons de sol, sélectionné pour représenter grands types de sols du territoire cartographié, la teneur en humus est déterminé par Walkley-Black méthode oxydimétrie modifiée par Gogoaşă.

Les données utilisées pour calculer l'indice utilisé pour évaluer le degré d'azote $IN = \frac{humus \cdot V_{AH}}{100}$ du sol assurance d'azote

**D. Phase de bureau**

Comprend les activités dirigées par la cartographie et l'étude - agrochimie département - de la réception du rapport d'analyse et de finaliser l’agrochimie fichier, y compris l'approbation des travaux.

La phase de bureau est à finaliser la base de la phase topographique, dessin cartogrammes, bulletins avec des données analytiques supplémentaires, des diagrammes et des états de synthèse sur la réaction du sol et le niveau de phosphore et de potassium approvisionnement.

Dans la phase documentaire et les recommandations sont des doses d'engrais chimiques, des modifications, basées sur les rendements attendus et de s'approvisionner en nutriments du sol.

En ce qui concerne l'état de la réaction du sol, la situation et de synthèse des tests de laboratoire, les éléments suivants:

- 15,37 hectares, représentant 51% de la superficie totale de 30 ha, étaient faiblement réaction acide,
- 12,15 hectares, représentant 41% du total, une réaction neutre,
- 2,48 ha, représentant 8% du total, ont été faibles réactions alcalines.

De ce qui précède, il semble que la réaction du sol (pH) est la plage optimale pour le développement des cultures de fruits et de baies dans des conditions normales. (Fig. 1).

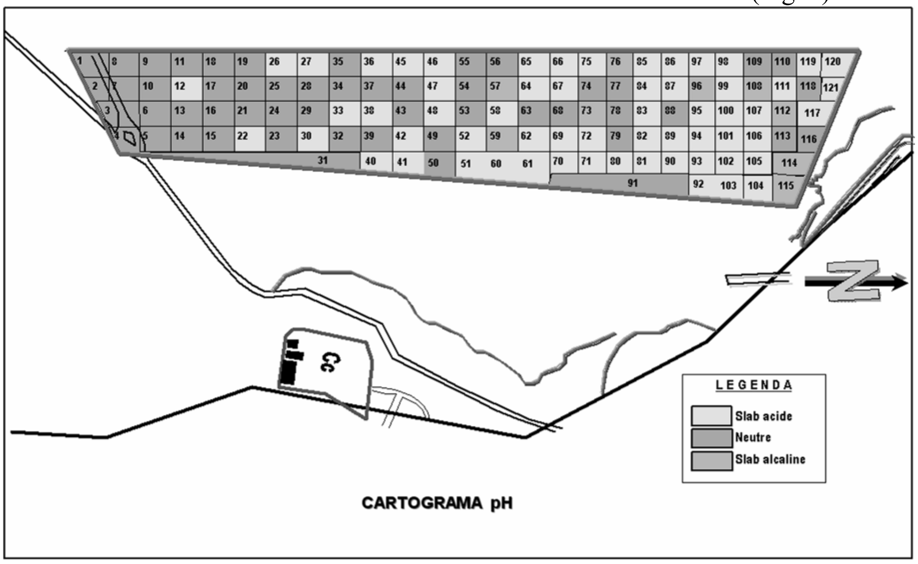


Fig. 1 Cartogramme pH

### 3. ÉTABLIR LA NECESSITE D'ENGRAIS CHIMIQUES

Les engrais sont des moyens fondamentaux de production a augmentés dans la plupart des plantes de culture et selon la dose appliquée et les conditions dans lesquelles ils peuvent influencer à la fois la croissance des plantes positifs et négatifs et de développement [3]

Besoins en minéraux nutritifs des plantes cultivées pour répondre à des formes entièrement assimilées des réserves existantes dans le sol ou fixé au sol par des agents biologiques, d'engrais naturel (appliquée régulièrement) et d'engrais chimiques (produits par l'industrie) qui doivent compléter le stock de minéraux au niveau requis pour la formation de cultures économiques.

Invariablement trouve l'analyse agrochimique des changements de réaction du sol et la teneur en phosphore et en potassium mobiles dans les formes et dans de nombreux cas et l'accumulation de nitrate d'ammonium dans le sol et fécondé. [4]

Engrais ne viennent que pour compléter le stock de nutriments dans le sol, ce qui rend nécessaire de faire varier leur dosage en fonction des besoins nutritionnels des cultures et l'état de fertilité du sol. (Fig. 2.)

#### 3.1. Les engrais chimiques avec de l'azote

Sauf pour le riz (terres cultivées inondées périodiquement), toutes les autres plantes cultivées – non légumineuse prendre l'azote du sol sous forme de nitrate.

La dose optimale est atteinte par l'expérimentation à stationnaire et une rotation des cultures qui est incorporé en eux et l'effet résiduel des engrais azotés appliqués aux cultures avant, et l'influence spécifique sur la formation des nitrates dernier et d'autres processus physiques et biologiques dans le sol.

Interprétation de l'état de l'assurance du sol avec de l'azote est donnée par:

$$IN = \frac{H \cdot V}{100} \qquad (1.)$$

où:

H = quantité d'humus;

V = degré de saturation en bases.

Pour surface de 30 ha de décharge approvisionnement en azote a étudié la situation est la suivante:

- zone entière (30 ha) dans 100% a une alimentation faible en azote (IN = 0,1 à 0,3).

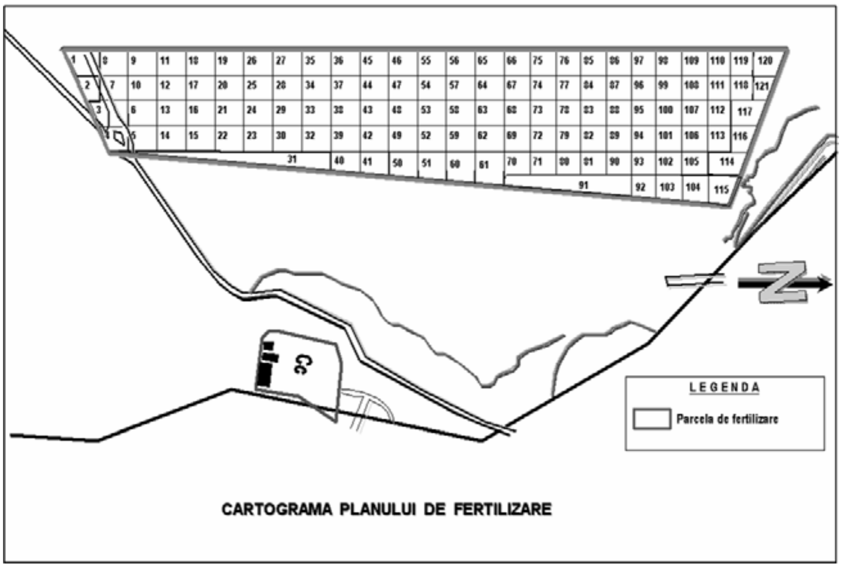


Fig. 2 Plan de fertilisation cartogramme

La dose recommandée d'application d'engrais azoté économiquement optimale.

$$DOE_{\text{de N in kg/ha s.a.}} = (R_p \cdot C_s \cdot C_{IN} \cdot C_p) + (N_{pp} - N_g + N_{RA}) \qquad (2.)$$

où:

- $R_p$ = récolte prévue, kg/ha
- $C_s$ = consommation spécifique
- $C_{IN}$ = pondération en fonction de ces
- $C_p$ = pondération en fonction de veiller à phosphore du sol
- $N_{pp}$ = influence de la pré installation, kg/ha
- $N_{RA}$ = quantité d'azote ajoutées ou supprimées en fonction de l'approvisionnement en eau du sol.

**3.2. Les engrais chimiques au phosphore**

L'effet des engrais de phosphore sur le niveau et la qualité des cultures dépend de nombreux facteurs qui sont étroitement liés les uns aux autres au cours de la végétation.

Parmi ces les plus importantes sont: les caractéristiques des espèces et variétés, caractéristiques physico-chimiques du sol, conditions climatiques, le type de technologie utilisée dans les engrais et son application dans le sol, teneur du sol en phosphate des plantes disponibles, et le degré d'assurance avec différents nutriments du sol, en particulier l'azote.

✓ **Assurance état du sol en phosphore**

Des données de laboratoire et de synthèse d'assurance le statut d'État du sol en phosphore mobile à la surface de 30 ha a étudié le dump résultant:

- 0,50 ha, 2% de la superficie totale, a une alimentation très faible en phosphore;
- 3,22 ha, 11% de la superficie totale, a une alimentation faible en phosphore;
- 5,70 ha, 19% de la superficie totale, a un apport de phosphore moyennes;
- 4,46 ha, 15% du total, ont un bon approvisionnement de phosphore;
- 16,12 hectares, le pourcentage de 53% de la superficie totale, a une alimentation très bonne du phosphore.

A partir des résultats ci-dessus que les 68% de l'offre totale de phosphore sont bons et très bons et 32 %de l'offre totale est très pauvre.

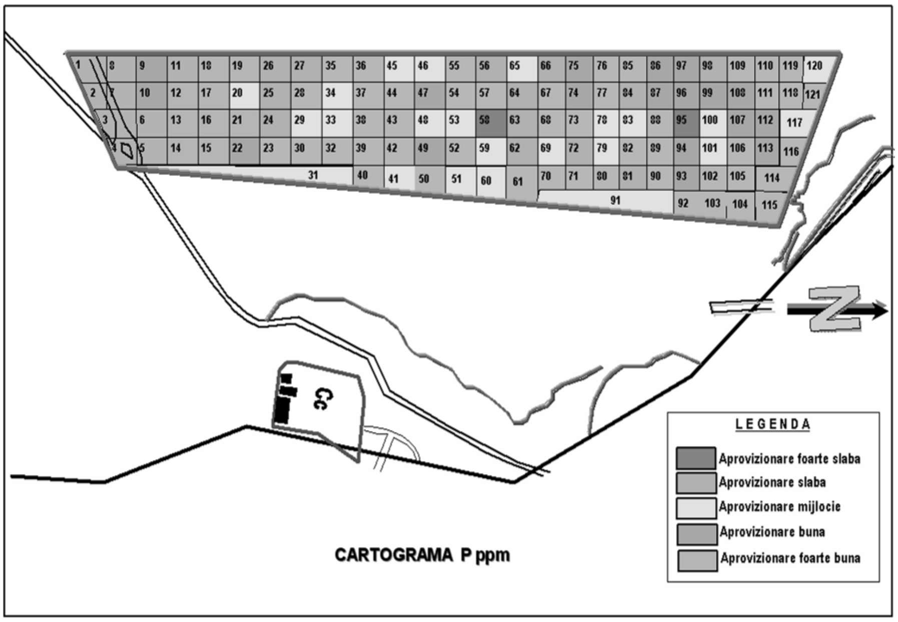


Fig. 3 Teneur en phosphore cartogramme

**3.3. Les engrais chimiques par du potassium**

Besoins en engrais de potassium est soumise à un certain nombre de facteurs, les plus importants sont: le type de sol, la culture de plantes et de l'offre du sol avec d'autres nutriments.

Les doses d'engrais varie considérablement selon le contenu du sol de formes disponibles de potassium, de l'espèce, la production prévue.

✓ ***Assurance état du sol en potassium***

Suite de laboratoire et de synthèse du statut d'assurance état du sol avec le mobile de potassium pour la zone d'étude, la zone de 30 ha, ce qui suit:

- 29,26 hectares, représentant 98% du total, ont une alimentation faible en potassium (fig. 4);
- 0,74 ha, 2% de la superficie totale, dispose d'une alimentation moyenne de potassium.

Dans 98% de l'offre totale de potassium mobiles est faible, nécessitant économiques doses optimales d'engrais contenant du potassium.

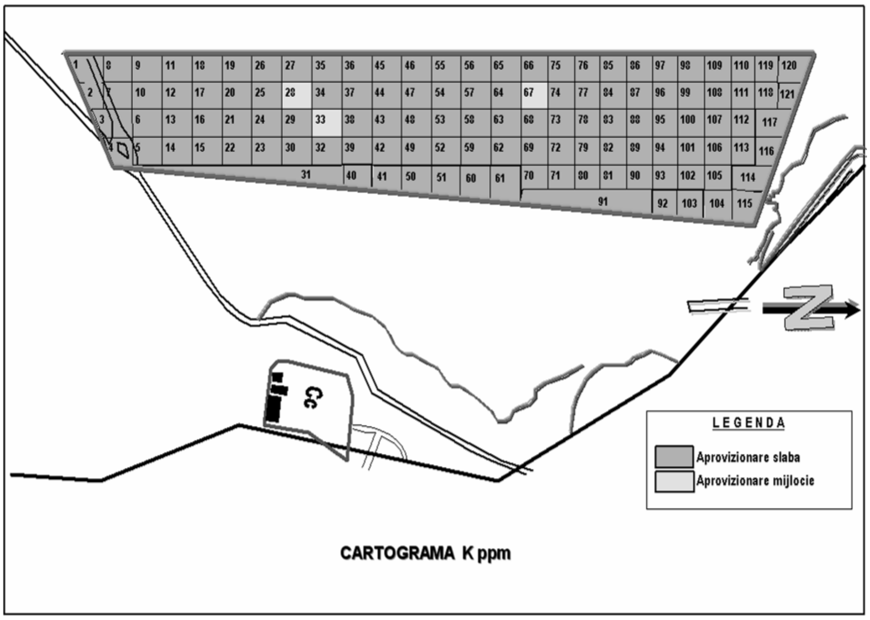


Fig. 4. Cartogramme teneur en potassium

**4. LES ENGRAIS ORGANIQUES (NATURELS)**

Outre leur rôle en tant que sources de nutriments, le fumier, le lisier et le fumier des animaux d'autres non fermentés, influencent la croissance des plantes bonnes et développement et en améliorant les caractéristiques physiques du sol et biologiques.

Toutes les cultures réagissent positivement à la fertilisation avec du fumier rationnelle dans les conditions du sol. [3]

En comparaison, les légumes, les pommes de terre, betteraves, le maïs et la luzerne font des ordures meilleur effet dans l'action directe, tandis que les céréales d'automne et de printemps de l'action ont restantes (après) la poubelle lancer appliquée à houe.

L'équivalence de l'effet du fumier et d'engrais sur les plantes avec des engrais chimiques facteurs suivants sont pris en compte par l'utilisation des nutriments contenus dans les engrais organiques.

**Tableau 1. Utiliser les coefficients des nutriments contenus dans les engrais organiques**

| Spécification | L'an d'application | L'an 2 | L'an 3 |
|---|---|---|---|
| N | 25÷30 | 20÷30 | 10÷20 |
| $P_2O_5$ | 25÷35 | 15÷25 | 10÷14 |
| $K_2O$ | 45÷55 | 25÷35 | 15÷25 |

Ainsi, une tonne de fumier avec 0,6% de N, 0,4% $P_2O_5$ et $K_2O$ 0,7%, résultant de la fermentation de la plate-forme (pour 3-4 mois de fumier de bovins avec de la litière) équivaut à l'effet sur les plantes avec les quantités suivantes (kg) de nutriments provenant des engrais chimiques.

**Tableau 2. Effets sur les végétaux avec les quantités suivantes (kg) de nutriments provenant des engrais chimiques**

| Spécification | L'an d'application | L'an 2 | L'an 3 |
|---|---|---|---|
| N | 1,6÷1,8 | 1,2÷1,4 | 0,8÷1,0 |
| $P_2O_5$ | 1,0÷1,2 | 0,7÷0,8 | 0,4÷0,5 |
| $K_2O$ | 3,3÷3,5 | 1,8÷2,0 | 1,2÷1,4. |

La consommation moyenne des nutriments dans les formes assimilables à du fumier et autres engrais organiques (naturels) ou chimiquement déterminé, peut être évaluée en utilisant des expressions:

$$N_g = Gt_{1\to 3} \cdot 10 \cdot Nt(0{,}06 + \frac{0{,}27}{t_{1\to 3}}) \qquad (3.)$$

$$P_g = Gt_{1\to 3} \cdot 10 \cdot Pt(0{,}07 + \frac{0{,}24}{t_{1\to 3}}) \qquad (4.)$$

$$K_g = Gt_{1\to 3} \cdot 10 \cdot Kt(\frac{0{,}5}{t_{1\to 3}}) \qquad (5.)$$

où:

- Ng, PG et Kg = contributions de N, $P_2O_5$ et $K_2O$ kg / ha d'engrais organiques;

- $Gt_{1\to 3}$ = quantité de déchets et autres engrais organiques (en tonnes / ha) appliqué dans le plan (t = 1) avant la culture (t = 2) et la culture ante avant (t = 3);

- Nt, Pt et Kt = teneur totale en N, P et K dans le fumier et autres engrais organiques appliqués dans le plan de pré et cultures ante avant en% de N, $P_2O_5$ et $K_2O$ en masse humide (à l'humidité de l'application) d'engrais.

## 5. CONCLUSIONS

Suite à l'analyse effectuée dans le domaine, le bureau et ont laboratoire les conclusions suivantes:

- trouve invariablement une analyse agrochimique des changements de réaction du sol et la teneur en phosphore et en potassium mobiles dans les formes et dans de nombreux cas et l'accumulation de nitrate d'ammonium et dans les sols fertilisés;

- zone entière (30 ha) dans 100% a une alimentation faible en azote (IN = 0,1 à 0,3);

- sur les 68% de l'offre totale de phosphore est bon et très bon et 32 % de l'offre totale est très pauvre;

- sur 98% de l'offre totale de potassium mobiles est faible;

- croissance de la plante du fumier influences et développement et l'amélioration de la physique et la terre biologiques.

Il est recommandé d'appliquer des engrais organiques tous les 4-5 ans dans des quantités de 4-6 t/ha, mais cette année a été reçue d'engrais azotés.

Selon l'offre du sol et des nutriments culturaux à être situé fera des recommandations pour les doses d'engrais chimiques, la substance active dans le plan de fertilisation dépotoir Tismana II surface intérieure de 30 hectares.

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Scientific Reviewers:
Prof. PhD. Eng. Romulus Sarbu

# SITE SELECTION AND CHARACTERIZATION FOR $CO_2$ STORAGE CAPACITY ESTIMATION

**ROTEA OANA ELENA***

## 1. INTRODUCTION

Carbon dioxide ($CO_2$) capture and geological storage (CCS) is a means of reducing greenhouse gas emissions into the atmosphere. The determination of carbon dioxide storage capacity and the selection and characterization of potential sites for $CO_2$ storage are key issues in taking CCS forward.

A distinction is made between available pore volume (a theoretical estimate of the amount of pore space that can be used to store CO2 in subsurface geologic formations) and storage capacity (the pore volume constrained by economic or engineering feasibility limitations). Because of uncertainties inherent in subsurface evaluation, exact quantification of geological properties is not possible and therefore storage capacity is always, at best, an approximation of the amount of pore space into which $CO_2$ can be injected. Hence, the likelihood of contingent and prospective storage volumes achieving commerciality is determined probabilistically, utilizing high, low and best estimates. The selection of storage sites suitable for significant volumes of $CO_2$ comprises mainly geological evaluation of the applicable storage system (e.g. saline formations, depleted or near depleted oil and gas reservoirs and/or coal systems) on various levels of detail. Site characterization is the most time-consuming and costly part of the $CO_2$ storage site selection process. Site characterization typically involves collection and analysis of more detailed information than basin assessment investigations and may involve re-evaluation of regional geology and generation of new data and/or updating of existing data such as static (geologic and seismic) and dynamic (flow simulation and injection) data.

The ultimate goal of a storage project is commercial site deployment, which requires all the geological, engineering, economic and regulatory considerations of a site being taken into account. Site deployment therefore requires estimation of *operational storage capacity*.

Geological storage of carbon dioxide is the process whereby $CO_2$ captured and separated from a source is transported and injected into the geological subsurface for long-term storage. Conventional geological constraints on finding the right place to store $CO_2$ include having a porous and permeable reservoir rock (e.g. sandstone) to allow injection and storage of the $CO_2$, overlain by an impermeable seal rock (e.g. clay stone) to retain the injected CO2 in the geological subsurface. However, recent studies suggest that due to the behavior of $CO_2$ in the subsurface, additional mechanisms may also be effective for long term safe storage of $CO_2$.

* *student PhD. Eng., University of Petrosani*

## 2. GEOLOGICAL STORAGE SYSTEMS FOR $CO_2$

Carbon dioxide can be stored geologically in a variety of different “storage systems” (Figure 1). Of these, the three main alternatives are: saline formations, depleted oil and gas fields, and coal systems.

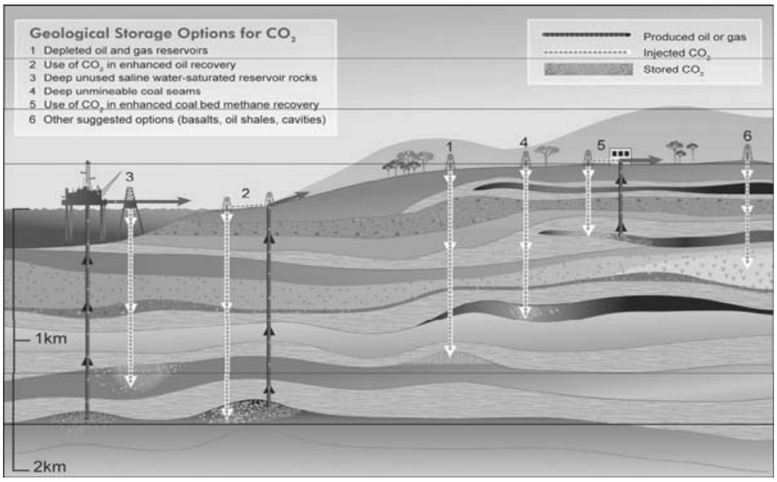


Figure 1: Options for the geological storage of carbon dioxide

## 3. SALINE FORMATIONS

Saline formations are deep porous sedimentary rocks saturated with formation waters that are considered unsuitable for human consumption or agricultural or industrial use. They have been identified by many studies as one of the best potential options for large volume geological storage of $CO_2$. Supercritical $CO_2$ can be effectively stored in deep saline formations because of its high density and high solubility in formation water at the relatively high formation pressures encountered. However, these formations are commonly less understood (in comparison to shallow freshwater aquifers or hydrocarbon bearing reservoirs) and any assessment of their $CO_2$ storage potential typically includes significant uncertainty because of the lack or scarcity of subsurface data. In addition, the containment potential of the seal rock is usually untested and there is uncertainty regarding potential for undiscovered natural resources. However, their main advantages are that they are distributed widely over the world and their potential storage capacity is large. $CO_2$ can be stored in saline formations by a number of different trapping mechanisms, including structural/stratigraphic, hydrodynamic, residual, solubility and mineral trapping.

## 4. OIL AND GAS FIELDS – DEPLETED OR ENHANCED RECOVERY

$CO_2$ can be geologically stored in oil and gas fields once they have been depleted and are no longer producing, or can be used to enhance oil or gas recovery (EOR/EGR) in fields that are still producing. The main advantages of storage in depleted oil and gas fields over saline formations is that the containment potential of the site has been proven by the retention of hydrocarbons for millions of years and there are typically large amounts of geological and engineering data available for detailed site characterization. Possible drawbacks, however, may be the physical size of the structural/stratigraphic trap (i.e. potential storage volume may be limited), the possibility that pore pressure depletion has led to pore collapse (which will reduce the potential storage volume), the presence of existing old wells which may provide potential leak points, and the timing of availability of depleted fields with respect to the source of $CO_2$, the $CO_2$ is used to incrementally increase the amount of hydrocarbons extracted by either immiscible or miscible flooding, thus providing an economic benefit whilst also storing

$CO_2$. As with depleted oil and gas fields, the potential storage capacity may be limited due to the physical size of the field and also due to EOR operational issues such as the rate at which the $CO_2$ is recycled.

## 5. COAL SEAMS – DEEP UNMINEABLE OR ENHANCED METHANE RECOVERY

$CO_2$ storage in coal seams is very different to storage in saline formations or oil and gas fields, as the trapping mechanism is by adsorption as opposed to storage in rock pore space. $CO_2$ is preferentially adsorbed onto the coal micro pore surfaces, displacing the existing methane ($CH_4$). In contrast to saline/hydrocarbon formations, storage density (i.e. storage capacity) is greatest in coals at depths less than 600 m, when CO2 is in the gaseous phase, not supercritical. $CO_2$ can be geologically stored in coal seams that are considered economically unmineable or can be used to enhance coal seam methane recovery (ECSM). Since coals have a higher adsorption affinity for $CO_2$ than for CH4. $CO_2$ injection in coal, coupled with CSM production, is potentially an attractive option for $CO_2$ storage. In reality, all $CO_2$ coal storage projects must be in conjunction with an ECSM recovery program, both to create permeability so that the $CO_2$ can be injected and the space for the $CO_2$ to be stored. It is also vital that the methane released from the coal matrix does not become an emission to the atmosphere as it has a higher greenhouse effect (21 times stronger by weight) than $CO_2$.

The $CH_4$ therefore needs to be captured to ensure a net greenhouse emission mitigation outcome. Technical challenges for $CO_2$ storage in coal seams focus around the feasibility of injecting the $CO_2$, due to the typically low permeability characteristics of the coal cleat system (especially with increasing depth). Coal sorption and permeability varies with coals of different character (rank, grade and type). It is also dynamic and changes during both gas extraction (matrix shrinkage) and injection (matrix swelling) as the coal interacts with the $CO_2$. In addition, the economic viability of enhanced methane recovery can potentially be compromised due to the large number of wells that may need to be drilled to overcome injectivity issues relating to low permeability. It can also be compromised if the price of coal increases to such an extent that coal beds previously regarded as uneconomic to mine suddenly become economically mineable. Research into $CO_2$ storage in coal is still at quite an early stage and further work needs to be conducted to fully understand the processes involved and the most suitable coal characteristics for $CO_2$ storage.

## 6. STORAGE CAPACITY

$CO_2$ storage capacity is an estimate of the amount of CO2 that can be stored in subsurface geologic formations. Because of uncertainties inherent to subsurface evaluation, exact quantification of geological properties is not possible and therefore storage capacity is always at best an approximation of the amount of $CO_2$ that can be stored. Storage capacity estimates therefore rely on the integrity, skill and judgment of the evaluator and are affected by the geological complexity, stage of exploration or development, amount of existing storage and of available data. Use of the definitions should sharpen the distinction between the various classifications and provide more consistent reporting.

Factors affecting $CO_2$ storage capacity include the density of the $CO_2$ at subsurface reservoir conditions, the amount of interconnected pore volume of the reservoir rock and the nature of the formation fluids. Due to the flow behavior of $CO_2$ in the subsurface, not all potentially available pore volume of the reservoir will become occupied during injection and migration, with flow preferentially occurring either upward due to buoyancy forces or laterally below low permeability zones (i.e. spreading out in thin layers beneath intra-formational seals or the regional top seal rather than filling the entire pore volume). This can make $CO_2$ storage capacity volumes difficult to calculate, particularly in the reservoir rocks underlying defined structural or stratigraphic closures, where much of the available rock pore volume can be bypassed by $CO_2$ preferentially utilizing higher permeability zones.

The potential $CO_2$ storage capacity should therefore be assessed in terms of available interconnected pore space, accounting for factors such as injection rate, rate of $CO_2$ migration, the dip of the reservoir, the heterogeneity of the reservoir and the potential for fill-to-spill structural closures encountered along the migration path. In addition, long-term prospects for storage, including residual trapping, dissolution into the formation water or mineral trapping (formation of new minerals) can also be considered (especially for estimating potential storage volume within deep saline formations). Such issues are best addressed by building geological models and running numerical flow simulations to test the importance of the various factors inherent to each specific site.

There are two major works providing methodologies for the estimation of storage capacity of $CO_2$ in geological formations, but both of this studies use the term “storage capacity” in its widest sense to cover all the categories referred to within this work. In effect, their use of the term Storage Capacity does not incorporate a commercial perspective and refer to $CO_2$ storage capacity as a geological resource, whose availability can be expressed in the same manner as resources and reserves are classified in other commodities (e.g. oil and gas, gold, uranium, iron, coal, etc.). For this reason the newest approach for storage capacity, based on the existing works, take into consideration all the commercial aspects and propose a classification for the storage volume capacity system as it’s shown in the figure 2.

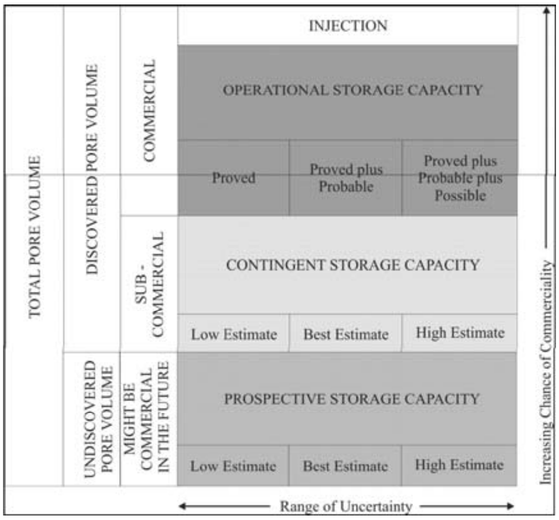


Figure 2 New $CO_2$ storage volume classification system

The relevant definitions for the proposed CO2 storage capacity classification system are given below.

**Total Pore Volume**. Total Pore Volume is defined here as the entire volume which is estimated to exist in sedimentary basins, naturally occurring storage systems or potential storage sites, plus that volume which may already be in use to store CO2, plus the estimated pore volume yet to be identified. Total Pore Volume may be subdivided into Discovered Pore

Volume and Undiscovered Pore Volume, with Discovered Pore Volume being limited to known ( i.e. well characterized) storage sites.

**Discovered Pore Volume**. Discovered Pore Volume is defined here as that volume which is estimated, on a given date, to remain in known storage sites, plus that volume already used for storage. Discovered Pore Volume may be subdivided into Commercial and Sub-commercial categories, classified as Commercial Storage Capacity and Contingent Storage Capacity respectively, as defined below.

**Operational Storage Capacity**. Operational Storage Capacity is defined here as an estimate of that volume of pore space which will be technically and commercially available for injecting CO2 into known storage sites from a given date forward. Storage capacity is separated into proved , proved plus probable and proved plus probable plus possible categories following petroleum industry standards  Proved Operational Storage Capacity will be limited to that which is commercial under current techno-economic conditions, while Probable and Possible Operational Storage Capacity may be based on anticipated future techno-economic conditions. In general, pore volume should not be classified as Operational Storage Capacity unless there is an expectation that the storage site will be developed and used to store CO2 within a reasonable timeframe. The definitions of "commercial" and "technically feasible" for a storage site will vary according to local conditions and circumstances and is left to the discretion of the operator or jurisdictional (country/state) authority concerned. In general, Proved operational storage capacity is the subset of storage capacity applicable to bankable storage projects.

**Contingent Storage Capacity**. Contingent Storage Capacity is defined here as that quantity of pore space which is estimated, on a given date, to be potentially technically and economically feasible for $CO_2$ injection into known storage sites based on anticipated future techno-economic conditions, but which is not currently considered to be commercially viable. In certain circumstances, Operational Storage Capacity may be assigned even though development may not occur for some time.

**Undiscovered Pore Volume**. Undiscovered Pore Volume is defined here as that pore volume which is yet to be discovered, but is estimated to be available for storage at some future date "after discovery". The estimated Undiscovered Pore Volume is classified as Prospective Storage Capacity, as defined below.

**Prospective Storage Capacity**. Prospective Storage Capacity is defined here as that quantity of pore space into which it is estimated, on a given date, that CO2 will be technically and economically potentially injectable into as yet undiscovered storage sites.

**Aggregation**. Quantities of pore volume classified as Storage Capacity, (Operational Storage Capacity, Contingent Storage Capacity or Prospective Storage Capacity) should not be added to one another ("aggregated") without due consideration of the significant differences in the criteria associated with their classification. In particular, there may be a significant risk that storage sites containing Contingent Storage Capacity or Prospective Storage Capacity will not be commercially viable.

**Estimated Ultimate Injection**. Estimated Ultimate Injection (EUI) is not a category as such, but a term which may be applied to an individual storage site of any status/maturity (discovered or undiscovered). Estimated Ultimate Injection is defined here as that quantity of CO2 which is estimated, on a given date, to be technically and economically injectable into a storage site, plus those quantities of CO2 which may already be stored therein.

**Range of Uncertainty**. The Range of Uncertainty, reflects a reasonable range of estimated potentially injectable pore volumes for CO2 at a specific storage site. Any estimation of capacity at a storage site is subject to both technical and commercial uncertainties, and should, in general, be determined in a probabilistic manner and quoted as a range. In the case of Contingent and Prospective Storage Capacity the terms Low Estimate, Best Estimate and High Estimate are recommended. The term 'Best Estimate' is used here as a generic expression for the estimate closest to the quantity that will actually be injected into the storage site between the date of the estimate and the time of abandonment. The terms ‘Low Estimate’ and ‘High Estimate’ should provide a reasonable assessment of the range of uncertainty in the Best Estimate. For undiscovered pore volume (Prospective Storage Capacity) the range will, in general, be substantially greater than the ranges for discovered pore volume (at specific storage sites). In all cases, however, the actual range will be dependent on the amount and quality of data (both technical and commercial) which is available for that storage site.

## 7. STORAGE CAPACITY ESTIMATION IN SALINE FORMATIONS

DOE (2006) provides a relatively simple volumetric equation for the calculation of $CO_2$ storage capacity in saline formations (Equation 1 and Table 1) based on the concept that $CO_2$ occupies the pore space (or parts of it) within a permeable rock:

$$G_{CO_2} = A h_g \varphi_{tot} \rho E \qquad (1)$$

Table 1: Volumetric equation parameters for capacity calculation in saline formations

| Parameter | Units* | Description |
|---|---|---|
| $G_{CO2}$ | M | Mass estimate of saline-formation $CO_2$ storage capacity |
| A | $L_2$ | Geographical area that defines the basin or region being assessed for $CO_2$ storage-capacity calculation |
| $h_g$ | L | Gross thickness of saline formations for which $CO_2$ storage is assessed within the basin or region defined by A |
| $\varphi_{tot}$ | $L_3/L_3$ | Average total porosity of entire saline formation over thickness hg |
| ρ | $M/L_3$ | Density of $CO_2$ evaluated at pressure and temperature that represents storage conditions anticipated for a specific geologic unit averaged over the depth range associated with hg |
| E | $L_3/L_3$ | $CO_2$ storage efficiency factor that reflects a fraction of the total pore volume that is filled, or contacted, by $CO_2$ |

* L is length; M is mass

Saline formations generally have limited data available to assess storage capacity volumes, and additional information and data will inevitably be required. In addition, there are a number of different trapping mechanisms for geological storage of CO2 in saline formations. The specific mechanism needs to be defined at either the basin-scale assessment or site characterization part of site selection (discussed later), as there will be variations in the storage volume and storage volume assessment method for each trap type. These trap types include: (1) structural/stratigraphic trapping; (2) hydrodynamic trapping; (3) residual trapping; (4) solubility trapping; and (5) mineral trapping.

## 8. STORAGE CAPACITY ESTIMATION IN DEPLETED OIL AND GAS FIELDS

$CO_2$ storage capacity estimations in depleted (or near depleted) oil and gas fields are generally easier than estimates for coal seams or saline formations because there is typically a greater amount of data associated with oil and gas fields and hence they are better characterized. Also, unlike coal seams and saline formations, oil and gas fields are considered as a single discrete system. This means that estimates of $CO_2$ storage volume in oil and gas fields can either be based on the effective pore space volume (as determined for saline formations), the calculated original oil and gas in place or from the volume of oil and gas produced from the field. In general, storage in depleted oil and gas fields is based initially on two primary assumptions:

- The volume previously occupied by the produced hydrocarbons will become available for $CO_2$ storage; and
- The existing caprock seal will also contain the $CO_2$ provided the pressure does not increase above the original reservoir pressure prior to production.

The first assumption is generally valid for fields that were not in hydrodynamic contact with an aquifer, or that were not flooded during secondary and tertiary oil recovery (i.e. pressure-depleted fields). The invasion of pore space by formation waters during oil and gas production leads to an increase in the water saturation to balance the residual hydrocarbon saturation. When subsequently introducing $CO_2$ each phase may have a relative permeability such that the space previously occupied by oil or gas may no longer be available for $CO_2$ storage. This may be due to wettability, capillarity, viscous fingering and gravity effects The relative permeability for a non-wetting fluid during drainage is different from that during imbibitions. It should also be noted that the original hydrocarbon pool was filled over geological time. When re-filling the trap with CO2 over a period of a few years, lower permeability parts of the reservoir might not be accessible if a limit on injection pressure is maintained.

The volumetric-based $CO_2$ storage capacity estimate (Equation 2 and Table 2) uses standard industry methods to calculate original oil in place (OOIP) or original gas in place (OGIP). A bulk rock volume is calculated by multiplying together the reservoir area (A), net oil column height ($h_n$) and a geometric factor which accounts for the geometry of the trap (i.e. 4-way dip structural versus stratigraphic). An average effective porosity ($\varphi_e$) in combination with the bulk rock volume (A $h_n$ g) provides an estimate of the pore space available for storage and the storage efficiency factor (E) provides a measure of the fraction of total pore volume from which oil and/or gas has been produced and that can be filled by $CO_2$

$$G_{CO_2} = Ah_n g h_n \varphi_e \rho E \qquad (2)$$

Table 2: Volumetric equation parameters for storage capacity in oil and gas reservoirs

| Parameter | Units* | Description |
|---|---|---|
| $G_{CO2}$ | M | Mass estimate of hydrocarbon reservoir CO2 storage capacity |
| A | $L_2$ | Area that defines oil or gas reservoir that is assessed for CO2 storage capacity calculation |
| $h_n$ | L | Net hydrocarbon column height in the reservoir |
| g | $L_3/L_3$ | Geometric factor based on the trap type |
| $\varphi_e$ | $L_3/L_3$ | Average effective porosity over net thickness $h_n$ |
| ρ | $M/L_3$ | Density of CO2 evaluated at pressure and temperature that represents storage conditions in the reservoir averaged over $h_n$ |
| E | $L_3/L_3$ | CO2 storage efficiency factor that reflects a fraction of the total pore volume from which oil and/or gas has been produced and that can be filled by $CO_2$ |

* L is length; M is mass

In some situations, compositional simulation models can be used to estimate the volume of CO2 able to be stored per stock tank barrel of original oil in place. In such cases Equation 2 should be modified to Equation 3 as follows:

$$G_{CO_2} = A h_n g \varphi_e \, {}^{1}\!/_{B_o} \left(1 - S_w - S_{oirr}\right) \rho V \qquad (3)$$

where

$B_o$ is the oil shrinkage factor,

$S_w$ is the average water saturation,

$S_{oirr}$ is the average irreducible oil saturation within the gross rock volume

V is the volume of $CO_2$ able to be stored per stock tank barrel of original oil in place ($scf_{CO2}/stb_{OOIP}$).

**9. STORAGE CAPACITY ESTIMATION IN COAL SEAMS**

Gas storage in coal seams is different to storage in oil and gas reservoirs or saline formations, as the trapping mechanism is mainly by adsorption onto the coal medium as opposed to storage in rock pore space. Hence, the assessment of coal seam storage capacity requires additional knowledge of a coal's adsorption capacity at a given depth and temperature, and it will vary depending on the quality (rank, grade and type) of the coal. Moreover, competition for access and utilization of the coal resource for mining, coal seam gas extraction or *in situ* gasification must also be considered to ensure that coals are not sterilized for future use. It should be noted that $CO_2$ storage in coal seams is a technology that is only in the demonstration phase the commercial success (or failure) of which will affect the application and evaluation of its capacity. In summary, the basic parameters that describe $CO_2$ storage capacity and injectivity in coals are seam thickness, adsorption capacity, and permeability. The volumetric equation for $CO_2$ storage capacity in coal seams is presented in Equation 4 and Table 3:

$$G_{CO_2} = A h_g C \rho E \qquad (4)$$

Table 3: Volumetric equation for storage volume estimation for $CO_2$ storage in coal seams

| Parameter | Units* | Description |
|---|---|---|
| $G_{CO2}$ | M | Mass estimate of $CO_2$ storage capacity of one or more coal seams |
| A | $L_2$ | Geographical area that outlines the coal basin or region for CO2 storage capacity calculation |
| $h_g$ | L | Gross thickness of coal seam(s) for which CO2 storage is assessed within the basin or region defined by A |
| C | $L_3/L_3$ | Concentration of $CO_2$ standard volume per unit of coal volume (adsorption capacity at a given pressure or depth as determined by Langmuir volume or alternative); assumes 100% CO2-saturated coal conditions; if presented on dry-ash-free (daf) basis, then A and h must be corrected for daf |
| ρ | $M/L_3$ | Density of $CO_2$ under (PT) conditions present in coal seam |
| E | $L_3/L_3$ | $CO_2$ storage efficiency factor that reflects a fraction of the total coal bulk volume that is contacted by $CO_2$ |

* L is length; M is mass; P is pressure; T is temperature

**10. CONCLUSIONS**

Carbon dioxide capture and geological storage is a means of reducing greenhouse gas emissions into the atmosphere. The estimation of how much storage capacity there is, and where it is located are fundamental issues for the commercial deployment of CCS. Current storage capacity estimates are imperfect and there is a need for more development and more general agreement on assessment methodologies for site selection. Previous attempts to assess $CO_2$ storage capacity have used a range of approaches and methodologies, and data sets of variable size and quality, resulting in widely varying storage estimates of inconsistent quality and reliability. The main efforts to date is to develop on base of the previous schemes, of a new methodology for site selection and storage capacity estimation, acceptable for industry, the scientific community and regulators, but also acceptable to the financial, banking and insurance sectors.

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Scientific Reviewers:
Prof. PhD. Eng. Romulus Sarbu

# PERFORMING IN SAFE CONDITIONS THE LABORATORY TESTS IN CONTROLLED EXPLOSIVE MIXTURES

**CSASZAR TIBERIU[*]**
**VASILESCU DRAGOŞ[**]**
**BURIAN SORIN[***]**
**IONESCU JEANA[****]**
**DARIE MARIUS[****]**

**Abstract:** *This paper contains the authors' research on performing, in safe conditions, the laboratory tests with the remark that these tests are performed with explosive air-gas mixtures*

**Key words:** *laboratory tests, explosive mixtures, security*

## 1. THEORETICAL AND PRACTICAL PREMISES

Having in mind the specific of laboratory tests [1], which uses the test mixtures consisting of explosive air-gas mixtures that are always within the explosion limits, it requires special attention regarding the safety of the operator in the course of testing activities in this laboratory.

The specific technical literature [2], [3], considers the human safety in the workplace as that state of the work system that excludes the possibility of injury and occupational disease. Defining the safety as a risk function y = f (x), where y = 1/x, one can say that a system will be that much safer, with the level of risk will be lower and vice versa. Thus, if the risk is zero, from the relationship between the two variables results that safety tends to infinity, according to relation 1, and if the risk tends to infinity, safety tends to zero, according to relation 2, and this is presented in figure 1.

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[*] *student PhD. Eng., CS III, INCD-INSEMEX Petrosani*
[**] *PhD. Eng., CS III, INCD-INSEMEX Petrosani*
[***] *student PhD. Eng., CS II, INCD-INSEMEX Petrosani*
[****] *PhD. Eng., CS II, INCD-INSEMEX Petrosani*

$$y = \frac{1}{0} \rightarrow +\infty \qquad (1)$$

$$y = \frac{1}{+\infty} \rightarrow 0 \qquad (2)$$

Relative to this context, in practice, a limit of minimal risk shall be accepted, respectively a low risk level, in order to consider that the system is safe; and a limit of maximum risk, which is equivalent to a lower security level so that the functioning of the system shall not be allowed.

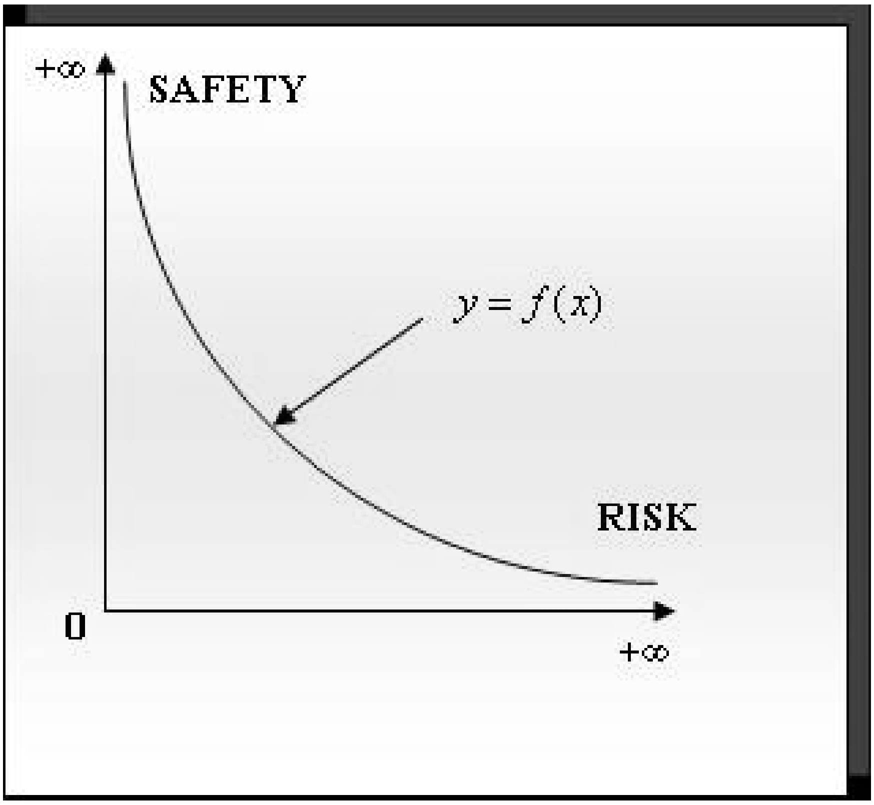


**Figure 1 Risk – safety relationship**

## 2. CONCEPT OF ACCEPTABLE RISK

The risk was defined in the specific technical literature in the occupational safety area [2], as the probability with which an accident or professional illness comes in a work process, with a certain frequency and gravity of the consequences.

If we assume some risk, we can represent it, depending on the gravity and the probability of consequences, by the area of an F1 rectangle, developed vertically. But the same area can be represented by an F2 square or an F3 rectangle extended horizontally as shown in figure 2.

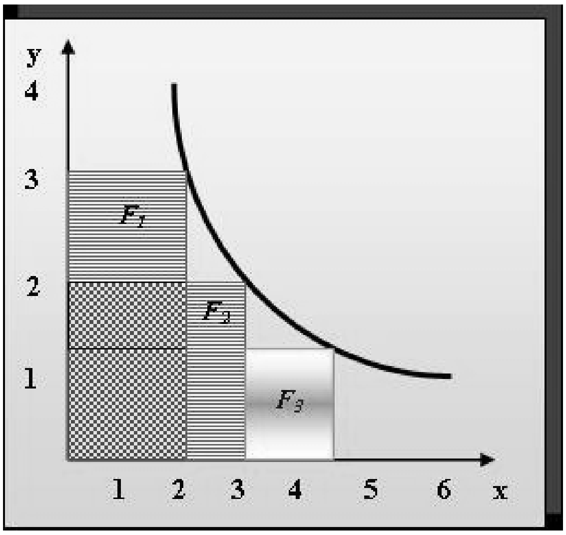


**Figure 2** Graphical representation of risk equivalence characterized by different couples of gravity – probability

In all three cases the risk is the same high. As a consequence, we can assign some different gravity - probability couples, the same level of risk. For representation of risk according to gravity and probability, in the specific technical literature such a curve is defined as "risk acceptability curve" [5]. This curve allows differentiation between acceptable and unacceptable risk. Thus, the risk of an event A with serious consequences, but very low frequency, below the acceptability curve is considered acceptable; and the risk of an event B, with less serious consequences, but with a higher probability of occurrence, of which coordinates are above the curve, is unacceptable (see fig. 3).

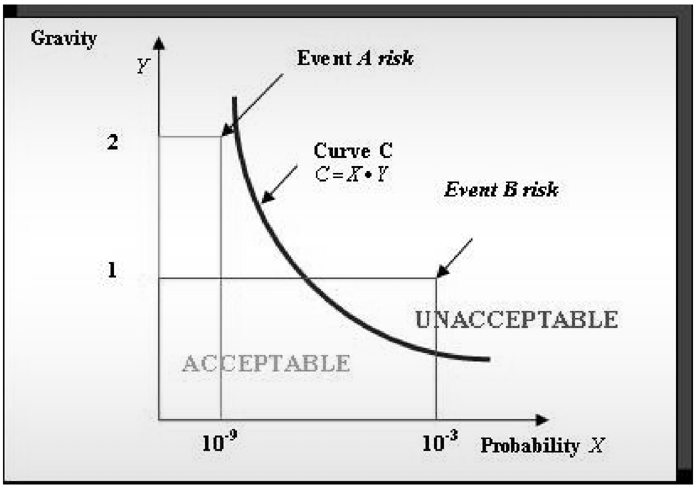


**Figure 3** Risk acceptability curve

## 3. OCCUPATIONAL RISK DIMINUTION IN THE TEST LABORATORY

When the assessed risks are located in the unacceptable risk area, the procedure of analysis and diminution of them is applied, by application of an appropriate program of technical and organizational measures, in order to prevent and combat the causes for occurrence of unwanted events.

In this sense, the „Risk analyzer" is used, which was built on the basis of grids provided with classes of corresponding values for the two parameters, the probability of an unwanted event, "p" and the gravity of the consequences, "g" [5], [7].

The grids corresponding to safety and health parameters at work are presented, as follows: table 1 for the grid scale of the gravity of the consequences parameter, "g"; table 2 for grid scale of the occurrence probability of unwanted events parameter "p"; and table 3 for the attitude scale towards the risk level.

**Table 1-**Parameter grid for gravity of consequences

| Classes of gravity | Consequences | Gravity of consequences "g" |
|---|---|---|
| **1** | Negligible | Minor reversible consequences with maximum 3 days predictable work disability |
| **2** | Small | Reversible consequences with 3-45 days predictable work disability that requires medical treatment |
| **3** | Medium | Reversible consequences with 45-180 days predictable work disability that requires medical treatment and hospitalization |
| **4** | Large | Irreversible consequences with a decrease in working capacity of at least 50%, the individual being able to perform a professional activity (III$^{rd}$ degree disability) |
| **5** | Grave | Irreversible consequences with loss of 100% of working capacity, but with the possibility of self-service and self-governing (II$^{nd}$ degree disability) |
| **6** | Very grave | Irreversible consequences of total loss of work capacity, self-service, self-governing or spatial orientation (I$^{st}$ degree disability) |
| **7** | Maximum | Death |

**Table 2** The grid for probability parameter of unwanted events generation

| Probability classes | Events | Probability of consequences „p" |
|---|---|---|
| **1** | Extremely rare | (extremely low)<br>P > 10 years |
| **2** | Very rare | (very low)<br>5 years < P < 10 years |
| **3** | Rare | (low)<br>2 years < P < 5 years |
| **4** | Less frequent | (medium)<br>1 year < P < 2 years |
| **5** | Frequent | (high)<br>1 mounth < P < 1 year |

| Probability classes | Events | Probability of consequences „p” |
|---|---|---|
| 6 | Very frequent | (very high)<br>P < 1 mounth |

**Table 3** Attitude scale toward the risk level

| Level of risk | Assessment of risk level | Attitude to risk level |
|---|---|---|
| 1 | Minimal risk | No special action is taken |
| 2 | Very low risk | |
| 3 | Low risk | |
| 4 | Medium Risk | Monitoring the dangerous situations is made and supplementary corrective measures can apply taking account of cost-efficiency ratio |
| 5 | High risk | Efforts will be made to reduce the level of risk, but the costs of prevention should be measured carefully. The risk level diminution measures are implemented in close determined periods of time. |
| 6 | Very high risk | Activities can not continue until the risk level is not diminished! Resources shall be assigned to reduce the risk. |
| 7 | Maximum risk | Test activities can not be run until the risk level is not diminished! If you can not immediately reduce the level of risk, then working in these conditions is FORBIDDEN! |

Based on theoretical premises presented above, an integrated software application was made for occupational risk assessment in the laboratory testing work, to ensure its legally safe condition. In this sense, the method used, [4], was implemented into an integrated software [1], for quantitative determination of the risk level/safety of testing activities carried out on electrical equipments designed for use in industrial areas with hazard of potentially explosive atmospheres, based on systemic analysis and risk assessment of occupational accident and illness.

The application is finalized with two centralizing documents respectively:

- assessment sheet for testing laboratory, including the global risk level for that activity and,
- sheet of technical and organizational measures proposed to prevent and combat the causes that may lead to undesired events in laboratory test work (accidents at work and/or occupational diseases).

## 4. DEVELOPMENT OF SOFTWARE PROGRAM REGARDING THE INTEGRATED APPLICATION IN ORDER TO RUN THE LABORATORY TESTS

In the next place is presented the program in executable format, written in Visual Basic programming language, to develop system documents, in the area of laboratory tests in safe conditions. The developed program called "MSSM.EXE 01" represents a tool used to run operative, procedural and systematic laboratory tests in safe conditions, to ensure that the test results are in compliance with applicable requirements.

Risks of accident and/or occupational illness that may occur during the performance of laboratory tests were expressed function of the variation of dangerous factors elements amount with synergistic action over the occupational safety climate, particularly by prevailing a minimum number of relevant information about environmental work, work task, equipments and executant, thus creating a database through which processing the systematic analysis process and complex evaluation of the risk level could be made. As results, we obtained centralizing documents of laboratory sheet type and proposed prevention measures sheet.

For operational purposes, were dimensioned the maximum predictable consequence gravity, the action of each risk factor on the operator, obtaining a class of gravity, and the intervals at which it was assessed that unwanted events can happen were included in the classes of probability. The combination between the gravity of the consequences and their probability express the risk level of each risk factor separately.

The overall risk level on test laboratory or type test was calculated as a weighted mean of the risk levels established for identified dangerous factors, as a weighted element being used the rank of the risk factor, so that the factor with the highest level of risk will have the highest rank.

The formula for calculating the overall risk level is shown in relation 3:

$$Nrisc_{profesional} = \frac{\sum_{i=1}^{n} k_i R^{(1)}{}_i}{\sum_{i=1}^{n} k_i}, \qquad (3)$$

where :

- $R^{(1)}{}_i$ - the partial risk associated with the risk factor i,
- $k_i$ - risk factor rank i;
- $Nrisc_{profesional}$ - global risk level of laborator/type of test

Pressing the start button the software application is launched in execution displaying the main window that contains four distinct zones. Figure 4 shows the working window where the user will choose one of four areas:

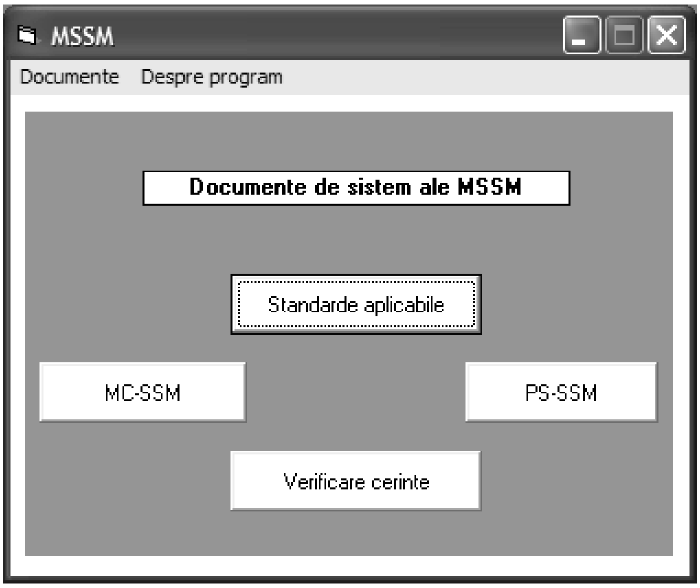


**Figure 4** The working window of the "MSSM.EXE 01" program

These areas offer the following facilities:

1. The "**Standarde aplicabile**" areas, from where the applicable standards can be consulted in detail about the testing field of the testing laboratory, transposed in a write-protected format.
2. The "**MC-SSM**" area, where the SSM management manual model can be accessed, provided with instructions to fill in each point of its structure. When preparing this system document, the model was built by using links and with their help the working areas of the document can be passed through easily in order to browse instructions and properly complete of the SSM management manual.
3. The "SP-SSM" area which allows access to the list of the 13 system procedures, facilitating the entry into their models, also provided with instructions to fill them. The way to browse and complete these models is similar to that of the SSM management manual presented above. Having in mind the formula for the design of the program, the 13 models of system procedures can be open even sequentially or randomly function of user's choice, as shown in figure 5.
4. The " Verificare cerințe " area, which gives the possibility for verification of fulfilling the requirements of SR OHSAS 18001:2008 referential, in order to develop accurate and complete system documentation (MC-SSM and SP-SSM). By accessing this area opens the document containing the description of the above mentioned referential requirements, which is built on the same system with links that eases the view of the corresponding requirements.

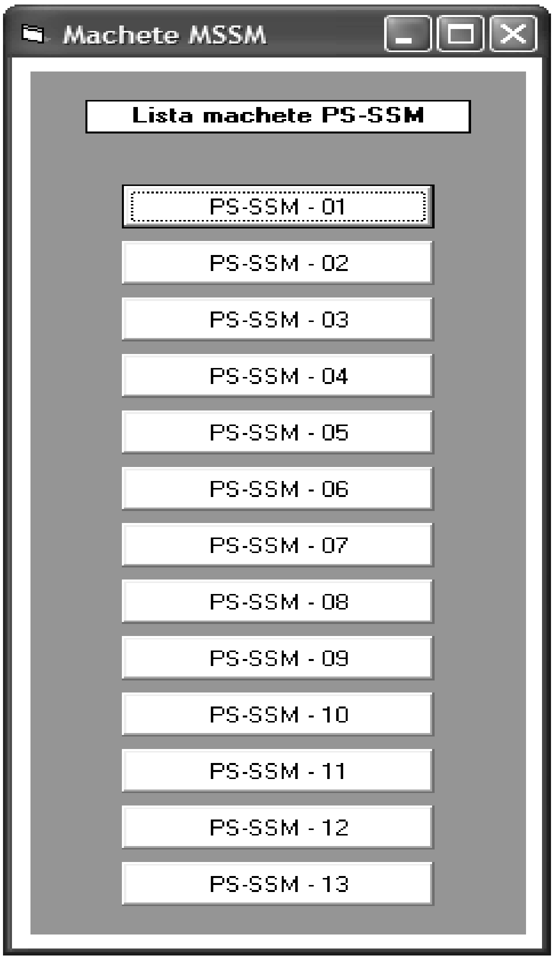


**Figure 5** Working window with the list of system procedures models

The software "MSSM.EXE 01" provide an operative and procedural development for system documents in the MSSM area, based on the analysis and evaluation of particular mode of manifestation of all aspects of safety and health at work managed at economic agents level that activates in hazardous explosive and/or toxic environments.

The use of this program is not limited, requiring a minimum PC configuration and the use of the appropriate operating system. Data and information required to be inserted in the program are those required according the instructions for requirements of the health and safety at work integrated management model application guide.

This program is at first version and allows updating and improvement of information and application whenever significant changes occur in its main documents.

Taking account of the given arguments specified above, the "MSSM.EXE 01" program may be a viable solution to solve operative and procedural problems in the health and safety at work field, namely:

- planned and documented approach to health and safety problems at work;
- defining areas of responsibility;
- knowledge and awareness of SSM issues;

- ensuring a stable social climate, favorable and performance in the area of allocated human resources;
- improving health and safety management with measurable results;
- increasing safety at work in laboratories that use explosive test gas mixtures.

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**[7]** ***EN ISO 12100-1:*** *2010 Securitatea maşinilor. Concepte de bază, principii generale de proiectare. Terminologie de bază, metodologie*

**[8] * * *** *Directive 1992/92/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 1999, an minimum requirement for improving the safety and health protection of workers potentially at risk from explosive atmospheres (15th individual Directive within the meaning of Article 16(1) of Directive 89/381/EEC)*

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· (14 points)

· (14 points)

**The first name and the family name will be written with CAPITAL LETTERS, BOLD, CENTERED, 130 mm width, Times New Roman, 12 points, each name being followed by number,** *and in the footnote the didactic and scientific degree, the position and place of work of the authors (possibly fax, E-mail) are indicated, with italics, 130 mm width, Times New Roman, 11 points.*

· (12 points)

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<Tab> **Abstract: (Times New Roman, 10 points, bold)** The Abstract will only be in English and will have between 50 and 100 words, arranged all over the entire width, single, left – right alignment, all over the width of the printed space, Times New Roman, 10 points.

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<Tab> **Key words: (Times New Roman, 10 points, bold)** 5 – 10 words, in English, along the entire width, Times New Roman, 10 points.

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The paper will be edited in a language of international circulation (English, French, German) on A4 format (210 x 297), page setup: top 5,6 cm, bottom 4,6 cm, left 3,7 cm, right 3,7 cm, in WORD or WORDPERFET or WINDOWS and the number of pages must be even between 4 and 16. The size of the symbol is given next and is written in the instructions used to assist in editing the text. It indicates a blank line and does not show in the text of the paper, being obtained by pressing <ENTER>. The size of a <Tab> is 1,27 cm. No blank line is left between the paragraphs. Between the last line before the title and the title of the chapter and between the title and the first next line a blank line is left for each.

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The text is written in new paragraph and not continuing the subtitle, an 11 point blank line being left between the subtitle and the following text.

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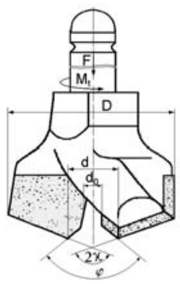


**Fig. 1.** Detachable bit

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## 4. PRESENTATION OF THE MATHEMATICAL EQUATIONS

· **(**11 points)

The mathematical equations will be with times New Roman, 11 points, center of the page and numbered on the right with Arabic numbers between round brackets.

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$$X^2 + Y^2 = Z^2 \tag{1}$$

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  Assoc. Prof. PhD. Chim. Dorina BACIU - North University of Baia Mare

- **MINING GEOLOGY:**
  Prof. PhD. Eng. Vlad CODREA - University of Babeş Bolyali - Cluj Napoca
  Prof. PhD. Eng. Grigore BUIA - University of Petroşani

- **ROCK ENGINEERING:**
  Prof. PhD. Eng. Victor ARAD - University of Petroşani
  Prof. PhD. Eng. Ioan BUD - North University of Baia Mare

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