ISSN 1454-9174

1948

UNIVERSITATEA DIN PETROȘANI

ANNALS
OF THE
UNIVERSITY OF PETROȘANI

MINING ENGINEERING

vol. 24 (LI)

UNIVERSITAS PUBLISHING HOUSE
Petroșani – ROMÂNIA, 2023

ISSN 1454-9174

Editorial office address: University of Petroșani, 20 University Street, 332006, Petroșani, Romania, Phone: (40) 254/54.29.94, 54.25.80, 54.25.81, 54.25.82, 54.97.49, Fax. (40) 254/54.34.91, 54.62.38, www.upet.ro, E-mail: ibol@upet.ro

CONTENTS

RECLAMATION OF WASTE DUMPS IN THE BERBEȘTI MINING AREA BY ESTABLISHING FRUIT SHRUBS CROPS - A CASE STUDY

FLORIN, FAUR [1], DANIEL, MOISUC-HOJDA [2]

Abstract: *The ecological restoration of lands degraded by the mining industry constitutes for the coming years an interesting theme and a challenging field of application in landscape architecture, and this both from a qualitative point of view, through the interesting objectives of the disciplines involved in restoration, and from a quantitative point of view, through the large number of different situations and by expanding the portion of the landscape that can be involved. In the case of waste dumps, ecological restoration aims at concepts for improving the quality of anthropogenic protosoils, identifying cultivation directions and identifying and applying technologies for arranging the dumps for this purpose. The ecological restoration of waste dumps resulting from mining operations depends on the geographical area in which they are located, on the local climate, on the properties of the materials that make up the dump, on local or social interest, etc. This article presents a proposal for the ecological restoration of the West Berbești waste dump, for this purpose, the specific stages of the planning and implementation of a restoration program being completed.*

Keywords: *Open pit, restoration, stability, waste dump, West Berbești*

1. INTRODUCTION

Open pit mining affects the environment, on one hand, by changing the landscape, and on the other, by the brutal intervention in the natural processes and rhythms of the ecosystems. All these effects led to the appearance of a conflict of interests between the need to extract mineral raw materials and the requirements regarding environmental protection to such an extent that mining companies began to be seen as "environmental destroyers" [1, 2].

For this reason, in many countries environmental groups have requested the limitation of activities in existing open pits and preventing the opening of new ones. All these restrictions sometimes led to the impossibility of supplying some industrial branches with indigenous raw materials.

Although the negative effects of open pit mining are important and indisputable, this industrial branch has at hand multiple possibilities to minimize the negative impact on the environment and, more than that, to restore the affected areas.

[1] *Florin, Faur, Assoc. prof. dr. eng., University of Petrosani*
[2] *Daniel, Moisuc-Hojda, Lect. dr. eng., University of Petrosani*

The ecological reconstruction and rehabilitation (restoration) works of lands degraded by human activities must be carried out in accordance with the political and economic objectives of a country. The main objectives of this activity are [3]:

- Long-term planning and the conscious construction of a territory or portions of territory, which correspond to the economic requirements and the material, cultural and aesthetic needs of the population;
- Restoration of the degraded land surfaces to be carried out in the shortest possible time, in order to achieve the highest and most stable income as a result of their use, which corresponds to local conditions and guarantees the reconstruction of the ecological balance.

The major role played by land and the need to increase the quality of life of the inhabitants requires the application of planning and management principles, which are diverse and new, and which are respected in current practice.

Ecological restoration is a complex process of regaining the productivity of lands degraded by socio-economic activities. It is a process that aims to create a new landscape on degraded places, that will meet the multiple requirements of humans, that will render to the economic circuit these optimally organized, cultivated and ecologically balanced surfaces [4].

The ecological restoration process has its own specificity for each area that is to be rendered into the economic circuit. The most important directions for enhancing the value of degraded lands are [3]:

- Naturalistic recovery, which aims to recreate the rhythm of the territory with minimal interventions;
- Agricultural recovery, which aims either to restore these dumps as arable land, or to arrange them as pastures and hayfields;
- Forestry recovery, i.e. the establishment of forests with a commercial role or with a role to protect and restore the soil and biodiversity;
- Energy crops, i.e. the establishment of crops with high energy potential (eg. different species of willow);
- Recovery for hygienic-sanitary purposes, i.e. recreational areas, parks, golf courses, tourist areas, etc.;
- The arrangement of lakes with different destinations: reservoirs, fishing lakes, lakes with the role of regulating the hydrological regime, sports pools, etc.;
- Recultivation with the aim of improving the habitat for wild animals, bringing better conditions for hunting and fishing;
- Setting up industrial or commercial platforms, households, etc.

The directions of restoration and the technologies for arranging the waste dumps must be established before the start of the mining activity in order to make a selective extraction and deposition of the horizons, especially for the lands to be recovered for agriculture and forest plantations. Before starting the restoration process, the following studies must be carried out [3, 4]:

- Pedological and agrochemical mapping of the areas that will be affected, with the determination of the thickness of the fertile horizon that will be excavated;
- The physico-chemical characterization of the lithological materials that form the waste dumps resulting from the excavation;

- Agrochemical mapping on a depth of 0.4 m of the surfaces of the dumps to be restored and the elaboration of cartograms with the restrictive factors in the recultivation process.

2. GENERAL DATA REGARDING LOCATION OF THE OBJECTIVE

2.1. Location of the Berbești mining basin

The Berbești mining basin is geographically located in the Getic Plateau, along the parallel of 45° north latitude, at the border of Gorj and Vâlcea counties, being delimited to the west by the Gilort river, and to the east by the Bistriţa river [5].

It has a length of over 45 km and a development of 2.5 - 5 km. The lignite deposit was divided into four mining perimeters: Gilort-Amaradia, Amaradia-Tărâia, Tărâia-Cernişoara and Cernişoara-Bistriţa. Inside each mining perimeter, several mining fields were outlined, these being the object of exploitation of some mines (closed at present) or open pits (some in conservation).

The West Berbești mining field (fig. 1) is delimited as follows [6]:

- To the north, by Mateești commune, respectively the outcrop area of the lignite layers;
- To the south, by Alunu commune and the town of Berbești;
- To the west, by the Olteț mining field;
- To the east, by the Tărâia river.

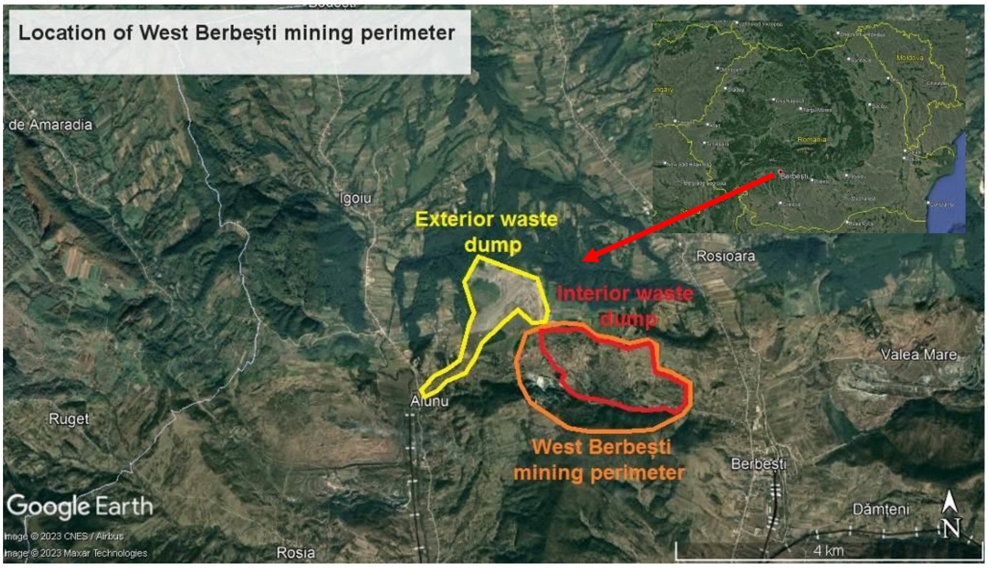


Figure 1. Location of West Berbești mining field, modified after [7]

2.2. Relief – morphology and morphometry of the area

From a geomorphological point of view, units of the Subcarpathians and the Getic Plateau are known in the region, which develop up to the vicinity of the high piedmont plain located in front of the moesic platform. The Subcarpathian hills have moderate heights, being fragmented by a strong transverse hydrographic network [8].

The highest regions are at the contact with the Subcarpathians (756 m), also increasing from west to east (from 219 m in Olteţului Valley to 542 m in Bistriţa Valley).

Although in geological time natural factors played an essential role in the morphogenesis, humans surpassed them, having one of the most dynamic behaviors within the geomorphological systems. The results of human actions are observable in short periods of time.

The action of the anthropic factor is realized through a new morphology, characterized by relief inversions, as well as an artificial restructuring and redevelopment of the materials. The mining technostructures, the triggered geomorphological processes and the micromorphology associated with them represent a consistent confirmation of human morphogenetic action [8].

Following the field studies, it was found that the most frequent geomorphological processes present in waste dumps are: landslides, erosions, settlemets, subsidence, surging, dry flows of material, pseudosoliflixions, creep, etc.

2.3. Geology of the deposit

The geological formations present in the Berbeşti mining basin are made up of rocks belonging to the Pliocene and the Quaternary (fig. 3) [5, 6, 9].

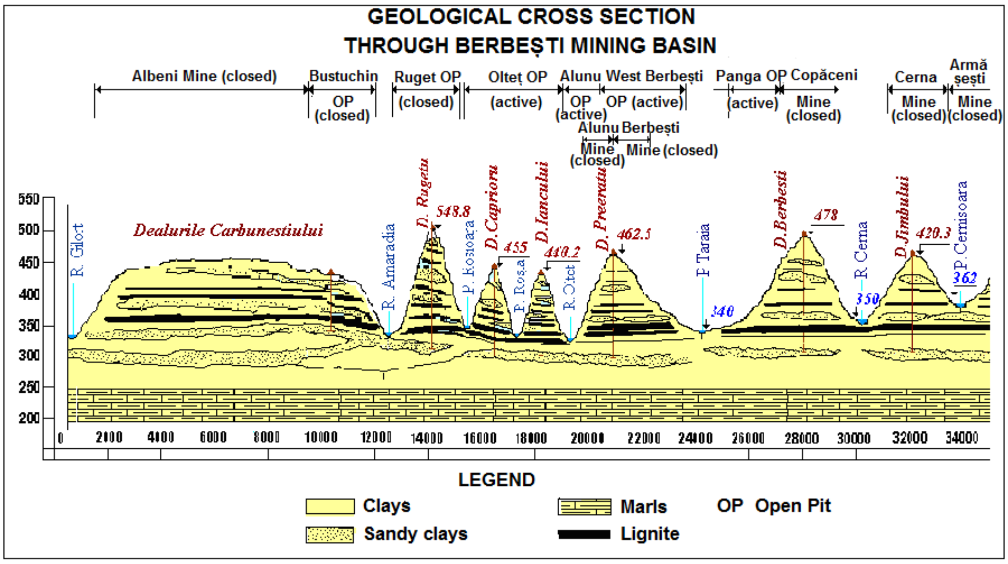


Figure 2. Longitudinal section through Berbeşti mining basin [10]

The nine layers of coal (lignite) with different thicknesses, which make up the deposit, are framed by clayey or clayey-sandy rocks. Layer I is the most important one from a quantitative and qualitative point of view, having the largest thicknesses and extending over almost the entire surface of the mining field. It emerges in the north and west of the perimeter, on the slopes of the valleys that cross the region. The thickness of layer I vary between 0.3 m and 7.9 m. Layer I from the Berbeşti basin can be assimilated with layer V from the Motru - Jilţ - Rovinari basins, because it is placed above the lumachelle horizon, considered a landmark in the entire sedimentation area of Oltenia [5].

Regarding the lignite layers that make up the coal complex (the lignite deposit) in the Berbeşti mining basin, we can specify the following [6]:

- Layers I, II, III and less often IV are of economic importance, while the upper layers are partially or totally eroded showing thicknesses that make them unexploitable;
- The intercepted lignite layers, due to the way of sedimentation, have different continuity and thicknesses, sometimes they taper to the point of disappearance, they separate into banks or come together in a single bank. The discontinuity of the strata is favored by erosion, which allowed the upper strata to surface along the main valleys;
- In some areas, the volume of lignite reserves replaced as a result of their erosion with newer quaternary terrace deposits (sand, gravel) is very large.

The lignite deposit in the Berbeşti Mining Basin is not affected by major tectonic disturbances, compared to the deposits in other mining basins.

2.4. Soils

The soils belong dominantly to the clay - loam class (luvisoils 58%), with a distribution imposed by the development of the relief. Thus, on the interfluvial bridges and on the terraces there are brown soils from weak loess to whitish luvisoils (luvosoils). On deposits with a significant share of clay, weak and medium pseudoglayed soils appear, and between Oltețu and Tărâia – vertisoils (pelisoils). On the slopes, the variety of inclinations, rocks and humidity conditions imposed a multitude of soils: on sands and gravels, eu-mesobasic brown soils (eutricambosoils 23%), loess brown soils (luvosoils) and even acid brown soils (districambosoils), on a marly substrate, pseudorendzines (faeciums) developed, in the micro-depressions on the landslides, glee soils (gleiosoils) are present, on the larger slopes, subject to surface runoff, the erodisoils (about 10%) were individualized, etc. In the meadow areas there are alluvial soils (about 9%), in different stages of evolution (alluvium, protosoils, alluvial soils, etc.). The most common soils are brown clay-iluvial ones [8, 11].

2.5. Hidrography

From a hydrographic point of view, the perimeter is located in the balance zone of the two large hydrographic basins, the Jiu basin to the west and the Olt basin to the east [8].

The main watercourses that cross the region are: Gilort and Amaradia, which flow into the Jiu River, respectively Olteţ, Cerna, Bistriţa, with a general flow direction from north to south, tributary to the Olt River. The tributary valleys of the Gilort, Amaradia and Oltețu rivers, as well as their major tributaries: Cornăţel, Tărâia and Cernişoara, have a torrential regime, being devoid of water for a large part of the year.

The hydrogeological research carried out in the Berbeşti basin highlighted sandy horizons with variable thicknesses and very varied granulometric constitution, from fine clayey sands to medium and sometimes coarse sands [11].

2.6. Climate

The Berbești mining basin is located at the intersection of the 24º east longitude meridian with the 45º north latitude parallel, which is why it is characterized by a temperate-continental climate, with average annual temperatures of 9 - 11°C and extreme temperatures that can reach -26°C, respectively +40°C [8].

The average duration of the interval with temperatures higher than 10ºC is around 190 days. The average temperature drops below +10°C around October 10, and the first frost usually occur between October 16 and 20. The maximum depth of frost is 0.60 m.

The annual average of precipitation is between 700 and 800 mm water column (l/m²).

Winds have an average intensity, and those with speeds exceeding 70 km/h are very rare, as a consequence of the relief.

The temperate climate is, through some of its elements, one of the triggering factors of the geomorphological changes. The long-lasting rains during autumn and spring play an important role in triggering landslides, where the other potential factors are also favorable. Added to these are the summer rains, which extend these processes [11].

2.7 Flora and fauna

More than a third of the surface of the study area is covered with deciduous forests, in which *Fagus silvatica* and *Quercus sp.*, can form massive individual forests. They can also be found in combination with other species, such as: *Carpinus betulus, Fraxinus excelsior, Acer compestre, Plopulus alba, Malus silvestrias, Pirus piraster, Tilia tomentosa*. Among the shrubs that accompany the edges of the forests, also found on unproductive lands, the following are mentioned: *Corylus avellana, Rubus, Rosa canina, Cornus sanguinea, Prunus spinosa, Sambucus nigra*, etc.

Until the leaves and herbaceous carpet appear in the spring, the landscaping is completed by the diversity of wildflowers, such as: *Galanthus L., Scilla bifolia, Tussilago farfara* (which is specific to lands poor in nutrients), etc.

The hays are composed of clover, lucerne, sedges, or combinations of such plants. Arable lands are generally cultivated with corn, wheat, oats, potatoes and sunflower.

The fauna, especially that of the forest, is varied, encountering a number of species such as: *Capreolus capreolus, Vulpes vulpes, Lepus europaeus, Sciurus sp., Meles meles*, and in the massive and bushy forests, *Sus scrofa* can be found.

The ornithological species are represented by *Turdus merula, Luscinia megarhynchos, Turdus philomelos, Sturnus vulgaris, Phylloscopus sp., Cuculus* *canorus, Passer domesticus, Paridae, Perdix perdix,* and in the last period, it was successfully populated with *Phasianus colchicus*.

Both on cultivated land and in forests, there is a diversity of small reptiles, among which we can remember: *Natrix tessellate, Natrix natrix, Lacerta viridis, Lacerta agilis, Anguis fragilis* and *Caudata*.

The transition from terrestrial fauna to aquatic fauna, in addition to some of the mentioned reptiles (the largest being the turtle), is also carried out by amphibians. The ichthyological fauna is represented by *Carassius carassius, Barbus barbus, Perca fluviatilis, Alburnus alburnus, Sabanejewia romanica, Chondrostoma nasus,* etc.

2.8 Economic activities

The basic occupation of the inhabitants of the area where the Berbeşti mining basin extends was agriculture, based on animal husbandry and the cultivation of agricultural land with corn, wheat, potatoes, sunflowers, but also vines and fruit trees of various varieties. Beekeeping is one of the major concerns of the residents, especially in Berbeşti [8].

The dramatic decrease in electricity consumption imposed another energy strategy, as a result of which the mines (underground operations) in the Berbești mining basin were completely closed, and Romania's new commitments, to give up coal-based energy production, entail the gradual closure of the last four open pits in operation, thus raising the issue of first of all ensuring the stability of the lands in these perimeters, so that they too can be reintroduced into the economic circuit in the shortest possible time.

3. DESCRIPTION OF THE MINING FIELD AND OPERATIONS

The total area of the West Berbești mining field, established in the documentation for obtaining the exploitation license, is 479.84 ha [12].

The deposit is located in the hilly area developing on a level difference of 68 m (between 430 m and 362 m).

The exploitation method used at the end of the productive activity, is the "exploitation method with the transport of waste rocks in the internal dump".

In the period between 2001 and 2018, the production capacity was of 500,000 t/year [12].

The working steps are executed with BWEs in combination with downward excavations executed with classic machines, with the movement of the excavators on a 2° slope from west to east, on several steps and sub-steps with heights between 5 - 15 m.

The waste rocks are transported on conveyor belts to the internal waste dump (considering the unavailability to deposit waste rocks in the external dump, which slided in June 2017).

Dumping of waste rocks in the internal dump is done by means of dumping machines (spreaders) type A.6500.90 (fig. 3) and dumping trucks.

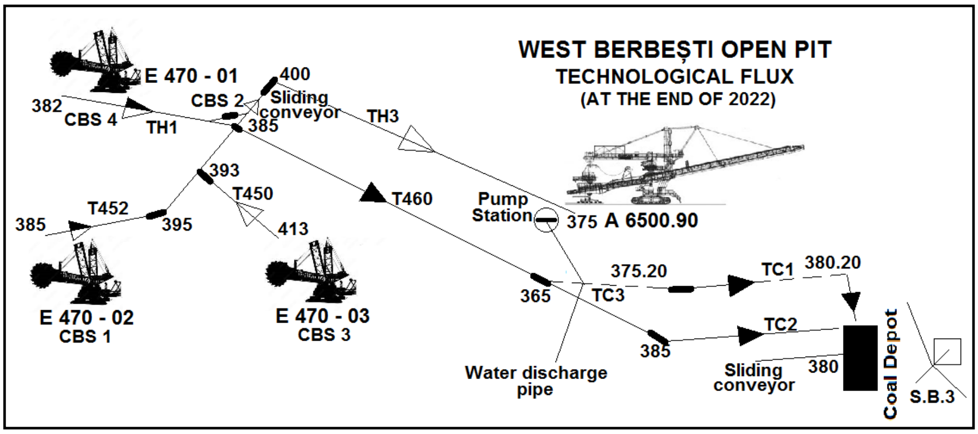


Figure 3. Technological flux at the end of 2022 [12]

Dumping of the excavated waste rocks is done only in the internal dump, in dump steps with a maximum height of 10-15 m, both under and above the track, using the TH3 conveyor. After the month of June 2017, when the slide of the external dump occurred, the dumping machine was moved to the internal dump where it was used until the end of the concession period, i.e. the end of 2022. The waste rocks deposition started from the south-eastern side, elevation +375, after draining the water and leveling/arrangement of the forward step [12].

4. CHOOSING THE ECOLOGICAL RESTORATION TYPE

The ecological restoration of waste dumps requires special attention from the point of view of the legislative and normative framework, which allows a great flexibility of forecasts and the possibility of changing the destination of land surfaces, taking into account the attractions and characteristics of the territory based on on a complex process of analysis of the built landscape, through the most modern working methods [3, 4, 13].

The lithological materials in the waste dump are poor in biological activity and mineralogically diverse (clays, sands, marls, etc.), which makes the fertility potential low. In this context, it is self-obvious that a few species of weeds have spontaneously settled on the dump: the sedge, the wind grass, the moss, etc.

The situation is very different from the original one, when these lands were covered with forests, and obviously the disappearance of the vegetation (but also other elements of stress such as the noise and dust resulting from the mining activity) led to the disappearance of the fauna specific to the area.

After analyzing 4 possible options (agricultural recovery, forestry, productive with fruit shrubs and naturalistic), we opted for the third one, namely the establishment of a plantation of fruit shrubs, more specifically of blackberry and raspberry species.

The need for ecological reconstruction of the West Berbești internal dump is related to the reconstruction of a functional ecosystem, even if it is slightly different from the one existing before the start of the mining activity, on an area of 203 ha, and the increase of the productive capacity of the land.

It must be specified that the chosen species were an integral part of the original ecosystem, in the wild version, but did not occupy the entire surface.

All the planned ecological reconstruction works contribute to restoring the environmental factors affected by the coal extraction activity, especially on the soil and flora.

By planting fruit shrubs, the anthropogenic soils from the waste dump restore their structure over time, with a role in increasing the stability of the slopes, the accumulation/retention of nutrients and water in the soil. Planting fruit shrubs on the West Berbești internal waste dump contributes to the restoration of the spontaneous herbaceous flora, to the return of the fauna characteristic of the area and implicitly to the restoration of the ecosystem as a whole.

Increasing the planted areas has a role in restoring air quality (decreasing thermal amplitudes, increasing atmospheric humidity, increasing the amount of oxygen produced by filtering and fixing particles in suspension from the atmosphere, reducing noise) in the area. Of course, improving air quality has positive effects on the health and mental state of the population. Restoring the landscape also affects the mental state of the population but also contributes to increasing the tourist potential of the area.

Any project of ecological restoration of degraded lands has as its main goal an improvement of their quality, at least by returning them to their original capacity, to ensure their subsequent use.

This project is one that fits in with the surrounding area from a landscape point of view and is able to provide medium and/or long-term economic benefits to the local community (by capitalizing forest fruits).

In the case of the ecological restoration of the West Berbești waste dump, we are in the situation of substituting or partially replacing an ecosystem. The replacement of the natural ecosystem consists of new combinations of native species, which are assembled to suit the conditions of the new land.

In order to achieve the proposed objective, namely the ecological restoration of the West Berbești dump and the productive recovery of the land, two essential stages must be completed [3]:

1. The stage of technical-mining redevelopment, which must be carried out by the mining operator responsible for the degradation. During this stage, investigations are carried out regarding the technical condition of the dump, works to combat erosion, the creation of access roads, capital leveling, etc.;
2. The stage of biological recultivation, which has the role of increasing the fertility of the dumped materials including the amelioration measures as well as the specific techniques and technologies of recultivating the dumps.

In order to render the West Berbești interior dump to the productive circuit by establishing a plantation of fruit shrubs, the following stages must be completed:

1. Analyzing the technical condition of the dump (stability of the dump);
2. Possible territory organization works (modeling of definitive slopes, canceling erosion phenomena, leveling, setting up access roads, etc.)
3. Fertilization works on the dump;
4. Planting works;
5. Monitoring.

5. RESEARCH ON THE TECHNICAL CONDITION OF THE WASTE DUMP

The dumps from mining exploitations are engineering constructions that are made on the basis of legally approved technical-economic documentation and represent accumulations of barren (sterile) rocks resulted by removing the overburden [14].

The exploitation methods assume the use of high-capacity dumping machines (spreaders) for the construction of the dumps, both for depositions in internal and external ones [15].

The waste rocks stored in the dumps comes from the overburden and from the sterile intercalations between the exploited lignite layers, being a heterogeneous and inhomogeneous material, directly dependent on the area and level of excavation. This inhomogeneity is manifested along the deposition steps in their direction as well as in the structure of each step [10].

In order to carry out analyzes regarding the stability of the individual slopes and the system of characteristic steps for the West Berbești internal waste dump, the first stage was represented by the realization of an analysis section. Thus, from the situation plan, the section in figure 4 was materialized with the help of the specialized software Slide [16], in which the values of the physical and geomechanical characteristics of the rocks were entered.

Depending on the share of the rocks in each geotechnical drilling performed [12], their average weighted values were calculated. For the rock mixture in the Waste Berbești waste dump [10]:

- Volumetric weight 18.27 kN/m^3;
- Internal friction angle 21.6°;
- Cohesion 21 kN/m^2.

For the rocks in the direct foundation (compact sandy marl) [10]:

- Volumetric weight 19.33 kN/m^3;
- Internal friction angle 21.0°;
- Cohesion 45 kN/m^2.

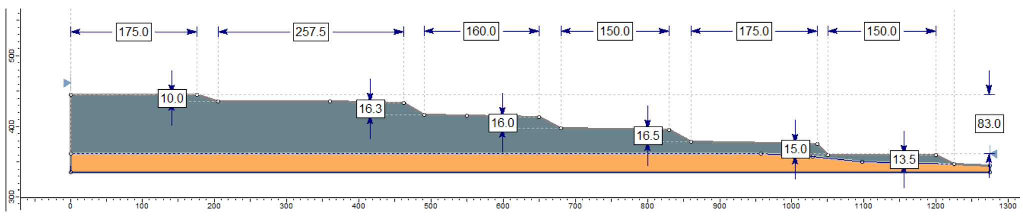


Figure 4. Cross section through West Berbești waste dump [10, 17]

In the next step, the stability of each individual step was analyzed, as well as the stability of the whole system of steps. Because it is estimated that a lake will form in the remaining gap of the open pit, up to the level of the first step of the internal dump, the situation in which this first step is submerged was also analyzed.

For this purpose, the stability analyses were performed using classic (based on limit equilibrium theory) methods (Fellenius, Bishop, Simplified Janbu and Morgenstern-Price), these methods being the commonly used methods (in engineering practice) for determining the safety factor of a slope, as they proved their reliability and are easy to understand by mining operators [18]. Most of them assume that the sliding surface is a circular one, and the applied computing algorithms are based on this assumption [19 - 25].

The results of the stability analyses are presented in Table 1.

Table 1. Stability analyzes of individual steps and the system of steps [10, 17]

Slope	Geometry		Nature of the rocks	F_{S1} (Fellenius)	F_{S2} (Bishop)	F_{S3} (Janbu)	F_{S4} (M-P)
	H (m)	α (°)					
Tr1	13.50	27	Mixture of waste rocks	1.623	1.719	1.656	1.715
Tr2	15.00	45		1.294	1.375	1.311	1.373
Tr3	16.50	29		1.884	2.142	1.895	2.142
Tr4	16.00	28		2.413	2.772	2.413	2.772
Tr5	16.33	31		1.953	2.214	1.971	2.215
Tr6	10.00	18		2.311	2.588	2.385	2.586
Tr1 submerged	13.50	27		2.448	2.600	2.516	2.598

In the case of the steps of the West Berbești interior dump, following the stability analyzes, it can be concluded that they have a sufficient stability reserve. Therefore, given the medium-term stability, all the steps analyzed can be considered stable.

In the conditions in which the first step is submerged, and in the body of the dump the pore pressure is manifested, a stability factor of 2,448 is obtained, superior to the one obtained under normal conditions (with the material at natural humidity and without the presence of water accumulation in the remaining gap) [10, 17].

This result is in accordance with the theory that, under the conditions of submerged slopes, the water exerts a hydrostatic pressure on the slope behaving like a supporting prism [10, 21, 25, 26, 28] and is supported by the results of previous studies published in specialized journals [27, 29].

However, as previous studies have shown [27], during the filling of the remaining gap with water, especially if the flooding occurs exclusively by natural means, due to the relatively long time required to raise the water level, the rocks initially unsaturated in the dump are in contact with water for a longer period. These conditions allow the rapid saturation of the rocks and the increase of the hydrostatic level in the body of the dump (due to the capillary pores that allow the water to rise in the body of the dump), without being counteracted by the hydrostatic pressure exerted on the slopes by the water in the lake. Such a situation leads to an initial decrease in the stability factor, increasing the risk of negative geomechanical phenomena, such as landslides or liquefaction of the deposited material [10, 17, 18, 21, 25, 26, 28].

The period in which this decrease in the stability factor is observed is limited in time, and can be counteracted by accelerating the rate of filling the remaining gap with water. This acceleration can be achieved through adductions [17, 27]. The flooding process itself and the behavior of the dump during this period must be monitored, at least through observations, so that it can be intervened if there are signs of loss of stability (superficial landslides, plastic flows, abnormal settlements, tension cracks, etc.).

6. LANDSCAPING AND REVEGETATION OF THE WASTE DUMP

6.1. Species determination

As specified at the end of paragraph 3, the chosen option for the productive recultivation of the West Berbești interior waste dump, namely with fruit-bearing shrubs, involves the use of two species: blackberry (*Rubus fruticosus L.*) and raspberry (*Rubus idaeus*) (fig. 5).

a. Blackberry plantations

b. Raspberry plantations

Figure 5. Fruit-bearing shrub plantations

These species were not chosen randomly, but taking into account two very important aspects:

- These species are characteristic of the bio-pedo-climatic zone in which the waste dump is located;
- The good results obtained in Romania by growers of such fruit shrubs.

In addition, as the data demonstrates, the return on investment begins in the second year for raspberries and in the third year for blackberries, which means a rapid amortization and transition to a profit regime within a maximum of 5 - 6 years.

6.2. Landscaping and soil amendment

On the site plan presented in Figure 6, the two planting zones have been outlined for each chosen species. Thus, starting from the upper berm of step 1 and up to the upper berm (inclusive) of step 3, blackberries will be planted. The main reason is represented by the position of these steps, close to the open pit core, in a shadier and moister area, considering the formation of the lake in the remaining gap (up to the level of step 1). This species prefers shadier and moister areas, unlike raspberries. The rest of the waste dump (steps 4 - 6) will be cultivated with raspberries (a species that prefers light and warmth).

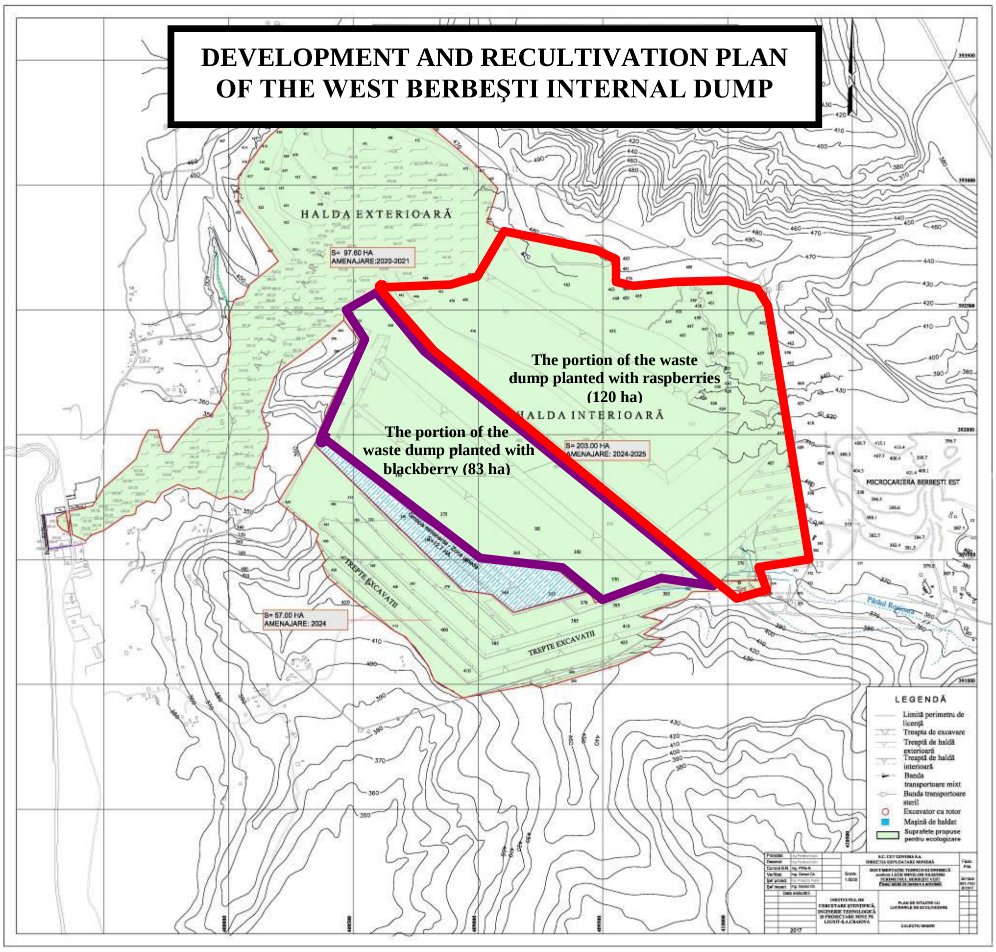


Figure 6. Plan for landscaping and recultivation of the West Berbești interior waste dump (modified after [12])

Taking into account that these species are characteristic of hilly areas with local variations, the only leveling work required will be carried out concurrently with the application of amendments, when they are incorporated into the waste dump material.

Overall, the lithological materials from the waste dump exhibit:

- Coarse texture (NL - L) or fine texture (AL - A);
- Presence of the mineral skeleton at the surface and in the profile;
- Soil reaction (pH) weakly alkaline (7.5 - 8.5);
- Low supply of nutrients (N P K) and low humus content.

Even though physically and chemically different, the current lithological cover, in accordance with the new soil classification system approved by Order no. 519/08/2003, falls under the class of Protosoils, type Entrianthrosoil. This classification represents soils in the process of formation, developed on anthropogenic parental materials [30].

Although the species selected for the productive utilization of the land on the West Berbești waste dump are not demanding regarding soil conditions, to increase the chances of success for the future plantation, the application of amendments is recommended.

According to the pedological study, the administration of fertilizers with phosphorus and potassium is recommended. Within this project, the planned administration includes simple fertilizers with phosphorus and potassium to provide the necessary doses, as follows [31]:

- Superphosphate P_2O_5 45% w/w – 1000 kg/ha
- Potassium salt K_2O 45% w/w – 1200 kg/ha

Total = 2200 kg/ha

For the surface area of 203 hectares, the required amounts are:

- Superphosphate – 203 tons
- Potassium salt – 243.6 tons

Total = 446.6 tons

The work involves the administration of fertilizers in a mixture with a MA 3.5 (fertilizer spreading machine with a 3.5 - ton hopper) and incorporation into the waste material through plowing at a depth of 18 - 20 cm using a mechanically driven plow.

The execution of basic fertilization without subsequent crop establishment leads to the loss of mineral substances through their consumption by spontaneous vegetation that establishes itself, as well as losses due to unstructured lithological materials from the waste dump, which cannot retain mineral substances.

Therefore, crop establishment should be carried out as soon as possible after fertilizing the land.

6.3. Planting scheme and procurement of biotic material

For the proposed area of land for reintroduction into the productive circuit, the necessary biotic material consists of blackberry and raspberry cuttings (saplings). Generally, these are planted at a distance of 1.5 m in rows and 2 m between rows, alternating, to allow optimal access to light (fig. 6).

Another reason why the distance between rows is set at 2 meters is the possibility of access for workers and small-sized equipment, especially during the harvest period and for crop maintenance.

For an area of 6 m^2, 18 cuttings are required (regardless of the species), which leads to a total need for cuttings of 6.090.000, to which approximately 600.000 (10%) are added for completing the plantation after one year.

It is obvious that the acquisition and planting of such a large number of cuttings are almost impossible in a single year. Therefore, the vegetation works for the entire surface of the waste dump must be staggered over at least 10 years.

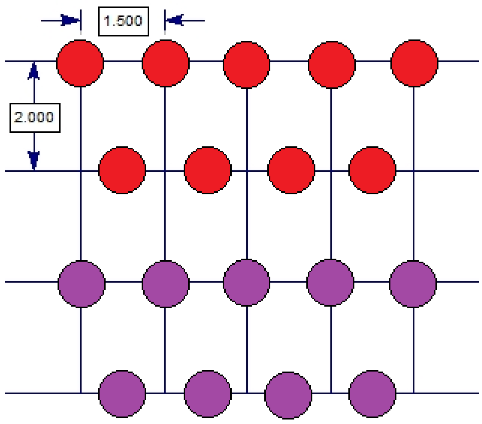


Figure 6. Planting scheme

The cuttings will be procured from specialized units (nurseries) with a health certificate.

The transportation of the cuttings to the waste dump is done using a type of transport where they are not exposed to dehydration or other factors that could lead to their destruction.

At the planting site, the cuttings are stored in special pits (width 50 cm and depth 40 cm), where they are covered with moist soil over the roots, up to 2 - 3 cm from the stem.

Before planting, the cuttings undergo root pruning, and during planting, they will be carried in buckets with water and soil. Before planting, especially in spring, the seedlings roots will be soaked in water for 24 - 48 hours.

6.4. Determination of planting methods and works planning

First Year - Establishment of the Plantation

Land staking - Marking of the places where cuttings are planted is done before, using distinctive signs (stakes). Staking must be carried out by forestry personnel specially trained for this purpose.

Land preparation - The proposed land preparation involves the previously mentioned works, followed by the digging of planting holes.

Planting period - In the autumn, during the months of October and November, after the leaves have fallen, before the occurrence of frost. Planting can also be carried out in the spring after the thawing of the soil, up until the onset of vegetation (March-April).

Proposed planting procedure - Planting the cuttings in holes of various sizes, depending on the species requirements, the nature of the crop, land preparation, etc. In this case, for blackberry and raspberry: - holes of 30/30/30 cm.

The pruning of the cuttings stem is carried out in the spring before the start of vegetation, both for spring and fall plantations (to prevent winter freezing of the cut).

The operation is performed with vine scissors, 1 - 2 cm above the collar. This operation also aims to establish a balance between transpiration through the stem and absorption through the roots during the transplantation of cuttings from the nursery to the field.

For the control of insects (aphids) that can hinder and even destroy the growth of the terminal shoots in young cuttings, aged 1 - 3 years, an annual treatment is proposed over a period of 3 years. The task can be carried out manually with mechanical devices worn by workers, through fine spraying with insecticides such as Decis or Fastac, at doses of 0.015-0.025 in the months of June-July.

Second year - Rebuilding the density (replenishing of the plantation) and maintenance work

For adjusting the density of the plantation, interventions are made through replenishments. The necessity and volume of replenishments are determined by placing control reliefs (annual control of regenerations)."

Based on the experience gained from establishing fruit shrub crops, replenishments reach around 10%.

Replenishments are carried out with cuttings of the same species (blackberry or raspberry) depending on the established cultivation zones. All other works are similar to those presented in the planting technology (acquisition, storage, digging holes, planting, fertilizing), including maintenance tasks (hoeing, loosening, pest control, etc.).

6.5. Monitoring the revegetated area

Stability and deformations monitoring

Direct observations aim to technically characterize the state of the waste dump. These observations will be practically carried out on a daily basis by technical staffs, who are obligated to report any deformations that occur in the body of the dump.

For greater rigor in these observations, specially trained personnel (mixed teams from the environmental, topography, and geology departments) will conduct field visits weekly. They will identify the type of deformations encountered and mark them on an updated site plan.

Monitoring the recultivated area

In this phase, it is necessary to monitor the soil quality to ensure the conditions required by the fruit shrubs crops. Soil quality deterioration can occur due to leaching of nutrients caused by acid rain. The monitored parameters will focus primarily on fertility, and microbiological analyses are also recommended (soil microorganisms being indicators of its quality and the presence of potential harmful compounds).

Due to the relatively slow pace of changes in soil quality, the frequency of determinations will be annual.

Crops Monitoring

The crops monitoring will be carried out by specialists (agricultural engineers, researchers from land improvement institutes, etc.), and they will observe the growth rate of plants, the number of plants reaching maturity, the rate of coverage with mature plants of the area reintegrated into the economic circuit, etc.

To conduct these determinations, observation plots will be established, which should be representative of the entire area reintegrated into the productive cycle, and the frequency of determinations will be in accordance with the development periods of the cultivated species.

Reviewing the plantation after adverse weather conditions (rain, winds, freeze-thaw, etc.) is absolutely necessary. A detailed review is proposed in the year following planting for the entire area.

7. CONCLUSIONS AND RECOMMENDATIONS

The area where the West Berbești interior waste dump is located is characterized by a specific climatic regime of the Getic Subcarpathians and the Getic Piedmont, with an annual average air temperature ranging between 16.0°C and 16.4°C. The average annual precipitation level is 753 mm, and the wind regime is significantly influenced by the nearby hills, with the frequency and intensity of winds mainly from the N-NW direction.

The soils in the studied area are mostly of alluvial nature, formed from coarse material deposited over a layer of gravel.

Generally, soils affected by mining activity differ based on geological and geomorphological conditions, with their productive potential ranging from low to medium. As a result, they fall within the fertility classes ranging from 2^{nd} to 5^{th}.

The materials deposited in the waste dump are highly heterogeneous both physically and chemically. They are generally poor in biological activity and extremely diverse in mineralogical composition (sands, gravels, clays, marls), resulting in a reduced fertility potential, falling into 4^{th} and 5^{th} classes.

The stability analyses conducted in this study have led to the conclusion that the West Berbești interior waste dump is stable as long as the deposited material is at natural moisture. Increasing its moisture towards the saturation limit can lead to instability phenomena and trigger landslides. The West Berbești interior waste dump has not been affected by landslides in the past.

In order to determine the level of intervention for the ecological restoration of the West Berbești interior waste dump, the first step was to study how the land was used before mining activities commenced."

The selection of possible crops and plantations for future application was done considering the climatic zone, soil nature, and positive experience gained in the field up to the present.

Several options for the ecological reconstruction of the West Berbești interior waste dump were considered, and to determine the final option, namely planting with fruit shrubs, the principles of ecological planning were taken into account. The principle of globality or intercausality was considered, indicating that the territory must be viewed as a whole.

Most important is the fact that the needs of local communities were taken into account, as well as the closure plans for the mining facility and the extent to which these plans have already been included in the territorial development plans elaborated by local authorities.

Beyond its productive function, the plantation will also ensure the reintegration of the waste dump into the surrounding natural environment.

In order to carry out the ecological restoration project of the West Berbești interior waste dump, the existing physical, chemical, and pedological conditions were analyzed, and solutions for their restoration were identified by establishing the necessary works.

Following the completion of this study, some general recommendations can be formulated:

Most important is the fact that the needs of local communities were taken into account, as well as the closure plans for the mining facility and the extent to which these plans have already been included in the territorial development plans elaborated by local authorities.

Beyond its productive function, the plantation will also ensure the reintegration of the waste dump into the surrounding natural environment.

In order to carry out the ecological reconstruction project of the Berbești West inner waste dump, the existing physical, chemical, and pedological conditions were analyzed, and solutions for their restoration were identified by establishing the necessary works.

Following the completion of this study, some general proposals can be formulated:

1. Progressive recovery of active waste dumps through planting works with various forestry or agricultural species on the portions of the dump that have reached the projected level and have been freed from technological burdens;
2. The use of species with a fast growth rate, whose maintenance does not involve high costs, that also exhibit tolerance to weather conditions, and have low requirements regarding soil fertility;
3. Using hydrophilic species in areas where water accumulations have been observed (in surface depressions or where the deposited material has high moisture);
4. Using species that allow for a rapid recovery of the initial investment.

8. REFERENCES

[1] Fodor D., Baican G., Impact of the mining industry on the environment (in Romanian), Infomin PH, Deva, 2001.
[2] Fodor D., Mining and environment (in Romanian), Corvin PH, Deva, 2015.
[3] Lazăr M., Rehabilitation of degraded lands (in Romanian), Universitas PH, Petroşani, 2010.
[4] Guozhen Z., Jiaxin C., Lihong Z., Shuai W., Yiqing L., Guangyao S., Ecological restoration of coal mine waste dumps: A case study in Ximing Mine, China, International Journal of Mining, Reclamation and Environment, Vol. 37 (5), pp. 375-397, 2023, DOI: 10.1080/17480930.2023.2199379
[5] Fodor D., Dican N., Open pit exploitation of coal deposits from Berbești mining basin, Mining Revue, Vol. 19 (2), pp. 2-11, 2013. https://www.upet.ro/revistaminelor/archive/rmpdf2013/nr2en.html
[6] Fodor D., Dican N., Exploitation of coal deposits in the Berbești mining basin, Mining Revue, Vol. 19 (3), pp. 2-9, 2013. https://www.upet.ro/revistaminelor/archive/rmpdf2013/nr3en.html
[7] ***, Google Earth Pro. https://www.google.com/earth/index.html

[8] Chiriță R.V., Lazăr M., Faur F., Critical analysis of the geomorphological changes as a result of mining activities in Berbeşti basin, Annals of the University of Petrosani, Mining Engineering, Vol. 19, pp. 132–145, 2018. https://www.upet.ro/annals/mining/pdf/Annals%20of%20UPET%20-%20Mining%20Engineering%20Vol%2019-2018%20(XLVI).pdf
[9] Lazăr M., Faur F., Apostu I.M., Stability conditions in lignite open pits from Romania. Case study: Olteţu open pit, Applied Sciences, Vol. 12, 9607, 2022. https://doi.org/10.3390/app12199607
[10] Faur, F., Lazăr, M., Apostu I.M. Rada C., Moisuc-Hojda D., Assessment of the stability state and the risk of landslides within Berbeşti mining basin (Romania) post closure. Inżyneria Mineralna - Journal of the Polish Mineral Engineering Society, Vol. 2, pp. 59–70, 2022. http://doi.org/10.29227/IM-2022-02-07
[11] Dican N., Modern solutions for rendering in the economic circuit of waste dumps and lands degraded by mining activity in the Berbeşti mining basin (in Romanian), Doctoral Thesis, University of Petroşani, 2014.
[12] ***, Documentation CET Govora, Mining Division, 2021-2023.
[13] Baican G., Boldor, C., Ianc I., Rehabilitation of waste dumps resulting from the extraction of lignite in the open pits from the mining basin of Oltenia, The IVth World Mining Environment Congress – 25 - 30 of June 2001, Băile Felix, Romania.
[14] Fodor D., Open pit mining of deposits of useful mineral substances and rocks (in Romanian), Vol. 1, Corvin PH, Deva, 2008.
[15] Fodor D., Open pit mining of deposits of useful mineral substances and rocks (in Romanian), Vol. 2, Corvin PH, Deva, 2008.
[16] RocScience, Inc. Slide 2D Limit Equilibrium Slope Stability Program [User's Guide], Version 6.0.2.5. 2013. www.rocscience.com.
[17] Faur F., Lazăr M., Apostu I.M., Land stability in the influence areas of lignite open pits. A case study for the Berbeşti mining basin (Romania), Lambert Academic Publisher: London, United Kingdom, 2022. https://www.lap--publishing.com/catalog/details/store/gb/book/978-620-5-52831-0/land-stability-in-the-influence-areas-of-lignite-open-pits?search=Faur
[18] Toderas M., Florea V.A., Itu R.B., Stability analysis of the tailings dam for the purpose of closing, greening, and ensuring its safety - Study case, Sustainability, Vol. 15, 7606, 2023. https://doi.org/10.3390/su15097606
[19] Duncan J.M., Wright S.G., Brandon, T.L., Soil strength and soil stability, 2nd ed., JohnWiley & Sons Inc.: Hoboken, NJ, USA, 2014. https://istasazeh-co.com/wp-content/uploads/2021/11/Soil-Strength-and-Slope-Stability-1.pdf
[20] Duncan C.W., Rock slope engineering. Civil and mining, 5th ed., CRC Press – Taylor & Francis Group, New York, 2018. https://www.routledge.com/Rock-Slope-Engineering-Civil-Applications-Fifth-Edition/Wyllie/p/book/9781498786270
[21] Stănciucu M., Stability of natural and artificial slopes (In Romanian); Technical PH, Bucharest, Romania, 2018.
[22] Hoek E., Bray J.W., Rock slope engineering, 3rd ed., Institution of Mining and Metallurgy: London, UK, 1981. https://doi.org/10.1201/9781482267099
[23] Derek H.C., Landslides in practice: investigation, analysis, and remedial/preventative options in soils, John Wiley & Sons Inc.: Hoboken, NJ, USA, 2005.
[24] Huang Y.H., Slope stability analysis by the Limit Equilibrium Methods: fundamentals and methods; ASCE Press: New York, NY, USA, 2014. https://doi.org/10.1061/9780784412886
[25] Rotunjanu I., Stability of artificial and natural slopes (in Romanian), Infomin PH, Deva, 2005.

[26] Apostu I.M., Faur F., Identification and analysis of geotechnical risks in the conditions of flooding of the remaining gaps, MATEC Web of Conferences, Vol. 290, 11002, 2019. https://doi.org/10.1051/matecconf/201929011002
[27] Lazăr M., Faur F., Apostu I.M., Influence of the flooding speed of former lignite open pits on the stability of final slopes, MATEC Web of Conferences, Vol. 305, 00040, 2020. https://doi.org/10.1051/matecconf/202030500040
[28] Apostu I.M., Geotechnical risks in the conditions of flooding of remaining gaps of lignite open pits (in Romanian), Universitas PH, Petroșani, 2021.
[29] Bajcar A., The influence of selected weather conditions on safety of slopes of post exploitation lignite pits filling with water, Górnictwo Odkrywkowe (Surface Mining), Vol. LXIII (4), pp. 30-32, 2022
[30] Florea N., Munteanu I., Romanian System of Soil Taxonomy (SRTS) (in Romanian), Estfalia PH, Bucharest, Romania, 2003.
[31] OSPA (Office for Pedological and Agrochemical Studies), Methodology for elaboration of pedological studies (in Romanian), 2011.

ECOLOGICAL REHABILITATION OF LANDS AFFECTED BY COAL EXPLOITATION. CASE STUDY

SUSANA ECATERINA APOSTU[1], ALEXANDRA ȘOICA[2], BOGDAN-ZENO COZMA[3]

Abstract: *The mining and processing industry implies a reciprocal relationship between nature and society as well as between economy and ecology. In addition to extracting the useful mineral substance, the mining and processing industry also has the task of solving the complex problem of removing its negative effects on the environment. Solving this problem requires the collaboration of specialists from different fields: geology, geotechnics, mining, territorial planning, agronomy, forestry, sociology. Our purpose was to find a solution for the lands of our region, lands that are affected by coal exploitation.*

Keywords: *tailings dumps, mining, mineral resources, environment*

1. INTRODUCTION

Losses of combustible mass in the tailings discharged to the warehouses result from the primary technological process of raw coal preparation. In some areas of the dumps, the calorific value exceeds 1500 kcal/kg. The components present in the preparation tailings constitute the secondary resources resulting from the primary technological process.

Reusable secondary resources represent a part of secondary resources that can be extracted or reused efficiently economically and depend to a large extent on the potential of the resources, on the technologies used for recovery as well as on the reference level of the costs of energy and usable materials, having a dynamic character over time.

The sterile deposits of the preparation plants in Jiu Valley can constitute reusable secondary resources, at least from the point of view of the recovery of the combustible mass.[1]

To design and carry out an impact study, the starting point is the definition of environmental, economic and territorial interest objectives in the analyzed area.

Techniques used in this phase may consist of checklists for a first selection of important effects. The project proposal must be overlapped and intersected with projects

[1] *Lecturer, Ph.D. Eng., University of Petrosani, apostu_susana@yahoo.com*
[2] *Assistant, Ph.D. Eng., University of Petrosani, alexandra_valynikalay@yahoo.com*
[3] *Assoc. Prof. Ph.D. Eng., University of Petrosani, bogdancozma@upet.ro*

of environmental interest, which are regional plans, basin plans and plans of other sectors of activity.

It is important to take into account the fact that for any type of extractive and preparation activity appropriate analysis criteria must be defined and consequently, it is necessary to carry out a specific sensitivity mapping for each of them, in addition to performing significant syntheses, if the analogy of the results allows it.

The next phase, of impact synthesis and forecasting, based on simulation techniques, requires the use of modeling for the construction of evolution scenarios and decision simulations. In relation to the importance of the estimated effects, the following must be pursued: avoiding the concentration of landscape degradation, excluding the risk of water pollution in sensitive areas in terms of water supply.

The storage of tailings from the extraction and processing activity in dumps causes functional alterations or the destruction of the location territory, and the vegetation in that habitat is destroyed. Many times, due to the coarse granulometry of the landfill material, the water retention capacity disappears, and due to the large slopes of the slopes, the re-establishment of vegetation on them becomes difficult.

The major impact of the mining activity is felt on the soil and, in particular, on the landscape. The potential effects that the extractive and preparation activity can have on the landscape are multiple and refer to several aspects:

- Changing the morphological configuration;
- Changing the real consistency and the relationships between the soil cover and the existing anthropogenic elements;
- The introduction of foreign elements in the context of the unity of the landscape;
- Disturbance of the chromatic and form elements;
- Disturbance of overall perception;
- The introduction of perceptible foreign elements: noises, dusts, vibrations.

The quantitative evaluation of the effects of the extractive and preparation activity on the components of the natural environment: vegetation, flora, fauna, ecosystem, is very complex and due to the spatial and temporal interdependence of the different factors. The severity of the impact can be classified according to several criteria, including:

- the vulnerability of the environment;
- the possibility of mitigating the impact: when possible, through the appropriate choice of exploitation methods and techniques;
- persistence of degradation: total or immediate; reversible or irreversible;
- the possibilities of environmental recovery.

Any component action of the extractive activity involves inevitable interactions with the soil and subsoil components, which represent the natural seat of such an activity.

The impact on the soil and subsoil can have the following forms of manifestation:

- change in morphology;
- modification of hydrological characteristics;
- modification of the hydrogeological characteristics;
- change of land use.

Such changes can lead to soil and subsoil degradation, being the cause of ecological imbalance phenomena, altering the process of natural evolution of soil and landscape.[2]

The mining redevelopment of the surfaces affected by the mining and processing industry must be seen as a component of the mining activity and can be defined as the methodical modeling of the surfaces used by the mining and processing enterprises, taking into account the public interests.

The responsibility for this activity is borne by the person who causes the damage to the surfaces. Through the redevelopment works, the previous economic potential of the region must be recreated, corresponding to the current conditions.

The mining and processing industry implies a reciprocal relationship between nature and society as well as between economy and ecology. In addition to extracting the useful mineral substance, the mining and processing industry also has the task of solving the complex problem of removing its negative effects on the environment. Solving this problem requires the collaboration of specialists from different fields: geology, geotechnics, mining, territorial planning, agronomy, forestry, sociology.[3]

The reuse of areas affected by mining is oriented in the following directions:

• agricultural areas;
• forest areas;
• fishing areas;
• waste depots;
• gardens, recreational areas, sports fields;
• natural reservations.

The rehabilitation of the areas occupied by solid mining residue deposits requires the realization, in a first stage, of a mine redevelopment, which must create the necessary conditions for the regeneration of soil fertility and the cultivation of plants, or conditions for constructive purposes, and in another stage of a biological redevelopment, which consists in the environmental recovery of the surfaces of the warehouses.

In order to carry out their mining redevelopment with a high efficiency and quality and thus to have the premises of restoring the economic circuit of the affected surfaces according to the proposed purpose, the technical mining measures must be oriented from the beginning in the sense of redevelopment. Thus, the following requirements regarding the landfill surfaces must be taken into account:

• The share of the surface

• The surfaces intended for agricultural or forestry recultivation or that will be used as a construction base must have an elevation above the future hydrostatic level.

• The shape of the surface

For agricultural recultivation, flat land surfaces with a large extension and low slopes are required, while for forestry recultivation, surfaces with a higher slope, including slopes, can be used.

Mining redevelopment of tailings deposits includes the following stages:

- Recovery and conservation of the vegetable soil;
- Arrangement of dumps;
- Leveling of landfill surfaces;
- Depositing topsoil on level surfaces;

- Improvement of the lands on the landfills.

The technological stages that make up the mining redevelopment are carried out partially or totally, depending on the final destination of the dump surfaces.

The return to the economic circuit of the lands degraded by the mining industry represents a complex of measures and works that are carried out to transform these surfaces into productive areas for agriculture, forestry, fish farming, to create rest and leisure spaces or to create the conditions for the reuse of voids underground remains after the exploitation of deposits of useful mineral substances.

Following the process of closing the mines, the technological and administrative constructions, except for those kept for other purposes, will be demolished.[1]

The demolition works will consist of the decommissioning of construction machinery and equipment and the demolition of the building, including the foundations.

It is necessary to promote waste recovery, where reducing the amount of waste intended for shredding saves natural resources, in particular it helps reuse, recycling and energy recovery from waste. At the end of a correct management of the waste resulting from the demolitions, the reduction of the final shredding of the waste produced must be encouraged by:

a) reuse and recycling;

b) other forms of recovery by obtaining raw materials from waste;

c) adopting economic measures and determining the conditions for the reuse of materials recovered from waste to encourage such a market;

d) the main use of waste as fuel or other measures for energy production.

The reuse, recycling and reuse of raw materials must be considered preferable to other forms of recovery

Reclamation of landfill sites it is an operation that is performed in order to improve the acidity of the landfilled soil, being a more recently applied solution.

In the complex of measures undertaken for land refertilization, improvement has a very important role, because it directly influences the subsequent production that will be obtained on the respective lands. The repercussions of the years following the improvement can hardly be deduced, that is why it must be executed very demandingly and according to technical projects.

The land improvement technology is specific to each dump, being established on the basis of geological expertise, which highlights the quality of the soils, the type of recultivation, the precise contents of the ameliorating substances and the crops that lend themselves to each individual land.[3]

Improvement can be done with calcium, coal ash or phenols contained in industrial waters. Lately, natural zeolites have been used to improve land. They are widely used in plant culture, but also in animal husbandry and fish farming. In the form of an agricultural amendment, these minerals contribute to soil aeration, act as acid soil neutralizers and control the release of ammonium, nitrogen and potassium from fertilizers.

A. Amelioration with calcium

The acidity of the natural soil and the power of water absorption by the land must be improved primarily by the addition of calcium, and the absorption ensured by the base of the dump. A sustainable action is ensured only by applying large amounts of lime, i.e., pure CaO, to achieve rapid dissolution and infiltration into the depth of the strata together with the groundwater. Administration of calcium in the landfill is done in the quantities indicated in the project, through the prescribed doses. As a rule, a dose is 100 t Ca / ha, but depending on the acidity of the soil, submultiples of the dose can be administered, 25 t Ca / ha; 50 t Ca / ha as well as dose multiples.

Calcium improvement consists of the following works:

- transportation of lime on the dump;
- spreading lime on the landfill;
- tillage after spreading lime.

B. Amelioration with ash

The process uses the ash resulting from combustion in thermal power plants for improvement.

The amount of ash used varies depending on the nature of the land, with values of 700 m3 / ha or 600 t / ha. The transport and storage of ash from the power plant in a warehouse located near the dump is done mechanically or hydraulically.

In the case of the mechanical process, the ash from the warehouse is loaded and spread over the entire surface of the dump, in a layer with a thickness of 40-50 cm. Spreading the ash is done with the same methods presented when improving land with calcium, with spreading equipment, after which all other operations are repeated in the same sequence.[4]

In the case of the hydraulic process, a 1:5 mixture of ash and water is made, which is transported through main pipes made of steel, reinforced concrete or plastic material, directly to the landfill designed for this purpose. Usually, this process is associated with the one used for the hydraulic deposition of topsoil, so that the necessary arrangements are common. Thus, together with the fertilization of the soil, it is also improved.

C. Enhancement with phenols

The process uses phenol which is contained in the industrial waters resulting from the coke ovens, in combination with lime and a little sulfur from the fly ash.

The amount of industrial water required is approx. 7000 m3 / ha and year. The transport of the resulting mixture is carried out hydraulically on pipes with a diameter of 600 mm, to a buffer pool, from where it is deposited on the surface of the dump by spraying.

2. METHODOLOGY AND RESULTS

We carried out a study of public necessity of local interest, regarding the planting of tailings dumps with energetic willow.

The particularly favorable results recorded entitle us to say that the situation of the land lot affected by the tailings dump can be radically improved by planting them with energetic willow. These plants, in addition to the fact that they stabilize such lands extremely quickly and well, can also be used for burning, due to the special energetic qualities they possess.

In this way, 2 desired goals can be achieved, especially by the energy companies that have to manage such lands:

- ecological stabilization of landfills;
- obtaining alternative energy resources.

Along with humanity's concern to find new non-conventional energy sources, researches have turned to different variants of non-conventional energy sources, to agricultural crops, which can be reproduced annually, and which represent an energy source as safe as possible. The fields in which remarkable results have been tried and obtained are diverse, starting from solar energy, wind energy, heat pumps, biomass.

In the agricultural field, various plants have reached the list of generically named "energo", such as: rapeseed, cane, energy grass and various woody species such as acacia, poplar and willow.

The most spectacular results were obtained in the field of willow. If the rest of the forest plants need 3-5 years before they can be harvested and used for energy purposes, the willow can be harvested annually, having a volume of woody mass of 40-60 t/ha of dry material.

The varieties cultivated for this purpose and registered have main characteristics such as: a very large volume growth - 3-3.5 cm growth/day; they are resistant to bad weather and various diseases; they have a high calorific value approx. 4900kcal/kg.

The most important feature for which it has gained ground in its cultivation in recent years; Sweden over 50,000 ha, Hungary over 2,000 ha, Poland, is the one with rapid growth both in the length of the fields and in volume, but in addition to this advantage we can list a number of other advantages, which is why in the last 3-4 years of came to the fore in the EU as well, where the decision was made to be subsidized as an energy plant. These more important advantages are:

- it can be cultivated on land with permanent or periodic swamps.
- It has an evapo-transpiration capacity of 15-20 l water/day. This advantage gives it an undisputed place as a plant to make usable thousands of hectares of waste land. This has been noticed by countries like Sweden - where already for 8 years the energetic Willow has been cultivated on the surface of more than 50,000 ha, finding a very economical use for hitherto unusable land, and on the other hand cultivating a very profitable unconventional energy source economic.

It also has the capacity to annually receive 20-30 t/ha of sludge from wastewater treatment. This property, in addition to the advantage that it can be located in an area where the plantation can be flooded with waste from treatment plants, grows faster, has the great advantage that waste water does not need to be biologically treated and on the other hand, the water resulting from sewage treatment plants - they end up in very clean rivers, avoiding water pollution but also additional costs due to payments as a penalty for the inadequate quality of discharged water

In principle, this species was experimented to serve as an energy source in a different form of fuel: wood chips - for power plants, briquettes, pellets. The high calorific value of 4,900 kcal/ha makes it comparable to other fuel sources such as natural gas, coal, oil. Making a summary calculation - on the assumption that 20,000 ha of plantations would be established in Romania, in Sweden there are over 50,000 ha, Hungary - in the energy program sent to the EU for the period 2007-2013 - foresees the expansion of energy willow plantations to 36,000 ha, a quantity of 1,000,000t of biomass would be obtained, from which 1,000,000t of pellets would be made, which means a thermal energy source of 4,900,000 Gcal energy - produced on currently uncultivated surfaces - and this source is repeated annually.

The thermal energy that can be obtained from this source ensures the heating of 145,000 conventional apartments annually. By expanding the plantations of energy willow, in addition to being a source of renewable energy, it puts unused land to use, forest deforestation generated by the growing need for cheap fuel is avoided

3. CONCLUSIONS

Through the study we carried out, we debated the problem of tailings dumps in Jiu Valley, their exploitation and rehabilitation. The proposal to rehabilitate the lands resulting from mining exploitations was the attempt to treat them and plant plants that can adapt to a land poor in mineral substances. This objective must be determined with the consultation of all interested parties: governmental, local institutions and community.

REFERENCES

[1]. Arad, S., Arad. V. *Study on the environmental impact of mine closure activity in the coalfields from India and Romania.* Rekultivienrung im Bergbau Freiberg Forschungsforum 61/ FORSCHUNGSHEFTE Reihe C - Geowissenschaften, ISBN 978-3-86012-396-6, ISSN 0071-9404, pp. 212-219, Medienzentrum der TU Bergakademie Freiberg, Germania, 2010, Katalog Der Deutschen Nationalbibliothek: http:// www. dnb.ddb.de

[2]. Arad, V., Arad, S., Iancu (Apostu), S., Bărăiac, O., 2012, The impact of coal mining in Jiu Valley on environment and rehabilitation of the area, Papers SGEM 2012 / Proceedings, Albena, Bulgaria, Vol. 1, p. 877 – 884

[3]. Arad, S., Arad, V, Irimie, S., Cosma, D.,Management of Waste in the Mineral Processing in the Baia Mare Area. Proc. of the 17 th International Mining Congress and Exhibition of Turkey, IMCET 2001, pp. 177- 181, Eds.: Unal, E.; Unver, B., Tercan, E., ISBN 975-395- 417-4, Ankara, Turkey, 2001, Indexed ISI Web of Knowledge

[4]. Stanimirescu, (Șoica) A., Egri, A. *The influence of tailing dumps on the environment from a chemical and pedological point of view at the level of the Berbesti-Alunu basin.* Annals of the University of Petroşani, Mechanical Engineering, 24 (2022), 145-150.

[5]. Davidescu, G. *Valea Jiului și șocul viitorului*. Editura Focus, Petroșani, 2006.

[6]. Dumitrescu, I., Poluarea mediului, Editura Focus, Petroşani, 200210

[7]. Dumitrescu, I. – Impactul activităţilor antropice asupra mediului, note de curs,Petroşani, 2006

[8]. Munteanu, A.M. *Mișcarea ecologista și jurnalist de mediu.* Editura Universitară, București, 2015.

[9]. Marinescu, D., Petre, M.-C. *Tratat de dreptul mediului*. Editura Universitară, București, 2014.

MINERALOGICAL AND PETROGRAPHIC ANALYSIS OF THE ALLUVIUM FROM THE GRAVEL PIT AT CORNETU ROBEȘTI (GORJ COUNTY)

MIHAELA POSTOLACHE[1]

Abstract: *Cornetu-Robeşti gravel pit is located in Tirgu Jiu intra-hillock depression, in the alluvial plain of the river Jiu. This form of relief has several terraces composed mainly of gravel and large, thick boulders. They are associated to fine, medium, and coarse gravel terraces.*
Petrographic analyses on mineralogy-pit samples from Cornetu-Robeşti highlighted the prevalence of the following types of rocks: amphibolite, ortho-gneiss and para-gneiss, quartzite and granite rocks, as well as pegmatite, aplite and rocks migmatised.
As far as the source area is concerned, we can say that rocks amphibolite gneiss and extracted ballast from Cornetu-Robeşti probably come from the existing Danube in the south-western Carpathians.

Keywords: *Gravel, gravel grades, rock deposits, minerals*

1. LOCATION AND DESCRIPTION OF THE AREA WHERE THE BALLAST IS LOCATED

From a geomorphological point of view, Cornetu-Robeşti gravel pit is included in the Târgu-Jiu intra-hillock depression, at its southern edge, in the transition zone between the Sub Carpathians of Oltenia and the Getic Plateau (Piedmont). [1] The researched gravel pit is located in the minor bed of Băiaşu stream in the alluvial deposits of current Upper Holocene age. For the most part, the aggregates extracted here come from the lower and middle terraces of the Jiu, formations that the Băiaşu stream crosses. Fig 1. [3]

2. MINERALOGICAL-PETROGRAPHIC ANALYSIS OF THE SORTS

From the granulometric point of view, the exploited ballast is heterogeneous, a fact that required its sorting. The alluvial deposits' exploitation in ballast is made through mechanical chisel, obtaining the following grades: 0 – 8 mm; 8 – 16 mm and 16 – 31 mm.

[1] *Corresponding author: Mihaela Postolache, Lect. PhD. Eng., University of Petroșani, Petroșani, Romania, contact details (University st. no. 20, Petroșani, Romania mihapos@yahoo.com)*

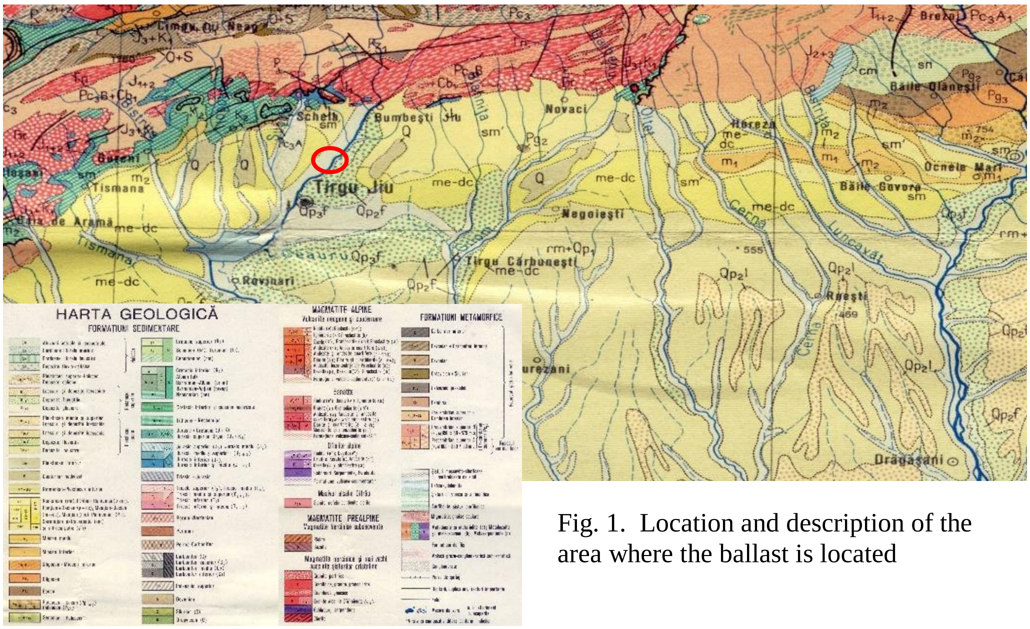


Fig. 1. Location and description of the area where the ballast is located

The first sort of 0 – 8 mm comprises an aleuritic (siltitic), psammitic (arenitic) and even psephytic (ruditic) material, which is partially coarser.

The shapes of the components are also variable, namely: R (rounded), SR (sub-rounded), SA (sub-angular) and A (angular-cornered).

The components of the mentioned sort are heterogeneous and microscopic; they consist of rounded, sub-rounded and angular fragments of ortho-gneiss, para-gneiss, quartzites, mica-schist and amphibolite rocks. To these are added fine muscovite and sericite lamellae, fine grains of quartz and feldspars, as well as sporadic fragments of heavy minerals.

From a structural point of view, the rock fragments are granoblastic, in the case of ortho-gneisses, glanolepidoblastic in the case of para-gneiss, crystalloblastic in the case of quartzite fragments, lepidoblastic in mica schists, granonematoblastic and nematoblastic in amphibolite rocks (amphibolite gneisses and amphibolites).

The texture as well as the structure could only be determined on the coarser components, with the help of the stereographic microscope.

Thus, the texture of ortho-gneiss is weakly schistose (figure 2), in para-gneiss and mica-schist; it is typically schistose, in the case of quartzites and amphibolite; it is un-directed (massive), Figure 3, and in some varieties of amphibolite rocks it can be weakly banded and weakly shale.

The mineralogical composition of the 0-8 mm sort was determined under a microscope for each type of rock. Thus, orthogneisses are composed of quartz, orthoclase feldspars, and plagioclase, muscovite, biotite, zircon, apatite and sporadic heavy minerals (figure 3); the paragneisses, in addition to quartz, have higher percentages of micas (muscovite and biotite), to which feldspars, garnets and apatite are added.

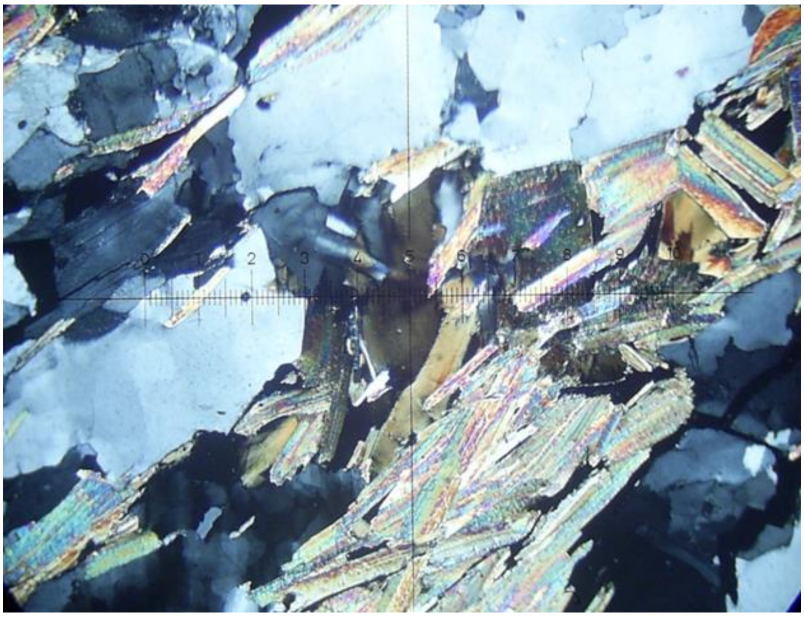


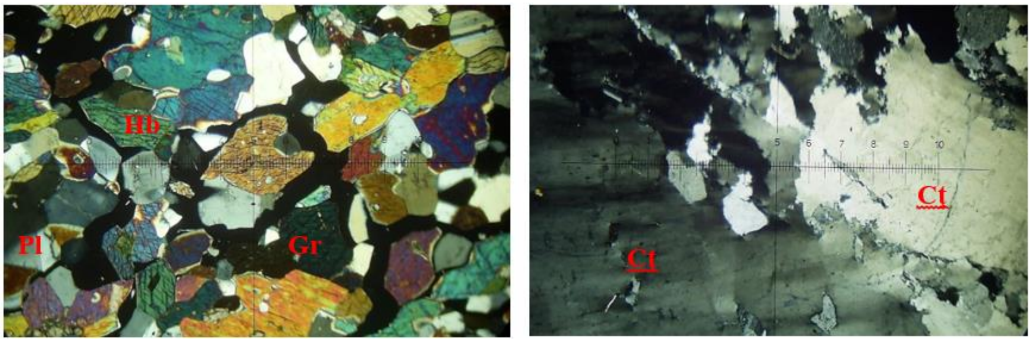
Fig. 2. Weak schistose texture in ortho-gneiss
Ct = quartz, Or = orthoclase feldspar, Pl = plagioclase feldspar,
Mv = muscovite, Bt = biotite, N+, 60x

The quartzites are predominantly composed of quartz, but in some fragments, rare muscovite and biotite flakes with an advanced stage of limonitization are observed.

Amphibolitic rocks contain predominantly hornblende, which is subordinately accompanied by plagioclase feldspars and biotite and in uniform percentages of garnets, titanite and opaque minerals.

The mineralogical-petrographic characteristics, presented above, are sufficient to show that the 0 – 8 mm sort consists of coarse polymictic sand.

The 8 – 16 mm sort, taken from the same open ballast bed in the bed of Băiaşu stream, is made up of a psephytic (ruditic) material in which there are components, both rounded (R), sub-rounded (SR), and sub-angular (SA). and angulation (A).



A **B**

Fig. 3. Un-oriented massive texture in amphibolite (A) and quartzite rocks (B)
Hb = hornblende, Pl = plagioclase, Gr = garnets, Ct = quartz for quartzites, N+, 60x

The components consist of the same types of metamorphic rocks, which were described in the case of the 0-8 mm sort, with the mention that apart from quartz, the mineral fragments are missing. The 8-16 mm sort from the Băiaşu stream is a polymictic gravel. The 16 – 31 mm sort, extracted from the ballast mentioned above, is a coarse ruditic rock, in which the (R) rounded and (SR) sub-rounded forms are predominant.

Regarding the components, in addition to the metamorphic rocks found in the types described above, there are also fragments of phyllonian acidic magmatic rocks, such as pegmatites and aplite.

The mineralogical composition of the pegmatites consists of orthoclase and plagioclase feldspars, quartz, sporadic muscovite lamellae and actinote needles, apatite, zircon, sericite, kaolinite, sometimes limonite films.

Aplite rocks have a simpler composition, namely: plagioclase and orthoclase feldspars, quartz and apatite.

Granulometric structural and petrographic characteristics lead to the name of this type of polymictic boulder. [2]

3. CONCLUSIONS

Cornetu-Robeşti gravel pit is located in the Târgu-Jiu intra-hillock depression, i.e. in the alluvial plain of the river Jiu. This form of relief includes several terraces made up predominantly of gravel and boulders with fairly large thicknesses. These are also associated with terraces where fine, medium and coarse gravels are the most common.

The mineralogical-petrographic analyses carried out on the samples collected from Cornetu-Robeşti ballast have highlighted the predominance of the following types of rocks: amphibolites, ortho-gneisses and para-gneisses, quartzites and granitic rocks. Completely subordinated to them, pegmatites, aplite and migmatized rocks were also encountered.

From a granulometric and petrographic point of view, the above-mentioned grades consist of: coarse polymictic sand (0 – 8 mm), polymictic gravel (8 – 16 mm) and polymictic blocks (16 – 31 mm).

Regarding the source area, it can be said that the amphibolite and gneissic rocks extracted from the ballast of Cornetu-Robeşti construction site probably come from the Danube domain existing in the south-western extremity of the Southern Carpathians.

REFERENCES

[1] **Giuşcă D., Pavelescu L.**, 1955
Contributions to the study of the granite massifs of Şuşita and Tismana. Stud.cerc.geol.Acad. R.P.R. Bucureşti.

[2] **Postolache M.**, 2022
Endogenous and exogenous petrology, Ed. Universitas, Petroșani

[3] **Savu H. e.a.**, 1972
Petrographic and geochemical study of synorogenic and late orogenic granitoids from the area of the Şuşita pluton. (Southern Carpathians), An.Inst.Geol. XXXIX, Bucureşti

ANALYSIS OF CLIMATE RISK PHENOMENA IN THE AREA OF OCNELE MARI SALT MINE

CIPRIAN NIMARĂ[1]

Abstract: *Climate risk phenomena occur and manifest in the atmosphere or on the surface of the Earth and consist of a precipitation, a suspension, a deposition of liquid or solid particles, or an optical or electrical manifestation. Climate risk phenomena are forms of violent manifestation of the weather, in the short term, causing, in the medium and long term, loss of human life, material damage and environmental degradation.*
This paper wants to analyze the risk effects of climatic phenomena on the local population, the tourist flow from the analyzed area and on the environment as well.

Keywords: *climate risk, salt mine, meteorology, mining tourism*

1. INTRODUCTION

The tourist mine Ocnele Mari is located in the locality of the same name, 8 km from Râmnicu Vâlcea, in a picturesque area (close to the Oltului Valley), with a tradition of spa tourism (Olăneşti, Călimăneşti - Căciulata) and religious tourism (the Cozia monastery) [1].

The settlement is in a depression, at an altitude of about 320 m, being guarded by hills with an altitude between 400 and 600 m. Under these hills there is a massif of salt about 600 m thick, which is the main natural resource of the place and which has been exploited since ancient times, also giving the name of the town

One of the horizons where exploitation ended was opened to the public and transformed into a tourist area in 2009, with visitors' access being ensured by minibus transportation from the surface to the interior of the salt pan. The visiting area is laid out 225 meters below sea level and covers an area of approximately 20,000 square meters. The temperature is relatively constant throughout the year, slightly oscillating around 13-15°C.

The last years are characterized by a continuous development of human society, whose impact on the climate has become more and more pronounced.

The management of climate risk phenomena is essential for assessing and anticipating their negative effects on the environment. The dangerousness of

[1] *lecturer Ph.D., University of Petroșani, Mining Faculty, Department of Environmental Engineering and Geology (E-mail: ciprian.nimara@yahoo.com)*

meteorological phenomena requires the issuance of warnings regarding both the scale of evolution and the destructive potential.

2. CLIMATE RISK PHENOMENA

2.1. Thunderstorms

The Onele Mari area, due to its location and physical-geographical conditions, represents a favorable territory for the occurrence of electrical discharges all year round, but more frequently between April and September, with a multi-annual average of approximately 50-51 days during the period 1993-2022.

The annual number of days with thunderstorms during this period varies between 35 days in 2002 and 65 days in 2001 and 2008.

As can be seen from figure 1, the maximum deviation from the multiyear average was about 15 days. In the first part of the interval, it can be observed that, with the exception of 1993, the annual number of storms is below the multi-year average, so that in the following period the annual number above the average will prevail.

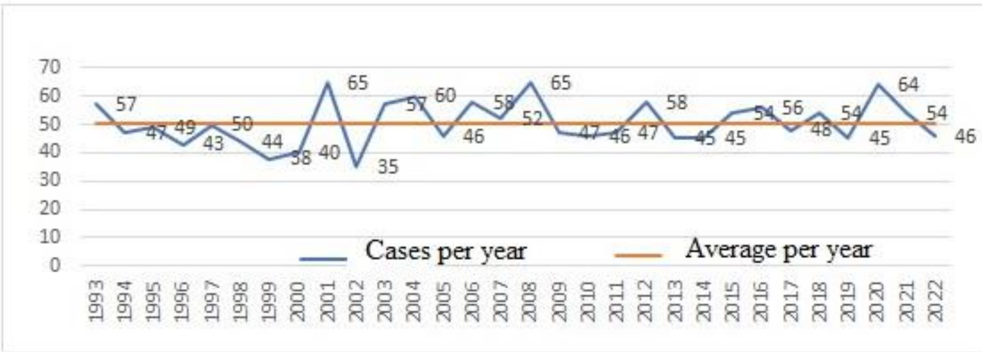


Figure 1. *Number of thunderstorms per year*

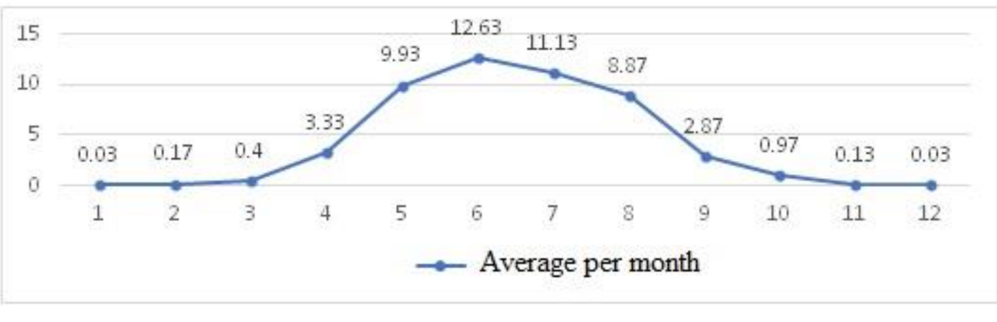


Figure 2. Monthly average of days with thunderstorms during the 1993-2022 period

During the year, the most days with thunderstorms are recorded in the months of May-August, with the maximum frequency in June, so that in the cold season their average number drops sharply, reaching at most 1 day in the period 1993-2022, in most years being practically absent.

As can be seen from Figure 2, the multi-year monthly average of thunderstorm days during the period 1993–2022 showed a slight increase from January to March, after which it increased rapidly until June, when it reached a maximum value of 12-13 days. From June it decreased again until winter, in December and January reporting only one day with a thunderstorm in 2012.

Thunderstorms, most of the time, accompanied the storms with rain showers, but also those with hail.

2.2. Hail

The average number of hail cases is the parameter that reflects the qualitative aspect of the phenomenon. Knowing the number of hail cases has a great practical significance, because it gives indications on the possibility of the presence of this phenomenon and therefore, on the possibility of damage.

The average monthly number of hail cases increased from April into the summer, peaking in June, then decreasing sharply in August, followed by a slight increase again in September (figure 3).

Figure 3. Average monthly number of hail cases during the 1993-2022 period

It is also noted that during the analyzed period, there was only one case of hail in August, in 2007, when hailstones reached a diameter of 30 mm.

The maximum frequency of hail cases occurred in the last decade in the years 2018 and 2021 and was six cases. An increase in the frequency of the phenomenon is observed in the last ten years, in the first and second decade there was only one year with three cases each, namely 1993 and 2009. It is also important that the phenomenon was completely absent in only 5 years.

Being a climatic phenomenon in the genesis of which the degree of heating of the active surface has a determining role, the hail usually occurred in the afternoon.

However, over the years there have been cases when it happened in the morning or in the evening, and sometimes even at night.

There were also days when two consecutive cases were reported.

Due to its particularities (shape, consistency, dimensions, weight, speed of fall), associated with rainfall and wind speed, hail can cause great damage to the national economy and the local geographic landscape.

Being a phenomenon whose maximum frequency occurs in the warm period of the year, it surprises crops, vegetables and greens, vines and fruit trees in different stages of development, affecting the proper development of the biological cycle. A single case of hail in a critical phase of plant development is enough for the entire crop to be compromised.

This summer climate phenomenon has great repercussions on the national economy and on the local geographic landscape. Its production is difficult to predict due to its rather complex genetic conditions. That is why the means of combating it are more difficult to apply.

2.3. Frost

During the cold period of the year, the interval with negative temperatures is often interrupted by intervals with positive temperatures, as a result of the invasion of warmer tropical air, which causes the temperature to rise.

Frost is a phenomenon characteristic of winters in the analyzed area. In the period 1993-2022, the frost occurred between October and April.

Analyzing the minimum air temperature, it is found that the average date of the first autumn frost was placed in the first decade of November, on the 6th, and of the last spring frost, in March, on the 28th. This results in an average frost-free interval of 223 days, i.e. 61% of the year.

The earliest frost that occurred in the period 1993-2022 was recorded on October 5, 2013, and the latest on April 22, 1994 and 2019.

The figure shows an increase in the number of frosty days from October to January, after which it decreases again until April. The maximum frequency occurred in the middle of the winter season, in the months of December, January and February, while at the beginning and end of it, i.e. spring and autumn, it occurred less often (figure 4).

The average annual number of frosty days from 1993 to 2022 was 88 days. Until 2008, with the exception of 1996 and 2004, the annual number exceeded the multiannual average, so that in the following period, with the exception of 2013 and 2014, it was below average.

From year to year, the number of days with frost is characterized by a marked variability.

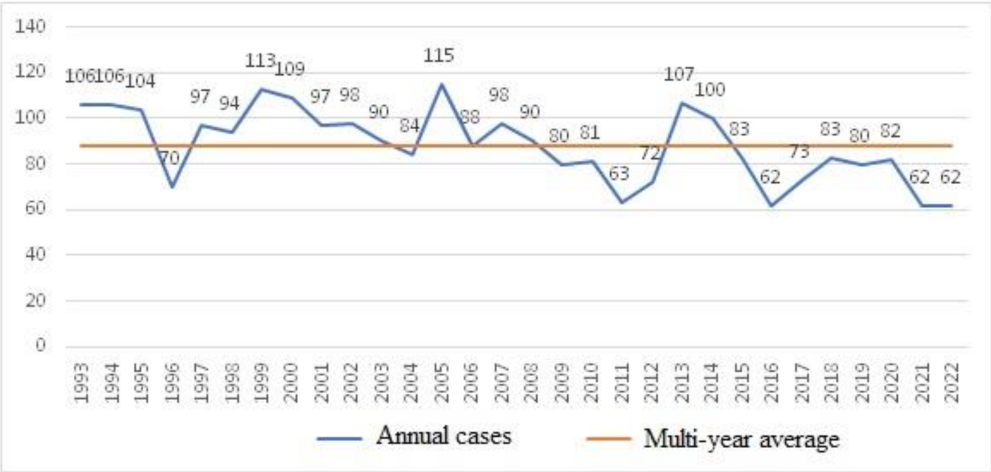


Figure 4. Annual number of frost days relative to the multiyear average (1993-2022)

The years in which the highest number of days with frost occurred were 2007 and 2001, with 115 and 113 days, respectively, a direct consequence of the long anticyclonic activity of continental origin. The years with the fewest frost days were 2016, 2021 and 2022 with 62 days.

In the lapse with possible frost (between autumn and spring frost), frost days are interrupted by days when the minimum air temperature remains positive.

Compared to the number of days with frost calculated based on the temperature recorded in the weather shelter, the number of days with frost on the ground surface is higher, determined by the fact that the minimum temperature below 0°C on the ground has a higher frequency.

Frost can cause negative effects on both the national economy and the geographic landscape, with the greatest damage occurring at the beginning and end of it. A single early (October) or late (April) frost is enough for the crop to be affected.

2.4. Snows and snow showers

In winter, as a result of lower temperatures, generally the smallest amounts of precipitation are accumulated, due to the low water vapor content of the air masses.

In the analyzed period, the first snowfall was generally in November, in October snowfall occurred only in two years, in the first decade. In the last decade, the average date of the first snowfall was in December, so that in the winter of 2019-2020 the first snowfall occurs on March 23, being also the winter with the fewest days with snow, namely 5 days.

The average date of the last snowfall was recorded in March, there were also a few days when it snowed in April, mostly in the first part of the analyzed period, and in the second half only in 2020. The latest snowfall in this interval was on April 17, 1997. Due to the positive temperatures on the ground, the snowflakes melted on contact with the active surface, unable to form a snow layer.

The annual number of days with snow and sleet during the period 1993-2022 varied from the multiyear average, which was about 21 days. For the past eight years, with the exception of 2020, the annual number has been below the multi-year average. The most snowfall occurred in the year 1998, 49 days, and the least snowfall was in 2022, 6 days.

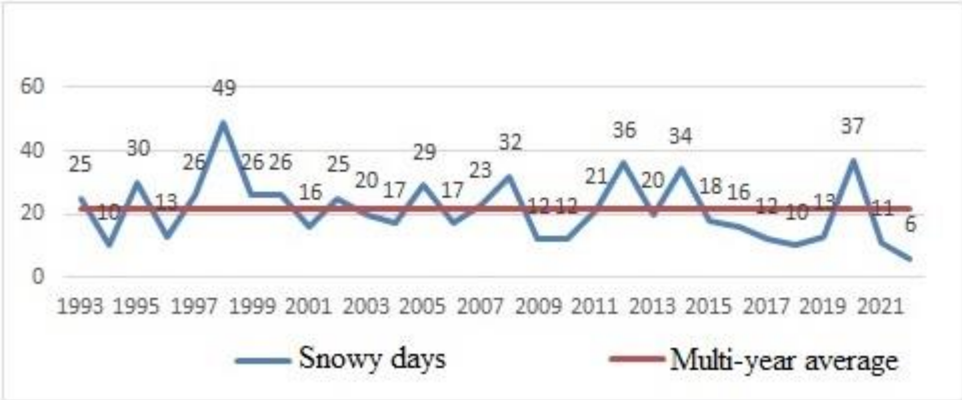


Figure 5. Annual number of days with snow and snow showers compared to the multi-year average during the period 1993-2022

Due to the recent warming, the number of days with snow shows decreasing trends and the average thickness of the snow cover is getting smaller.
Snow can occur early, at the beginning of the cold season (October-November) and quite late, at the end of it (March-April), being able to catch vegetables, greens, vines and fruit trees during the growing season and causing the same damage as and in the case of the earliest and late frosts and frosts.

2.5. Blizzard

Strong winds associated with heavy snowfalls generate blizzards. The blizzard is a particularly complex climatic phenomenon, in the production of which two important elements compete: wind speed and the amount of fallen snow.

The genetic causes that lead to the appearance of blizzards are determined by the peculiarities of the general circulation of the atmosphere, under the influence of the characteristics of the active surface.

The meteorological parameters that define the blizzard phenomenon are: the decrease in horizontal visibility, major intensification of the wind, atmospheric precipitation and a consistent layer of snow, which, due to the high speed of the wind, are transported from open to sheltered places, thus disrupting economic activities.

In the analyzed area and in the 1993-2022, no case of blizzard was reported, thanks to the shelter created by the mountains, which protect the space from the invasions of cold air from the east and northeast of the country. Consequently, the territory's vulnerability to the action of such a phenomenon is reduced.

The blizzard produces many negative effects, related to human activity. It is a risk factor when heavy snowfall is accompanied by wind speed greater than or equal to 16 m/s (strong blizzard), which produces piles of snow on open portions of land.

2.6. Fog

Fog has meteorological importance in the sense that it reduces insolation, reduces evaporating, reduces effective radiation and therefore excessive cooling of the soil and plants, reducing the danger of frost in the spring and autumn seasons.
It occurs most frequently in the transitional seasons of the year and winter, especially in the evening and morning.

In Călimănești - Căciulata, the phenomenon of fog is reported quite frequently, especially in the cold period of the year, as a result of the penetration of warm and humid air on the cooled surface of the territory. And in the warm period, fog is reported, due to the fact that the air entering from outside the territory is cooler compared to the temperature of the active surface.

The highest monthly frequency of fog during the year occurred in the winter months, especially in January and December. In the spring and autumn it had a moderate frequency, and in the summer months the phenomenon made its presence very rarely, only in 3-4 days.

In the analyzed period of time, the annual average number of days with fog was 31 days and the largest deviation from the mean was 19 days. Due to the great variety of the active surface the annual number of days with fog is unevenly distributed, varying between 12 days in 2016 and 49 days in 1991 and 2014.

The fog appeared predominantly in the night and morning hours, lasting between 1-2 hours and several consecutive days. Visibility varied between a few tens of meters and 1000 m.

Fog drops, falling on material objects under the open sky, contribute to the corrosion of metals. Fogs contribute to the increase in air pollution in large cities by accumulating the products emitted by industrial enterprises.

3. CONCLUSIONS

The analyzed area is vulnerable to risk climatic phenomena, especially to those with rapid development, such as torrential rains, electrical discharges, hail, but also to frost and fog phenomena in the off-season.

It represents a favorable territory for the occurrence of electrical discharges especially during April-September, with the maximum frequency in June, having a multi-year average of approximately 50-51 days. The annual number of days with thunderstorms varies from year to year, in the first part of the interval it is observed that it is generally below the multi-year average, so that in the following period the annual number above the average prevails.

Another climate risk phenomenon, which occurs during the warm period of the year (April-September), is hail, with maximum frequency also in June. There is an increase in the frequency of the phenomenon in the last decade, when 5 cases of hail were reported in 2018 and 2021. Knowing the number of hail cases has a great practical significance, because it gives indications on the possibility of the presence of this phenomenon and therefore, on the possibility of damage [4].

Frost is a phenomenon characteristic of the October-April period, with an average number of frost-free days of 223, i.e. 61% of the year. In the second part of the analyzed interval, the frequency of this phenomenon is lower and lower. The earliest frost occurred on October 5, 2013, and the latest on April 22, in 1994 and 2019.

Frost can produce frost. Frost and frost phenomena are dangerous phenomena when they occur outside their characteristic season, in autumn, until October 15, and in spring, after March 20.

REFERENCES

[1]. Nimară C., *Analysis of the thermal and pluviometric regime in Ramnicu Valcea, in the context of climate change*, Annals of the University of Petroșani, Mining Engineering, 22 (2021), ISSN 1454-9174;

[2]. *** *Adapting to the Impacts of Climate Change*, (2010). National Research Council;

[3]. *** *Impacts of Europe's changing climate. An indicator-based assessment*, European Environment Agency, Report No 2 (2004);

[4]. *** *Planul de menținere a calității aerului în județul Vâlcea perioada 2020-2024,* Consiliul Județean Vâlcea;

[5]. *** www.meteoromania.ro;

[6]. *** www.inmh.ro;

THE ACTION MECHANISM OF BACTERIA ON THE REDUCTION OF SULFUR CONTENT IN COALS

CAMELIA BĂDULESCU[1]

Abstract: *Recently, an increased attention has been devoted to the development of coal technologies and effective combustion which burden the environment in a minimum way. The set of such technologiies is called „ Clean Coal Technologies". They are being developed in three directions: technologies are developed which minimalize air pollution during combustion (e.g. desulphurization, of combustion products, removal of sulphur from coal prior to combustion processes); efficiency of combustion and combustion facilities are being increased (e.g. improvement of furnace chamber, new combustion systems); new methods of fundamental coal chemical preparation prior to its tiliozation are sought - mainly tranformation of coal into liquid and gas fuel.*

Keywords: *coal desulfurization, T.ferrooxidans, coal desulphurization biotechnologies*

1. INTRODUCTION

Biological desulphurization has been established as a technique in the laboratory by using bacterial cultures (thermophilic or mesophilic), with a high capacity to oxidize pyrite, thus implicitly removing sulfur from coal. Recent studies on coal desulfurization from coal wastes have highlighted the successful application of biological techniques.[4],[7]

Physical, chemical or biological techniques can be applied having a double effect: removing sulfur on the one hand and reducing the degree of susceptibility of the waste to oxidation on the other. The choice of the most feasible technique requires extensive experimental studies, while their application requires the use of advanced technical procedures, the main objective of which must be to protect the environment.

The removal of sulfur from coal with the help of bacteria is a feasible process, this process requires simple equipment, a small amount of reagents, but a long time to treat the water resulting from this process, water with a high content of ferrous sulfate. The microbiological process is feasible in reactors, when the particle size is below 0.5 mm. At particle sizes greater than 0.5 mm the coal can be treated in piles.

[1] *Associate Professor, Dr.,Eng., University of Petrosani, Romania*

2. THE ACTION MECHANISM OF BACTERIA ON COAL SULFUR

Conventional technologies for removing pyrite from coal have as a general principle the elimination of pyritic inclusions through physical separation, especially of large inclusions, which require a long time for biodegradation. In Romanian coals, pyrite forms very frequent associations with darite, either as simple disseminations or as nodules, bands, lenses or nests. The vast majority of pyrite in the Valea Jiului coals is very finely dispersed in the coal mass, generally having dimensions below 0.1-0.25mm. The origin of pyritic sulfur in coals is not fully elucidated.[2] There are theories that state that the origin of pyritic sulfur can be internal, from genetic material, or external, from percolation waters.

Lafar (1956) believes that bacteria would play a decisive role in the formation of pyrite. These seem to be responsible for the formation of finely and very finely disseminated pyrite in the coal. Balme (1956) shows that bacteria reduce SO_4^{2-} or SO_3^{2-} to S^{2-} (as H_2S) which, with iron salts, precipitates FeS triolite, a very thermodynamically unstable ore which passes under pressure and heating to 200-250^{0}C in pyrite, according to the equation:

$$2FeS^- \rightarrow FeS_2 + Fe \qquad (1)$$

It is very likely that the reactions that led to the formation of pyrite were not identical in all carboniferous basins, differing according to:

- local conditions;
- the concentration of salts of the percolation waters;
- pH, temperature, pressure;
- degree of decomposition of the carbonaceous material.

Also, it seems that the anaerobic microorganisms that were found in many peatlands and whose structure is found in coal, played an important role in the formation of pyrite.

2.1. Bacterial oxidation of pyrite

The bacterial oxidation of pyrite is part of the biohydrometallurgical treatment applied to the recovery of metals from ores or poor concentrates containing sulphides, as well as to the removal of inorganic sulfur from coal.

Bacterial oxidation of pyrite is carried out by two mechanisms, which take place simultaneously, namely:[5],[6].

- direct oxidation in which bacteria attach to the pyrite particles;
- indirect oxidation through which the bacteria constantly regenerate ferric sulfate, which is the main leaching agent of pyrite.

As a result of the oxidation of metal sulphides, the ferric ions are reduced to the ferrous stage, and then the bacteria oxidize them to ferric ions. The direct contact is independent of the action of ferrous ions, requiring the direct action of the bacteria on the mineral with sulfur, under aerobic conditions.

Sulfur is removed from coal naturally, through the chemical oxidation of pyrite, in a low proportion. Through biological oxidation, the reactions are faster, being catalyzed by bacteria. *Thiobacillus thiooxidans* and *T.ferrooxidans* were the first species mentioned, with a major role in this process. The general mechanism of pyrite oxidation is:

$$2FeS_2 + 2H_2O + 7O_2 \xrightarrow{T.ferrooxidans} 2FeSO_4 + 2H_2SO_4 \qquad (3)$$

The products resulting from this reaction are sulfuric acid and ferrous sulfate, which are used by *T.ferrooxidans* to oxidize ferrous ions to the ferric stage:

$$4FeSO_4 + O_2 + 2H_2SO_4 \xrightarrow{T.ferrooxidans} 2Fe_2(SO_4)_3 + 2H_2O \qquad (4)$$

The resulting ferric sulfate can react with pyrite leading to the formation of ferrous sulfate that will be used again by *T.ferrooxidans*, realizing the indirect mechanism of pyrite oxidation.

$$Fe_2(SO_4)_3 + FeS_2 \xrightarrow{chimic} 3FeSO_4 + 2S \qquad (5)$$

The last two reactions complement each other in that the ferric sulfate provides oxygen to the pyrite, which cannot come into contact with free oxygen.
The role of *T.ferrooxidans* in the oxidation of pyrite is that of oxidizing elemental sulfur to sulfuric acid:

$$2S + 3O_2 + 2H_2O \xrightarrow{T.ferrooxidans} 4H^+ + 2SO_4^{2-} \qquad (6)$$

T. thiooxidans also participates in this reaction in the oxidation of elemental sulfur. The resulting sulfuric acid favors the development of these acidophilic bacteria

In figure 1 the direct and indirect mechanism of bacterial leaching of pyrite present in coals is presented.[11]

Coal mine drainage is the result of the interaction between sulphide-containing minerals with oxygen, water and bacteria. Minerals such as: pyrite (FeS_2), arsenopyrite (FeAsS), chalcopyrite ($CuFeS_2$) and others containing Fe, Cu, As, Sb, Bi, Se or Mo can produce acidic solutions through oxidation. Pyrite is the major source of acidity in coal mine drainage. The main and secondary reactions that occur are the following:

$$2FeS_{2(solid)} + 7O_{2(apă)} + 2H_2O \rightarrow 2Fe^{2+} + 4H^+ + 4SO_4^{2-} \qquad (7)$$

$$4Fe^{2+} + 7O_{2(apă)} + 4H^+ \rightarrow 4Fe^{3+} + 2H_2O \qquad (8)$$

$$FeS_{2(solid)} + 14Fe^{3+} + 8H_2O \rightarrow 15\ Fe^{2+} + 2SO_4^{2-} + 16H^+ \qquad (9)$$

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_{3(solid)} + 3H^+ \qquad (10)$$

$$Fe^{3+} + SO_4^{2-} + 7H_2O \rightarrow Fe(OH)SO_{4(solid)} + H^+ \qquad (11)$$

$$Fe^{3+} + 2SO_4^{2-} + 7H_2O \rightarrow (H_3O)Fe_3(SO_4)_2(OH)_{6\,(solid)} + 5H \qquad (12)$$

$$CaCO_{3(solid)} + 2H^+ \rightarrow Ca^{2+} + H_2O + CO_2 \quad ; \ (pH< 6,4) \qquad (13)$$

$$Ca^{2+} + SO_4^{2-} + 2H_2O \rightarrow CaSO_4 \cdot 2H_2O \qquad (14)$$

In the first two reactions (7) and (8), sulfur and iron oxidation reactions are presented, with the participation of various sulfur and iron-oxidizing bacteria. Among these, the best known is *T.ferrooxidans*.

Reaction (9) shows the oxidation of pyrite by ferric iron, the final product of the previous reaction. The result of the oxidation reaction in the presence of Fe^{3+} consists in: the decrease of the pH value and the increase of the pyrite oxidation rate, as a result of the release of a large number of H^+ protons. Pyrite oxidation by Fe^{3+} is much faster than oxidation in the presence of oxygen.A part of Fe^{3+} or even the entire amount of iron resulting can precipitate as $Fe(OH)_3$ or in the form of related compounds, such as ferric sulfates or ferric hydroxides (reactions (11), (12).The dissolution of calcium carbonate and the formation of gypsum are the last two steps in the oxidation of pyrite from coal waste (reactions (13) and (14).The biooxidation process of pyrite is a process studied by many researchers, mainly due to the ability of the bacterium *T.ferrooxidans* to adhere to the pyrite particles, which constitute the energy support for growth.[9]

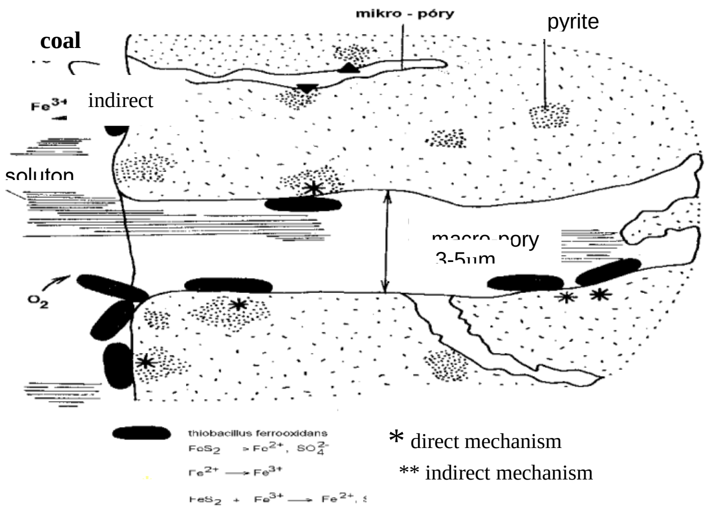


Fig.1. The direct and indirect mechanism of bacterial leaching of pyrite from coal

Generally, the processing of minerals takes place through the oxidative leaching of pyrite, a process achieved by the adhesion of bacteria to sulfur minerals. In the process of flotation of minerals with sulfur, under controlled conditions, it was found that the buoyancy of minerals (pyrite, chalcopyrite, molybdenite and galena) varied between 90-98%.

After the addition of the *T.ferrooxidans* culture, the buoyancy of pyrite decreased significantly, reaching below 20%, while the buoyancy of the other sulfur-containing minerals remained at values close to those presented previously, namely 81-98%. Due to the presence of the *T. ferrooxidans* culture, 77-95% of the pyrite was removed in the flotation process. These results suggest that flotation with the addition of cultures of sulfur and iron oxidizing bacteria can represent a new biotechnological application, which is based on the adhesion of bacterial cells on pyrite particles.

Townsley (1986) tested the ability of *Thiobacillus ferrooxidans* bacteria to adhere to pyrite in the coal flotation process, decreasing the buoyancy of the pyrite, which can thus be easily removed.

In laboratory-scale pyrite leaching experiments, where the solid/liquid ratio was 2/6, *T.ferrooxidans* bacteria were effective, removing 80% and 63% of pyrite in 240 hours and 340 hours, respectively. The natural buoyancy of pyrite was significantly reduced in the presence of bacteria. Using a bacterial suspension made in distilled water (pH -2.0), the buoyancy was reduced by 85%, while using culture medium, this reduction was 95%, the optimal bacterial density is 3.25 x 1010 cells /g pyrite, at a solid density of 2%. The degree of reduction of pyrite extraction by bacteria is influenced by particle size and to a lesser extent by pH and temperature.

In the cultivation media of *T.ferrooxidans*, partial precipitation of ferric iron takes place, reducing its concentration and its inhibitory effect. The pyrite oxidation process can be inhibited by: the high concentration of Fe^{3+} (over 10 g/l) and the too high concentration of cells. The inhibitory effect of higher cell concentrations is not very strong when the Fe^{2+} concentration is low. Interestingly, Fe^{3+} inhibits Fe^{2+} oxidation by *T.ferrooxidans* to a lesser extent at low temperatures. It is possible that the cell envelope made of Fe^{3+} prevents the contact between ferrous iron and oxidizing bacterial cells. The sulfur in the sulfide is completely oxidized to sulfate and the ferrous iron to ferric.
These reactions generally take place at pH values between 1.5-2. At pH values higher than 2.5, Fe^{3+} has an extremely low solubility, tends to hydrolyze and precipitates as jarosite, basic iron sulfate or hydroxide, after the following reactions:

$$3Fe^{3+} + 2SO_4^{2-} + 7H_2O \rightarrow H_3OFe_3(SO_4)_2(OH)_6 + 5H^+ \quad (15)$$

or

$$Fe^{3+} + 7/2H_2O + 2/3SO_4^{2-} \rightarrow 5/4H^+ + 1/3Fe_3(SO_4)_2(OH)_5^- + H_2 \quad (16)$$

or

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+ \quad (17)$$

At the same time, a competitive reaction for hydrolysis can take place, through which basic ferric sulfates with the formula $XFe_3(SO_4)_2(OH)_6$ are formed, where x can be represented by K^+ (potassium jarosite), NA^+ (sodium jarosite), NH_4^+ (ammonium nitrate).
Jarosites can be found in acid mine drainage sediments. the formation of jarosite precipitates is dependent on the pH, the composition and the concentration of ions in the environment and constitutes an impediment in the processes of microbial leaching of metals from sulfur minerals. The precipitates are deposited on the ore particles subjected to biooxidation, hindering or stopping the contact of bacteria or leaching agents resulting from the bacterial oxidation process.

In acid mine waters, *T. ferrooxidans* is present alongside T. *thiooxidans*. the natural association of these two species gave rise to the question to what extent *T.thiooxidans* can accelerate the pyrite oxidation process. It was found that adding the culture of *T.thiooxidans* to the leaching mixture does not increase the intensity of the biological process of pyrite oxidation.

3. COAL DESULPHURIZATION BIOTECHNOLOGIES

3.1. The international stage

It is considered that the birthplace of modern bioleaching processes was in the coal mines of Pennsylvania. 60 years ago, the importance of Thiobacillus bacteria was highlighted, through the connection between them and the pollution of the surrounding environment (pollution of the Ohio River), through the contribution of tributaries from the coal mine. The water of these tributaries contained considerable amounts of sulfuric acid, produced by the bacterial oxidation of pyritic sulfur, present in coal.

The first to demonstrate that bacteria have a very important role in iron oxidation were Colmer and Hinkle, in 1947. In their experiments, they used water samples with an acidic pH, treated with bacteriostatic agents or sterilized, and on the other hand they used water as such (untreated). The obtained results showed that iron oxidation does not occur in the treated waters, due to the lack of bacteria or their inhibition by the treatment.

Later, in the 1970's, Singer and Stum, conducting studies of the kinetics of the formation of acid mine drainage, found that, at a temperature of 25^0C, an oxygen pressure of 0.20 atm. and at pH below 3.5, the half-life of the ferrous iron content was 100 days. Comparing the rate of oxidation of ferrous iron from sterile mine water (without microorganisms) with non-sterilized mine water, it was found that the presence of bacteria accelerates the reaction at a rate greater than 108. The presented results highlighted the importance of *T.ferrooxidans* bacteria and *T.thiooxidans* in the oxidation of pyrite. As a result, this capacity of the bacteria was extended to coal desulphurization, by oxidizing the pyritic sulfur in the coal.

The oxidation of coal pyrite by bacterial action can have economic applications. The approach to this problem on a global level dates back several years, when studies began to determine the optimal bacteriological conditions to reduce the sulfur content of coal in the optimal time, to the point where the sulfur dioxide released by its combustion does not exceed the standard values allowed.

In 1977, the study program directed by the Italian Research Council was initiated, with the aim of analyzing the possibilities of bacterial desulfurization of coal. The first researches within this program referred to testing the ability of the bacterium *T.ferrooxidans* to remove sulfur from coal and to one of the factors that influence desulphurization, namely the optimal percentage of solid parts existing in the coal / culture medium mixture. Later, research in this field also expanded to countries such as the USA.

Biological coal desulfurization techniques can be applied in piles or reactor, prior to waste disposal. In this case, special attention must be paid to the collection, neutralization and disposal of the produced effluents, in order to prevent groundwater contamination as well as secondary waste storage. Particular attention must be paid to these measures, especially during the winter, in order to maintain the bacterial activity at an operational level.

Recent research on the removal of sulfur from coal, carried out in a reactor with a batch culture of *T.ferrooxidans*, has shown that the bio desulphurization of coal is a 3-phase process:[10]

- in the first phase, which can last up to 4 days, the pyrite is oxidized directly by bacteria, resulting in the removal of 28% of the pyritic sulphur;
- in the second stage, lasting 4-10 days, the oxidation is both direct and indirect, with 51% of the sulfur removed from the pyrite;
- in the third phase, elemental sulfur precipitates, jarosite and ferric sulfate are deposited, resulting in a reduction in the concentration of pyrite and ferric iron in the leaching solution.

Acidithiobacillus sp. was used in experiments to remove sulfur from 3 types of coal with high sulfur content: 2 came from India (Assam and Rajasthan) and one from Poland (Libyaz). The first stage of the study consisted in investigating and establishing the optimal conditions for maximum total sulfur removal. The working parameters were:
- initial pH 1.5 (2.5 for Assam coal);
- particle size of 4.5 microns;
- solid/liquid ratio of 2g/100ml;
- the incubation period of 30 days at 350C, in the presence of 44.2 g/l ferrous sulfate (concentration considered optimal) in the environment;

Under these conditions, 91.87% of total sulfur was removed from Rajasthan lignite, 63.13% from Libiaz coal and 9.44% from Assam coal. The low removal of sulfur from the Assam coal is due to the precipitation of jarosite, to which is added the preponderance of sulfur in this coal in the form of organic sulfur, which is difficult to remove with the help of this bacteria.

Following his research, Klein (1998) stated that until now there is no known biochemical pathway for the degradation and/or desulfurization of these organic compounds with sulfur present in coal.

The removal of sulfur from coal was also experimented by Turkish researchers, using lignite tailings and a culture of *Rhodococcus rhodochrous*, a bacteria capable of removing sulfur. In 72 hours, the amount of pyritic sulfur removed was 30.2%, and the organic sulfur was 27.1%.

The reduction of organic sulfur occurred in the presence of sodium acetate, as an energy substrate for bacteria. Sulfur from sulfate was completely reduced after 24 hours of incubation, in the presence of lignite as a substrate in the culture medium. In the presence of lignite, acetate and glycerol, the amounts of sulfur as sulfate are higher in the culture liquid. The presence of sodium acetate in the culture medium results in the removal of appreciable amounts of organic sulfur from lignite.

Bayram et al. (2002) experimented in a reactor, under stirring and aeration, to remove organic sulfur from lignite using the mesophilic bacterium *Rhodococcus rhodochrous*. The experiments were carried out at 28^0C, pH 6.5.

Experimental tests were also carried out in the Czech Republic on brown coal from the Libik mine.

For good sulfur removal from coal, particles below 0.5 mm in size are preferably desulfurized in bioreactors, while those larger than 0.5 mm should be treated in heaps. The cost of investment and application must be assessed and established on an industrial scale.

For the bio desulphurization of coal, piles are made with an impermeable base and a liquid collection system. Remedial techniques are based on minimum precipitation and infiltration or on modification of acid generation potential. The drastic reduction of precipitation and infiltration can be achieved by isolating the waste in the pile from the surrounding environment, by applying an impermeable layer. Regarding the modification of the acid generation potential, this can be counteracted by adding neutralizing and stabilizing agents.

Desulfurization technologies are widely applied and are used before coal combustion. This consists in breaking the pyritic matrix, followed by the removal of the acid generation potential. Desulphurized waste can be stored in the environment or underground, safely, not being a risk of pollution.[14]

Biological desulfurization was studied in the laboratory by using cultures of thermophilic or mesophilic microorganisms, which have the ability to oxidize pyrite and implicitly to remove sulfur. The selection of bacterial cultures of *T.ferrooxidans* can be achieved by adapting them to these operations, as well as adapting them to the presence of toxic elements such as Mn, Sr and Se.

Special attention must be paid to maintaining the activity of crops in the cold periods of the year and preventing the migration of effluents into the soil or even into the ground water. The tolerance of bacterial cultures to the toxicity of some ions, the establishment of the optimal parameters must be determined by laboratory tests. Although numerous studies have been carried out on bacterial desulfurization of different types of coals, it is difficult to successfully apply biological treatments to the wastes resulting from coal processing as feasible techniques. However, several studies have highlighted that microbiological desulfurization of coal can also be applied to waste resulting from coal processing.

Compared to oil, bio desulphurization of coal is more difficult. The efficiency of the microbial oxidation of pyrite depends on a number of parameters, some mentioned, to which are added the composition of the culture medium and the design of the reactor. For the application of the desulfurization process on a large scale, different reactor systems have been proposed and developed. In general, one can choose between leaching in heaps and in suspension.

Coal leaching in heap has a lower cost price compared to that in suspension. Slurry leaching rates achieved in high-capacity, high-aeration bioreactors are faster, but they require fine coal grinding and a longer reaction time.

For example, encouraging laboratory results have allowed the treatment of coal slurries on an industrial scale, in large-capacity Pachuca-type reactors. These are suspension reactors, the main function of this reactor is to maintain optimal conditions for the growth and development of microorganisms participating in the oxidation of pyrite, such as: temperature, pH value, mass transfer.

In figure 2. is presented the technological scheme of bio desulphurization of coal on an industrial scale.[15]

In order for the desulphurization process to become efficient from an economic point of view, in-depth research on depiritization is necessary, especially in terms of increasing the leaching rate and removing in addition to inorganic and organic sulfur.

In general, the removal of organic sulfur is more difficult than that of inorganic sulfur. Bozdemir et al. (1996), cited by *Prayuenyong* (2002), mentions the role in this process of the bacterium *Rhodococcus erythropolis*, which can remove in 96 hours 55.2% sulfate, 20% pyritic sulfide, 23.5% organic sulfide and 30.2% sulfide total, from lignite.

A new way of removing sulfur from coal was experimented by Lee and Yen (1990) cited by *Prayuenyong* (2002). The authors demonstrated the possibility of biodesulfurization of coal using solutions composed of finely dispersed water in oil emulsions (micelles) alongside *T.ferrooxidans* cells and their enzymes. Following this treatment, it was possible to remove 48% of the total sulfur in 24 hours of treatment, longer periods of experimentation led to the removal of 70% of sulfur.

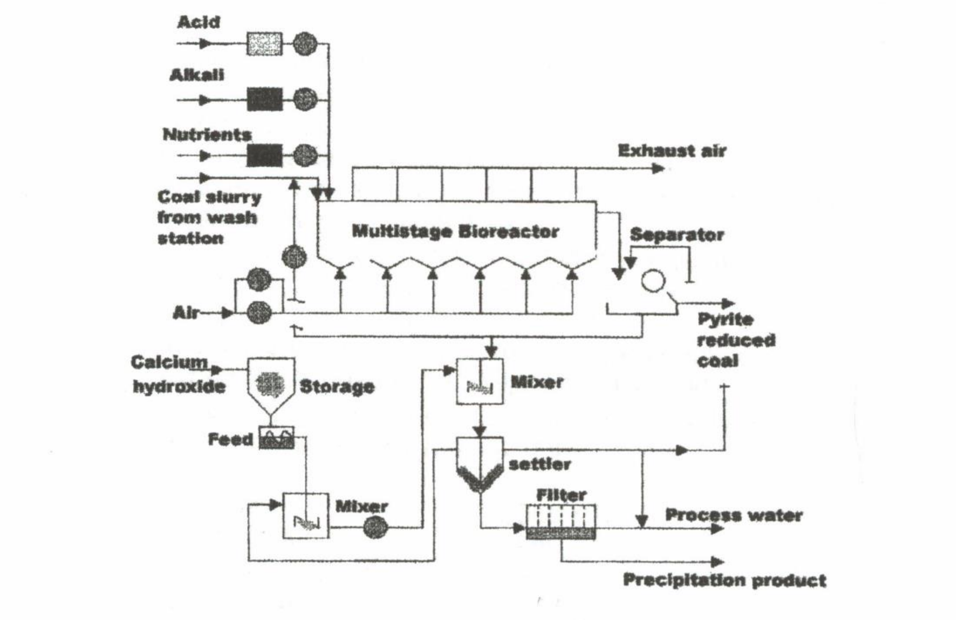


Fig. 2. Scheme of an installation on an industrial scale, for the process of biodepiritization of coal

4. CONCLUSIONS

Biological desulfurization has been established as a technique in the laboratory by using bacterial cultures (thermophilic or mesophilic), with a high capacity to oxidize pyrite, thus implicitly removing sulfur from coal. Recent studies on coal desulfurization from coal wastes have highlighted the successful application of biological techniques.

The removal of sulfur from coal with the help of bacteria is a feasible process, this process requires simple equipment, low quantity of reagents, but a long time to treat the water resulting from this process, water with a high content of ferrous sulfate. Sulfur is removed from coal naturally, through the chemical oxidation of pyrite, in a low proportion. Through biological oxidation, the reactions are faster, being catalyzed by the bacteria *Thiobacillus thiooxidans* and *T.ferrooxidans.*

Bacterial oxidation of pyrite is part of the biohydrometallurgical treatment applied to the recovery of metals from ores or poor concentrates that contain sulfides, as well as to the removal of inorganic sulfur from coal In the experiments of pyrite leaching at the

laboratory level, in which the solid/liquid ratio was 2/6, *T.ferrooxidans* bacteria was effective, removing 80% and 63% of pyrite in 240 hours and 340 hours, respectively.
In order for the desulphurization process to become efficient from an economic point of view, in-depth research on depiritization is necessary, especially in terms of increasing the leaching rate and removing in addition to inorganic and organic sulfur.

REFERENCES

[1.] **Abel, W.T**., *Removing Pyrite from Coal dry-Separation Methods*, Bureau of Mines, USA, 1973;

[2.] **Badulescu C**., *Biotehnologii in protectia mediului*, Ed Universitas, Petrosani, 2010

[3.] **Belly R.T., T.D.Brock ,** *Ecology of iron-oxidizing bacteria in pyritic materials associated with coal.* Journal of Bacteriology, 117 (2), p.726-732,1974;

[4.] **Deurbrouck,A.W, Jacobson, P.S.**, *Coal Cleaning* , State of the Art; Coal Utilization Symposium- SO_2 Emission Control, National Coal Conference, Louisville, 1994;

[5.] **Fečko P**.– *BIOTECHNOLOGY , technologies of 21 century.* Institute of Environmental Engineering Mining University of Ostrava, Czech Republic, 2007;

[6.] **Fecko P**.,*Bacterial Desulphurization of Coal from Lupeni in Romania*, Proceedings of the 7-th International Mineral Processing Symposium, Istambul, pg.361-366, 1998;

[7.] **Kecko .,** *Biotechnology –technologies of 21 century,* Institute of Enviromânmental Engineering Mining University of Ostrava, Czech Republic, , 2007

[8.] **Murray H.H**., *High Intensity Magnetic Cleaning of Bituminous Coal* , Second Symposium on Coal Preparation, Loisville, Kentucky, 1976;

[9.] **Malik, A., Dastidar, M.G., Roychoudhury, P.K**., *Factors limiting bacterial iron oxidation in biodesulphurization system*, International Journal of Mineral Processing, vol.73, No.1, 2004.

[10.] **Tomus N., Cismasiu M.C., Deak E.S**.,*Tehnologie curata pentru desulfurarea carbunilor în scopul reducerii bioxidului de sulf la arderea în termocentrale*, Buletin CENTIREM, nr.8/2014, pag.60, 2014;

[11.] **Wierzchovski K. Sablik .J**., *Extragerea piritei din concentratele de flotaţie a cărbunelui, funcţie de dimensiunea particulelor de pirită.* Coal international.Mineralurgy, nr.35, 1998 p.175, 2000.

[12.] **J. Klein,** *Technological and economic aspects of coal biodesulfurisation.* Biodegradation, 9, p.293-300,1998;

[13.] **T.O.Bozdemir, T.Durusuy, E.Erincin, Y. Yürüm,** *Biodesulfurization of Turkish lignites*. Fuel, 75, p.1596-1600,1996;

[14.] **R.M. Fakoussa, M.Hofrichter**, *Biotechnology and microbiology of coal degradation,* Appl.Microbiol.Biotechnol., 52, p.25-40,1999;

[15.] **Y.Konishi, S.Yoshida, S.Asay**, *Bioleaching of pyrite by acidophilic thermophile Acidiannus brierleyi.* Biotechnology and Bioengineering, 48, p.592-600,1995;

INJURY AND PROFESSIONAL ILLNESSES RISK ASSESSMENT: SPECIFIC TOOL AND CASE STUDY IN A GOLD ORE QUARRY

CĂTĂLIN VALENTIN DREGAN [1], ROLAND IOSIF MORARU [2]

Abstract: *The assessment of risks of professional accidents and illnesses is the basic pillar of a company's occupational health and safety risk management processes. In our country, since 2006, when the new Law on health and safety at work made risk assessment mandatory, various techniques have been developed and applied for this goal in each company and workplace. Risk assessment involves identifying all risk factors in the analyzed system and quantifying their size based on the combination of two parameters: severity and likelihood of the maximum possible consequence on the human body. The article provides brief description of the theoretical premises, applied principles, description of the method (structure, tools, work procedure), for the method developed by the Romanian Association of Mining Professionals. A specific case study for particular work system is included alongside results issued for a mining company operating a gold ore quarry in Romania. The benefits and drawbacks of the proposed tool are discussed in the article with a view to highlight its strengths and weaknesses.*

Keywords: *occupational health and safety, risk assessment, quarry, ore crusher.*

1. INTRODUCTION

Currently, evolutions in the European Union regulatory framework legislation are driving forces in the development of risk assessment tools and techniques in the occupational health and safety field, because risk assessment is a major stage in the overall risk management process. In Romania, since 2006, when the new Occupational Health and Safety Act [1] have stated that the risk assessment is compulsory in any workplace, several approaches were in use but only one method is extended in application [2]. The manner of approaching any professional risk assessment must meet the criteria provided in the Occupational Health and Safety Act no. 319/2006 introducing measures to encourage improvements in the safety and health of workers at work [3].

Various methods are used to rank risks and to define priorities for actions - what is certainly very desirable - but often this is done by neglecting the analysis of the elements defining these risks and the means of improving the situation. Based on the analysis of the current risk ranking methods from other countries and their adjustment to the concrete conditions of Romania, a new tool was developed, in co-operation with the

[1] *Ph.D. Student,University of Petroşani*
[2] *Professor, Ph.D., University of Petroşani*

Romanian National Institute for Research and Development in Occupational Health and Safety [4].The present paper outlines another methods' development and aims to clarify and to highlight the efficiency in subsequent stages of practical application of this tool developed by the Romanian Mining Professional Association [5].

We consider that risk assessment cannot be complete without a deep and thorough analysis of likely hazardous situations. Possibilities to complement this type of information are including: checklists; (group) discussions or interviews with technicians (human factors) and foreseeable use experts and scientists, completed by observational studies [6]. An adequate risk assessment tool should provide an unambiguous system to estimate the risk level of a specific risk scenario [7-8]. In practical risk assessment, as we strive to do in this research, a simplification of the real contributing risk factors is sometimes necessary [9]. Essential factors that should always be considered include the frequency of use, the probability of a hazardous interaction and the probability of an injury in each hazardous interaction [10]. A necessary condition for proper risk evaluation is that common criteria are used to assess the acceptability of the risk; this remains a challenge for further development. The aim of method developed by is to provide a conservative estimate of global risk to hypothetical members of selected population groups using a semi-quantitative approach. One potential use of the presented approach may be as a "*screening*" tool, to identify areas for more detailed analysis [11].

2. MATERIAL AND METHOD

Within this research, the method of assessing the level of risk in the workplace, workshop, section, unit or branch of activity developed by the Professional Mining Association of Romania was systematically applied [12]. In the initial stage, the necessary data and information are collected, the work tasks and associated operations are identified, all members of the analysis team are selected and informed. The information base includes: job descriptions, work instructions, technical equipment books, maintenance guides, reports on statistics of accidents, occupational diseases and previous incidents, interviews with workers, video footage. The aim is to make a comprehensive list of work operations, and to identify sources of hazard. For the inventory of hazard sources, a logical sequence is followed: interviewing the workers, the coordinators of the work processes, clarifying the way of carrying out the productive operations, highlighting the problematic situations, the potential equipment failures and the deficiencies of the working methods, looking for deviations from normal. The steps of applying the method include:

- Formation and training of the assessment team;
- Description of the analyzed work system;
- Identification of risk factors;
- Assessment of the occupational injury and / or illness risks;
- Hierarchy of risks and setting priorities for their prevention;
- Establishing measures to prevent and combat risks.

The overall occupational risk level (Nr) is calculated using the formula below:

$$Nr = \left[\frac{\sum_{i=1}^{n} r_i^2 \cdot R_i}{\sum_{i=1}^{n} r_i^2} \right] \cdot \frac{t_e}{t_i} \cdot C_1 \cdot C_2 \cdot C_3 \cdot C_4 \qquad (1)$$

where:
n- the number of risk factors identified;
R_i – the risk level of the risk factor "i", the scale of classification of the risk / safety levels being represented in table 1;
$R_i = R_i - 1$ the rank of the risk factor „i".

Table 1. Scale for rating risk / safety levels

Risk level (R)		Severity x Likelihood coupling (SXL)	Safety level (S)	
1	MINIMUM	(1X1),(1X2),(2X1)	25	MAXIMUM
2	VERY LOW	(1X3),(1X4),(2X2),(3X1),(4X4)	18	VERY HIGH
4	LOW	(1X5),(1X6),(1X7),(2X3),(2X4),(3X2),(3X3),(4X2) (5X1),(6X1),(7X1)	12	HIGH
7	AVERAGE	(2X5),(2X6),(2X7),(3X4),(3X5),(4X3),(4X4) (5X2),(5X3),(6X2),(7X2)	7	AVERAGE
12	HIGH	(3X6),(3X7),(4X5),(4X6),(5X4),(5X5),(6X3), (6X4),(7X3)	4	LOW
18	VERY HIGH	(4X7),(5X6),(5X7),(6X5),(6X6),(7X4) (7X5)	2	VERY LOW
25	MAXIMUM	(6X7),(7X6),(7X7)	1	MINIMUM

n_r - the level of rectification that takes into account the number and level of risk factors, given by:

$$n_r = n_7 \cdot 0.7 + n_6 \cdot 0.5 + n_5 \cdot 0.35 + n_4 \cdot 0.2 + n_3 \cdot 0.1 + n_2 \cdot 0.05 + n_{1 \cdot 0.02} \qquad (2)$$

where:
n_7 - the number of risk factors with the level 25;
n_6 - the number of risk factors with the level 18;
n_5 - the number of risk factors with the level 12;
n_4- the number of risk factors with the level 7;
n_3- the number of risk factors with the level 4;
n_2- the number of risk factors with the level 2;
n_1- the number of risk factors with the level 1;
t_e – average time of exposure to risks (hours/shift)
t_1 – normal working time (h/shift)
C_1, C_2, C_3, C_4- coefficients of influence of the risk level, made explicit in the tables 2, 3, 4 şi 5.

Table 2. Values of C_1 coefficient considering the special environmental conditions

Working environment	C_1
Collieries	1.15
Salt mines	1.02
Other mines	1.10
PCaves	1.07
Aquatic environment	1.05
Underwater environment	1.10
Swamp environment	1.12
Aerial environment	1.20
Cosmic environment	1.30
Radioactive environment	1.15
Dangerous car traffic	1.12

Table 3. Values of the coefficient C_2 that take into account the total number of workers in similar jobs

Number of workers	C_2
1-50	1.00
51-100	0.98
101-150	0.96
151-200	0.94
201-300	0.92
301-500	0.90
501-1000	0.88
1001-2000	0.86
Over 2000	084

Table 4. Values of the coefficient C_3 that take into account the number of people who can be subjected to collective accidents

Nr. crt.	No. of people exposed to collective accidents	C_3
1	3-5	1.03
2	6-10	1.06
3	11-20	1.09
4	21-50	1.12
5	51-100	1.15
6	101-300	1.18
7	301-500	1.21
8	501-1000	1.24
9	1001-2000	1.27
10	Peste 2000	1.30

Table 5. Values of the coefficient C_4 that take into account the age of the hazardous technical equipment

Nr. crt.	Age of hazardous technical equipment	C_4
1	< 1 year	1.00
2	1-3 years	1.01
3	3-6 years	1.03
4	6-10 years	1.05
5	10-15 years	1.08
6	15-20 years	1.10
7	> 20 years	1.15

The risk level of a macro-system (workshop, section, sector, subunit or economic unit) is calculated with the following formula:

$$Nr_m = \frac{\sum_{i=1}^{n} Nr_i \cdot L_i}{\sum_{i=1}^{n} L_i} \qquad (3)$$

where: $Nr_m = Nr_a$, Nr_s , Nr_{su} or Nr_u;

Nr_a- the level of risk per workshop; Nr_s- the level of risk per department; Nr_{su}- the level of risk per subunit; Nr_u- the level of risk per unit; n- number of workplaces (assessment sheets) within the workshop, section (sector, subunit or unit) for which the risk level is calculated;

Nr_i – the level of risk of the “i” workplace within the macrosystem;

L_i – the total number of employees at that workplace „i”.

The acceptable risk level, below which it is considered that additional mitigation measures are not necessarily necessary, is estimated at 7, i.e. equal to the average risk level. In order to improve the safety level of any work system, it is necessary to take into account the hierarchy of risks assessed and therefore to implement, as a matter of priority, measures to combat and prevent risks with the highest level. Therefore, the preparation of the proposed file of measures, which is the last stage of the risk assessment of a microsystem (workplace), is performed in descending order of the level of risk factors, respectively25÷1. Also, when drawing up the file of measures, the hierarchical order of the prevention measures will be taken into account:

- Intrinsic prevention measures (eliminating risks);
- Collective protection measures (isolating risks);
- Organizational measures and rules of behavior (avoiding risks);
- Personal protection measures (by which workers are isolated).

The application of the method ends with the drafting of the evaluation report. This is an informal document, which must contain, as clearly and succinctly as possible, the following:

- How the assessment was carried out:;
- The people (assessors, technical staff, workers etc) involved in this action;
- The results of the evaluation, respectively the job descriptions with the risk levels;
- Prevention measures sheets;
- Calculation of the risk level per workshop, section (sector), subunit or unit.

3. CASE STUDY: OCCUPATIONAL RISK ASSESSMENT IN THE INVESTIGATED QUARRY

The branch of Roşiamin S.A. is part of CNCAF Minvest Deva, the object of activity of the mining unit being that of extraction, transport and processing of gold-silver ore, from the Roşia Montană deposit in Alba county. The branch of ROŞIAMIN it had in its structure several sectors of activity, namely:

- Quarry (open-pit mine) sector Cetate – Cârnic Napoleon
- Vehicle transport base;
- Sector I with the compressor station;
- The underground-surface transport sector Gura Minei – Aprăbuş;
- Fore-crushing sector stage II and III Aprăbuş;
- Ore processing plant sector Gura Roşiei;
- Tailing dam Valea Seliştei.

In the following will be briefly present the ore mining sector open-pit Cetate-Cârnic Napoleon. The quarry sector is located between elevations +873 m and +1150 m, the two elevations being the lowest and highest points of the massifs in operation. The method of exploitation applied in this case is "The mining method with the transport of sterile rocks to outer dumps", the deposit being located in the breccia and in the dacite.

The form of ore presentation in the deposit is in the form of veins, chairs, vaults and disseminated in the rock mass in the form of golden pyrite. The extraction of the ore from the massif is done by using blasting technologies with drilling holes and mine boreholes, while the loading of the ore in 16 t dump trucks is done with the help of 5 m^3 excavators, front loaders; there is a group of crushers providing the granulometry necessary for the transport of the ore towards the intermediate sectors. Within the analyzed mining sector are found the workplaces summarized in table 6.

Table 6. Situation of workplaces in the analyzed mining sector

Crt. no.	Job (workplace)	Location		No. of staff
		Open-pit	**Workshop**	
1	Crusher operator	x	-	12
2	Excavator operator	x	-	4
3	Front loader servers	x	-	4
4	Bulldozer operators	x	-	4
5	Drilling rigs operators	x	-	2
6	Open-pit miners	x	-	8
7	Blasting operators (open-pit)	x	-	3
8	Open-pit electricians	x	-	4
9	Quarry machine mechanics	-	x	5
10	Gas / electric welders	-	x	2
11	Maintenance mechanics	-	x	4
12	Lathers	-	x	3
13	Warehouseman	-	x	1
14	Vehicle drivers	x	-	15
1	Mine foremen			4
2	Electromechanical foremen			2
3	Electromechanical engineer			1
4	Head of sector			1
TOTAL PERSONNEL OPEN-PIT SECTOR				79

CRUSHER OPERATOR RISK ASSESSMENT

The destination of the workplace is the crushing of the ore by mechanical process with the help of jaw crushers type C 12090 and GMC 127.

THE MEANS OF PRODUCTION used is the jaw crusher type C 12090 and Mobile Crushing Group type HAMEROCK GMC 127.

Other tools used are:

- Row of 2 m;
- Shovel;
- Hoe;
- Pick.

The WORKING TASK of the servants consists of the following activities:

- Ensuring the optimal granulation for the transport to surface of the ore to the intermediate sectors;
- Unlocking the equipment's silo;
- Cleaning of redundant material at workplace (fine sands).

WORK ENVIRONMENT

The crushing station is located inside the quarry in the north-eastern part on the +894 m level, and the ore supply of the machine is made from the +902 m stage, by tilting, it has no mechanical ventilation, because the crushing process is done in open environment.

The specific noxae of the workplace are:

- Dust resulting from the operation of unloading ore, crushing and loading into vehicles;
- High intensity noise;
- Vibrations caused by machine operation.

The results of the risk assessment are summarized in Table 7.

Table 7. Risk assessment sheet for the workplace CRUSHER OPERATOR

Unit: Roşiamin Branch Sector: Quarry	**RISK ASSESSMENT SHEET**		**No. Of workers exposed: 12 Exposure duration : 8 hours/ shift**			
WORKPLACE: CRUSHER OPERATOR		Assessment Team Members				
Component of the work system	Risk factors	Concrete form of manifestation of risk factors (description, parameters)	Maximum forecasted consequence	Severity (S)	Likelihood (L)	Risk level (R)
1	2	3	4	5	6	7
Equipment	Hazardous movements	1. Grip on hands or feet (fractures, amputation)	Death	7	2	7
	Leakages	2. Fluid leakage	7-45 days LTI	2	5	7
	Falls	3. Falling from heights	Death	7	4	18
	Collapse	4. Collapse front face, slopes	Death	7	3	12
	Ejecting objects	5. Objects ejection (nuts, pressure hoses, rock pieces)	Death	7	2	7
	Jet of fluids	6. Liquid jet - due to system failure (impact, total blindness)	INV gr. I	6	3	12
	Hazardous surfaces or contours	7. Stabbing, cutting of hand, foot, body, etc.	1-7 days LTI	1	6	4

		8. Slippery surfaces, danger of falling from handling, falling on the feet	III Degree Invalidity	4	5	12
	High temperature surfaces	9. High temperature of hydraulic couplings (50-100°C)	1-7 days LTI	1	4	2
	Electrical hazard	10. Direct touch electric shock	Death	7	2	7
	Toxic substances	11. Poisoning due to gas resulting from explosions	1-7 days LTI	1	5	4
	Explosive materials	12. Explosion hazard due to improper use of explosive material by blasting master	Death	7	2	7
Work environment	Noise	13. Permanent noise level over 87 dB (max 95 dB)	III Degree Invalidity	4	3	7
	Lighting	14. Very low lighting level	III Degree Invalidity	4	3	7
	Airborne dust particles	15. Inhalation of airborne dust particles and silicogenic powders (fibrosis, silicosis)	II Degree Invalidity	5	3	7
Working task	Wrong tasks	16. Wrong working tasks	Death	7	2	7
	Missing steps in task	17. Incomplete working tasks	Death	7	2	7
	Unfitted methods	18. Wrong sequences of operations	Death	7	2	7
	Physical stress	19. High dynamic effort at mass manipulations (50 – 80 kg.)	III Degree Invalidity	4	4	7
		20. Forced and vicious working positions due to narrow spaces, orthostatic working position	II Degree Invalidity	5	5	12
	Mental stress	21. Psychic stress due to difficult decisions in a short time, at the occurrence of extreme cases	Death	7	2	7
		22. Complex operations due to the specifics of the work	Death	7	2	7
Human error	Wrong actions	23. Faulty executions of front operations	Death	7	2	7
		24. Asynchronizations of operations	II Degree Invalidity	5	4	12
		25. Starting or stopping technical equipment outside the workload	Death	7	2	7

		26. Walking or staying in dangerous areas	Death	7	2	7
		27. Falling at the same level by slipping, unbalancing or tripping	1-7 days LTI	1	5	4
		28. Falling from height by collapse, sliding, unbalance or obstruction	DEATH	7	2	7
	Accidental communica tions	29. Accident-prone communications due to inattention, noise, etc.	INV. Gr. II	5	3	7
	Omissions	30. Omission of certain operations (proper housekeeping, front control, failure to insure equipment at accidental start)	Death	7	2	7
		31. Non-use of safety and protection means (PPE)	Death	7	2	7
LTI: Lost Time Injury						

$$Nr = \left[\frac{\sum_{i=1}^{n} r_i^2 \cdot R_i}{\sum_{i=1}^{n} r_i^2} \right] \cdot \frac{t_e}{t_i} \cdot C_1 \cdot C_2 \cdot C_3 \cdot C_4 = 9.055$$

4. RESULTS AND DISCUSSION

Based on the acceptable level of risk, various uses of determining the level of risk in a work system can be established. A first use is the prioritization of workplaces according to the risks of accidents and occupational diseases and the establishment, according to articles 1 and 2 of the Methodological Norms of workplaces with special hazard, as those greater than the acceptable risk.

Another use of quantitative determination of the level of risk in a work system is the differential granting of the hazard bonuses (incentives). Table 8 presents a grid for granting the hazard bonus according to the level of risk of the jobs, mentioning that the bonus percentages, can be established in another way, by mutual agreement between the employer and the union management from each economic unit, depending on the financial possibilities of the respective unit.

Determining the level of risk can also be used to classify economic units according to occupational risks.

Table 9 presents a classification grid of economic units according to the risk level, noting that this classification can be made within closer limits of the risk level, in a wider range of classes.

Table 8. Hazard bonus grid proposal depending on the level of risk

Crt. no	Risk level (Nr)	Hazard bonus (% from salary)	Bonus class
1	7÷9	6	1
2	9÷11	9	2
3	11÷13	12	3
4	13÷15	15	4
5	15÷17	18	5
6	17÷19	21	6
7	19÷21	25	7
8	>21	30	8

Table 9. Classification grid of economic units according to the risk level

Crt. no.	Risk level of the unit (Nr_u)	Unit class	Hazard level
1	<3	1	Very low
2	3÷5	2	Low
3	5÷10	3	Average
4	10÷15	4	High
5	15÷20	5	Very high
8	>20	6	Extremely high

Also, depending on the respective risk levels, the workshops, sections (sectors) or subunits within a unit can be classified. All these hierarchies and classifications can be used at:

- Correct placement of jobs, workshops, sections, subunits or units in work groups;
- Calculation of the contribution to the insurance fund for accidents at work and occupational diseases;
- Establishing the share of participation in state social insurance (C.A.S.).

For the entire investigated company, applying the calculation formula for determining the level of risk (considering $n_1 = 0$ and $n_2 = 1$ in the case of all evaluated workplaces) to the workplaces in the mining sector analyzed, values between 8.715 and 10.416 are obtained. , values that according to table 10 belong to the bonus class 2, and the hazard bonus (% of the salary) has the value 9.

Table 10. Summary of risk assessment results in the investigated mining company

Crt. no.	Workplace	n	n_7	n_6	n_5	n_4	n_3	C_1	C_2	C_3	C_4	N_r
1	Crusher operator	31	0	1	5	19	3	1.10	1	1.03	1.08	9.055

2	Excavator operator	30	0	1	5	20	2	1.10	1	1.03	1.08	9.055
3	Front loader servers	31	0	1	5	22	2	1.10	1	1.03	1.03	9.177
4	Bulldozer operators	30	0	1	5	21	2	1.10	1	1.03	1.08	9.177
5	Drilling rigs operators	31	0	1	5	23	2	1.10	1	1.03	1.05	9.636
6	Open-pit miners	29	0	1	4	21	3	1.10	1	1.06	1.01	8.715
7	Blasting operators (open-pit)	32	0	1	4	23	3	1.10	1	1.03	1.01	8.983
8	Open-pit electrician s	33	0	1	5	23	3	1.10	1	1.03	1.08	10.034
9	Quarry machine mechanics	32	0	1	5	23	2	1.10	1	1.03	1.08	9.911
10	Gas / electric welders	34	0	1	5	23	3	1.10	1	1.03	1.03	9.569
11	Maintenan ce mechanics	30	0	1	5	21	2	1.10	1	1.03	1.01	8.811
12	Lathers	29	0	1	4	21	2	1.10	1	1.03	1.05	8.744
13	Warehous e man	34	0	1	4	23	3	1.10	1	1.00	1.03	8.983
14	Vehicle drivers	33	0	1	5	22	2	1.12	1	1.09	1.08	10.41

Applying the calculation formula for determining the risk level of the macro-system (workshop, section, sector, etc.), a value of 9.305 is obtained, a value that corresponds to the average danger level, and the sector falls into units that have class 3, according to table 9. From the point of view of the distribution on generating sources, it can be noticed that the majority share of the means of production factors occupies 36.37%, following as weight by the factors specific to the work environment 12.12%, own factors due to the workload 21.21% and the share of the human errors, by 30.30%. (figure 1).

Depending on the severity of the consequences that the risk factors produce on the participants in the work process, it can be noticed that the highest share is detained by the risk factors that produce death 51.52%, following the risk factors that produce INV degree III 12, 12%, INV degree II 12.12%, INV degree I 3.03%, LTI 1-7 days 9.09%, LTI 7-45 days 12.12% (Figure 2).

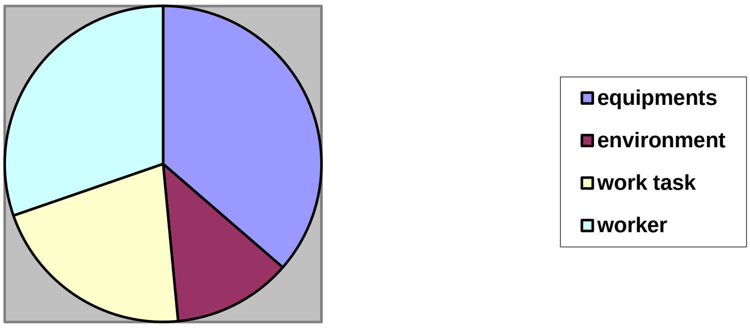


Fig. 1. Distribution on generating sources of risk factors

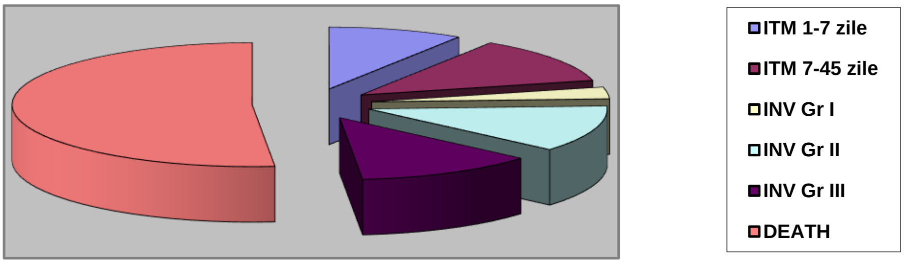


Fig. 2. Distribution of identified risk factors according to the severity of the consequences generated

5. CONCLUSIONS

The starting point in optimizing the activity of prevention of work accidents and occupational diseases in a system is the risk assessment in that system. Whether it is a workplace, a workshop or a company, such an analysis allows the ranking of risks according to their size and the efficient allocation of resources for priority prevention and protection measures. Risk assessment involves identifying all risk factors in the analyzed system and quantifying their size based on the combination of two parameters: the severity and frequency of the maximum possible consequence on the human body. Thus, partial risk levels are obtained for each risk factor, respectively global risk levels for the entire analyzed system.

To facilitate the fulfillment of the legal obligations of employers in the field of risk assessment of occupational injury and illness, a relatively large number of methods have been designed and are currently used. From the multitude of methods used worldwide and nationally for assessing the risks of accidents and occupational diseases, in this paper we chose to use the method developed by the Professional Mining Association of Romania. The obtained results allowed the establishment of the acceptability of risks, the prioritization of intervention needs and the prevention and protection measures necessary to minimize the risks of accidents and occupational diseases for all 14 categories of occupations / jobs in the investigated open-pit ore mine.

REFERENCES

[1] **Acuner O and Cebi S.** *An effective risk-preventive model proposal for occupational accidents at shipyards.* Brodogradnja 67(1):67–84, 2016..

[2] **Aven T.** *Risk assessment and risk management: Review of recent advances on their foundation*. Eur J Oper Res 253(1):1–13. doi:10.1016/j.ejor.2015.12.023, 2016.

[3] **Băbuţ, G.B., Moraru, R.I.** *Critical analysis and ways to improve the I.N.C.D.P.M. Bucharest for the assessment of the risks of accidents and occupational diseases*, "Quality - access to success", vol. 14, no. 137, pp. 55-66 2013.

[4] **Darabont, Al., Pece, Şt., Dăscălescu, A.** *Occupational safety and health management* (vol. I and II, in Romanian), Publishing House AGIR, Bucureşti, 2001.

[5] **Fera M and Macchiaroli R.** *Appraisal of a new risk assessment model for SME*. Saf Sci 48 (10):1361–68. doi:10.1016/j.ssci.2010.05.009, 2010.

[6] **Goerlandt F, Khakzad N, and Reniers G.** V*alidity and validation of safety-related quantitative risk analysis: A review*. Saf Sci 99:127–39. doi:10.1016/j.ssci.2016.08.023, 2017.

[7] **Moraru, R.I., Băbuţ, G.B.** *A Romanian occupational health and safety risk assessment tool: premises, development and case study*. In: *Risk assessment and management*, Zhang, Z. (Ed.), Academypublish.org (Publishing Services LLC), Cheyenne, WY, USA, pp. 292-311, 2012.

[8] **Moraru, R.I., Băbuţ, G.B., Cioca, L.I.** *Rationale and criteria development for risk assessment tool selection in work environments*, Environmental Engineering and Management Journal, Volume 13, Issue 6, pp. 1371-1376, 2014

[9] **Pece, Şt.** *Risk assessment in the work system*, Publishing House Rubin, Galaţi, 2010.

[10] **Pinto A, Nunes IL, and Ribeiro RA.** *Occupational risk assessment in construction industry–Overview and reflection.* Saf Sci 49(5):616–24. doi:10.1016/j.ssci.2011.01.003, 2011.

[11] **Silvestri A, De Felice F, and Petrillo A.** *Multi-criteria risk analysis to improve safety in manufacturing systems*. Int J Prod Res 50(17):4806–21. doi:10.1080/00207543.2012.657968, 2012.

[12] * * * Metoda de evaluare a nivelului de risc pe loc de muncă, Asociaţia Profesională Minieră din România, 2006, https://www.scribd.com/document/51960826/METODA-DE-EVALUARE-A-NIVELULUI-DE-RISC-PE-LOC-DE-MUNC%C4%82

AN ANALYSIS OF THE EVOLVING REGULATORY FRAMEWORK OF MAJOR INDUSTRIAL ACCIDENTS: PARTICULARITIES FOR CIVIL USE EXPLOSIVES

ROLAND IOSIF MORARU [1]

Abstract: *The intended purpose consisted in the analysis and synthesis of the evolving regulatory framework related to the field of research associated with major industrial accidents, by conducting a documented study on the temporal, principled and evolutionary development of the normative/legislative framework that regulates the control of the major accidents hazard, with specialization dedicated to statistical data related to unwanted events in this category generated by explosive materials. The particular aspects regarding explosive and pyrotechnic sites were detailed in parallel with the specific regulations in the field of civil explosives, highlighting the fact that the rapid progression of explosive accidents is critical when considering emergency response. The results of the analysis carried out in this work allowed - further - to detail the research with reference to the risk analysis/assessment tools associated with industrial sites for the storage/production of civil explosives, in order to provide experts, researchers and practitioners in the field with cohesive and useful material in order to effectively solve the particular aspects of the management of this type of risk, characterized by the high severity of the potential consequences.*

Keywords: *major industrial accident, Seveso Directives, civil explosives, explosive and pyrotechnic materials (E&P)*

1. INTRODUCTION

Currently, measures are regulated at the national level to prevent major accidents involving hazardous substances, as well as to limit their consequences on human health and the environment, to ensure a high level of protection throughout the national territory, in a consistent manner and effective, given that our country ranks 10th among European countries in terms of the number of objectives that fall under the scope of the Seveso Directive. In order to analyze the evolving regulatory framework for major industrial accidents, we outlined a synthetic exposition of the main regulations applicable at international, European and national level in the field of major accident risk assessment specific to industrial sites intended for specific operations with explosive materials.

Starting from the SEVESO paradigm, explained from the beginning and as a legislative-regulatory evolution, we have synthetically illustrated the temporal evolution

[1] *University of Petroşani, Romania*

of the European Union legislation dedicated to major industrial accidents and - very relevant - the status of the implementation of the Seveso III Directive on the European level. From the perspective of this analysis, successful implementation has meant that EU Member States have effectively adopted national measures and that the number and severity of accidents is decreasing. Reporting on Member States' implementation of Directive 96/82/EC over the past 7 years has indicated that implementation continues to improve with each reporting period. The number of "sites" was increasing, but the number of major accidents remained stable. For that period, an average of 27 major accidents were reported each year. Of particular note was the significant drop in the number of deaths and injuries. Another point to mention is that the Office for Major Accident Risks (MAHB) of the European Commission's Joint Research Center provides political, scientific and technical support to Member States in the implementation of Seveso III. MAHB also provides an industrial accident risk analysis reference center for benchmarking models and tools and for site-specific risk assessment applications and general policy implementation, as well as accident data management and analysis systems.

The responsibility of preventing the risks of major accidents in the industrial field and limiting the consequences of a dangerous event rests with the risk generator, authorities and local administrations, considering four ***priority axes***:

- *reducing risks at the source* (modernization of industrial processes, methods of transporting and storing hazardous substances, replacing certain substances with less dangerous ones, etc.);
- *reducing vulnerability* (limiting the exposure of people and goods through urban planning measures, which will reduce - for new constructions - the exposure of people);
- *operational response planning* with the following components:
    - *internal emergency plan*, drawn up by the economic operator in order to limit the consequences of an accident, protect employees, put the installations in the safest state;
    - *risk analysis and coverage plan*, drawn up by the town halls of the localities that may be affected;
    - *external emergency plan*, drawn up by the inspectorate for emergency situations and approved by the prefect, to ensure the protection of the population; this plan defines the missions to be executed by all the participating forces (firemen, gendarmes, police, public health department, local communities), but also by the economic operator until the arrival of the support forces; the external emergency plan/internal emergency plan/risk analysis and coverage plan are closely related; they must be perfectly coordinated to ensure that each participating force carries out its missions efficiently and effectively.
- *informing the population* about the nature of the risks, the possible consequences and the necessary behavior to be adopted in the event of an incident or accident.

Particular aspects of explosives and pyrotechnic sites (E&P) were detailed in parallel with the specific regulations in the field of civil explosives, highlighting the fact that the rapid progression of explosive accidents is critical when considering emergency response. Although E&P hazards are broadly similar, they cover different scales of both risk and consequence. This diversity is reflected in the different nature of the spectrum of major accident risks associated with explosives.

2. THE SEVESO PARADIGM: ORIGIN AND LEGISLATIVE-REGULATORY EVOLUTION

Industrial accidents like the Flixborough (1974) or Seveso (1976) explosions or the Union Carbide disaster at Bhopal (1984), or the Chernobyl disaster (1986) and many others show that technology failures or operator failures lead to fatal consequences with many mortally wounded. persons or seriously injured. These failures also lead to enormous property damage and long-term or irreversible ecological damage [1].

As is well known, in 1976 a major accident that occurred in a small chemical plant in Seveso (near Milan, Italy) changed forever our approach to risk assessment. Dioxin dispersed into the atmosphere and local environment as a result of depressurization venting following a reactor failure induced skin disease in about 250 people and caustic soda burns in about 450 people. A large area of land, about 17 km^2, was contaminated, and about 4 km^2 became uninhabitable. The accident occurred when a disk on a chemical reactor „failed", resulting in the release of a dense white cloud. The cloud contained a small "deposit" of the highly toxic substance known as 2,3,7,8-tetrachlorodibenzop-dioxin ("TCDD" or "dioxin"). Following the accident, several errors were identified, including the incorrect operation of some procedures, as well as inadequate exhaust/ventilation and reactor control systems. In addition, there was no device to collect, evacuate or destroy the toxic substances. Information on released chemicals and associated hazards was not available at the plant. Communication between the unit and local and regulatory authorities was confusing and inadequate [2].

This undesirable event led to the development of the first Seveso Directive, intended both to prevent major hazards and to protect workers and citizens [9]. With these deficiencies identified, it became apparent that there was a growing need to adopt specific legislation on the prevention and control of major industrial accidents. For the European Union (EU), *Council Directive 82/501/EEC of 24 June 1982 on Major Accident Hazards associated with Certain Industrial Activities* (known as SEVESO I) was developed. The purpose of SEVESO I was to adopt provisions relating to any industrial activity that involves (or has the potential to involve) hazardous substances and that may have serious consequences for people and the environment in the event of a major accident. The responsibility has been placed on the manufacturer/holder to take the necessary measures to prevent such accidents and to limit the consequences of any such accidents. SEVESO I emphasized the need to train and provide information to workers on any industrial site [3].

Operators of sites where hazardous substances are handled should take all necessary measures to prevent major accidents, mitigate their consequences and recover from them. Such facilities range from explosives depots and fuel and gas depots to complex process industries. They are called "*Seveso sites*" (further classified into lower and upper level units). The purpose of SEVESO was simple. A major accident was considered the materialization of a major hazard, such as a major emission, fire or explosion, resulting from uncontrolled developments during an industrial activity, leading to a serious hazard to persons, immediately or after a certain period of time, in inside or outside the facility and/or the surrounding environment and involving one or more hazardous substances. Hazardous substances subject to the SEVESO I Directive have been listed in the annexes to the directive. The provisions of SEVESO were not immediately applicable. EU directives are pieces of legislation that set targets that all EU countries or member states must achieve. While the directive's measures must be implemented in national law, individual countries have the power to adopt their own legislation to achieve the objectives of the original directive. In other words, member states could maintain or adopt stricter measures than those contained in the SEVESO Directive [4].

The operators have the obligation to provide information to the competent authorities established by the state, in the form [5]:

- a *major accident prevention policy* (MAPP) which sets out the operator's overall approach, measures (including the safety management system) to control major accident hazards;
- a *safety report* (for higher level sites) to demonstrate that everything necessary has been done to prevent major accidents and to prepare emergency plans and response measures. The operator is obliged to revise the safety report at least once every five years;
- information from inspections to demonstrate that the data and information in the safety report adequately reflect the conditions in the facility;
- information to assess the effects on human health and the environment of a major accident that has occurred;
- information and data available at any time, if requested.

Some EU member states and associated countries have also developed specific methods to regularly collect and monitor such information. This would also allow competent authorities and states to assess the risk trends of Seveso sites. However, there is no consolidated approach for such periodic monitoring. A risk analysis study is usually carried out during the design phase or the early existing phase of a system and generates a static picture of its safety measures. While the system is constantly evolving or degrading, the Seveso site safety report is updated approximately once every five years – or in the event of a major accident or following inspections by the competent authority [6].

As mentioned before, the original SEVESO was not the end of the line for European legislation on major industrial accidents. On the occasion of the discussions held within the framework of the 4th (1987) and 5th (1993) Environmental Action Program, the member states of the European Union requested a general revision of the Seveso I Directive aiming, among other things, at broadening scope and better risk and accident management. In the same period, the revision of the Seveso I Directive was also requested by a resolution of the European Parliament. A text proposal for the new directive was drawn up at the beginning of 1994. After being amended several times, this proposal, which was originally known as the "COMAH" (Control of Major Accidents Hazards) Directive, was finally approved in December 1996 when Directive no. 96/82/CE on the control of activities that present the risk of major accidents involving dangerous substances was issued[7].

In fact, following other major product accidents around the world - in Bhopal (India), Mexico City (Mexico), Toulouse (France) and Enschede (Netherlands) - the original version of SEVESO was reformulated in the *Council by Directive 96/82/EC of December 9, 1996 on the control of the dangers of major accidents involving dangerous substances* (SEVESO II). The Seveso II Directive introduced a new conceptual framework, as well as important changes regarding the approach to major accidents [8].

One of the main focuses in the second reiteration of the directive was the adoption of measures to address the hazard that arises when hazardous facilities/sites and riverside are located in close proximity to each other. New zoning regulations have been included when new facilities/sites are authorized and when urban development in the inner city takes place around existing facilities [9].

Almost 40 years after Seveso I, on June 1, 2015, the member (and associated) states of the European Union (EU) put into force the laws, regulations and administrative provisions necessary to comply with the EU Directive called Seveso III. It replaces the previous Seveso II Directive and responds to the need to ensure adequate precautionary actions for a high level of protection for citizens, communities and the environment throughout the Union. The major accidents produced after the year 2000, as well as the evolution of scientific and technical knowledge, determined the appearance, at the level of the European Union, of several documents aimed at amending the Seveso II Directive. In 2012, this third iteration of the legislation was adopted, entitled *Directive 2012/18/EU of the European Union of the Parliament and of the Council of 4 July 2012 on the Control of the Hazards of Major Accidents Involving Hazardous Substances, with the amendment and repeal of the Directive Council 96/82/EC* (SEVESO III). SEVESO III introduces two different classes of sites, revises the list of hazardous substances and strengthens requirements for providing information to the public [10] .

Figure 1 synthetically illustrates the temporal evolution of the European Union legislation dedicated to major industrial accidents. The new directive specifies the obligation to develop and apply a major accident prevention policy for all classified sites regardless of the classification level, stating that for sites classified as minor risk, the major accident prevention policy must be implemented through a safety management system, designed in accordance with the nature and complexity of the location. It is also expressly provided for the mandatory review every five years. An active way of informing the general public about the Seveso sites is required. The older directive imposed the obligation to inform the public for locations classified as a major risk, then the provision became valid for locations classified as a minor risk. Instead, the period for revision is increased - at least once every five years compared to three years, previously provided. In addition, it is required to make the information available to the public permanently and in electronic format. Feedback after a major accident can also be appreciated as a novelty: the authorities are obliged to provide the public with information about the accident and the measures taken.

Fig. 1. Evolution of major industrial accidents EU legislation development

The main new elements introduced by the Seveso III Directive in relation to Seveso II are the following [11]:

- the scope of the directive remains essentially unchanged; the order of parts 1 and 2 of Annex I has been reversed, so that Part 1 of Annex I lists the categories of hazardous substances according to their generic hazard classification (according to the CLP Regulation), and Part 2 lists the names of some hazardous substances or groups of substances for which, without contradicting their generic hazard classification, inclusion on a specific list is justified; the main differences regarding the content of annex I are the following:
    - the main change concerns health hazards; the former "*very toxic*" category was aligned to the Clasiffication, Labelling, Packaging (CLP) category "*acute toxicity 1*", and the "*toxic*" category to "*acute toxicity 2*" (all routes of exposure) and "*acute toxicity 3*" (routes of exposure - dermal and through inhalation);
    - several specific CLP categories for physical hazards, which did not exist before, replace the former more general categories for oxidation, explosion and ignition hazards; these, together with the environmental hazard categories, are a direct transposition and maintain as close as possible to the current scope of such hazards; for the new category of flammable aerosols, the limit values have been proportionally adapted to those currently applied based on their flammable properties and components, and for reasons of consistency, the group of pyrophoric substances has been completed by including pyrophoric solids.

  - part 2 of the new annex I largely leaves former part 1 unchanged; the only changes are an updated reference to the CLP Regulation on flammable liquefied gases, the inclusion of anhydrous ammonia, boron trifluoride and hydrogen sulphide in the list of substances, previously covered by inclusion in the corresponding hazard categories, to keep their limit values unchanged, the inclusion of heavy fuel oils under the petroleum products heading, clarification of notes on ammonium nitrate and updating of toxic equivalence factors for dioxins.

- the definitions for „site", „operator" and „installation" have been clarified and definitions have been added for „inspections", „public", „targeted public", as well as for different types of sites that fall within the scope of the directive;
- correction mechanisms are provided to adapt Annex I, if necessary, through delegated acts; this is necessary, in particular, to respond to the unwanted effects resulting from the alignment of Annex I to the CLP Regulation and from the subsequent adaptations to that regulation, which could lead to the automatic inclusion or exclusion from the directive of some substances and some mixtures, possibly regardless of whether or not they present a major accident hazard;
- the requirement was introduced for the public to express their point of view in certain cases related to the development of the territory, changes to external emergency plans, etc; the provisions are largely based on Directive 2003/35/EC, with the aim of better aligning the Seveso II Directive with the corresponding provisions of the Aarhus Convention;
- new privacy rules are introduced, which are based on Directive 2003/4/EC implementing the provisions of the Aarhus Convention on public access to environmental information, which place greater emphasis on openness and transparency, while ensuring non-disclosure of information in thoroughly justified cases where it is necessary to maintain confidentiality;
- a requirement is introduced that better aligns the directive with the Aarhus Convention by requiring Member States to ensure that the interested public, including interested environmental NGOs, have access to administrative or legal procedures to challenge any acts or omissions that could violate their rights related to access to information or related to consultation and participation in the decision-making process.

The other changes proposed by the Seveso III Directive are relatively minor technical adaptations of the existing provisions.

3.HOW DOES SEVESO WORK TODAY? THE STATUS OF THE IMPLEMENTATION OF THE SEVESO III DIRECTIVE AT THE EUROPEAN LEVEL

Seveso III adopted the concepts of its predecessors with some additional measures. As mentioned above, a directive must be formally implemented and adopted through national legislation. Each Member State has the obligation to ensure that the applicable measures are incorporated into the national requirements. Before tackling national implementation, it is important to understand the fundamental requirements of Seveso III [12].

Similar to Seveso and Seveso II, Seveso III applies to operators who control sites carrying out activities where hazardous substances are present in one or more installations, including infrastructure or common or related activities. Locations are classified as either ***lower level*** or ***upper level*** [4]:

If there are several hazardous substances in the unit, the summation rule applies, which is detailed in note 4 of Annex I to the directive. Member States are obliged to ensure that the operators of these facilities take all necessary measures to prevent major accidents and to limit their consequences. Examples of such requirements include [13]:

- notification of all involved locations (article 7);
- implementation of a major accident prevention policy (article 8);
- drawing up a safety report for higher level units (article 10);
- development of internal emergency plans for higher level units (article 12);
- providing the requested information in case of accidents (article 16).
- drawing up external emergency plans for higher level sites (art. 12);
- implementation of the territorial planning for the location of the units (article 13);
- making relevant information available to the public (article 14);
- ensuring that all necessary measures are taken after an accident, including emergency measures, remedial measures and measures to inform people who may be affected (article 17);
- reporting accidents to the European Commission (article 18);
- prohibiting the illegal use or operation of sites (article 19);
- carrying out inspections (article 20).

One of the main changes is that the list of substances in Annex I has been updated and aligned to "*Regulation (EC) no. 1272/2008 of the European Parliament and of the Council of 16 December 2008 on the classification, labeling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC and amending Regulation (EC) no. . 1907/2006 (CLP Regulation)*". Two examples of substances that have been added to Annex I are anhydrous ammonia (entry 35) and hydrogen sulphide (entry 37) [14].

Member States were required to adopt implementing legislation by 31 May 2015. As White (2017) documents, to date all Member States have incorporated SEVESO III requirements into national legislation [5]. Seveso III sets minimum requirements for the implementation of legislation and it is interesting how member states have managed to embed the concepts of prevention and protection of major industrial accidents in the culture of their countries. For example, in the United Kingdom, the "*Control of Major Accident Hazards Regulations 2015*" (COMAH 15) came into force on 1 June 2015 to implement most of the Seveso III requirements. Northern Ireland enacted its own legislation and land use planning requirements were implemented through planning legislation. The concepts of lower and upper tier sites are respectively consistent with the Directive in relation to substances listed in Schedule 1 to COMAH15. List 1 includes the list of substances applicable to classification, labeling and packaging (CLP Regulation), which aligns with Seveso III. The COMAH15 structure aligns with SEVESO III.

From the perspective of this analysis, successful implementation has meant that EU Member States have effectively adopted national measures and that the number and severity of accidents is decreasing. Reporting on Member States' implementation of Directive 96/82/EC over the past 7 years has indicated that implementation continues to improve with each reporting period. The number of "sites" was increasing, but the number of major accidents remained stable. For that period, an average of 27 major accidents were reported each year. Of particular note was the significant drop in the number of deaths and injuries [15].

Due to the improvements observed, the focus of Seveso III was not placed on dramatically improving the rigor of the measures, but on harmonizing legislation and ensuring public access to information. The European Commission has not yet published reports on Seveso III and statistics have not been widely published for the post-Seveso III implementation period. As this information becomes available, it will be interesting to review the success of the implementation.

Another point to mention is that the ***Major Accident Hazards Bureau (MAHB***) of the Joint Research Center of the European Commission provides political, scientific and technical support to Member States in the implementation of Seveso III. MAHB also provides an industrial accident risk analysis reference center for benchmarking models and tools and for site-specific risk assessment applications and general policy implementation, as well as accident data management and analysis systems. The Major Accident Hazards Bureau (MAHB) was established with the specific mission of providing independent scientific and technical support to the Commission and ensuring the successful implementation and monitoring of EU policy on the control and prevention and mitigation of major accident hazards [11].

In addition, to fulfill its information exchange obligations towards Member States, the Commission has established the Major Accident Reporting System (MARS), the Seveso Plant Information Retrieval System (SPIRS) and the Community Industrial Risk Documentation Center (CDCIR), which are managed and maintained by MAHB. The main clients of MAHB's services, apart from the Commission, include all actors in legislative, regulatory and management activities related to the safety of processing facilities, (e.g. national and local authorities, industry, research organisations, consultants safety, trade, trade unions). To facilitate an efficient and effective exchange of information, MAHB has developed and maintains a dedicated website (http://mahbsrv.jrc.it) from which information, guidance documents, scientific publications and software can be accessed and downloaded.

4. MANAGEMENT OF MAJOR ACCIDENTS WORLDWIDE

Other states around the world are adopting requirements regarding the prevention of major industrial accidents. Here is a list of examples of applicable law in a few states. So [16]:

i. ***Canada***: The Environmental Emergencies Regulations (SOR/2003-307) set out the notification and reporting requirements for any person who possesses or has charge, management or control of a substance listed in Schedule 1 to the Regulations.

ii. ***China***: "*Identification of facilities with a major hazard of hazardous chemical substances - GB 18218-2009*", states that a facility with a major hazard refers to a facility or workplace that usually or temporarily produces, processes, transports, uses or stores the hazardous substances/chemicals listed in the standard. The implementing measures of the "*Regulations on the Safe Production Permits of the Hazardous Chemicals Manufacturing Industry*" and the "*Provision on the Supervision and Management of Major Hazard Sources of Hazardous Chemicals*" provide concrete requirements.

iii. ***India***: *The Major Accident Hazards Control Rules* (1997) and the *Manufacture, Storage and Import of Hazardous Chemicals Rules* (1989) apply to industrial activities or isolated storage involving a hazardous chemical. The scope of the requirements in these two pieces of legislation is similar, but the applicability is somewhat different.

iv. ***Mexico:*** "*NOM-028-STPS-2012, Workplace Management - Chemical Process Safety*" sets out processes and rules for the safe handling of chemicals to prevent major accidents and protect against worker injury and workplace damage.

v. ***United States of America***: "*1910.119 - Process Safety Management and Highly Hazardous Chemicals*" establishes the Process Safety Management (PSM) framework and requirements for addressing unexpected releases of toxic, reactive or flammable liquids and gases in processes involving hazardous chemicals. One of the key provisions of PSM is Process Hazard Analysis (PHA) – a careful analysis of what could go wrong and what safety measures need to be implemented to prevent the release of hazardous chemicals. "*OSHA 3132 – Process Safety Management*" and "*OSHA 3133, Process Safety Management – Guidelines for Compliance*" provide a detailed analysis of the requirements.

Returning to the European level, it should be mentioned that Seveso III mentions specific procedures for safety performance indicators and/or other relevant indicators, to be used for monitoring the performance of safety management systems. Paltrinieri and Reniers (2017) made a relevant synthesis from this point of view (table 1) [17].

Table 1 summarizes not only how the indicators are used (or suggested), but also how past events are taken into account. In fact, they are centralized by the competent authorities of all EU and associated countries and can themselves indicate the safety performance of a Seveso site and can be identified as retrospective indicators [18].

Table 1. Characteristics of Seveso monitoring approaches in selected EU and associated Member States, **(** adapted from Paltrinieri and Reniers, 2017)

State	**Indicators**		**Additional classification of Seveso sites**	**Remarks**
	History of events	**Safety performance indicators**		

Great Britain	The related incidents and dangerous events are not only reported to the relevant authorities but also regulated by RIDDOR (Reporting of Injuries, Diseases and Dangerous occurrences). The causes of reported incidents are reviewed periodically.	The competent British authorities (Health and Safety Executive, Environment Agency and SEPA) requests all sites under the scope of the directive and business owners to monitor their the performances through process safety performance indicators (PSPI).	The Competent Authorities realize prioritization of Seveso sites in terms of the safety of people and the environment. They are classified into four safety groups (A-D).	The COMAH Regulations 2015 implement the majority of the Seveso III Directive in Great Britain (Northern Ireland produces its own regulations).
France	Accidents and incidents are collected in the ARIA (Accident Analysis, Research and Information) database. The French Ministry of Ecology, through BARPI (Bureau for the Analysis of Risks and Industrial Pollution), annually presents files with incident indicators and KPIs (Key Performance Indicators).	The French National Center competent for industrial safety and environment protection (INERIS) identified the need to use indicators for industrial security. It has been defined for a specific method to develop, select and apply an appropriate "Safety Performance Indicator System" (SPIS).	-	Decrees 2014-284 of 3 March 2014 and 2014-285 of 3 March 2014 is implementing Seveso III Directive in France.
Italy	Incidents and accidents are reported to the competent authority.	Italian regulations provide that safety performance monitoring should rely on at least on the evaluation of the indicators and their trend of evolution.	-	Incidents and accidents are reported to the competent authority.
Netherlands	A special approach to accident collection	The new Dutch decree introduce the use of the indicators that	-	The Brzo Decree (Besluit risico's

	involving hazardous substances in the Seveso sites was developed. The "Risk Control" Department of the Labor Inspectorate operates. The database involves approximately 260 accidents occurred in the period 2004-2018.	provides information about the safety performance of the companies they work with hazardous substances. The National Institute for Public Health and the Environment (RIVM) has drawn up a guide for the use of such indicators.		zware ongevallen) (2015) implements Seveso III in the Netherlands.
Finland	The Finnish Authority for Technological Security (TUKES) uses accidents, incidents, error and failure lists to assess the performance of safety management systems.	Other indicators are used to evaluate performance safety management: investments in terms of safety, the level of order and cleanliness, registration defects, safety audits, etc. are used as indicators.	The Seveso locations are classified based on some legislative elements, technical, operational and organizational.	Decree 685 of May 21, 2015 is implementing the Seveso III directive In Finland.
Norway	Norwegian Directorate for Civil Protection and Emergency Situations (DSB) centralizes non-conformities, incidents and accidents in accordance with Seveso regulations.	The Norwegian research institute SINTEF proposes a methodology for establishing the safety evolution trend inside/outside the Seveso sites, based on safety performance indicators.	-	A new regulation was defined for the Seveso sites (FOR - 2016-06-03-569), which is implementing the Seveso III directive in Norway.

One of the most comprehensive monitoring approaches is suggested in the United Kingdom, where competent authorities require the systematic centralization of past events and safety performance indicators. Such information may be revised periodically based on a priority classification of Seveso sites.

Relatively recently, with the advent of the Sendai Framework for Disaster Risk Reduction, the EU Better Regulation Agenda, as well as OECD and cross-country initiatives to justify the costs of regulation, attention has returned to measuring the effectiveness of government programs, including of those aimed at reducing chemical accident risks. These initiatives have stimulated some reflection among the EU and OECD communities of government experts on how to measure the impact of chemical accident risk regulation and whether regulation is effective in reducing those risks. As early as the 1980s, a number of chemical companies were already studying their chemical accidents to understand their associated risks. In 1984, the European Commission began collecting data on chemical accidents reported by its member states under the first Seveso Directive of the European Union (EU) (82/501/EEC) in the MARS database, now eMARS. By the 1990s, it was widely accepted that data collection and accidents/incidents were important inputs to understanding and correcting risk control system weaknesses. Currently, some databases (such as MARS) have become public or are available by subscription. The main purpose of these databases was to promote learning from incidents. With the advent of the Internet, considerable data and information about chemical accidents have been made public to facilitate the dissemination of lessons learned.

5. PARTICULAR ASPECTS REGARDING E&P SITES. SPECIFIC REGULATIONS IN THE FIELD OF CIVIL EXPLOSIVES

The European Commission's Joint Research Center (*EC-JRC*) has analyzed a wide range of data on chemical accidents from different sources in recent years. According to its findings, chemical accidents are still a relatively common occurrence in all industrialized countries and raise important questions about the adequacy of disaster risk reduction efforts [19].

Figure 2 summarizes information taken from global media reports on chemical incidents collected by the EC-JRC. The data shows unplanned releases of hazardous substances occurring on fixed sites, offshore platforms, in the transport of hazardous substances and in pipelines during calendar year 2019. These figures are significant because they indicate that, overall, chemical incidents are relatively common across the world. On the one hand, as shown in figure 2, OECD countries, representing the world's most industrialized economies, have far fewer deaths from chemical accidents than non-OECD countries.

These data show that efforts to control the risk of chemical accidents in these countries have been very successful in reducing deaths from the vast majority of chemical incidents that occur. On the other hand, this positive trend is not necessarily reflected in a reduction in the frequency of high-impact chemical catastrophes. The list of disasters that have occurred in the last 10 years is evidence of the persistence of catastrophic risk from chemical hazards in industrialized countries. Some notable events include the Deepwater Horizon oil spill in the Gulf of Mexico (USA, 2010), the Ajka alumina sludge spill (Hungary, 2010), the West Texas ammonium nitrate fire and explosion (USA, 2013), the tank car explosion Lac -Mégantic (Canada, 2013) and the explosion at the Arkema chemical plant following Hurricane Harvey (USA, 2017).

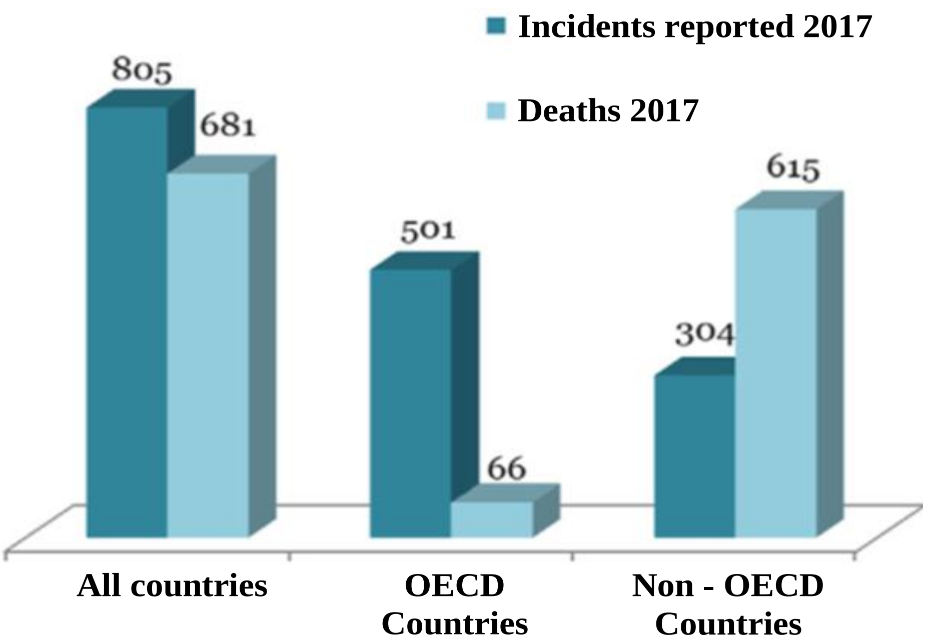


Fig. 2. Chemical incidents that occurred in 2017 reported in the world media (Database of chemical accidents reported in the world media. Joint Research Center of the European Commission-SPIRS)

Moreover, while the rate of serious chemical accidents (for example, relative to increases in production volume or GDP) may have decreased over the past 30 years, there is evidence that the absolute exposure of populations to the risk of chemical accidents has not has not decreased in any way. Industrialized countries continue to experience serious chemical accidents with regular frequency.

These serious accidents do not necessarily qualify as disasters, but they still cause multiple deaths or otherwise significantly impact communities or the environment. These events are exemplified by the BASF plant fire and explosion (Germany, 2016), the West Footacres warehouse fire (Australia, 2018) and the LPG tanker explosion on a motorway near Bologna (Italy, 2018).

These incidents and others like them are a clear sign that the risk of chemical accidents in developed countries remains an ongoing concern. As additional evidence, figure 3 shows that major chemical accidents reported in the EU eMARS database have averaged around 30 per year since 1994. These findings are hardly surprising given that OECD countries account for more than 50% of global GDP and continues to grow.

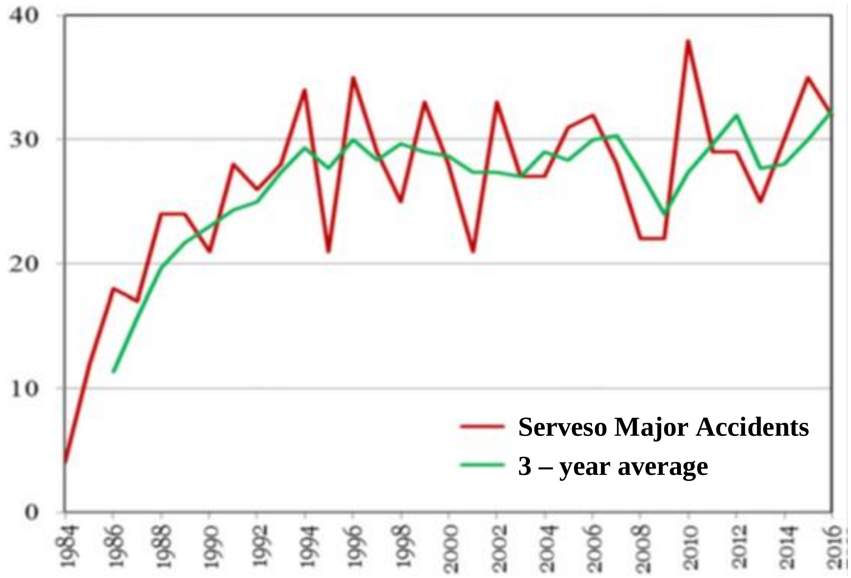


Fig. 3. Major chemical accidents reported in the eMARS database 1984–2017
(eMARS Major Accident Reporting System. Joint Research Center of the European Commission)

In particular, as shown in figure 4, high-risk industries, especially the oil and gas industry, as well as the chemical processing industry and related storage and transportation industries, remain high-hazard industries.

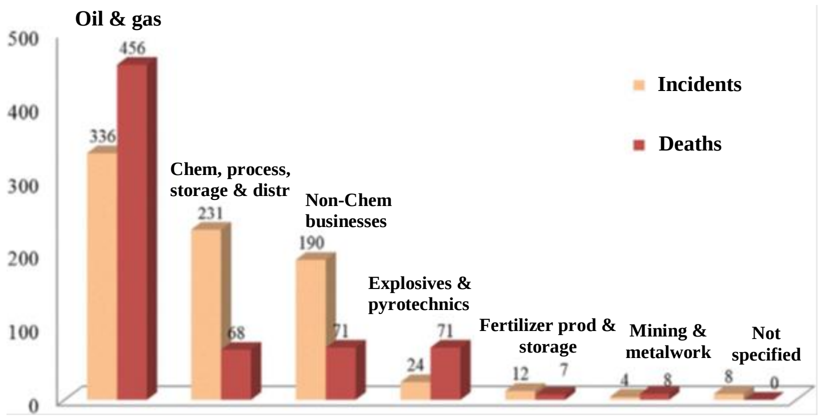


Fig. 4. Chemical accidents and associated fatalities reported in global media by industrial sector in 2022
(eSPIRS database of Seveso facilities. European Commission Joint Research Centre. https://espirs.jrc.ec.europa.eu/en/espirs /content).

Why it is difficult to measure the degree of reduction in the risk of major accidents using available accident data?

i. Hazard sources vary considerably due to different industries, substances, processes and equipment. ***Aggregate statistics can be misleading***.

ii. ***The risk of a major accident is not a stable figure***. Numerous variables influencing risk make it more likely that actual levels of risk will fluctuate significantly over time.

iii. High severity chemical accidents are low frequency events. ***Accident data may greatly underestimate the real risk***.

iv. The sources of risk are distributed across many industries and geographies. ***It is a challenge to have a complete picture***.

v. Accident causation data mainly belongs to companies. ***Data about what caused the accident is not usually available to the government***.

vi. ***Accident loss data belong to many actors*** and are difficult to collect and quantify.

For example, the EU's eMARS database collects data on chemical accidents occurring in more than 12,000 fixed installations that qualify as major hazards under the Seveso Directive. As a source of lessons learned from chemical accidents, it is a valuable resource. However, for assessing the frequency and severity of accidents, it is incomplete, not including incidents in pipelines, transport and hazardous installations not covered by the directive [20].

Figure 5 illustrates the distribution of the approximately 10,000 Seveso sites (high hazard fixed installations) in the European Union as reported by Member States in 2019.

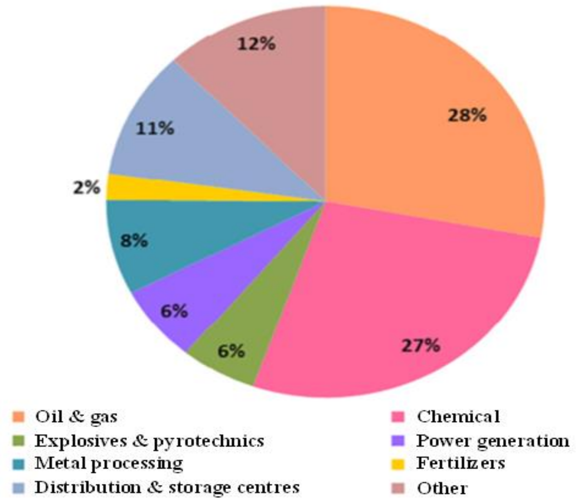


Fig. 5. Distribution of Seveso locations in the EU and EEA states in 2022
(eSPIRS database of Seveso units. Joint Research Center of the European Commission. https://espirs.jrc.ec.europa.eu/en/espirs/content).

Of these sites, 61% belong to the chemical, ***explosives and pyrotechnics*** and oil and gas industries , while the rest are in other types of industries. A site is identified as a Seveso site if hazardous toxic, flammable or explosive substances are present above certain threshold amounts. Preliminary analysis of 2021 reports indicates more than 12,000 reported Seveso sites [20].

The explosives industry, which involves the manufacture and/or storage of explosives, fireworks and other pyrotechnic articles, are important sources of major accident risk. While the number of deaths and other injuries resulting from a major accident is routinely collected, equivalent data are not consistently collected for other types of impacts, including environmental damage and cleanup costs, the number of people evacuated or sheltered, traffic disruption, power outages and other service disruptions, lost production and jobs, and supply chain disruptions. Currently, the cumulative effect of chemical accidents on society cannot be quantified due to the lack of accurate data on these impacts, as well as the variation in how such impacts are measured. The European Severity Scale for Industrial Incidents (Table 2) is an example of a model that could provide a solution in this sense. The French ARIA database has been applying this scale to technological incidents for over two decades. Its scoring mechanism equates different damage thresholds in each category with a specific impact level from 1 to 6. Hazard profiling and hazard source classification has become a widespread mechanism in some countries, especially in member states of EU, for understanding the risks from many hazardous sources in a region and for prioritizing government intervention. Hazard profiling often involves ranking sites against other sites in a given jurisdiction with respect to certain risk factors [21].

Table 2. Criteria for economic consequences, European Severity Scale for Industrial Incidents. Committee of Competent Authorities for the Seveso Directive. (https://www.aria.developpement-durable.gouv.fr/en-casd accident/echelle-europeenne-des-accidents-industriels/)

Economic consequences (C expressed in millions of euros)	**1**	**2**	**3**	**4**	**5**	**6**
Material damage on the site	0,1 < C < 0,5	0,5 < C < 2	2 < C < 10	10 < C < 50	50 < C < 200	C > 200
Production losses	0,1 < C < 0,5	0,5 < C < 2	2 < C < 10	10 < C < 50	50 < C < 200	C > 200
Material damage or off-site production losses	-	0,05 < C < 0,1	0,1 < C < 0,5	0,5 < C < 2	2 < C < 10	2 < C < 10
The cost of cleaning, decontamination, environmental rehabilitation	0,01 < C < 0,05	0,05 < C < 0,2	0,2 < C < 1	1 < C < 5	5 < C < 20	5 < C < 20

As shown in Figure 6, objective risk indicators such as type and quantity of hazardous substances, type of industry are usually combined with data specific to the individual location or operation, e.g. accident history, compliance record and inspection findings, etc.

These assessments can be useful indicators of the relative levels of hazard exposure between sites and transmission lines, including sites that perform well in risk management. They can also identify patterns in terms of relative risk associated with certain specific processes or activities in the industry. The hazard profile can also help national and local governments select different levels of attention and focus (e.g. more or less frequent inspections, changes in inspection strategy).

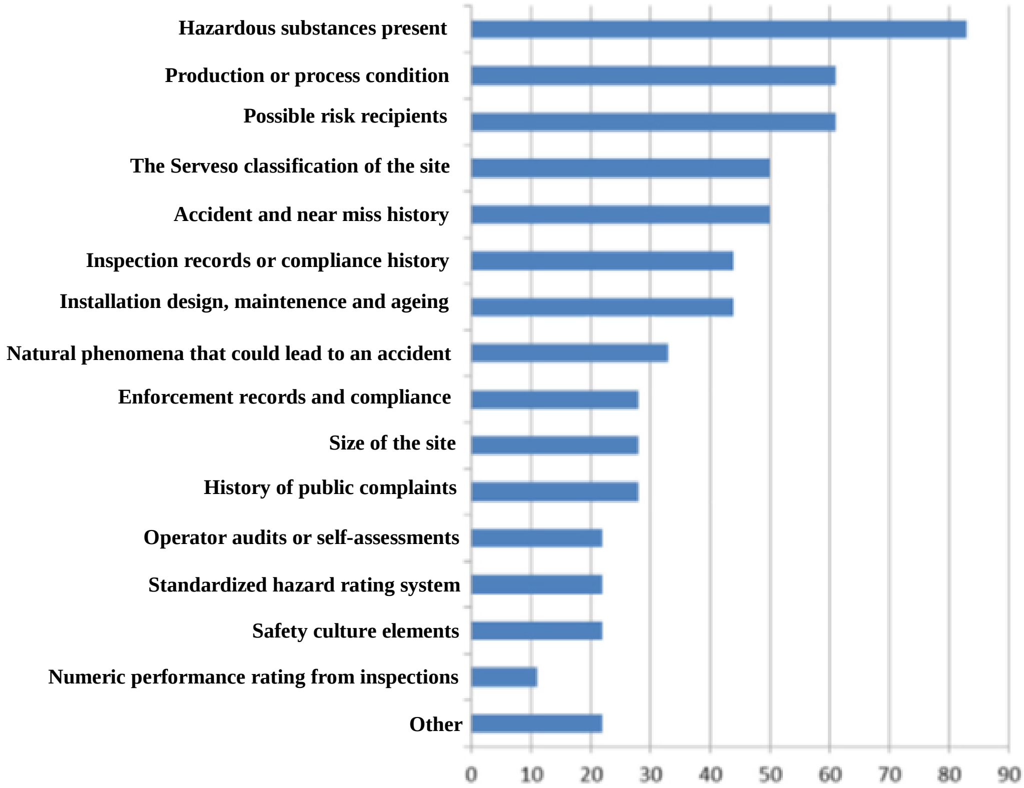


Fig. 6. Variables used to calculate hazard scores in 18 EU/EEA and UNECE TEIA by percentage of countries using them (European Commission Joint Research Center, EC-JRC, and UNECE -United Nations Economic Commission for Europe). At a Glance overview of the methodologies for assessing the dangers of industrial sites. https://minerva.jrc.ec.europa.eu/en/shorturl/minerva/jrc101613 engfinal_hazard_rating_guide3nov_2016onlinepdf)

Explosives and ***pyrotechnics*** (E&P) sites represent approximately 6% of the more than 12,000 Seveso sites in European Union and European Economic Area (EU/EEA) countries. Accidents involving explosives still occur regularly. Since 2000, almost every year there have been two to four major accidents recorded in the EU's eMARS database (figure 7) In the last five years alone, there have been twenty major accidents in Europe involving explosives [23].

In accordance with Law 126/1995 which regulates the field of explosives on a national level, there is an obligation for all explosives warehouses to keep a strict record of their inputs, outputs and consumption [24].

Also, in the field of civil explosives, the two European Directives were transposed into national legislation, which regulate the placing on the European market of civil explosives, respectively their unique identification and their traceability: Directive 2014/28/EU, transposed in the Romanian legislation by HG 197/2016; Directive 2008/43/EC, transposed into Romanian legislation by Decision 519/2009 on the establishment of a unique identification and traceability system for civil explosives [25], [26].

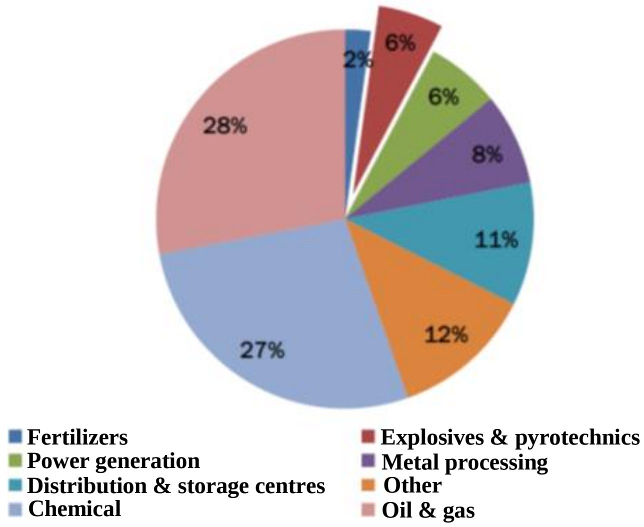


Fig. 7. Share of E&P sites in total Seveso sites in the EU/EEA

According to GD 197/2016, it is necessary to ensure that economic operators in the civil explosives sector have an explosives tracking system that allows the identification at any time of those who possess such hazardous products. Also, in accordance with Law 126/1995, there is an obligation for all explosives warehouses to keep a strict record of their inputs, outputs and consumption. At the same time, the record books within these storage facilities have a special regime. Thus, any unjustified absence of explosives from the management of a warehouse, losses or thefts must be immediately notified to the police and the Territorial Labor Inspectorate within whose radius the event occurred. Pursuant to this law, the warehouse manager as well as his substitute are liable for the entrusted management, in the conditions of defective or bad faith performance of their duties, whether disciplinary, administrative, civil or criminal.

6. CONCLUSIONS

The development of process industries involving the processing and storage of hazardous substances has determined the increase in the cases of technological and chemical incidents and accidents in particular and not only, revealing the need for a particularly careful and serious control of chemical processes, in order to prevent events with particularly serious consequences.

The SEVESO Directives, which were developed in the EU following the historic technological accidents of Flixborough (1974), Seveso (1976), Bhopal (1984), Baia Mare (2000), Toulouse (2001), etc., regulate prevention and control measures of this category of risks, simultaneously with the minimization of the effects on vulnerable targets, to ensure a high level of protection, in a performant, efficient and coherent way. In this framework, the activities related to the production, storage, transport, use or discharge of hazardous substances are uniformly regulated, in order to limit the consequences for humans and the environment. In the European context, risk management from the perspective of land use planning deals with the following areas: natural disasters (floods, avalanches, earthquakes, etc.); long-term or permanent impacts (industrial or municipal emissions, etc.); anthropogenic catastrophes (accidental spills/leaks/leaks); NATECH-type disasters (natural disasters that are the triggering factor of technological accidents/incidents) . The available methods for risk assessment/analysis in the territorial planning activity are among the methods frequently applied by industrial operators, experience shows that in most cases there is a close connection between risk assessment for establishing the safety of industrial activities and risk assessment in the context of territorial planning . Thus, the categories of risk assessment methods recommended in the "*Land Use Planning Guidelines*" guide edited by the European Commission can be selected from the following categories: *Consequence-based methods*, *Risk-based methods*, *Deterministic approach* and *Combined methods*.

The replacement from 01.06.2015 of the Seveso II Directive with the Seveso III Directive constituted a challenge to which the specialists and competent authorities in Romania must further respond effectively. The alignment with the provisions of the CLP Regulation, which is the main reason for the amendment of the Seveso II Directive, has led to major changes in the way in which the risk analysis and assessment approach for a Seveso-type site is currently structured. The conceptual and methodological deficiencies that are manifested are added to those related to establishing the correspondence between the classification of hazardous substances and that of the CLP Regulation, considering that the new classification changes the names, pictograms and standard phrases assigned to different types of hazards, as well as classified "*substances*" and "*mixtures*", provided that the risks of a given product or process for workers, distributors, consumers and the general public remain, of course, the same. The complexity and difficulty of aligning the Seveso II Directive with the provisions of the CLP Regulation was emphasized in all European Commission documents dealing with this issue. The methods of approach proposed until now have not managed to offer generally valid solutions, an aspect also highlighted by the difficulties generated by the practical transposition of the provisions of this regulation at the community level.

Regarding the field of explosives for civilian use, the two European Directives were transposed into national legislation (*Directive 2014/28/EU*, transposed into Romanian legislation by HG 197/2016 and *Directive 2008/43/EC*, transposed into Romanian legislation by Decision 519 /2009) which regulates the placing on the European market of explosives for civil use, respectively their unique identification and their traceability. E&P sites present special challenges for risk management and law enforcement. As the name suggests, substances at these sites are more likely, indeed, designed to explode. The reactivity and possible instability of their components, products and degraded materials means that there is sometimes no warning between initiation and explosive accidental effects, with blast and projectile damage over a very wide area and the potential for domino effects.

This characteristic requires a ***proactive approach to risk management*** that places particular emphasis on hazard identification and awareness, strict adherence to accident prevention procedures and passive mitigation measures that protect people and potential sources from domino effects such as use of separation distances or explosion-proof structures. Active mitigation involving human intervention is unlikely to be possible and could be lethal if attempted. The rapid progression of explosive accidents is critical when considering emergency response. Although E&P hazards are broadly similar, they cover different scales of both risk and consequence. This diversity is reflected in the different nature of the spectrum of major accident risks associated with explosives. Strengthening the collection of data on past accidents should be a priority. Data on past major accidents are fundamental to the global and national risk assessment of accidents involving hazardous substances such as civil explosives. However, these data are only a starting point to make ***a more solid and pragmatic assessment***. By itself, aggregate accident data can hide significant gaps and challenges in risk reduction efforts associated with specific economic sectors and technological and social change. Furthermore, the low frequency of severe accidents means that incident data associated with any one country or industry, or even across multiple countries and locations, is not a reliable indicator of underlying risk, particularly in locations where a certain level of risk control has already been achieved/implemented.

Industry and governments around the world, as well as some international organizations, are actively working to improve measures to provide feedback on their risk reduction performance. The last two decades in particular have witnessed innovative ideas that can form the basis of international recommendations for data collection and development of implementation models. It will take some time for these recommendations to be established, tested and implemented, so that more countries are encouraged to establish and implement their own major risk assessment and mitigation strategies.

REFERENCES

[1] **Băbuț, G.B.,Moraru, R.I., Dura, C.,** Conceptual and methodological framework for risk analysis and evaluation on Seveso) industrial sites (I) Risk evaluation terminology, objectives and stages, Quality - Access to Success”, **16**, no. 145/2015, pp. 111-116.

[2] **Băbuţ, M.C.,** Risk analysis and assessment methods applicable to SEVESO-type industrial sites, (in Romanian) Focus Petroşani Publishing House, 2011, ISBN : 978-973-677-252-8.
[3] **EEC,** Council Directive 82/501/EEC of 24 June 1982 on the major-accident hazards of certain industrial activities, Official Journal of the European Communities, L 230/05.08.1982, pp. 0001-0018.
[4] **CRAIM,** Guide de gestion des risques d'accidents industriels majeurs à l'intention des municipalités et de l'industrie, Conseil pour la réduction des risques d'accidents industriels majeurs (CRAIM), Montréal (Québec), Canada, 2007.
[5] **White, M.,** High Hazard Operations: SEVESO III : The Regulatory Framework for Major Industrial Accidents in the EU, Specialty Technical Consultants, Vancouver, BC, Canada, 2017. Disponibil la: http://www.specialtytechnicalconsultants.com/wp-content/uploads/Regulatory-Framework-for-Industrial-Accidents-in-EU-eBook-Vol-1.pdf, Accesat: 20.12.2023.
[6] **A.N.C.S.,** Guide for the management of major risks from various socio-economic activities, Project no. PN II 91-048/2007 - RTPIS_risk Research on the development of a complex (cognitive) structure aiming at the definition of major risk references in various socio-economic activities (in Romanian), National Authority for Scientific Research, Bucharest, 2010 (www.ovm-iccpet.ro/files/proiecte91_048/Ghid management de riscuri majore.pdf).
[7] **E.E.C.,** *Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances*, Official Journal of the European Communities, L 010/14.01.1997, pp. 0013-0033.
[8] **Băbuţ, M.C.,** Analysis of the way of transposition into national legislation of the provisions of the Seveso II Directive (in Romanian), Scientific Papers of the International Multidisciplinary Symposium "UNIVERSITARIA SIMPRO 2005", vol.: Ingineria Mediului, pp. 3-9, Universitas Publishing House, Petroşani, 2005.
[9] **Ursu, A., Stoleriu, C., Sfîcă, L., Roşca, B.,** Adapting the Corine Land Cover nomenclature to the specifics of land use in Romania (in Romanian), Geographia technica, nr. 1, pag. 193-198, 2006.
[10] **European Parliament**, Directive 2012/18/eu of the European Parliament and of the Council, of 4 July 2012, on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC
[11] **Gyenes, Z.,** Application of GHS Substances Classification Criteria for the Identification of Seveso Establishments - Report on the Work of the Technical Working Group on Seveso and GHS, European Commission, Joint Research Centre, Institute for the Protection and Security of the Citizen, Ispra, Italy, 2011 (mahb.jrc.ec. europa.eu/fileadmin/MAHB/downloads/guidance/id-34/Technical_report_Seveso_and _GHS.pdf).
[12] **Burdea, C., Burdea, F.; Vasilescu, G., Anghelache, D.,Vasilescu, V.G.,** Development of risk assessment methodological basis for establishments concerned by the requirements of SEVESO II Directive.18th International Multidisciplinary Scientific GeoConference (SGEM 2018) Conference Proceedings Section Exploration and Mining, SGEM 2018, Albena, Bulgaria 2 - 8 July 2018, Volume 18, Issue 1.3, Part A, pp.303-310
[13] **Delvosalle, C, Fievez, C., Benjelloun, F.,** Development of a methodology for the identification of potential domino effects in „Seveso" industries, Proceeding of the 9th International Symposium Loss Prevention and Safety Promotion in the Process Industries, pp. 1252-1261, May 4-7, 1998, Barcelona, Spain.
[14] **European Parliament,** Regulation (EC) no. 1272/2008 of the European Parliament and of the Council of December 16, 2008 on the classification, labeling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, as well as amending the Regulation (CE) no. 1907/2006, Official Journal of the European Union, L 353/1/31.12.2008.

[15] **eSPIRS, Database of Seveso establishments.** European Commission Joint Research Centre. https://espirs.jrc.ec.europa.eu/en/espirs/content (accesat 29 Octombrie 2022).
[16] **Wood, H.M., Fabbri, L.,** Challenges and opportunities for assessing global progress in reducing chemical accident risks, Progress in Disaster Science 4 (2019) 100044, www.elsevier.com/locate/pdisas
[17] **Paltrinieri, N., Reniers, G.,** Dynamic risk analysis for Seveso sites. Journal of Loss Prevention in the Process Industries, 49, 111-119, 2017; https://doi.org/10.1016/j.jlp.2017.03.023
[18] **Paltrinieri N, Tugnoli A, Cozzani V.** Hazard identification for innovative LNG regasification technologies.Reliab Eng Syst Saf 2015;137:18–28. doi:10.1016/j.ress.2014.12.006.
[19] **Wood M.,** Analysing accidents and lessons learned: you can't improve what you don't measure. Chem. Eng. Trans. 2018;67. https://www.cetjournal.it/index.php/cet/article/view/CET1867066. (accesat 16 aprilie 2021).
[20] e**MARS Major Accident Reporting System.** European Commission Joint Research Centre. https://emars.jrc.ec.europa.eu/en/emars/content (accesat: 19 Martie 2023).
[21] **Institute of Makers of Explosives,** Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (Blasting Caps), https://www.ime.org/aws/IME/pt/sp/imesafr
[22] I**nstitute of Makers of Explosives** Safety Analysis for Risk (IMESAFR) (Presentation - September 2020), Accesat 09.01.2023 la https://www.atf.gov/explosives/docs/guide/institute-makers-explosives-safety-analysis-risk-imesafr-presentation
[23] **European Commission Joint Research Centre** (EC-JRC) and UNECE (United Nations Economic Commission for Europe). An overview of methodologies for hazard rating of industrial sites. https://minerva.jrc.ec.europa.eu/en/shorturl/minerva/ jrc101613engfinal_hazard_rating_ guide3nov_2016onlinepdf; 2016.
[24] Romanian Government, Law 126/1995 on the regime of explosive substances with subsequent amendments and additions and the Rules of Application (in Romanian)
[25] **Romanian Government**, Decision 519/2009 on the establishment of a unique identification and traceability system for civil explosives (in Romanian)
[26] **Romanian Government**, Decision 197/2016 on establishing the conditions for making available on the market and control of civil explosives.

ENERGY SECURITY - AN IMPORTANT ISSUE OF NATIONAL ECONOMIC POLICY

CIPRIAN NIMARĂ[1]

Abstract: *Energy is an area of strategic importance for the fact that ensure at fair prices the economic influence through competitiveness, internal production capacity and the political authority of a country. The possibility of energy supply affects the well-being of a country and fluctuation in energy prices affect the national well-being. And not finally, the defense capacity of a country also depends on a very good energy supply.*
As a member of the European Union, Romania must become an energy security provider, for which purpose it will have to contribute to the support of its objectives and by appropriate actions at national level. This paper aims to point out the need of the energy security in the national economic growth.

Keywords: *energy security, fossil fuels, renewable energy, sustainable development*

1. INTRODUCTION

In the last years, the energy has become an important issue in world politics, an important part for human society development as a whole generating problems worldwide since the immediately period following the beginning of this century [3]. Currently, the oil and gas represent the biggest challenge, but at the same time and concern not only at the European level, but also at the world level. This one it depends on many keys: possession of energy reserves, countries control, politics, transit routes, geopolitical situation, economic power and diplomatic.

This word has been making a lot of noise recently, as it is considered the most important element of regional security: Any problem that can be traced back to energy infrastructure has military and political potential, as well as social implications.

However, a good energy security means, first of all, a good sources supply. This is where the major importance of transport projects comes from energy resources, in the case of oil and natural gas. [5]

At present, Europe is more and more dependent on energy and is therefore looking for new countries that can guarantee demand and security in this area. It is not something new that European Union was interested in developing projects in the Caspian

[1] *lecturer Ph.D., University of Petroșani, Mining Faculty, Department of Environmental Engineering and Geology (E-mail: ciprian.nimara@yahoo.com)*

area and North Africa simultaneously with the intention of limiting dependence on Russia.

The current consumption of the European Union is: oil 41%, natural gas 22%, coal 16%, nuclear 15%, renewables 6%. The European Union's energy dependency on imports is around 50% (Figure 1).

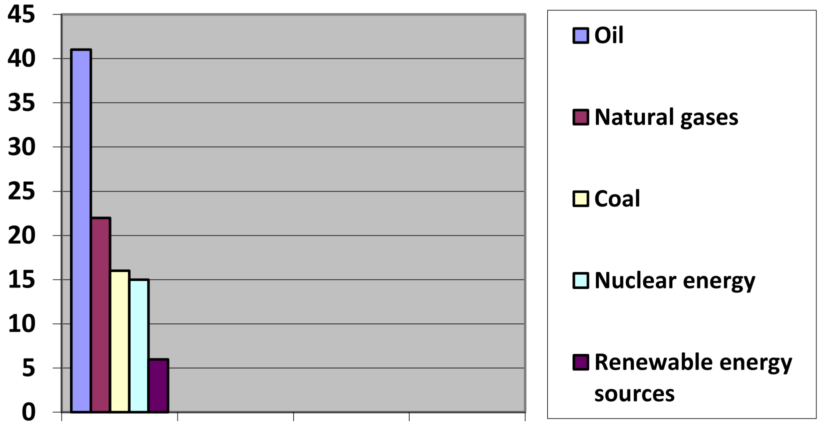


Figure 1. European Union's consumption of primary resources

The latter, in turn, as a supplier, Russia wanted to reduce its dependence on Ukraine, in terms of using the country for special transportation, turning its attention to Turkey and initiating alternatives to the projects promoted by the European Union. And all these have been in mind for 15 years ago.

Europe is dependent on imports. It owns the seventh part of the world's energy consumption and for about 50% of energy needs. European Union took over the role of leader in the development strategic partnerships with suppliers like - Russia, Norway and Algeria, as well as with alternative suppliers from the Caspian Sea area, Central Asia, North Africa and South America. Besides, not only the European Union, but also the most important military block, NATO, is concerned with energy security. [7]

In this context of circumstances, Romania is for the first time in a place where the geographical position, but also the geopolitical one, gives it a series of opportunities, which should valued at their true value.

2. COMPETITIVENESS AND SUSTAINABLE DEVELOPMENT

Around 50% of the European Union's gas consumption comes from Russia, Norway and Algeria. Around 45% of oil imports come from the Middle East. According to statistics, gas imports will rise to 80% in the next few years. If the European Union does not succeed in making its energy policy more efficient, around 70% of the Union's energy needs will be met by imports in the next decade, some of which will come from threatened, insecure regions.

European countries are highly dependent on oil and gas imports, currently 50% and 65-70% by 2030, which entails political and economic risks. Natural gas imports are expected to increase from 57% to 84% in 2030 and oil imports from 82% to 93% (Figure 2).

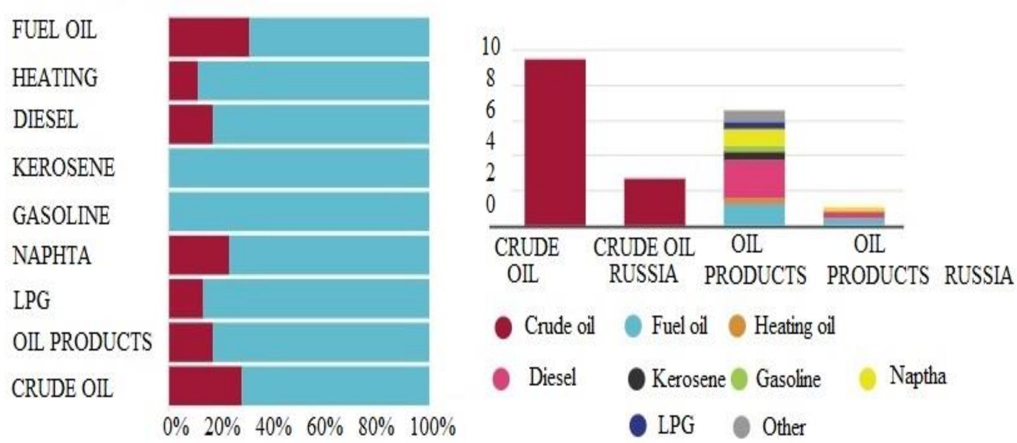


Figure 2. *European countries imports of oil and by-products*

Romania's energy security is ensured by:

- establishing different security patterns for installations, storage capacities, energy networks and infrastructures, including nuclear power plants;

- promotion of some possibilities to help investors for electricity production, which are necessary, in accordance with 2005/89/EC Directive;

- promotion of projects aimed at ensure an increase in the interconnection capacity of the electrical energy system with the systems of the countries of South-Eastern Europe (submarine cable with Turkey, 400 kV overhead power lines with Serbia, Hungary and the Republic of Moldova);

- the implementation of programs regarding the increase in the security of hydropower constructions;

- increasing the underground deposit capacities of gas;

- interconnection of the national transportation system with similar systems from states like:

- Hungary, Arad-Szeged connection;
- Bulgaria, Giurgiu-Ruse relationship;
- Ukraine, Cernăuţi-Siret connection;
- Republic of Moldova, Drochia-Ungheni route;
- Italy, Trieste - Constanța oil pipeline.

Competitiveness presumes liberalization of energy transit under controlled technical conditions of supply security and ensure permanent access to transport networks; increasing the interconnection of electricity networks from about 20% to the horizon of 2025.

According to INS data, the total energy resources in 2022 registered a decrease, accumulating 42.5 million tons of oil equivalent (toe), this evolution being caused by the decrease in primary energy production.

More significant decreases in resources were recorded in imported metallurgical coke (-25.1%), imported petroleum products (-18.5%) and coal (-12.1%). According to statistics, only crude oil resources increased (+1.634 million toe, representing 15%).

The energy production in 2022 was 22.26 million toe, with a decline of 737,000 toe compared to previous year, against the background of the decrease in the coal production, green electricity and crude oil. The production of usable natural gas increased by 98,000 toe (+1.3%).

The import of energy products increased in 2022 by 2.8% compared to 2021, due to the increase in crude oil imports (+27.6%). Imports of coal, usable natural gas and petroleum products registered decreases.

In 2022, final energy consumption, for the total economy, decreased by 1.339 million toe (-5.3%) compared to 2021, due to decreases in industry, agriculture and forestry and population. However, consumption from transport and other branches of the economy increased (8.3% and 3.5%, respectively).

As a share in the total final energy consumption, population consumption kept its first place (32.9%), followed by transport and industry (31.4% and 23.9%, respectively).

3. THE ECONOMIC AND GEOPOLITICAL ROLE OF ROMANIA IN THE BLACK SEA AND CASPIAN SEA REGION

The economic reality of the Black Sea region has changed a lot in the last decade by migrating of the gravity center of interest from the main poles of power towards the Ponto-Caspian space, close to Romania, which has the potential to become an entrance into the economic and political block of the European Union and transit area between Central Asian exporters and important European energy consumers (considering the proximity to energy resource, but also the oil pipelines network, the biggest refinery in the area, Midia Năvodari, the great topographical surface that does not assume special technical and economic difficulties.

Maximizing the capacity of the Cernavodă nuclear power plant and the special potential of bioenergetics are good alternatives for maintaining low energy dependence on external suppliers.

Romania is an important line of the Euro-Atlantic structures to the East (Turkey - larger and with a larger population - it is only a NATO member and Bulgaria is twice as many slightly extended and with a population three times smaller than Romania).

After the breakup of the Soviet Union (1991), the area has become conflictual, (Chechnya, Nagorno-Karabakh, South Ossetia) or frozen (Dagestan, Abkhazia, Transnistria, Crimea) [2]; add the conflict in eastern Turkey, inhabited by the Kurds and now the war between Russia and Ukraine.

Although Romania strives to be an active factor in the Black Sea, other important actors in the area are: Russia, Turkey and Ukraine (figure 3). The relationships between these, as well as between all the countries in the area remain very changeable, with surprising alliance establishment, which have an important effect on the energy corridors.

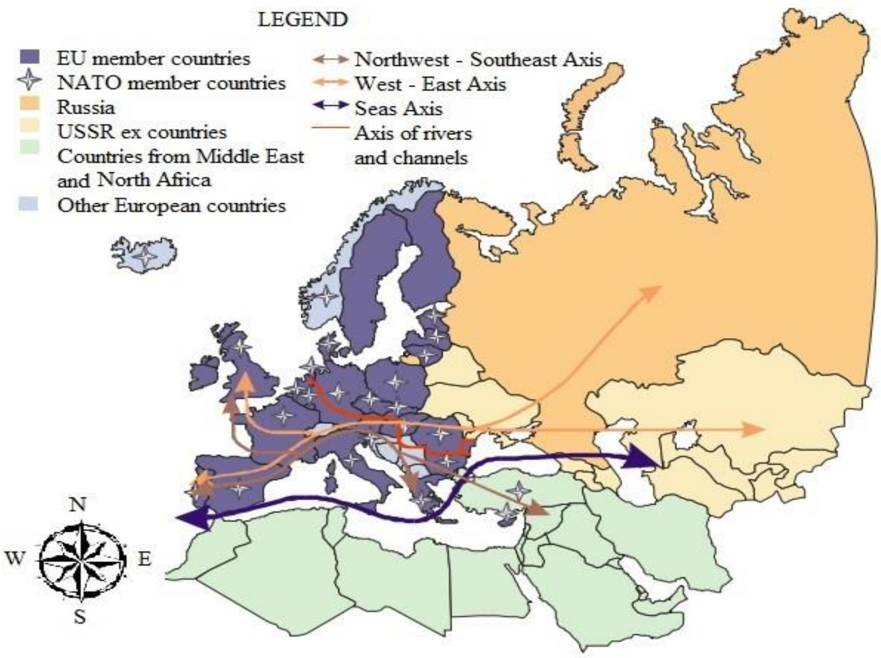


Figure 3. *Romania's strategic position*

The problem of resources in the Caspian Sea area is an economic and a political one. [4] Last year, the combined production of these countries was 131.26 million tons (well below potential): Kazakhstan - 85.8 million tons, Azerbaijan - 34.5 million tons and Turkmenistan - 10.96 million tons.

Two problems remain uncertain:

- the possibilities of financial resources to invest in the activity of prospecting and exploration;

- resource transportation, with the exception of the Baku - Tbilisi - Ceyhan pipeline. The existing oil pipelines make the connection with the Russia.

Because the oil from this area to have Europe as its final destination must be taken into account the fact that the oil pipelines in the Caspian area have as their destination the Eastern shore of the Black Sea and transit through the Bosphorus and Dardanelles straits is limited in terms of transport capacity.

Among the plans for oil transportation from this area to Europe are:

- Burgas - Alexandropoulis;
- Constanța - Omisalji - Trieste;
- Odessa - Brody - Gdansk;
- Turkmenistan to Central and Western Europe, via Azerbaijan and Georgia;
- Turkey - Bulgaria - Romania.

Although it has long maintained its opposition to the issues from this area, in 1996 Russia agreed to recognize an exclusive economic zone for each country of 45 miles (83.34 km) offshore and to negotiate with each country individually the national jurisdiction over oil and natural gas resources. Like this, Russia would ensure its control over the production and transport of oil and gas in the area. [4]

The amount reserves differ depending on the information sources. The American researchers claim that the reserves would reach 200 billion barrels, placing the region in second place on the Globe. Instead, the British researchers estimate the reserves at only 48 billion barrels.

Whoever controls the access to this region is most likely to win the economic prize. This consideration makes solving the problem of oil and natural gas pipelines essential for the future of the Caspian Sea area [1]. There are two possibilities:

a) keeping Russia the main exporter (so Baku-Tbilisi-Ceyhan pipeline is an exception). If the main pipelines will cross Russia, the region will stay in a state of political dependence, with Moscow having the ability to decide how the wealth of the area will be distributed. The Russian main supply is kept in the case of direct pipelines by Russia on preferential routes that it can fully control, for example:

- Novorossiysk oil pipeline (Russia) - Burgas (Bulgaria), Alexandroupoulis (Greece, Aegean Sea);
- the South Stream gas pipeline (900 km), to Bulgaria (Varna) and, further, through Greece to the Ionian Sea, southern Italy;
- AMBO oil pipeline (913 km): Bulgaria (Burgas port)-Macedonia-Albania (Vlorë port).

b) building as many pipelines as possible to avoid Russian territory:

- the Baku pipeline (Azerbaijan) - Supsa (Georgia port, on the Black Sea), with a length of 833 km with 145,000 barrels/day, which was put into operation in 1999;
- the Constanţa - Trieste oil pipeline;
- the NABUCCO gas pipeline.

4. CONCLUSIONS

Energy was and will always be the main engine of the world's economy because all the economic activities require energy. There are researches which have showed that slower economic growth reduces the demand for energy and reduced energy consumption shrink further economic growth. The same proportion has also been found for oil demand and economic growth, consistent with the fact that oil remains a driver of the energy sector. [6]

Europe owns the seventh part of the world's energy consumption and is dependent on imports for more than 50% of energy needs. The political and economic situation in the Black Sea area has changed in the last decade by migrating of the gravity center of interest from the main poles of power towards the Ponto-Caspian space, close to Romania, which has the potential to become an important entrance into the economic and political zone, being a place of transit between Central Asian producers and the main European energy consumers (Constanţa - Trieste oil pipeline).

The topographical surface that does not assume special technical and economic issues, such as expensive pumping stations, Constanța, the biggest port in the Black Sea basin, the biggest refinery on the Black Sea - Midia Năvodari, put Romania for the first time in a situation where the geographical position, but also the geopolitical one, gives it a series of opportunities, which should valued at their true value.

Whoever controls the main access to and from the Black Sea and Caspian Sea region is most likely to gain the economic battle. This consideration can solve the problem of oil and natural gas pipelines which are important for Central Asia area future and additionally, of the energy dependent European Union state members.

REFERENCES

[1]. Cherp, A., Jewell, J., (2010), *Measuring energy security. From universal indicators to contextualized frameworks*. The Routledge Handbook to Energy Security, Routledge;
[2]. Farrell, A., Zerriffi, H., (2004), *Energy infrastructure and security*, Annual Review of Environment and Resources, (29)1;
[3]. Gitelman, L., Magaril, E., Kozhevnikov, M. (2022), *Energy security: New threats and solutions*, Energies, vol. 16;
[4]. Karatayev, M.; Hall, S., (2020), *Establishing and comparing energy security trends in resource-rich exporting nations (Russia and the Caspian Sea region)*. Resour. Policy, 68;
[5]. Lindgren, M.; Bandhold, H., (2003), *Scenario planning: The link between future and strategy*; Palgrave Macmillan: London, UK;
[6]. Nimară, C., (2022), *The latest war in Europe and the generated energy crisis*, Annals of University of Petrosani, Minning Engineering, Vol.23;
[7]. Tatarkin, A.I.; Kuklin, A.A., (2012), *Changing the paradigm of region's economic security research*. Econ. Reg., Vol. 2
[8]. *** www.ec.europa.eu;
[9]. *** FMI. World 2021. Economic Outlook;
[10]. *** European Institute from Romania, (2008), Strategies and politics studies
[11]. *** www.ourworldindata.org;
[12]. *** www.bruegel.org;

THE SITUATION OF ENERGY POVERTY AND THE VULNERABLE CONSUMER IN ROMANIA

ADRIAN LUCIAN PAL [1], EMILIA CORNELIA DUNCA[2], MARIA ELENA BOATCA BARABAS[3], SABINA IRIMIE[4]

Abstract: *Energy poverty has become a global problem, a phenomenon that has grown alarmingly due to the crisis caused by the COVID19 pandemic, the crisis of high energy prices in 2021, followed by the invasion of Ukraine by Russia in 2022. These recent events, as well as those associated with the energy transition that occurred in the last decades, have highlighted, in addition to the involvement of government institutions in terms of the necessity of policies in the field of energy, the need to research the phenomenon of energy poverty as well as the need for awareness of the phenomenon among local authorities and of the citizens.*

Keywords: *energy poverty, energy efficiency, vulnerable consumer, transition, energy consumption pattern, energy indicators, awareness*

1. INTRODUCTION

Energy poverty must be understood as a momentary state that describes a household's inability to meet its minimum energy needs in a way that ensures its ability to function as full members of society. Energy poverty should not be confused with energy vulnerability, the use of the two phenomena as synonyms can generate confusion, which would ultimately affect the quality of public policies. Energy vulnerability represents a set of conditions that create the risk of a household entering, even temporarily, into a state of energy poverty, so energy vulnerability is what ultimately leads to energy poverty. [3]

The main factors that lead to energy poverty, with both socio-economic and health consequences for the population, are represented by high energy bills, low energy efficiency, respectively low income. These factors being characterized in turn by energy consumption habits, living patterns and energy accessibility.

The multidimensional structure, with a context-dependent character, of the factors that lead, intersecting, to energy poverty are shown in Figure 1.

[1] *Eng,, The Jiu Valley Social Institute Association (AISVJ), paladrianlucian@yahoo.com*
[2] *Assoc. Prof. Eng. PhD, University of Petroșani, EmiliaDunca@upet.ro*
[3] *PhD., The Jiu Valley Social Institute Association (AISVJ), mariaelena.boatca@gmail.com*
[4] *Prof. Eng.PhD., The Jiu Valley Social Institute Association (AISVJ), sabina.irimie@gmail.com*

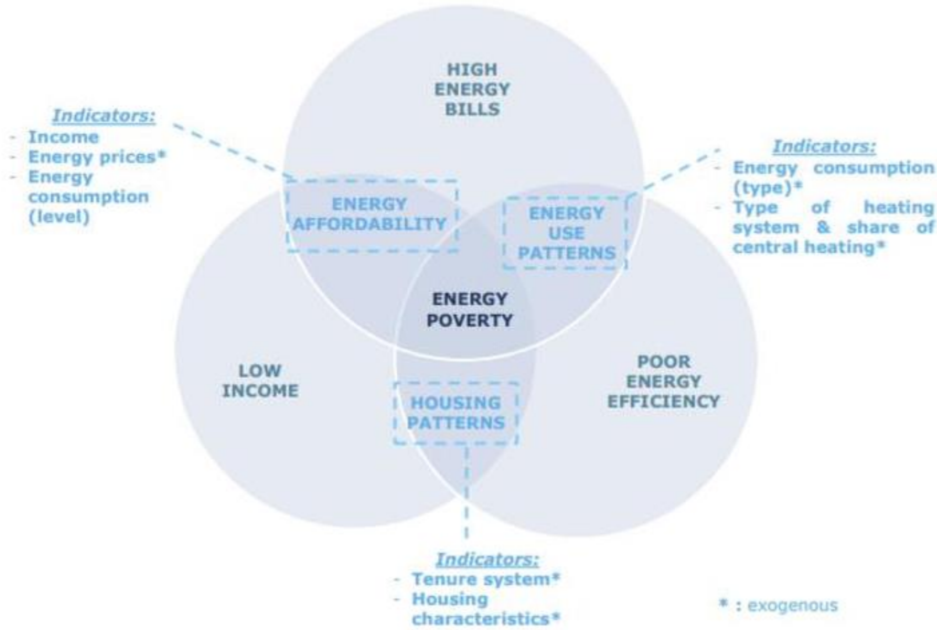


Figure 1. Factors that lead to energy poverty (Kakalejcikova, 2021)

Due to this context-dependent character by which it is characterized, it can be said that energy poverty is equal to income poverty, and that poverty, as a state of the citizen, is one of the main reasons for energy poverty. Due to this aspect, it is necessary that energy poverty be addressed in a combined manner of energy and social policies. Without specific interventions in the way we supply and consume energy, in terms of responsible energy consumption and the improvement of the energy infrastructure, energy poverty cannot be addressed in a sustainable and sustainable way. Energy poverty being at the intersection of different sectors increases the importance of the concept, also leading to specific challenges from a policy perspective. [2]

2. ENERGY POVERTY AND THE VULNERABLE CONSUMER IN ROMANIA

2.1. Concepts and definitions

Energy poverty does not benefit from a universal definition, the concept of energy poverty being a vast and complex concept, characterized in some way by an equivocal nature, with repercussions of a socio-economic and health nature, affecting millions of citizens at European and national level, however, in Romania, the notion of energy poverty has not always benefited from a clear definition, being often used together with the concept of vulnerable consumer.

In 2012, the vulnerable consumer was defined in the Electricity and Natural Gas Law as a vulnerable customer, that final customer who belongs to a category of household customers who, for reasons of age, health or low income, are at risk of social marginalization and which, to prevent this risk, benefits from social protection measures, including financial ones. [4]

In 2021, through the Law on social protection measures for the vulnerable energy consumer, the vulnerable consumer was identified as a single person/family, final customer belonging to a category of household customers who, for reasons of health, age, insufficient income or isolation from energy sources, are at risk of social marginalization and who, to prevent this risk, benefit from social protection measures, including financial ones, and additional services to ensure at least their minimum energy needs. [5]

Energy poverty is also defined in the same normative act, which consists in the impossibility of the vulnerable consumer to cover the minimum energy needs. The minimum energy needs are [5]:

- the minimum energy consumption of a single person/family for optimal lighting, cooling and heating of the home;
- supporting cooking facilities and providing hot water in the home;
- the use of means of communication that involve the use of energy;
- supplying medical devices to support life or to improve people's health.

2.2. Data and Statistics

According to ORSE (The Romanian Energy Poverty Observatory) in Romania, 87% of buildings were built before 1990, and 47.5% of living spaces (71% of single-family households) are located in rural areas. [8]

Table 1 shows the comparison between rural and urban areas in Romania, in terms of energy poverty

Table 1. The comparison between the rural and the urban environment in Romania [7] [8]

Rural environment	**Urban environment**
11.1% paying bills delay	17.2% paying bills delay
11.5% inability to keep the home warm	8.1% inability to keep the home warm
84% of homes are over 20 years old and over half over 50 years old	Most of the houses in the urban environment (74.5%) are panel-type blocks, built of concrete or prefabricated panels, during the communist period, being energy inefficient.
Almost all the houses are owned by mostly poor citizens	
About 80% of the rural population uses wood for heating, in outdated and inefficient stoves.	Buildings built from prefabricated panels have an energy consumption between 257-655 kWh/m2/year, above the European average consumption in the residential area, of 180 kWh/m2/year, according to the European Commission.

Figure 2 shows, over the last ten years, according to Eurostat data, the share of households unable to keep the house adequately warm, respectively of households with recurring arrears on utility bills, both for Romania and for the EU (average). As can be seen, the trajectory is descent with small fluctuations, and as regards Romania's trajectory, it was always above the average of the European values, for both situations shown in the figure. [9]

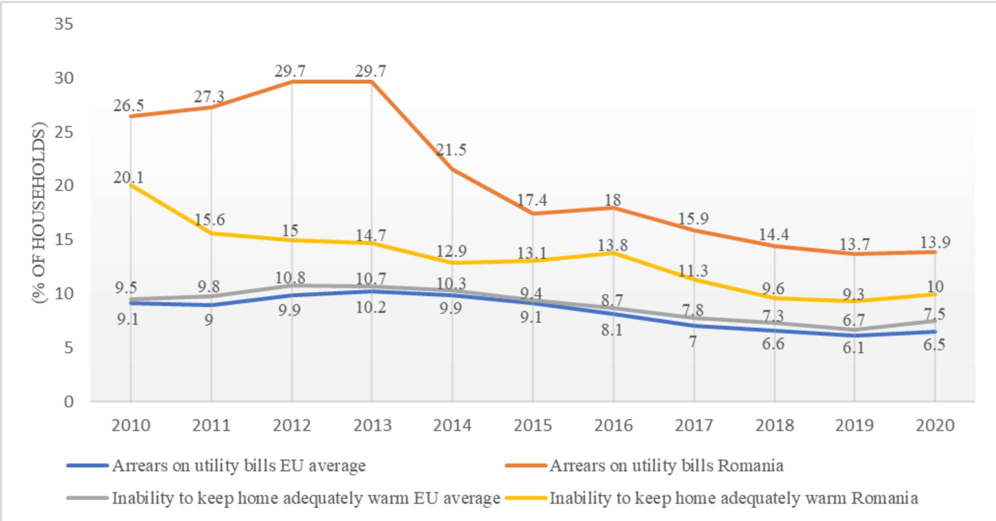


Figure 2. The evolution of energy poverty in Romania and EU (SocialWatt, 2023)

The following graph (figure 3) shows the energy evolution in Romania, also over a period of ten years, compared to Indicator M/2 which represents households with inappropriately low energy consumption, and the Indicator 10% that represents the households for which energy is too expensive in the daily shopping basket. [8]

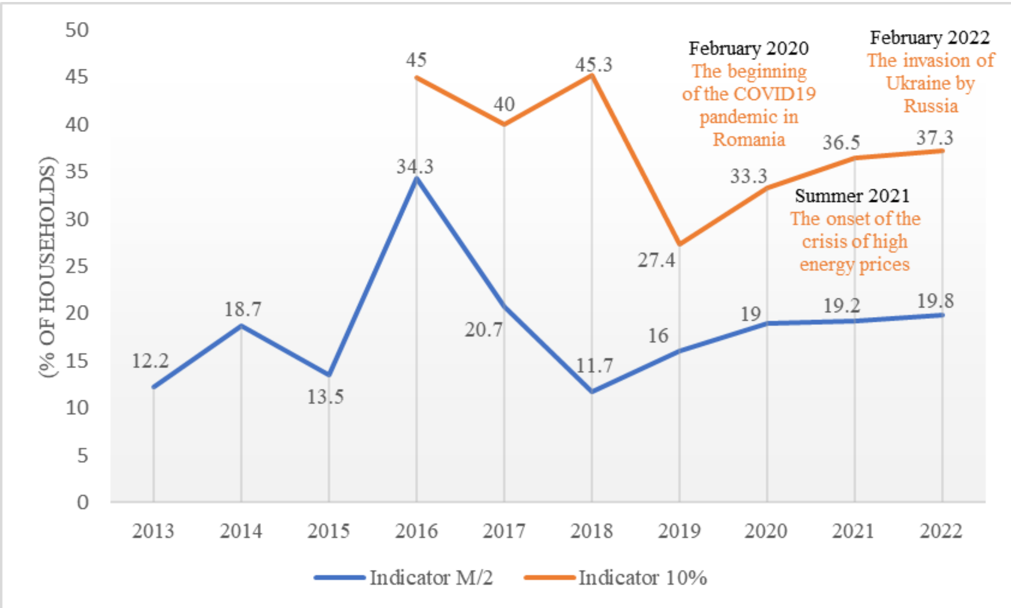


Figure 3. The evolution of energy poverty in Romania (ORSE, 2023)

Figure 4 represents the map of the global energy vulnerability index for the year 2023, made by Euromonitor International. The index classifies the performance of 100 economies by assessing their vulnerability to global energy pressures and potential energy market shocks. Euromonitor International used six groups of indicators to measure each country's level of energy vulnerability [6]:

- Energy self-sufficiency (30% of total score (TS));
- Alternatives to fossils (35% TS);
- Energy reserves potential (10% TS);
- Energy accessibility (5% TS);
- Energy efficiency (10% TS);
- Economic resilience (10% TS).

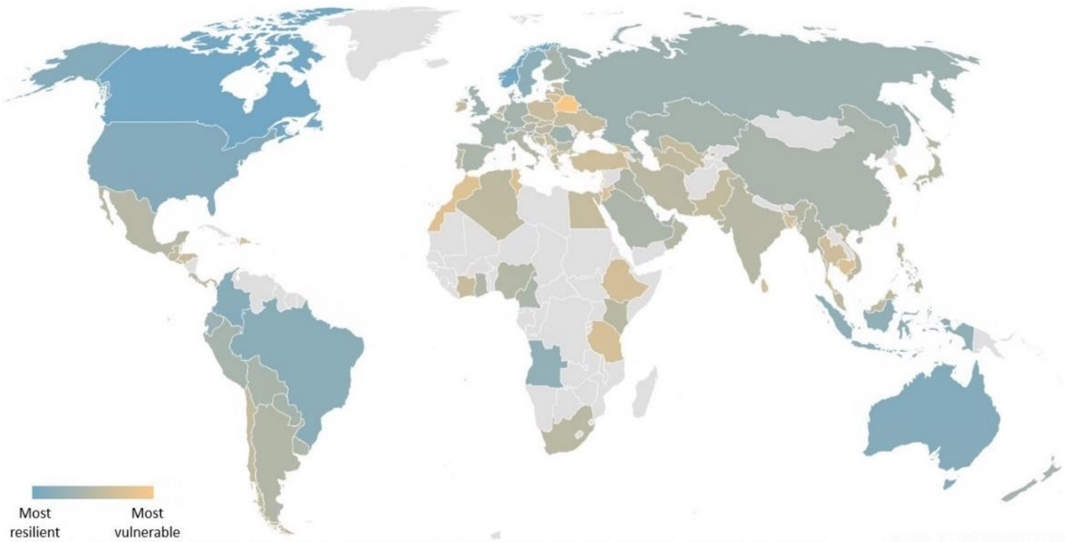


Figure 4. Global energy vulnerability index 2023 (Euromonitor International, 2023)

In this evaluation, Romania ranks 13th, ahead of the United Kingdom and after Russia. In order to see the position, respectively the values obtained within this evaluation related to the six groups of indicators listed above, table 2 shows these values related to Romania and the other two countries in the ranking.

Table 2. Global energy vulnerability index 2023 [6]

Coun-try	**Final rank**	**Energy self-sufficien-cy**	**Alterna-tives to fossils**	**Energy reserves**	**Energy accessibi-lity**	**Energy efficien-cy**	**Economic resilience**
Russia	12	19	63	2	19	95	65
Romania	13	53	9	18	58	30	53
UK	14	55	18	28	46	10	29

2.3. Programs addressed to vulnerable consumers

Table 3. Programs started, fully or partially addressed to vulnerable consumers in Romania [2]

Program/ Measure	**Implemen -tation period**	**Objective in the field of energy**	**Impact on vulnerable consumers**
Program for electrification of isolated households (2007/restarted in 2012)	Unimple-mented	- Extension of electricity networks in localities not connected to the network; - Installation of energy production technologies from renewable sources (solar/wind); - Installation of electrical generators based on fossil fuels.	- The program was intended for vulnerable consumers from households without access to electricity.
Heating help	Running since 2011	-Monthly financial aid to cover part of the expenses related to heating the home during the cold season.	- Strictly addressed measure to vulnerable consumers; - Between 500,000-1,500,000 families/single people.
The law on the minimum income of inclusion	From 2018	-Includes financial aid with the aim of fully or partially covering home heating expenses.	- About 800,000 vulnerable families; - It is not clear, there are no reports
AFM program for the installation of photovoltaic systems for isolated households	Started in 2019	-Financing the installation of photovoltaic panels for the production of electricity.	- It is addressed to households that do not benefit from electricity; - Approximately 800 households from 55 ATUs have benefited from the program.
The vulnerable consumer law	From 2021	-Heating/electricity allowances; -Prohibition to disconnect vulnerable consumers from the electricity network; -Aid for the purchase of energy-efficient equipment or for the purchase of products and services to increase the energy performance of buildings or for connection to energy sources.	-Approximately 650,000 families/single persons; - No funding programs have been opened yet.
Compensation scheme for electricity and	2021 2022	-Establishing fixed price ceilings for consumers.	-The scheme is not exclusively aimed at vulnerable consumers;

natural gas consumption			- 2021 - 5.2 million households compensated for electricity, and 3.6 million for natural gas; - 2022 - 8 million households plus non-household consumers.

The previous table (Table 3) shows the programs or measures addressed partially or fully to vulnerable consumers in Romania starting with the year 2011.

3. CONCLUSIONS

Energy poverty can lead to the degradation of general well-being, injustice, social inequality, etc. (socioeconomic consequences), but also to physical and mental illnesses and finally death (health consequences). Through the measures that can be taken to combat energy poverty and to come to the support of the vulnerable consumer, the problems of social justice can be diminished and the impact on the quality of life can be influenced in a positive way.

Although such programs and measures to combat energy poverty and to support the vulnerable consumer exist and have been applied (table 3), it cannot be said that the phenomenon has begun to decrease or be reduced, on the contrary, due to the pandemic, the energy crisis, respectively of the invasion of Ukraine by Russia, the phenomenon has intensified.

In our country, energy poverty has been the subject of several projects financed by the European Commission, which have been implemented or are being implemented.

Thus, the SocialWatt project [9] (September 2019 - March 2023) financed by the Horizon 2020 program is an energy efficiency project, aiming at connecting obligated parties across Europe to adopt innovative schemes towards energy poverty alleviation. The project presents the energy poverty action plans of seven utility/energy companies, developed under SocialWatt. Each plan includes a technical and financial analysis of the schemes to be implemented in Croatia, Greece, Ireland, Italy, Latvia, Romania and Spain.

The Just Transition and Empowerment against Energy Poverty project (JUSTEM) [10] (November 2022 - March 2025), financed by the Life program is coordinated by The Institute for European Energy and Climate Policy (IEECP) and analyzed the energy poverty situation in 6 countries (Spain, Bulgaria, Croatia, Greece, Poland, and Romania) in the context of the energy transition.

REFERENCES

[1]. Kakalejcikova, Z., Overview report on the energy poverty concept, Energy poverty in the privately-owned, multi-family environment, Community Tailored Actions for Energy Poverty Mitigation, 2021, https://www.bpie.eu/wp-content/uploads/2021/05/ComAct-D1.1_Overview-report-on-the-energy-poverty-concept_Final-version_UPDATED-1.pdf

[2]. Nazare, L., Producția descentralizată a energiei, o soluție pentru sărăcia energetică, Bankwatch România, București, 2022
[3]. Sinea, A., Jiglau, G., Saracia energetica in Romania si nevoia schimbarii de paradigma, De la "consumatorul vulnerabil" la "cetateni cu drept la energie", Centrul pentru Studiul Democrației, Cluj-Napoca, 2021, https://democracycenter.ro/application/files/7716/6756/8742/CSD_Saracia_energetica_in_Romania.pdf
[4]. LEGE nr. 123 din 10 iulie 2012
[5]. LEGE nr. 226 din 16 septembrie 2021
[6]. *** Euromonitor International, Global Energy Vulnerability Index, 2023, https://www.euromonitor.com/article/global-energy-vulnerability-index-unveiling-risks-and-opportunities
[7]. *** European Commision, 2018, energy-poverty.ec.europa.eu
[8]. *** Observatorul Român al Sărăciei Energetice, Sărăcia energetică în România și diferențele rural/urban, https://saracie-energetica.ro
[9]. *** SocialWatt, Country Factsheet Romania, 2023, https://socialwatt.eu/sites/default/files/news/SocialWatt_CountryFactsheet_ROMANIA.pdf
[10] ***JUSTEM project, https://ieecp.org/

ASPECTS OF REDUCING ENERGY POVERTY IN ROMANIA, IN THE CONTEXT OF CLIMATE CHANGE

CIPRIAN NIMARĂ[1]

Abstract: *Energy poverty has an indirect impact on several policy areas, including health, environment and productivity. Tackling fuel poverty has numerous potential benefits, including lower health expenditure for governments, reduced air pollution and CO2 emissions, greater comfort and well-being, more stable family budgets and increased economic activity. This paper aims to highlight the level of energy poverty in Romania and the need of its decrease, compared to another European Union member states, according to the electricity prices and energy potential, all in the context of climate change.*

Keywords: *energy poverty, climate change, fossil fuel, mining, energy efficiency*

1. INTRODUCTION

When a person or household cannot afford essential energy services (heating, cooling, lighting, mobility, and food preparation with electricity), it is referred to as energy poverty. This is because low income, high energy expenses, and inefficient domestic energy use all contribute to this condition. Energy poverty is the third pillar of the Covenant of Mayors for Climate and Energy and plays a major role in keeping this issue on the 2030 Agenda.

One type of poverty that has been linked to several detrimental effects on people's health and wellbeing is energy poverty. It shows up as respiratory, cardiac, and mental health issues that are made worse by chilly weather and the strain of expensive energy expenditures. Affected children may also perform poorly academically.

Romania's energy sector needs to adjust to the new development trends in light of the "Clean Energy for All Europeans" legislative package and the "European Environmental Pact," which call for the energy sector to change to a different systemic model based on clean, innovative technologies in order to compete in an integrated electricity market. In this profoundly changing energy landscape, decarbonization, energy demand, and energy security will all be intertwined. It is necessary to balance this interdependence with advancements in technology, storage, decentralization, digitization, and grid architectural adaption.

[1] *lecturer Ph.D., University of Petroșani, Mining Faculty, Department of Environmental Engineering and Geology (E-mail: ciprian.nimara@yahoo.com)*

The two biggest problems are still finance costs and pervasive energy poverty. Finance from Europe is essential in this situation. A significant amount of money must be invested in the energy system transition, and effective financing management and multi-year planning are essential. [1] Proactive action results in cost savings. Financial resources must be allocated effectively for investments that consider the unique characteristics of each country and promptly address the needs of the energy system.

2. ISSUES OF ELECTRICITY PRODUCTION

Romania has a diversified electricity mix, mostly based on domestic energy resources. Most of the generating capacity is more than thirty years old, with a relatively low number of operating hours remaining until the end of the technical service life. Old groups are frequently shut down for repairs and maintenance, some being preserved. There is a gap of nearly 3,400 MW between gross installed capacity and gross available capacity, of which approximately 3,000 MW is coal and natural gas-based capacity.

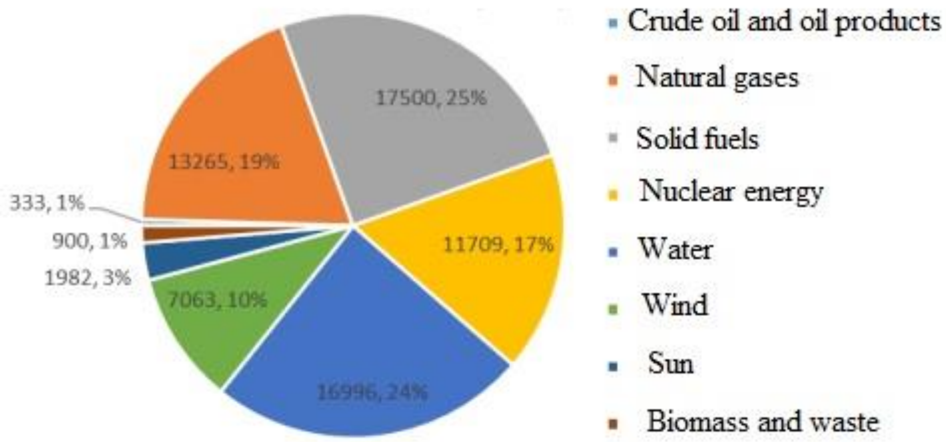


Figure 1. *Gross electricity production by fuel type (GWh) in 2022*

Under these conditions, Romania is one of the 14 member states of the European Union that keep the option of using nuclear energy open. Currently, the electricity generated by nuclear fission through the two units in Cernavodă covers about 18% of the country's electricity production; with the construction of the two new nuclear power plants in Cernavodă, the share will be about 28% in 2035.

Hydropower is the most important source of clean energy, which together with renewable energy sources covers around 45% of Romania's final electricity consumption.

The power installed in wind power plants is approximately 3,000 MW, a level considered close to the maximum for the safe operation of the national energy system, in its current configuration.

Based on current estimates, the overall energy potential of biomass is 318,000 TJ/year, or 7.6 million toe. There is a significant amount of uncertainty (20%) surrounding the statistics on the production of solid biomass, with a central estimate of 41 TWh.

3. ENERGY POVERTY

"Utility bill arrears" is a crucial metric for assessing energy poverty as it indicates the percentage of households facing financial challenges that prevented them from paying their utility bills on time. [2] Between 2010 and 2017, the EU-28's average for these circumstances decreased from 9% to 7%, however the range of circumstances is still very high. Financial issues were cited by 38% of Greeks, 30% of Bulgarians, and 21% of Croatians as reasons for late energy bill payments in 2017. The following nations exceed the 7% EU average: 16.3% in Slovenia, 13.9% in Hungary, 13.7% in Cyprus, 11.9% in Latvia, 8.5% in Poland, and 7.4% in Spain are among the countries mentioned. [5]

Over the past 15 years, the cost of electricity for ordinary households has increased gradually. From €0.18 in the first half of 2007 to €0.21 in the second half of 2022, the average cost per kilowatt hour increased. Denmark (€0.31), Germany (€0.30), Belgium (€0.29), Ireland (€0.25), and Spain (€0.24) are the five countries with the highest cost per kilowatt hour, including all taxes and charges. However, Bulgaria (€0.10), Lithuania (€0.10), Hungary (€0.11), Romania (€0.13), Malta (€0.13), and Poland (€0.13) are the Member States with the lowest cost per kilowatt-hour [6].

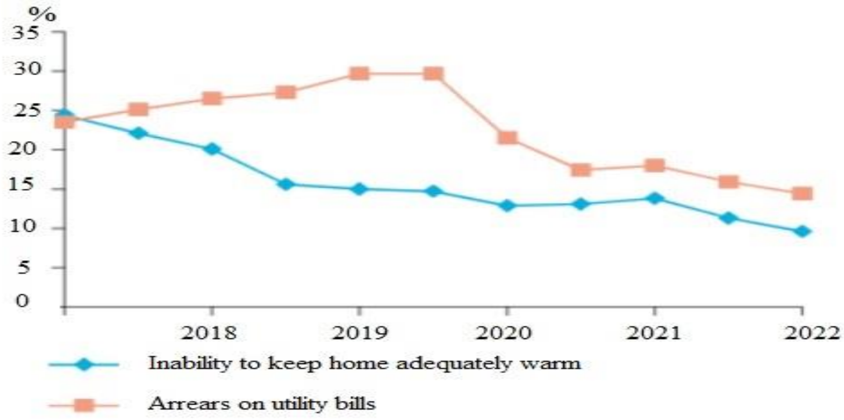


Figure 2. *Percentage of the population that is unable to keep the home adequately warm*

Countries in the European Union with high rates of energy poverty among households are required to include a target for reducing energy poverty in their integrated national energy and climate plans.

Romania's home electricity prices are among the lowest in the European Union, according to Eurostat data. However, affordability of the price is a first-order issue because to the comparatively low purchasing power, which results in high levels of energy poverty. [4]

The inability to heat the household to an adequate level is another indicator that quantifies the proportion of households that do not have this ability. The evolution of the indicator at the level of Romania and the European Union for the period 2017-2022 can be found below: (Figure 2, Table 1, Table 2).

There are around 8.5 million households in Romania, of which almost 7.5 million are inhabited. Of these, around 4.3 million are owner-occupied homes and 2.7 million are apartments in apartment blocks. Only five percent of homes have been modernized through thermal insulation. To the extent that the marketing of wood is better regulated and the prices for thermal energy and fuels are liberalized, heating costs will rise, which will encourage investment in thermal refurbishment measures for homes.

Table 1. Inability to heat the household

YEAR	EU AVERAGE	ROMANIA
2017	10.7	14.7
2018	10.2	12.9
2019	9.4	13.1
2020	8.7	13.8
2021	7.8	11.3
2022	7.3	9.6

Of the total number of households, only 1.2 million are connected to central heating supply systems (around 600,000 homes in Bucharest alone). One third of Romanian households (almost 2.5 million) are heated directly with natural gas, using central heating systems in homes, but also extremely low efficiency stoves (at least 250,000 households).

Table 2. Back payment on utility bills

YEAR	EU AVERAGE	ROMANIA
2017	7.0	15.9
2018	6.6	14.4
2019	8.7	14.2
2020	8.0	13.9
2021	7.2	13.4
2022	6.4	13.1

Around 3.5 million households (most of them in rural areas) heat with solid fuels - mostly wood and coal - in stoves.

In Romania, 14.4% of households were in arrears with their utility bills in 2022. In comparison, the European Union average for the same year was 6.6%.

4. INCREASING ENERGY EFFICIENCY

Reducing greenhouse gas emissions, decreasing energy poverty, and enhancing energy security can all be achieved through energy efficiency. About 11% of the population of the European Union (54 million European residents) are impacted by energy poverty.

The majority of EU member states continue to fail to identify and measure vulnerable energy consumers, making energy poverty mitigation efforts misguided.

Romania's energy efficiency has increased recently. Because of the restructuring of industrial activity, Romania had the largest average decrease in energy intensity (7.4%) among all EU member states between 1990 and 2013. In the period 2012-2016, final energy consumption in Romania decreased by 449 ktoe, from 22,766 Mtoe to 22,317 Mtoe, which corresponds to 1.97%. In the same period, GDP increased by 25.8%. Since 2014, however, the trend in final energy consumption has been pointing upwards, recording an average growth rate of 1.34%/year.

Transport and industry have the biggest shares of ultimate energy use, behind the residential sector. The industrial sector has a great deal of opportunity for the adoption of energy efficiency measures in the years 2023–2030, given its sizeable portion of energy consumption and the wear and tear of its equipment.

Although electricity is the most frequently used energy source in Romania, with over 90% of households connected to the electrical distribution network, the country's per capita electricity usage is 2.4 times lower than that of the European Union.

Less than half of Romanian houses have access to natural gas; approximately 44% of them are connected to the network, and one-third of them heat their homes directly with natural gas. Additionally, natural gas usage in households is on the lower end of the European Union average.

Simultaneously, considering the lower purchasing power of Romanian households in comparison to the European Union, it is imperative to guarantee that the final consumer can afford the energy price, highlighting the necessity of safeguarding susceptible customers. 14.4% of Romanian homes, according to a research study on the income and living conditions of European residents, report having trouble paying their electricity bills within a year.

With a percentage of 2%, Member States like the Netherlands, the Czech Republic, Sweden, and Austria are at the top, placing Romania in fourth place after Greece, Bulgaria, and Croatia.

Romania's projected energy consumption for 2030 is 32.3 million toe for primary energy and 25.7 million toe for final energy, which is a reduction of 45.1% and 40.4%, respectively, from the 2007 PRIMES scenario (Table 3).

Table 3. Final energy consumption by sector

Ktep	2022	2030
Industry	6.781	7.729
Residential	7.663	7.197
Transport	6.800	7.722
Tertiary	3.489	3.070

Total	**24733**	25.716

Primary energy consumption is predicted to increase from its current level of 32.1 Mtoe to 32.3 Mtoe in 2030, based on the assumptions and calculation projections used, which take into account the growth in industrial production and living standards reflected in the growth in energy consumption.

Before 1989, centralized thermal energy supply of cities was a common practice in Romania. During this period, more than 60 such plants were built, most of which also had combined heat and power plants.

After 1989, with the restructuring and even the disappearance of Romanian industry, the demand for thermal energy decreased from year to year and the plants became increasingly inefficient.

In recent years, a large part of the CHP production capacities of centralized thermal energy supply systems have been taken out of operation and even shut down because it was not financially possible to make environmentally friendly investments, but in some cases also because these groups (especially for industrial CHP) were not constructively compatible with the current requirements of the thermal energy market.

For these reasons, over the last 20 years, municipal heating systems have been massively separated from consumers who have opted for individual heating solutions.

5. CONCLUSIONS

Climate change and energy are inextricably linked; the more our climate shifts, the more energy we will need to adjust. But as we meet our growing energy demands, greenhouse gas emissions rise even more. Higher-income nations are nevertheless not exempt from the consequences of climate change.

In order to maintain a respectable quality of living, they also generate and utilize energy, whether it be for summer house cooling, winter heating and lighting, or assuring access to healthcare.

The energy industry is accountable for about 50% of the greenhouse gas emissions in the European Union.

Similar to climate change, energy poverty affects more than only low-income nations. For many low-income households in Europe, energy poverty persists despite a high average level of living.

The policies and actions Romania has suggested to meet the consumption targets are wide-ranging, and it might take more time to verify the results.

Because of this, the majority of the steady benefits on energy consumption reduction will become apparent starting in 2025, when the trend of reductions picks up, driven by the results of investments made between 2020 and 2025.

For instance, the trend indicates that savings for primary consumption increased from 38.4% in 2025 to 45.1% in 2030 and for final consumption from 34.0% to 40.4% in the same time frame.

Romania is expected to continue being a net exporter of electricity in terms of imports, albeit at a somewhat reduced rate than previously. It's also anticipated that imports of petroleum products and crude oil would continue to be high in order to meet demand.

In general, as primary consumption is expected to rise and output is expected to drop, there will likely be a greater reliance on imports. The mitigation of climate change is a worldwide aim that requires revolutionary acts and policies to be accomplished.

Accelerating the energy sector's shift to technologies that allow for a decrease in greenhouse gas emissions will be one of the most crucial actions. Due to the slow rate of development in the energy sector, many long-term changes are predictable.

REFERENCES

[1]. McWilliams, B., Sgaravatti, G., Tagliapietra, S., Zachmann, G. (2022) *A grand bargain to steer through the European Union energy crisis*, Policy contribution, Issue no.14/22;

[2]. Nimară C., *The latest war in Europe and the generated energy crisis,* Annals of the University of Petroșani, Mining Engineering, 23 (2022), ISSN 1454-9174;

[3]. *** *Adapting to the Impacts of Climate Change*, (2010). National Research Council;

[4]. *** Planul Național Integrat în domeniul Energiei și Schimbărilor Climatice 2021-2030;

[5]. *** European Commission, Directorate-General for Energy, *Member state reports on energy poverty 2020*, Publications Office, 2021;

[6]. *** Energy Poverty Advisory Hub, Energy Poverty Advisory Hub (EPAH) *Handbook 1: A Guide to Energy Poverty Diagnosis*, European Commission, March 2023;

[7]. *** European Commission (2022) REPowerEU Plan, COM/2022/230 final;

[8]. *** www.data.europa.eu;

[9]. *** www.europarl.europa.eu;

[10]. *** www.op.europa.eu;

[11]. *** www.ourworldindata.org;

THE VALUE OF THE MINING PROPERTY - BETWEEN THE PATRIMONIAL VALUE APPROACH AND THE FLOW VALUE APPROACH

SORIN-IULIU MANGU[1]

Abstract: *In today's world, the discovery of deposits of useful mineral substances is no longer the fruit of chance or the flair of a prospector. Patience, tenacity and luck have been replaced by systematic research programs and complex equipment for the structural analysis of the Earth's crust. However, this effort represents only the first step in the long process of transforming an "anomaly" in the basement into an exploitable deposit under certain technical and economic conditions. Certainly, the defining element of the process (with durations of the order of years, or even more) is the continuous investment of capital, ultimately materialized, in the end, in the building of a mining property. Its development in the form of an underground or surface mining enterprise requires other investment efforts, much higher than the previous ones. In addition, the very overall results of a mining enterprise in operation are decisively conditioned by the extent to which the operating expenses, as well as other expenses are "controlled".*

Keywords: *value, mining property, patrimonial value approach, flow value approach.*

1. THE MINIG PROPERTY AS THE OBJECT OF THE ASSESSMENT

The mining property represents a well-defined perimeter that is the object of either exploration activities for some resources of useful mineral substances with a view to their underground or open exploitation, or already of some activities of exploitation and capitalization of known reserves of useful mineral substances.

The evaluation of mining properties is a complex process, the development of which requires the use of the knowledge, skills and professional capacities of a large number of specialists, with various backgrounds (mining engineers, geological engineers, specialists in the economy of resources and the marketing of mineral products, accountants and financial experts, managers, evaluation experts, geostrategy experts). The reason is simple: the need to take into account, structure and exploit a large volume of information, of different natures, presented in various forms and with disparate origins, mainly related to reserves, underground mining works, surface constructions, operating conditions, capital expenses, operating expenses, maintenance expenses, taxes and fees, basic materials used, personnel numbers, environmental effects, specific legislative provisions, market, prices, competition, management, political aspects.

[1] *Lecturer Ph.D. Eng., University of Petroşani, mangusorin@yahoo.com*

More than in any other particular situation, the quality of estimates regarding the value of mining properties is conditioned by the validity of reasoning and the veracity of the information used.

In the evaluation of mining properties, a fundamental aspect must be taken into account: their value is conditioned, but not entirely determined, by the quantity and quality of the reserves of useful mineral substances located in their basement (that is, by the characteristics of the deposit production factor). This is because the development of reserves requires material and other efforts, the consumption of certain resources within a process with an economic dimension expressed, mainly, through capital expenditures, revenues and operating expenses. Hence the different ways of defining the value of a mining perimeter, namely:

-the value of a mining perimeter is a present value, expressed by the discounted sum of all the remaining benefits after subtracting from the sums of discounted future cash flows, over the entire economic life of the project (to value the perimeter), all investment expenses updated, prior to the commissioning of the mining enterprise or necessary to rehabilitate a mining enterprise in operation through modernization, reconstruction and development efforts;

-the value of a mining perimeter must be assimilated with the amount of money that a potential buyer (if the perimeter were to be sold at the time of evaluation) would be willing to pay for the reserves in the deposit and any work to enhance them;

-the value of a mining perimeter can be assimilated to the sums of money that its owner requests as royalties in the case of the concession of the perimeter or the part of the share capital (of the future mining enterprise) that the owner of the perimeter claims in the event of an action to continue the activity through association or partnership;

-the value of a mining perimeter is given by the remaining value invested in all the previous works of prospecting, exploration, opening, equipping with machines and equipment, value to be recovered on account of the exploitation of the remaining reserves at the time of the evaluation of the project to continue the activity.

2. THE APPROACH BASED ON THE PATRIMONIAL VALUE

The patrimonial value of the mining enterprise is related to the materialization of the previous efforts of sufficient knowledge and opening of the deposit, of equipping with specific machines and equipment, of the execution of the related assemblies, of the realization of the necessary constructions and surface arrangements, as well as the characteristic decisions and results the period from the start of operation to the evaluation.

The patrimony of the mining enterprise is reflected in its financial-accounting documents, and first of all, in the completed annual balance sheets. Based on them, the first indicator of the patrimonial value, the net accounting asset, can be established, either as the difference between the accounting values of the total assets and the total payable liabilities, or by assimilation with the accounting value of the equity capital. In principle, the net accounting asset should reflect the patrimonial value accurately enough, taking into account both the technical corrections of the accounting records offered by the current accounting system and the qualitative changes made at the level of the annual patrimony inventory actions.

However, the evaluation theory requires the transition to a higher qualitative stage, marked by the determination of the most reliable indicator of the patrimonial value, the revalued net asset (corrected accounting net asset), according to the following calculation relationships [6]:

[Revalued net assets] = [Revalued total assets] – [Revalued total payable liabilities]

[Total revalued asset] = [Total accounting asset] ± [Asset corrections]

[Total revalued payable liabilities] = [Total accounting payable liabilities] ± [Liability corrections]

The need to reassess the patrimony elements results from the following aspects, which cause plus or minus differences to appear between the accounting values and the economic values of the asset and liability items, namely:

-monetary depreciation;

-the depreciation system applied, compared to the real depreciation of fixed assets;

-the evolution of certain prices on the market;

-accounting methods, which can lead to very strong distortions between economic and accounting balance sheets.

In addition, one more mention must be made. The revaluation that the application of the patrimonial model implies is one with an economic content and not an administrative one. The economic evaluation of the heritage involves establishing the utility value of each asset necessary for exploitation and the market value of each asset outside of exploitation, based on specific rules and methods, and the corresponding restatement of all liability items.

In conclusion, it can be stated that the determination of the patrimonial value of a mining enterprise in operation consists in the reconstitution of the economic asset and the real payable liabilities, which will replace the accounting asset and accounting debts or obligations.

From the point of view of economic evaluation, the patrimony of a mining enterprise in operation presents a significant particularity: most of this patrimony has value not through the costs incurred for its construction, but through the economic results that will be reached following the exploitation of the reserves. Due to this particularity, there are appreciable differences between the accounting values and the economic values of construction assets (which constitute the significant part of the patrimony of mining enterprises). Previously, I showed that the economic evaluation of patrimonial assets involves establishing either their utility value (for those necessary for exploitation) or their market value (for those that can be disposed of). The utility value means the value of a replacement in new condition, corrected by two coefficients: one that expresses the wear (depreciation) and another that expresses the suitability to the new operating conditions. In conclusion, the determination of the utility value is based on the reconstruction costs of the mining assets. However, these assets have special destinations, they do not have a market, they have no transfer value, in other words, they have the character of "sunk" costs, past costs, definitively borne, whose main characteristic is the fact that they can be reduced in the future only through the operation of the mining enterprise and the exploitation of the reserves, any other alternative of capitalizing them being excluded (the capitalization through scrapping, in the form of recovered materials, proves, in most cases, to consume and not generate economic resources). In addition, the realization of the market value of the assets that have reached beyond exploitation is either not possible (because they have all the character of "sunk" costs), or it generates losses.

The special mining constructions have value only by appreciating them in connection with the mineral reserves to the exploitation of which they will "bring their input". However much money may be spent to execute and arrange a mining work, if, in the end, it turns out that said work cannot be used to exploit even a ton of useful mineral substance, the economic value of that work is zero and by no means the accounting value with which it appears in the accounting records. In this case, for the mining enterprise, the cost of carrying out the work is a "sunk" cost, a committed cost. The way in which this cost will be considered in the analysis of the results is particularly important, because an incorrect treatment can induce distortions capable of vitiating the correct foundation of some decisions regarding the current and future operation of the mining enterprise.

3. THE APPROACH BASED ON THE FLOW VALUE

Compared to the patrimonial approach, the approach based on value through flow materializes a totally different conception of the value of the enterprise. Thus, the heritage elements are ignored, and the enterprise is seen as a functional system, capable of generating certain results through future operation.

The value through flow can be properly substantiated by two different views on the results of the enterprise. The external global vision, influenced by current transactions with securities (carried out without the intention of changing its management and taking control of the majority stake), and which is limited to looking at the enterprise only from the point of view of financial placement, leads to the concept of financial value through flow. By contrast, the internal vision, characteristic of the owner of the enterprise, as the main responsible for its future, assimilates the enterprise to an economic project, accrediting the concept of economic value through flow. In what follows, we will consider the last situation, when the profit flows are evaluated through the prism of the future development possibilities of the enterprise, confirming or denying certain strategic options.

The (economic) flow value of an enterprise is represented by the discounted (present) sum of all future earnings resulting from operation, both in the form of future profits and in the form of the value that can be realized through resale or liquidation at a certain point in the future. By customizing the previous definition to the special case of the mining enterprise, its economic value by flow was established, in the form of the present (discounted) value of all future streams of earnings, reduced by the discounted values of all investment expenses prior to the commissioning of an enterprise new or necessary for the rehabilitation of an operating enterprise through investment efforts, modernization, restructuring, i.e. [6]

$$VI = \sum_{t=1}^{n} B_t (1+r)^{-t} - \sum_{t=1}^{n} I_t (1+r)^{-(t-1)} + V_n (1+r)^{-n}$$

where:

VI - the value of the enterprise (obtained by discounting future net profits);

I_t - the expected investment at the beginning of year t;

B - net profit achievable in year t;

V_n - the resale value of the enterprise in n years;

r - interest rate;

n - the update period (number of years).

The previous relationship acquires much simpler forms when several simplifying assumptions are taken into account. A first hypothesis, frequently used, is the one related to ignoring the resale value (not taking it into consideration), so that:

$$VI = \sum_{t=1}^{n} B_t (1+r)^{-t} - \sum_{t=1}^{n} I_t (1+r)^{-(t-1)}$$

A second hypothesis is related to the equality of annual net profits and the existence of a single capital expenditure, at the initial moment, in which case:

$$VI = B \frac{(1+r)^n - 1}{r(1+r)^n} - I$$

Finally, the third hypothesis is that of perpetuity, which involves taking into account a sufficiently extended discounting period (theoretically, infinite, practically, greater than 25-30 years), in which case the simplest form of the calculation relationship that allows the determination of the economic value by flow of the mining enterprise, namely:

$$VI = \frac{B}{r} - I$$

Always, in order to establish the economic value through flow of a mining enterprise, it is necessary to estimate as accurately as possible the following elements:

-future revenues achievable through the sale of production;

-future operating expenses;

-the provisions for depreciation of assets;

-specific mining taxes;

-the capital expenditures necessary to carry out the rehabilitation program.

The estimation of future revenues requires a careful analysis of the market, the identification of its evolution trends, the most accurate forecast of the sale prices of mining products depending on their quality, the correlation of exploitation programs with the demand for mining products and the characteristics of the deposit, the estimation as accurate as possible of the exploitable reserves, estimating the possibilities of expanding the reserves.

The future operating expenses are estimated in close connection with the annual operating programs. Thus, operating expenses are taken into account (expenses with direct and indirect productive personnel, expenses with consumable materials, expenses with various utilities, expenses with spare parts, expenses with repairs of machines, equipment and equipment), maintenance expenses (expenses with the necessary preparation works, expenses with the replacement of equipment), general expenses of the enterprise (administrative and sales expenses) and expenses with the various taxes and fees (according to the existing legislation). The annual production volumes expected to be achieved in the annual exploitation programs will serve as the basis for establishing the specific mining taxes.

The estimation of the capital expenditure required for the rehabilitation requires a detailed examination, on the spot, to establish the adverse conditions that could be encountered, the real situation of the existing assets (works, constructions, installations), with the aim of knowing these elements before the adoption decisions regarding exploitation methods, installations, machinery, underground and surface constructions, equipment, transport routes, necessary personnel, all with the aim of confirming or correcting solutions already proposed or documentation already developed.

A special estimation problem is raised by provisions for asset depreciation. These cost items should be established on the basis of the present value of the mining enterprise, a value that we do not yet know. In order to work with certain, not exactly random amounts of these costs, it becomes necessary to consider an initial value of the mining enterprise. This can only be a patrimonial value, established according to the requirements of the patrimonial model and in accordance with the mentions made previously in relation to the evaluation of special constructions. Here it would seem that we are entering a vicious circle. Again we appeal to the patrimonial value, which we previously fought for. In reality, the process of establishing the economic value through flow of the mining enterprise is an iterative calculation process, which starts from the consideration of a certain present value of it. Based on the considered present value, a certain percentage of the provisions for asset depreciation is established, which will be used further to establish a "new" present value of the mining enterprise. The new established value allows the consideration of a new quota for depreciation, thus the process of calculating the value of the mining property being resumed. Finally, after enough iterations, the obtained result comes to acceptably approximate the economic value by flow of the mining enterprise in operation.

3. CONCLUSIONS

In the literature related to the evaluation of mining properties, at least two distinct types of evaluation problems can be encountered, namely:

-the evaluation of a new or partially developed mining perimeter (being in the execution phase of the main opening works);

-the evaluation of a mining enterprise in operation.

The previously presented evaluation models consider the second case: the mining enterprise in operation. At the time of evaluation, such an enterprise presents a heritage, as a result of past decisions, but at the same time, it also represents a system established over time, characterized by certain economic results. Hence, the dual conception of the value of the mining enterprise, as heritage value and flow value. However, the particularities of the mining enterprise represent elements that require a certain circumspection when considering the establishment of the value by using traditional valuation models, patrimonial or based on results updates.

In addition, even if the purpose of the process is to determine the objective value (fair value) of the mining property, there may be a need to formulate correct answers to other questions, such as:

-what is the total amount of capital investments needed to bring the mining perimeter to a certain profitability situation?

-what is the period of time necessary to reach profitability?

-what is the value of the discounted annual profit and what part of it will be used to reward the shareholders (distribution in the form of dividends)?

-in what period of time can recovery of the initial capital expenses be ensured?

-what is the annual level of expenses necessary to maintain the production capacity of the perimeter?

-what is the expected rate of return of the mining perimeter development project?

-what are the possibilities of expanding the reserves known for certain at the time of the evaluation?

-in the context of the market and a certain economic situation, what would be the market value of the mining perimeter?

Finding the answers to such questions amplifies the difficulty of the mining property evaluation process, adding an obvious qualitative dimension to it.

REFERENCES

[1]. Asociaţia Naţională a Evaluatorilor Autorizaţi din România (traducere Institutul Canadian de Evaluare) – *Evaluarea proprietăţii imobiliare,* Editura IROVAL, Bucureşti, 2012.

[2]. Asociaţia Naţională a Evaluatorilor Autorizaţi din România – *Standarde de Evaluare a Bunurilor,* Editura IROVAL, Bucureşti, 2022.

[3]. Anghel, I. (coordonator) – *Evaluarea întreprinderii,* Editura Economică, Bucureşti, 2010.

[4]. Dragotă, V. – *Evaluarea acţiunilor societăţilor comerciale,* Editura Economică, Bucureşti, 2006.

[5]. Dumitrescu, D., Dragotă, V., Ciobanu, A. – *Evaluarea întreprinderilor,* Editura Economică, Bucureşti, 2002.

[6]. Simionescu, A., Mangu, S. I. – *Evaluarea întreprinderii,* Editura Focus, Petroşani, 2004.

[7]. Stan, S. (coordonator) - *Evaluarea întreprinderii,* Editura IROVAL şi Editura Invel Multimedia, Bucureşti, 2006.
[8]. Stan, S., Anghel, I. (coordonatori) - *Evaluarea întreprinderii,* Editura IROVAL, Bucureşti, 2013.

Annals of the University of Petrosani, Mining Engineering, 24 (2023)

PROSPECTIVE AND EXPLORATORY TOOL FOR THE MODELLING, ASSESSMENT AND MANAGEMENT OF TERRORISM RISK SPECIFIC TO UNDERGROUND TRANSPORT INFRASTRUCTURE

VLAD LĂUTARU [1], CLAUDIUS POPESCU[2], DENISA TUDOR[3], CARLA ENACHE [4], CRISTINA PITULICE[5]

Abstract: *The purpose of this article is to outline the principles on which a holistic tactical and strategic roadmap for modelling, assessing and managing terrorism risks to cyber, physical and organisational infrastructures should be based, taking into account the complex nature of terrorism risk assessment and management in which all relevant threats, costs and benefits need to be analysed in a multi-objective framework. There is a need to develop appropriate matrices to measure the effectiveness of risk management actions, enabling quantitative and holistic determination of terrorist threat factors based on centralized data and information variables used for terrorist risk modeling. This involves determining the need for strategic responses to complement short-term tactical actions depending on the nature and scale of threats, and developing a modeling roadmap for tactical and strategic responses to terrorism.*

The essential aspects of the need for a technical-scientific basis for a methodological mechanism for modelling, analysing and assessing the risk of terrorism, with a view to properly managing ways of eradicating this scourge that continuously affects modern society, are based on the following premises: The events of 11 September 2001 were a wake-up call for changing outdated practices in ensuring infrastructure security; The risks generated by terrorism worldwide cannot be assessed and managed through inefficient use of limited information resources and incomplete or superficial analysis; Embracing change involves assessing and managing these risks in a comprehensive systemic and holistic manner based on multi-criteria analysis; The myriad economic, organisational, institutional sectors form a complex system of large-scale interdependent subsystems, which are made up of numerous interconnected and interdependent cyber, physical and organisational infrastructures (subsystem components). All of these entities can be subject to vulnerability through various acts of maliciousness, exerting various types of

[1] National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petrosani, Department of Industrial Safety, G-ral V. Milea Street 32-34, Petrosani, Romania, vlad.lautaru@insemex.ro

[2] University of Petrosani, Doctoral School, Universitatii Street 20, Petrosani, Romania, claudiusandrei@yahoo.com

[3] University of Petrosani, Universitatii Street 20, Petrosani, Romania, deni_t.2301@yahoo.com

[4] University of Petrosani, Doctoral School, Universitatii Street 20, Petrosani, Romania, carla.enache91@yahoo.com

[5] University of Petrosani, Street 20, Petrosani, Romania, pitulicecristina04@gmail.com

terrorist threats against them. The relationships between these subsystems can be stochastic, dynamic, non-linear, partially distributed and hierarchical. Also, estimating and assessing the risk of extreme and catastrophic events specific to these complex infrastructure systems is of critical importance, and from this point of view, any technical-scientific approach to assess and manage them without a deep and prior knowledge of the terrorist threat factors that determine the type and extent of specific vulnerabilities will not be able to guarantee a plausible and predictable outcome.

Keywords: *terrorism threat, underground transport infrastructure, mathematical model, SCADA, risk assessment, Bayesian analysis*

1. INTRODUCTORY ASPECTS REGARDING THE MODELLING OF TERRORIST ATTACK SCENARIOS

An effective management of the risk of terrorism requires an appropriate management of the identification and analysis of the threat factors, in order to objectively determine the corresponding risks on appropriate technical and scientific bases, using established methodologies for modelling with maximum accuracy the scenarios of terrorist event. In order to effectively manage the risk of terrorism, it is necessary to properly identify and analyse the threat factors. This is so that the corresponding risks can be determined objectively based on the right technical and scientific bases, using well-known methods for modelling with the highest level of accuracy the worst-case scenarios of terrorist attacks.

So, the first step in evaluating the risk of terrorism is to find its main sources [Haimes, 2002]. These can include risks that affect people, such as law and freedom; risks to government, military, and intelligence infrastructures; risks to critical physical or cyber infrastructures; and risks for the economy. Figuring out at least these sources is "sine qua non" for making good decisions. This is needed for good strategic and tactical planning to be able to evaluate and handle the operational and optimal risks of the terrorist danger [Wolf et al., 2003], events with extremely severe consequences.

Thus, the first step in the terrorism risk assessment process is the identification of the main potential sources of this type of risk, which can generate [Haimes, 2002]: risks that can affect the human component, law and freedom; risks to organizational and societal infrastructures, including the security of government operations, military and intelligence infrastructure; risks to critical cyber or physical infrastructures; risks for economic sectors. The "sine qua non" condition for a sound decision-making process is the identification of at least these sources, so that effective strategic and tactical planning can be carried out, in order to assess and manage the operative and optimal risks of the terrorist threat [Wolf et al., 2003].

System modelling of terrorist networks

It is very important to look at terrorist networks and how they act from a systemic point of view, because their effects are a lot like those of risk sources, which set the specific input parameters of a threatened system (fig. 1). Haimes and the NRC both wrote in 2002.

The five stages of analysis below were created by Arquila and Ronfeldt [2001] to help us learn more about the culture, motivations, ways that terrorist networks work, and links between them. The following levels give a good picture of the state factors for the terrorist network system (see Fig. 1):

- Level of the group, as seen through how it is organized or run: Is it possible for a terrorist or a group of terrorists to work well together? Also, what does that network look like?

- The level of the story in this case: What made the people think there was a network? Why do they stay that shape? Question: What are the best ways to work together at the theory level? What are the pros of the network form of organization? How much technology is in the computer system: How and how much can an organization's network deal when it comes to moving information and calling each other? What kinds of tools allow them to happen?

People show their social level through close relationships that make people trust and stay true to each other. It's also important for members of a network to know each other and be connected to each other in a lot of different ways.

You can use these five state factors in the terrorist network system model to figure out where the risks are coming from in a certain dangerous area. And they need to add state factors like how much money terrorist groups get and how well-developed the technology is that these groups can use to plan specific actions based on their skills and goals.

Still, it's important to know what terrorist networks do, like why the economy is bad or why they are worried about politics (see Figure 1). Policymakers can then take effective steps to control and lower the risks in a certain threatened area by putting money and resources into areas that are poor and don't have enough schools, health care, or important infrastructure. Terrorism often starts or grows in these places.

Modelling the threatened system

I'll talk about a sample that has five state variables that are similar to those in the terrorist network system model. These are: governance (a free democratic society); resources (viable economic and organizational infrastructures that encourage technical, scientific, and technological performance and value individual creativity); owned structural facilities (cyber, physical, organizational, societal, and internal; traditional infrastructure

The above sample can be very helpful in finding important sources of risk and coming up with risk management policy choices based on the outcome of the evaluation process for this indicator. Carter [2001–02] lists eight steps in risk management (represented by decision variables) that can be used to keep a threatened area safe and secure: discovery, prevention, protection, interdiction, isolation, assignment, and analysis.

It's important to keep in mind that when terrorist fears come true, the emergency services may not be able to handle the extra work and the power may not be able to get to everyone. From this point of view, it is hard to model, assess, and manage the risks of terrorist attacks on ventilation systems in underground transportation systems because of the seven things listed above. These things make up a complicated system that is run by different government agencies and private companies, each with their own set of goals that are often at odds with each other.

Supervisory Control and Data Acquisition Systems (SCADA)

Cyberterrorism has a lot more effects than just cutting off customers' access to communication services. As more SCADA systems are used for data collection, monitoring, and control, they make ventilation systems more vulnerable to cyberattacks, just like other infrastructure. As an example of a terrorist danger to underground transmission infrastructures through SCADA systems, I will now talk about software viruses and sending wrong information. A computer hacker could open and close valves at the wrong times and in the wrong order, which would damage the ventilation system and taint the air that is transported along these routes, which could put people's health at risk (if the air contains dangerous toxic substances) or their lives and safety (if the air contains dangerous explosive substances).

2. SCIENTIFIC AND TECHNICAL ASPECTS OF TERRORIST THREAT ANALYSIS AND RISK ASSESSMENT

Stopping and fighting a terrorist threat rests on how much information is available to find and identify the people who are helping to plan, carry out, and support the attack. This kind of information comes from many places, like intelligence or forensic services watching people or things, different types of transaction records, and tips from many casual witnesses. There is a lot of information out there, so there needs to be a way to sort through it all and only look at the parts that are important to the goal, make sure they are correct, and get rid of the rest. The risk-based mythology behind creating terrorist threat scenarios, gathering intelligence, and analysing it to stop terrorist actions is based on the idea that people who plan, support, and carry out a terrorist plot will do a number of related activities for which there may be some plausible intelligence and other evidence that make up a threat scenario.

Information that fits with an actual threat scenario might help stop an impending terrorist attack; the rest of the data is not thought to be useful. So, a mythology needs a complete set of true threat scenarios that can be used to collect and analyse intelligence in a systemic way. The main questions for gathering and analysing information are: how to make a complete list of possible threat scenarios; how to narrow that list down to the most likely scenarios; what other information is worth looking for; how to judge the usefulness of the information that is already available; and how to check and analyse the data.

This methodology can be used as a structured way to figure out what terrorist groups are planning and how strong they are. It can also be used to create and compare different terrorist threat scenarios. This can help different authorities make decisions about how to collect and analyse intelligence and set priorities for effective collection to meet counter-terrorism needs.

Methodological approach

There isn't a single model or method that can solve all the technical problems that come up when trying to predict and track terrorist threats. These problems include making and organizing scenarios, keeping intelligence up to date and figuring out how much it's worth, putting scenarios in order of importance using a sound and risk-based system, figuring out how cost-effective the whole process of gathering and analysing intelligence is, and keeping track of terrorist attack plans. This section describes a way for dealing with these problems that is based on adapting and combining a number of good risk-based techniques.

We used a hierarchical holographic modelling approach to get a full picture of the parts that will be in the model. This involved using a lot of different types of literature knowledge from technologists, psychologists, political scientists, criminologists, and others to organize risk scenarios into sets and subsets of sequential manifestation. This analysis process led to the creation of a workable scenario model.

So that this method can be used more easily, the scenario model is made up of time variables that change based on the amount of work that needs to be done to make sure that all the information and data that supports the bad event is collected correctly and on time. So, the model that was made from the probable scenario's basic structure can automatically add or remove elements and data based on the system's workload. This is because it refers to a master model that includes all the parts that were found in the initial model. Setting up and keeping an eye on practical measures that show how busy the part of the system being studied is is necessary for this automatic feedback process to work. This also means doing research to come up with and try out different ways to change the functional models and search parameters in real time.

The created method sorts and prioritizes possible outcomes based on a methodical process of finding and setting them up. This is done to choose and establish the most likely danger states that need to be analysed and evaluated in terms of the specific risks of terrorist threats by committing crimes, as well as being constantly watched.

For this reason, we used Bayesian analysis of the factors that support and set up the different risk scenarios as a way to objectively look into the dangerous situations that can happen at the level of a civil or commercial target.

After creating a likely scenario based on available data and information that has been checked for accuracy and precision as a trait of an unwanted terrorist event, the next step is to look at what terrorists might do to get ready for an attack.

To do this, we can divide the set of possible observables into the following groups:1.Those that could be found and gathered by the right people on the ground (spy services); 2.Those that could come from ordinary people; and 3.Those that could be gathered by following new rules set at the national level.

To get important data and information in all three situations, the importance of the scenario must be closely linked to the importance of the elements needed for the analysis, the amount of work that needs to be done given the available time and money, and the risk of getting and interpreting the desired results. This means that Bayesian analysis of the chance of false alarms and missed detections is used to figure out how important the information from different sources that is linked to the three groups above might be.

When certain results are found, a decision tree with multiple goals is used to figure out what to do next. Objective functions are used to deal with and analyse unmeasured goals of the kind of work that needs to be done within a certain amount of time and that require the division of financial resources that are at risk. In this way, integrated operational reaction actions can include anything from asking for new special intelligence to getting experts to look over data more closely to stopping what is thought to be a terrorist act. It is especially important that the methods used to look at the results match the methods used to create the situations and gather the data and information that is needed. To do this, the intelligence community needs to combine old tools they already have with new ones that are related to the above-mentioned methodical mechanism, risk filtering methods, and Bayesian analysis models. Of course, scenario methodology and analysis tool designers need to work together to get the data and information they need. One very important thing they need to do is work with the intelligence analysis community to make systems that can handle processing properly and efficiently integrated data.

Here are some of the technical and tactical problems that come up when trying to keep track of terrorist attack plans: Planning terrorist attacks and keeping track of them by organizing scenarios; Giving scenarios priorities using a tried-and-true risk-based method; Putting together groups of scenarios that share common features and possible observables; Using Bayesian analysis to update and quantify intelligence value; Choosing the set of observables by figuring out how cost-effective the whole intelligence gathering and analysis process is.

Analysis of observable actions

The structure of the above scenario needs to be broken down into a set of actions that can be seen. In this way , intelligence officers can use them to find and set up terrorist scenarios that are already happening. This part shows different ways to look for observables (data and intelligence) that are unique to a terrorist action situation. So, to start, we divide a possible terrorist attack into six steps, which are:

Table 1 - Six stages of identifying plausible terrorist scenarios

Stages	Description
Intention	This is the earliest stage, where the terrorist develops feelings of hatred/hatred and intent to destroy/harm through an overall plan of attack.
Target acquisition	At this stage the terrorist chooses specific targets.
Preparation	This is a stage of full engagement. At this point the terrorist is preparing to launch the attack.
Execution	The attack is carried out.
Grace period	Depending on the nature of the attack, there is sometimes a time lag between a successfully executed attack and the impact of carrying it out.

These six steps, similar to the sections of a terrorist act, can be used to envision what might actually happen in such a situation. To figure out what can be e expected the right intelligence team and subject matter experts should work together to make guesses about the exact steps a terrorist would take. For example, the intelligence team could figure out what kinds of conversations and exchanges could occur.

Depending on the attack methods, a certain situation may have more than one expected situation. Therefore, each terrorist act creates a number of different situations that must all be linked by intelligence analysis tools. This process also sets up a way to deal with the real events, taking into account the time that each part of the story took place. Most importantly, this set of data could be used to figure out what to do before, during, or after the attack. First, we figure out which parts of the model might be good for observing. This is because the parts we got without doing any more research are like a list of separate weaknesses that a terrorist could use by making a specific plan for how to attack. So, it's important to figure out how to observe each part so that, as observations are made, both the chance of setting up a scenario and an operational plan can become clear. Figuring out how long it will take to carry out and finish a terrorist plot is very important, even if the events that happen don't follow a specific tactical plan. This part of the process should be closely linked to decision making, which makes sense since it's best for decisions based on observations to take into account how much time is left until the real plan is carried out.

Bayesian analysis of intelligence sensitivity and specificity

Every day, the security services get a lot of data, information, and other intelligence reports about different terrorist threats. These reports are meant to help them find terrorist networks' connections, motives, patterns, and plans so they can make a plan for how these networks will act. This shows that the field of intelligence needs rigorous quantitative and systemic analyses. So, let's say that there is a collection of information, e, about a certain terrorist attack, T. Most of the time, we think that the chance of T will be pretty low. Also, let's say that a terrorist attack T (for example, a spray terrorist attack on an underground transit system) has a 0.0001% chance of happening within a certain amount of time. Based on Bayes' theorem, the chance p(T/e) that the terrorist attack T will happen, given the information e, is:

$$p(T/e) = \frac{p(e//T)\ p(T)}{[p(e/T)\ p(T) + p(e/\bar{T}) p(\bar{T})]} \quad (1)$$

where p(T) is the probability that a terrorist attack does not occur. Note that p(T) is equal to 0.9999 for the presented situation.

If we divide the numerator and denominator of the equation for p(T/e) by the numerator, we can transform the equation for p(T/e) into the following form:

$$p(T/e) = \frac{1}{\left[1 + \left\{\frac{p(e/\overline{T})}{p(e/T)}\right\}\left\{\frac{p(\overline{T})}{p(T)}\right\}\right]} \quad (2)$$

For example, for the numerical values of p(T) = 0.0001 and p(T̅) = 0.9999, this equation becomes:

$$p(T/e) = \frac{1}{\left[1 + \left\{\frac{p(e/\overline{T})}{p(e/T)}\right\} 0{,}999\right]} \quad (3)$$

It is also clear that the value of P(T/e) will stay low if the ratio of p(e/T) to p(e/T), which we will call the "evidence ratio," is not big enough to make up for the small value of the starting ratio of p(T) to p(T). In other words, there isn't a good chance that a terrorist attack will happen unless there is a lot of evidence that a terrorist attack is much more likely than other options.

For example, Table 2 shows the sample values to show that the ratio of evidence must be very high to change someone's original guess that a certain terrorist attack is not likely to happen. To back up this working hypothesis, a lot of work needs to be put into gathering data about all three of the above areas of interest. Intelligence gathering isn't just done by intelligence forces. For instance, if authorities don't look at historical data, they have to rely on their limited experience (sometimes limited by the specifics of each terrorist event) with cyberattacks and incomplete information about what happened in other places. This doesn't provide a solid basis for analysing large amounts of information and making decisions.

Table 2 – Sample values

Evidence report	The probability of a terrorist attack $p(T/e)$
1,0	0,00010
10,0	0,000999
100,0	0,0099
1000,0	0,0909
10.000,0	0,50

Bayesian analysis of different scenarios

Bayesian analysis can be used to find patterns in terrorist attacks that are shown by one or more classes of scenarios. The data for (n–1) scenarios, such as s2,...,sn, can be thought of as functions of chance that can be used to update a different class of scenarios, such as s1. This is what happens when a terrorist group plans to attack at the same time, like if they want to ruin the air quality in the subway system in area X and the same system in area Y. We look at the simple case of keeping track of two groups of different scenarios, s1 and s2. Here, p(s1) is the prior probability of the group of scenarios s1 that are assumed to be true, and p(s2/s1) is the probability of the group of scenarios s2 that are assumed to be true, figuring out s1 and using the probability for scenario s1 as a function. So, the chance of exceeding the limit for case s1 is now p(s1/s2):

$$p(s1/s2)=\{p(s2/s1)p(s1)\}/(p(s2)) \quad (4)$$

$$p(s1/s2)=(p(s1,s2))/(p(s2)) \quad (4')$$

If you use more than one scenario as a likelihood function, you can add to this formula to get a posterior chance for s1:

$p(s1,s2,s3…sn)=(p(s1,s2,s3…sn))/(p(s2,s3…sn))$ (4″)

Along with the new information that scenario s2 gives us, we assume that the intelligence agency has also found new evidence e that is related to scenario s1 (another probability function), with a probability p(e,s1), assuming that scenario s1 is true. So, to find the probability that situation s1 will happen later than expected, we can use the following relationships to get the probability p(s1,s2,e):

$$p(s2,e,s1)=p(s2,e,s1)p(e,s1)p(s1) \quad (5)$$

Similar,

$$p(s2,e,s1)=p(s1,s2,e)p(s2,e) \quad (5')$$

Equating the above equations determines the (posterior) exceedance probability for s1:

$$p(s1,s2,e)=(p(s2,e,s1)p(e,s1)p(s1))/(p(s2,e)) \quad (5'')$$

It's clear that any unplanned division or compartmentalization of information sharing, scenario tracking, and analysis done in these situations could change the above Bayesian analysis. Tracking terrorist threat scenarios through careful information gathering and constant updates, on the other hand, can be strong ways to stop them from doing bad things.

Pate-Cornell [2002] gives a generalized Bayesian formula for situations with more than one data source. In this way, if we call the new set {S} = (s1, s2, s3,..., sn) and the case that is currently changing, sj, is not in {S} = (sj,{S}), the equation becomes:

$$p(sj,\{S\})=(p(sj,\{S\}))/(p(\{S\})) \quad (6)$$

Keep in mind that p({S})=p(sj)p({S},sj)+p(sj)p({S},sj), where (sj) à Why state factors are so important in risk and information analyses. Chances of extreme and disastrous events happening

Probability is a made-up number that doesn't describe a real thing, but scholars, businesspeople, and politicians all over the world are still interested in and inspired by the art and science of probability and statistics. Risk analysis has become a lot more popular in the last 30 years, which has brought more attention to how important odds are in making decisions. In his work to define probability theory and make clear the connection between events happening and the conditions under which they can be seen as a random process, to which probabilities can be attached, Gnedenko [1963] comes up with the question and the related answer: "Under what conditions does the quantitative estimate of the minimum probability of a random event A, by means of a defined number P(A) - called the mathematical probability of the event A, have an objective meaning, and what is that meaning?" A certain set of conditions q determines the occurrence of an event A with a chance p. This is the same thing as saying that there is a (pre)defined "given" between conditions q and event A.

Understanding randomness is important if one chooses to use probability theory to look at terrorist strikes that could have terrible results, like attacks with weapons of mass destruction. There are random patterns in nature that make probability theory very useful in the natural sciences. This is true whether you are studying physics, astronomy, chemistry, or medicine. In this way, Gnedenko [1963] says, "In probability theory, random events have a number of features that make them stand out. For example, they all happen in mass phenomena." Gndenko says that mass phenomena are things that show up in groups made up of a lot of equal or nearly equal parts, and the regularities are kept up by chance.

One of the problems that people who study risks have to deal with is figuring out how to measure the danger of terrorism in a way that makes sense and is representative. There are at least two main sources of information that can help them with this: the first source is the frequency of random events. For example, hydrological scientists do technical-scientific study on a huge database of all the rain and snow that falls every year. In this way, they can prove and think of good function models for the probability distributions that can best show the hydrological behaviour being studied, such as the Log-Pearson type III probability distribution. A similar way of thinking is also used in statistical analysis to keep an eye on things like air quality, made or transported goods, traffic accidents that happen below ground transportation systems, and more. Unlike the annual rainfall pattern, terrorist threat scenarios don't seem to follow a random process. This means that there isn't a probability density function (pdf) that can be used to show what we know based on reliable information and data about the likelihood of some terrorist scenarios. - The second problem is that there isn't a lot of data about terrorist attacks, like attacks with weapons of mass destruction.

The Bayesian view of probability states that, "The probability of an event occurring uncertain is the level of credibility or confidence (certainty) we have in the realization of that event." This can help you figure out how to handle the risks of attacks that have a not-unlikely chance of happening and having terrible effects on an area that is prone to many vulnerabilities. In this case, we give an uncertain event a chance of 0 or very close to 0 when we have almost no faith that it will happen. When our level of trust is very high, on the other hand, we give the chance 1 or very close to 1. A lot of different things can help you get to this level of trust, such as historical and statistical records, data and observations, expert evidence, simulations, and more. Lowrance wrote this in 1976.is the opposite of scenario sj. The trust that you have in one set of scenarios (S) can be used in Bayesian analysis to create probability functions for a different set of scenarios (S2), which makes it easier to build a chain of scenarios. These kinds of hierarchies can be set up based on the different points of view that the intelligence community cares about. Also, because they are so varied, scenarios can be broken down into different parts based on their nature and value. Different geographical, temporal, threat type (biological, chemical, radiological, or nuclear), various intelligence sources, or type of infrastructure can all lead to these kinds of views and breakdowns.

It's clear that these decompositions and the categories they create overlap, but each one gives us a different view and level of risk that we might not get from the others. Many theories, methods, tools, and processes have been created to help with the correct analysis and evaluation of the probability parameter so that this kind of knowledge base can be fully utilized for clear decision-making purposes.

For instance, if we were to categorize events as certain, impossible, chance, or unknown, the question that comes up is: "What would be the best way to categorize attacks with weapons of mass destruction that are so destructive?" When terrorists use weapons of mass destruction, the attacks are not always the same. One way to describe them is as unknown non-stationary random events, which is not the same thing every time. This is because the attacks are unknown, have never happened before, and change over time.

"How to deal with an extremely unlikely and possibly catastrophic event?" is the right question to ask about risk analysis.

Note: Something that is not unlikely means something completely different from something that is odd. The word "unlikely" means that the person observing has enough faith or authority to say that the event has a low chance of happening. However, "not at all improbable" means that the person observing has enough faith or trust to believe that the event can happen, but they don't know how likely it is to happen.

Definition of state variables in risk determination

Before trying to figure out how likely it is that extreme terrorist attacks will happen and have terrible effects, it is important to define some key words: vulnerability, threat, purpose, capability, and risk. We will use the basics of mathematical models, focusing on state variables, to explain what these terms mean in the context of systems security engineering.

In fact, the state variables of a system are the ones that make systems modelling and control theory work. For example, to control the output of steel, we need to know what its temperature, viscosity, and other physical and chemical properties are at any given time.

To make state variables in intelligence analysis and counter-terrorism work together, it is important to identify the following terms: Vulnerability is when a system's natural states (like physical, technical, organizational, or cultural) can be used by an enemy to hurt or damage that system. Assaulters' intent is their desire or reason to attack a target and cause harm; their capability is their ability and capacity to attack a target and cause harm; Threat means that someone wants to or is able to hurt or damage the system(s) by changing its states in a bad way.; Risk is what happens when a threat hurts a system that is weak already.

There are two levels of purpose and capability that could be used by people who want to use mass-destructive weapons (low and high). If we look at the following combinations of these levels, we can have the following situations: Low skill and high intent: This mix would be low risk, but not impossible; High skill and low intent: This would make the risk not unlikely: High capacity and high intention: This is the most dangerous combo because it creates a lot of risk.

Terrorist groups that want to change political and social situations, like going from a stable to an unpredictable government, from a working to an unworking traffic system, and from a trusted to an untrusted cyber system, are all threats to a system that is weak. The terrorist groups that are stalking a weak spot have the same goal as the people whose job it is to keep it safe: they both want to change the states of systems to reach their objectives. In order to protect infrastructure systems, the main goal of good data gathering is to find out what state the system being protected is in. Putting together the huge amount of intelligence data with how terrorist groups might choose a target and trying to make safe and secure areas of the world into risky areas.

3. CASE STUDY REGARDING THE ASSESSMENT AND COMBATING THE RISK OF A TERRORIST ATTACK ON UNDERGROUND TRANSPORT STRUCTURES

Our most important infrastructures, like telecommunications, power systems, gas and oil storage and transportation, banking and finance, underground transportation systems, water supply systems, emergency services, and so on, are much more connected and dependent on each other thanks to progress in information technology. As terrorist attacks on vital infrastructures become more likely, we need to learn more about and make progress in the art and science of modelling complexity and large-scale interconnected complex systems.

To show how complicated this is, we looked at underground transportation systems, which are big networks of related tunnels.
From a structural point of view, each grid is its own interconnected system, made up of many generators, distribution and control centers, transmission lines, converters, and other parts. The transmission system as a whole depends on these facilities working properly. In addition to being highly reliant on data communications, the national transportation system also relies on other infrastructure systems, especially those that handle communications, fuel supply, and transportation.
Supervisory Control and Data Acquisition (SCADA) command and distribution centers and traffic control centers get real-time (every few seconds) updates on the state of the transmission system through data communications. Data communications are used to handle field devices like ventilation networks, station control and monitoring equipment, and more from afar. Data communications also let generating units follow real-time signals from the control center. These signals are needed to instantly match the electricity production needed for ventilation equipment to work properly with consumer demand. Examples of data communications include long-range camera satellites, cellular systems, paging systems, network service providers, Internet service providers, and more.
To make sure that transportation infrastructures are stable, long-lasting, and usable, it is clear that we need to fully understand how they are connected and how complicated they are, as well as the risks that come with the general and specific features of these underground transportation structures. But, despite all the study that has been done so far, we still don't know much about these factors. The main reasons for this are the scary level of complexity and the fact that we still don't have a high-level global framework for modelling how complex large-scale, hierarchically connected transportation systems rely on each other.
Historically, many of the world's most important infrastructures were built and put into use at different times, so they didn't depend on each other very much. As an example, water supply systems were planned, built, and run without taking into account possible threats to their security, just like other important infrastructures. Today, the way that buildings are linked and depend on each other can be dangerous to society.
The Nobel Prize in Economics was given to Wassily Leontief in 1973 for creating what is now known as the Leontief "input-output" model of economics [Leontief, 1951a]. This model helps us understand how different parts of an economy are linked and guess what will happen to one part when something changes in another. An adaptable mental tool based on the Leontief "input-output" model of infrastructure can be used to keep track of how each critical infrastructure is linked to the others and how they are linked within each critical infrastructure.

The original Leontief I/O model

The basic Leontief "input-output" model [Leontief, 1951a, 1951b, 1986] is a way to look at how an economy works when it is in balance. The system being looked at is made up of several subsystems, which are separate parts of the economy or businesses.
This part, which is based on the ideas of Intriligator [1971] and Haimes [1977], gives a quick outline of a more simplified form of Wassily Leontief's "input-output" model for keeping track of an economy's resources and goods [Leontief, 1951a]. One way to look

at the economy is as a system of interconnected sectors or industries, and each "industry" makes a final good.
According to the original model for an industry to work, it needs inputs from other industries and goods from those industries that deal with it. Each industry has to make enough things to meet the needs of both internal and external customers. Internal customers are other industries in the group. External customers are other industries outside the group.
If we look at an economy that stays the same over time (equilibrium and competition) and has constant factors for a year, we can set the following parameters: The variables xj (the output for the whole economy) and ri (the input for the whole economy) are as follows: xkj (the amount of kth raw materials used to make the jth good, j=1,2,...,n) and rij (the amount of the ith resource used to make the jth good, j=1,2,...,n). Leontief's model assumes that the inputs, or goods and resources needed to make an output for the whole economy, are:

$$xkj = akj\ xj, \text{ where } j,k=1,2,...,n \quad (7)$$

$$rij = bij\ xj, \text{ where } i=1,2,\ldots,m \text{ and } j=1,2,\ldots,m \quad (8)$$

In addition, the output of any good is either used to make other goods or as the final desire for those goods. You can think of the above equilibrium equation as a key to the further growth of the Leontief-based equation: $xk = \Sigma\ xkj + ck$, where $k=1,2,\ldots,n$ (9)

Combining the above expressions yields the Leontief equation:

$$xk = \Sigma\ akj\ xj + ck, \text{ where } k=1,2,\ldots,n \quad (9')$$

Similarly, the proportionality hypothesis applies to resources:

$$rij = bij\ xj \quad (8')$$

$$\Sigma\ rij = \Sigma\ bij\ xj \quad (8'')$$

Since demand for resource i cannot exceed its supply, then:

$$\Sigma\ bij\ xj \leq ri\ ,\ ri \geq 0, \text{ where } i=1,2,\ldots,m \quad (10)$$

An "input-output" infrastructure model based on Leontief's ideas was made from the basic economy model above, but the factors are interpreted in a very different way.

Elaboration of the "input-output" risk model of inoperability

Leontief looked at an economy that uses m primary materials to make n goods as its output in his "input-output" model. For the "input-output" inoperability model, we looked at a system with n important, complex services that work together [Haimes and Jiang, 2001]. The idea of inoperability risk, which shows how badly a vital infrastructure is likely to stop working, is at the heart of the model. System intrusion is a bigger problem that shows up in an underground transportation system. It can be caused by a terrorist attack, an accident, or a natural disaster. The system's results are the risks that

come from the infrastructure not working because of the links between them. If you know what the dependency matrix is, this mode gets close to the steady state of the system being attacked.
In this model, we've looked at a number of systems that work together and with each other. It is possible for the inoperability exit to be activated by more than one failure, such as those caused by natural disasters, accidents, or terrorist attacks. For a system to be inoperable, it must be able to make sure it works normally and perform the security functions for which it was built. The risk of inoperability is the highest possible outcome based on the chance (likelihood) of the system not being able to work. It is shown as a percentage. The portion of a subsystem that can't work with other systems was used as a single, accurate way to measure the risk of inoperability caused by complexity and the number of connections within and between systems. The main goal is to figure out how complexity affects these systems' ability to keep working even when things go wrong.
It's important to note that the Leontief economic model's ideas of "supply" and "demand" now have a very different meaning, as they are mostly used in the "input-output" risk model of inoperability. The two models are built mathematically in a similar way, but they are interpreted in very different ways. In the "input-output" risk model of inoperability, the meaning has been turned around in some ways. Besides that, even though the mathematical parts of the two models are similar, they have very different ways of interpreting the factors. In the Leontief "input-output" model for the economy, dollars are the units used. For the transport infrastructure model, the units of risk of inoperability are shown above. They are a way to measure the likelihood (probability) and degree (percentage) of a system not working. If 100% of the equipment is not working at all, it is said to be totally inoperable. As was already said, inoperability can look different ways based on the type of system. One of the first things that applied modes do when they look at a certain infrastructure system is to identify the inoperability and risk in a way that best describes how that infrastructure works.
We looked at a system with n key transportation infrastructures that are all connected to each other. The result is their risk of inoperability, or the fact that they might not work if one or more of them fails because of an accident or an act of terrorism. Inoperability is thought to be a constant variable with a value between 0 and 1. A value of 0 means the system is fully operational, and a value of 1 means it can't work at all. It depends on the situation and the type of system that is inoperable what kinds of changes can happen. When production level is important, it's easy to define inoperability as unrealized production, which is the difference between the current production level and the expected production level. In the case of an underground transportation system, for example, inoperability can be thought of as the ratio of the amount of traffic that can flow (or can't flow) at a given time to the amount of traffic that can flow under standard, safe traffic conditions. In addition, the idea of inoperability tries to describe how well the system works. If the quality can be measured mathematically, a broken system whose performance is of degenerate quality is thought to be partially operable and has an inoperability value greater than 0. For instance, when cars can only move in one lane, the system transport is only partly usable, which means it has an inoperability value greater than 0.

Lastly, the fact that a system doesn't work isn't always an ongoing variable. There are times when it can take precise values, like binary values. This is where we talk about the ongoing case.

You can also think of the risk of not being able to use something as a continuation of the idea of instability. If a system works exactly at t=0, then there is a conditional probability that it won't work during a certain time period t. This is called unreliability. In fact, there is a chance that the system might not fail totally during this time, but it might fail in some ways. During this time, it could fail completely with a 0.1 percent chance, lose 50% of its functionality with a 0.4 percent chance, lose 10% of its functionality with a 0.8 percent chance, and so on (as long as the functionality can be found). As a result, it makes sense to take the average of all these possibilities, taking into account both the chance of failure and the amount of failure. By doing this, we get a number that shows what the projected level of failure will be over a certain amount of time. That is, if the expected value metric is used to define risk, then failure risk can be thought of as expected loss. Later, along with the expected value measure, a conditional measure of expected value will be shown.

There are many reasons why an infrastructure might not work, such as its location, its purpose, its availability at a certain time, or political issues. On the one hand, these and other points of view have a big effect on the numbers that are given to the chance (coefficient) of not being able to use the model. But each of them might be a good reason to make a different inoperability model that deals with a certain aspect. One example is not being able to communicate across an area or state, for a short or long time, when one function fails or when multiple parts of an infrastructure fail. In this case, each model will need its own unique odds of not being able to work together.

A model like this could also figure out how much the risk of not being able to work or damage to property, production, services, or people getting hurt in extreme natural or accidental situations or because of terrorist attacks is worth.

For the purposes of this study, we will assume that each infrastructure system has a specific job to do and that no two systems do the same job. To put it another way, we don't think about duplication in this first model. The types of systems we'll be talking about here are "non-parallel" systems.

Let j = 1, 2,...n be a positive integer. Let xj represent the total chance that the jth piece of linked and intranet infrastructure will fail due to an accident or an act of terrorism.

Let xkj be the level of inability caused by one or more failures in the kth infrastructure by the jth infrastructure. This can happen because of how complicated their internal and external infrastructures are connected.

The value akj for the chance of not being able to operate should show how much damage the jth infrastructure does to the kth infrastructure in this mathematical model. It should also show how dependent the kth infrastructure is on the jth infrastructure element. As an example, if akj=1, then destroying infrastructure element jth will destroy infrastructure kth completely. On the other hand, destroying infrastructure element jth will not destroy infrastructure kth if akj=0.

Let ck be a natural or human-caused risk factor in the vital infrastructure kth. It will be used as an input variable for the risk of failure. Input-output risk of inoperability model (of the Leontif model) is now set up as follows:

$$xkj = akj\ xj, \text{ where } j,k=1,2,\ldots,n \tag{11}$$

The equilibrium equation is the key to further development of the linear model

$$xk = \Sigma\ xkj + ck, \text{ where } j,k=1,2,\ldots,n \tag{12}$$

Combining the 2 mathematical expressions above yields the inoperability equation for the infrastructure model under analysis:

$$xk = \Sigma\ akj\ xj + ck, \text{ where } j,k=1,2,\ldots,n \tag{12''}$$

Translating this equation into matrix form is as follows:

$$x = Ax + c, \tag{13}$$

where: x = [x1, x2,…,xn]T, c = [c1, c2,…,cn]T, r = [r1, r2,…,rn]T, [.]T - column vector and A=[akj]n x n – matrix.
We define I=n x n - the unit matrix and assume that (I-A) is non-singular, then the inoperability vector x can be determined using the following matrix operation:

$$x = (I - A)\text{-}1c \tag{13'}$$

Prior to the field investigations, following the steps to answer the above equation can help in gathering useful data and details about how the various infrastructures are connected and affected by each other:
It is important to set the right resolution level and border conditions for each infrastructure, since a system can be looked at at different resolution levels. This amount of detail used in the analysis needs to be in line with the accuracy of the data and the ability to track the analysis (including finding "input-output" relationships);
Figuring out how buildings are physically connected to each other. As a general rule, element aij=0 if there are no physical links between sites i and j. When looking for physical links between different infrastructures, physical boundary conditions are very important. If there are deterministic correlations between any infrastructures, these relationships should be found first. aji=1 means that if infrastructure i fails, it will definitely cause infrastructure j to fail as well. Also, aji=0.5 if the failure of infrastructure i will definitely cause the failure of one of the two subsystems of infrastructure j, which performs 50% of the functions of infrastructure i, then aji=0.5. If the correlation between two infrastructures (like infrastructures i and j) is random, then all possible outcomes must be looked at and a statistical average must be calculated to get aij and aji. (For instance, if infrastructure i fails, infrastructure j is likely to fail completely 0.3 times and become 50% unusable 0.7 times, then aji=0.3x1.0+0.7x0.5=0.65). If the real data aren't enough, a simulation might help you get data for chance distributions.

Development of the dynamic "input-output" risk model of inoperability

The classical Leontief dynamic input-output model has the following form [Miller and Blair, 1985]:

$$\boldsymbol{x}(t) = A\boldsymbol{x}(t) + \boldsymbol{c}(t) + B\dot{\boldsymbol{x}}(t) \tag{14}$$

where: A is the interdependence matrix, c(t) is the final demand vector at time t, x(t) is the industrial output at time t, B is the square matrix of the traditional capital ratio
This model shows how ready the economy is to invest. Blanc [2003] says that, in order for the system to be stable, B must be negative. Also, the negative B-matrix is the only way for the dynamic model to behave in a way that is consistent with the static model, no matter what the starting conditions and ending demands are. Blanc looks into a special case when B = -1 in the equation above.

$$\mathrm{K} = \begin{bmatrix} k_1 & & \\ & \dots & \\ & & k_n \end{bmatrix} = Diag[k_1 \quad \dots \quad k_n] \tag{15}$$

So, K = -B-1 and for ∀i∈{1,2,…n}, ki=-1/bi, where bi is the diagonal element of matrix B, then the equation of the classic Leontief dynamic input-output model, becomes:

$$\dot{\boldsymbol{x}}(t) = K(A\boldsymbol{x}(t) + \boldsymbol{c}(t) - x(t)) \tag{16}$$

having as discretized form:

$$\mathrm{x(k+1) - x(k) = K(Ax(k) + c(k) + x(k))} \tag{17}$$

Regional breakdown
Regional breakdown makes it possible to look more closely at how different parts of infrastructure in a region are connected [Santos 2003]. Miller et al. (1989) and Lahr et al. (2001) looked into whether it was a good idea to "lock" the "input-output" analysis into a certain region (i.e., a single regional "input-output" framework instead of a more general, i.e., multi-regional framework), since feedbacks between regions are usually "small." It's the American approach's multiple regional "input-output" system that makes multipliers available for different regions in the US. Tests show that regional multipliers can be used instead of expensive and time-consuming surveys without lowering their accuracy [Brucker et al. 1990]. Analysts can, in fact, change and adapt national data to fit the area they are interested in. For instance, Isard [1960] and Miller and Blair [1985] use the following ratio to describe a simple location indicator (Ii): $I_i = \frac{\hat{x}_i^R/\hat{x}_S^R}{\hat{x}_i/\hat{x}_s}$ (18)

where: $\hat{x}_i^R$ is the regional output for the ith industry, $\hat{x}_S^R$ is the total regional output for all industries at the regional level, $\hat{x}_i$ is the national output for the i^{th} industry, i^{th}, $\hat{x}_s$ is the total national output for all industries at the national level.
The matrix of the regional technical coefficient AR for each individual industry, whose elements are denoted by a_{ij}^R, is established as follows:

$$a_{ij}^{R} = \begin{cases} a_{ij}(l_i), pentru\ l_i < 1 \\ a_{ij}, \quad pentru\ l_i \geq 1 \end{cases} \tag{19}$$

When I is used to represent the vector of location coefficients and Σ is the unit vector, the above equation can be written in matrix form as follows:

$$A^{R} = diag[Min(I, \sum)]A \iff \{a_{ij}^{R} = Min(l_i, 1)a_{ij}\}, \forall \text{i,j} \tag{20}$$

At the national level, the derived form of the demand reduction inoperability "input-output" model is q= A*q+c*, and the regional model has a similar form, respectively:

qR= A*RqR + c*R (21)
The term A*R can be expressed in terms of AR regional technical coefficients using the following identity:

$$A^{*R} = \left[\left(diag(\hat{x}^{R})\right)^{-1} A^{R}(diag(\hat{x}^{R})\right] \tag{20'}$$

We can express the regional technical coefficient matrix in terms of the approved national matrix (A). The A*R matrix can be established on the basis of location quotients, national technical coefficients for each industry and the "planned" output of regional industries.

$$A^{*R} = [diag(\hat{x}^{R})]^{-1}[diag[Min(I, \Sigma)][A]diag(\hat{x}^{R})] \iff \left\{a_{ij}^{*R} = Min(I_i, 1)a_{ij}\left(\frac{\hat{x}_j^{R}}{\hat{x}_i^{R}}\right)\right\}, \forall i, j \tag{20''}$$

Location coefficients from "personal income data" and "wage data" are often used to divide the national Leontief technical coefficient matrix into regions. A location coefficient shows how well an industry's production ability meets the needs of the local area. Also, as an industry's location coefficient number gets closer to 1, the amount of that industry in the area of interest gets closer to the amount of that industry in the whole country.

Application example no. 1
As an example, the next part shows how the "input-out" risk model of inoperability works. One was coal mining, two was oil extraction, five was water transportation, six was air transportation, seven was communication services like the phone and telegraph, eight was electrical services, nine was water supply and sewage systems, ten was banks, eleven was tourist spots, and twelve was hospitals. As an example, the interdependence matrix (A) for these areas, which can be seen in the next table, was made by changing the "input-output" matrices.

Let's say that someone attacks the electricity service infrastructure (k=8), which shuts it down by 20% (c8=0.20). Also, let's say that the rest of vector c's elements are all zero, since electrical services were the only infrastructure that was hit.
We use the equation x = Ax + c, which is based on the information in the table below. This shows the vector (x) of inoperability after the attack, when the systems are linked together.
The basis for our "input-output" infrastructure inoperability risk model is made up of the chosen infrastructures, where xkj and ck are the input variables for infrastructure k and ¯xkj} is the output variable for infrastructure k. The main thing that defines the problem is the matrix A=¯akj} in the table below.

Interconnection matrix (A)

	j=1	j=2	j=3	j=4	j=5	j=6	j=7	j=8	j=9	j=10	j=11	j=12
i=1	0,1130	0,0826	0,2236	0,0667	0,0060	0,0118	0,0090	0,1204	0,0000	0,0644	0,0370	0,0000
i=2	0,0000	0,0618	0,0026	0,0050	0,0010	0,0003	0,0015	0,0120	0,0000	0,0134	0,0036	0,0000
i=3	0,0000	0,0308	0,0617	0,0020	0,0002	0,0019	0,0010	0,0013	0,0000	0,0252	0,0067	0,0000
i=4	0,0000	0,0385	0,0025	0,1569	0,0003	0,0021	0,0148	0,0050	0,0000	0,0112	0,0080	0,0000
i=5	0,0002	0,0848	0,0020	0,0169	0,1247	0,0066	0,0046	0,0170	0,0000	0,1203	0,0151	0,0020
i=6	0,0000	0,1307	0,0014	0,0047	0,0006	0,0614	0,0245	0,0050	0,0000	0,0185	0,0576	0,0000
i=7	0,0000	0,0006	0,0001	0,0012	0,0000	0,0016	0,1236	0,0030	0,0000	0,0137	0,0055	0,0000
i=8	0,0144	0,0093	0,0338	0,0035	0,0008	0,0012	0,0018	0,0001	0,0000	0,0194	0,0046	0,0000
i=9	0,0000	0,1635	0,0313	0,4487	0,0000	0,0455	1,0060	0,7701	0,0000	0,8386	0,2021	0,0006
i=10	0,0000	0,0005	0,0001	0,0064	0,0000	0,0013	0,0062	0,0033	0,0000	0,0474	0,0038	0,0000
i=11	0,0000	0,0011	0,0008	0,0054	0,0000	0,0010	0,0023	0,0118	0,0000	0,0074	0,0150	0,0000
i=12	0,0000	0,0015	0,0009	0,0040	0,0000	0,0014	0,0047	0,0058	0,0000	0,0040	0,0168	0,0000

Inoperability results of the analysed infrastructure elements

Infrastructure, i	j=1	j=2	j=3	j=4	j=5	j=6	j=7	j=8	j=9	j=10	j=11	j=12
Inoperability, x_i	0,0279	0,0026	0,0004	0,0014	0,0044	0,0016	0,0007	0,2005	0,1574	0,0007	0,0024	0,0012

There is total security in a system when all of its parts work perfectly (xk=0 for all infrastructure elements and ~xk=0). This is called a basic state of functional/operational equilibrium.
This is what is asked during the risk assessment process: "What could go wrong?" How likely is it that something bad will happen? and What will happen as a result? The year 1981 by Kaplan and Garrick. To use these questions to look at the risks that come with a system of linked infrastructures, you need to define and fully understand the "So" element, which is the system's planned scenario. Anything that is different from So is a risk scenario (Si), which could make this method less useful. Hierarchical hologram modeling [Haimes, 1981, 1998] and scenario structuring theory [Kaplan, 1997] are good ways to figure out the So and Sis for a certain system when doing a risk assessment. Using both approaches together, as explained by Kaplan et al. [2001], creates a risk assessment framework for finding the many Sis that can hurt a system's S0 in a structured way.
So far, the way that investigations are done for "disruptions," which are events that make a system less useful, is in line with the risk assessment framework that was already stated. On the other hand, in the case of the 12 infrastructures, we especially look at a situation where the electrical system functionality of the infrastructure drops by 20%

(i.e. ck=0.2). We miss the important step that is needed to quantify this perturbation (c) when we do this. To follow the "input-output" risk model for assessing the risk of infrastructure not working, it should be necessary to first identify system risk situations before making specific cks. As an example, a bombing could cause a 0.2 (or 20%) drop in the ability of infrastructure to function k*. I think that c is a possible outcome (or return) based on a risk scenario that was created using a detailed scenario structuring process and the right valuation technique. Then, the disturbance c that comes from a certain risk situation is fed into the more complex model. The perturbation magnitude is also made with the partitioned multiobjective risk method [Asbeck and Haimes 1984; Haimes, 1998]. Since disturbances don't always happen in the same way, a distribution might be better than point values. One type of risk, for instance, can make a system less useful by at least 1%, or even worse, by 50%. The partitioned multiobjective risk method lets you look at different "what ifs" based on how you think a risk scenario is likely to spread out, and conditional expectations can help you tell the difference between high-impact, high-probability events and high-impact, low-probability events, which are also called "extreme events."

Application example no. 2

I'd like to solve the following problem to show how the Leontief equation can be used: Let's say we have a machine with two parts [Jiang, 2003]. The factors x1 and x2 show that these two subsystems can't work together. Let's say that if subsystem 2 fails, subsystem 1 will not work 80% of the time, and if subsystem 1 fails, subsystem 2 will not work 20% of the time. In this case, grid A looks like this:

$$A = \begin{pmatrix} 0 & 0{,}8 \\ 0{,}2 & 0 \end{pmatrix}$$

It's important to figure out if subsystem 2 can't work with subsystem 1 if subsystem 2 loses 60% of its usefulness because of an outside disturbance, like a terrorist attack on subway systems. When we put the matrix A into the Leontief equation, we get:

$$\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \begin{pmatrix} 0 & 0{,}8 \\ 0{,}2 & 0 \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + \begin{pmatrix} 0 \\ 0{,}6 \end{pmatrix} = \begin{pmatrix} 0{,}8x_2 \\ 0{,}2x_1 + 0{,}6 \end{pmatrix}$$

We get x1=0.571 and x2=0.714 when we solve the problem. This means that subset 1 is not usable, even if it wasn't directly attacked by terrorists. This kind of failure is only caused by how the two parts are linked to each other. The fact that subsite 2 is linked to subsite 1 makes it 0.114 times less useful.

We can also figure out what would happen to the machine if it was attacked with different levels of force. Let's say the attack is h times as strong as 100%. This means that subsystem 2 can't work at all because of the attack alone. This is the Leontief equation:

$$\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \begin{pmatrix} 0 & 0{,}8 \\ 0{,}2 & 0 \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + \begin{pmatrix} 0 \\ h \end{pmatrix} = \begin{pmatrix} 0{,}8x_2 \\ 0{,}2x_1 + h \end{pmatrix}$$

For h < 0.84, the answer is x1=0.952h and x2=1.190h. For h > 0.84, the answer is x1=0.8 and x2=1.0. Keep in mind that subset 2 doesn't work at all when the outside attack makes it 84% less useful, because $0 \leq x1$ and $x2 \leq 1$. The last 16% is taken away because it depends on subsystem 1.

Application example no. 3
This is the expression for the matrix A that goes with a system that has four subsystems: Subsystem 1 is a power plant; Subsystem 2 is a system of underground transportation infrastructure (tunnels, roads, signs, signalling installations, etc.); Subsystem 3 is a hospital; and Subsystem 4 is a grocery store.

$$A = \begin{pmatrix} 0{,}0 & 0{,}9 & 0{,}0 & 0{,}0 \\ 0{,}4 & 0{,}0 & 0{,}0 & 0{,}0 \\ 1{,}0 & 0{,}8 & 0{,}0 & 0{,}0 \\ 1{,}0 & 0{,}9 & 0{,}0 & 0{,}0 \end{pmatrix}$$

In this case, matrix A can be understood as follows: if the power plant goes down totally, the transportation system can only do 60% of what it's supposed to do, and the hospital and grocery store can't work at all. If the transportation system stops working totally, it will be impossible for workers to get to work and for trucks to deliver packages. Then the grocery store, power plant, and hospital can only do 10% and 20% of their full jobs, respectively. If the hospital or food store isn't working, on the other hand, it doesn't affect the plant or the transportation system. In fact, they don't really affect each other either. Say a big natural disaster (like an earthquake) or terrorist attack (like the use of dangerous and/or explosive materials) happens in the area and breaks down half of the transportation system. Many people can't get to work because of this disaster; traffic is also backed up, and delivery trucks can't get there on time. We have the following Leontief equation for the given matrix A:

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{pmatrix} = \begin{pmatrix} 0{,}0 & 0{,}9 & 0{,}0 & 0{,}0 \\ 0{,}4 & 0{,}0 & 0{,}0 & 0{,}0 \\ 1{,}0 & 0{,}8 & 0{,}0 & 0{,}0 \\ 1{,}0 & 0{,}9 & 0{,}0 & 0{,}0 \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{pmatrix} + \begin{pmatrix} 0{,}0 \\ 0{,}5 \\ 0{,}0 \\ 0{,}0 \end{pmatrix}$$

The answer is (x1, x2, x3, x4)=(0.70 0.78 1.00 1.00). So, the power plant loses 78% of its functionality, the transportation system loses 70% of its functionality, and the hospital and food store can't work at all because of the damage from the earthquake or terrorist attack.
As with the last case, we can also figure out how a system would work if it was attacked by an earthquake or a terrorist act of different levels of severity. Assuming that the attack is h times as strong as the transportation system, then the earthquake or terrorist attack alone makes the transportation system h times less useful. When you solve the Leontief equation, you get:

$$(x1,x2,x3,x4) = (1{,}41h \;\; 1{,}56h \;\; 2{,}66h \;\; 2{,}80h), \text{ for } 0 \leq h \leq 0{,}357$$

When h is equal to 0.357, x4's value equals 1. If you raise h to 0.376, the number of x3 will equal 1. This means that when the attack on the transmission system is 0.376, the power plant can't work for 0.53 seconds and the transmission system can't work for 0.59

seconds because of the direct attack and the power plant not being able to work together. Right now, neither the food store nor the hospital can be reached because neither the transportation system nor the power plant can work. When h gets to 0.641, x2 turns into 1, which means the whole transportation system stops working.

4. CONCLUSIONS

In the chapter, I talked about how creating a meaningful model that can capture the complex essence of how our critical infrastructures are connected and work within each other is, from every angle, a hard job that needs the help of many people from different fields. The Leontief equation-based infrastructure input-output model helps with the big work that needs to be done to better understand these dependencies and then better and more cost-effectively handle the terrorist threats and risks that key infrastructures face today. So, this model is another important part of a larger risk assessment and management framework that we need to keep our complex vital infrastructures safe and running.

Along these lines, we came up with a theory based on Leontief's input-output model to look into how input and interconnection can make a system with many parts (subsystems) not work together.

-We also talked about a way to use linearization approximation in different situations. As a first-order approximation of an extended model, we came up with the generic model based on the Leontief equation. We also looked at how the risk of not being able to work changed over time using a dynamic model based on the Leontief equation. In reality, there are three things that need extra attention before the model is used to solve complex problems. First, we need to define the inoperability for each of the subsystems so that the essence of the problem is captured and the characteristics of all subsystems that are important to the problem's goals are properly and effectively represented. Second, we need to make sure that the idea of linearization is correct. If the situation suggests that nonlinearity is the case, we must start with the Leontief equation and focus on the underlying relationships (dedicated mathematical functions), looking at the system's structure and links in more detail. The last thing I want to say is that matrix calculus is very important for both asking questions and finding answers. Figuring out the parts of any of these matrices could be very hard and require a lot of data mining and collection.

Researchers are interested in how well Leontief input-output models can be used to study how critical infrastructures depend on and are connected to each other. This is both an opportunity and a challenge for those who are responsible for making sure these infrastructures keep running. In this case, the Leontief equation-based input-output infrastructure model(s) are meant to be used for at least two things: The main purpose is to help us understand how impacts affect the continued and sustained operability of our critical infrastructures in all possible situations. The secondary purpose is to help us decide how to use our resources for a better risk assessment and management process. Specifically, the best way to make our vital infrastructures safer, more reliable, and more secure is to use a multi-objective risk management framework that looks at all the costs, benefits, and risks in a systemic way.

It will be hard to reach both goals until the necessary theoretical foundations, methodological tools, and an adequate, essential, and vast database are further developed. Many countries, including the US, have been able to make and use Leontief input-output models that work well for their economies. Their success in collecting similar amounts of data (for thousands of coefficients in the Leontief model) should give us hope and support as we work to make sure our complex critical infrastructures work.

REFERENCES

[1] Haimes Y.Y., 2002, Roadmap for modelling risks of terrorism to the homeland, Journal of Infrastructure Systems, 8(2), 35-41.
[2] Wolf et al., 2003, Strategic responses to risks of terrorism, Risk Analysis 23(3), 429-444.
[3] Arquila J., Ronfeldt D., 2001, Networks and Netwars, National Defence Research Institute, RAND, Pittsburgh, PA.
[4] Carter A., B., 2001-02, The architecture of government in the face of terrorism, *International Security* 23(3), 5-23.
[5] Pate-Cornell E., 2002, Fusion of intelligence information: A Bayesian approach, Risk Analysis 22(3), 445-454.
[6] Gnedenko B., V., 1963, The theory of probability translated from the Russian by B., D., Seckler, Chealsea Publishing, New York.
[7] Lowrance W., W., 1976, Of Acceptable Risk, Wiliam Kaufman, Los Altos, CA.
[8] Leontief W., W., 1951a, Input/Output economics, Scientific American 185(4).
[9] Leontief W., W., 1951b, The Structure of the American Economy, 1919-1939, 2nd, ed. Oxford University Press, New York.
[10] Intriligator M., D., 1971, Mathematical Optimization and Economic Theory, Prentice Hall, Englewood Cliffs, NJ.
[11] Haimes Y.Y., Jiang P., 2001, Leotief – based model of risk in complex interconnected infrastructures, Journal of Infrastructure Systems 7(1), 1-12.
[12] Kaplan S., Garrick B., J., On the quantitative definition of risk, Risk Analysis 1(1), 11-27.

SIMPLIFIED METHOD FOR RISK ASSESSMENT IN ONE-WAY ROAD TUNNELS FOR THE TRANSPORT OF DANGEROUS GOODS BY ROAD

VLAD LĂUTARU [1], DENISA TUDOR[2], CLAUDIUS POPESCU[3], CIPRIAN MATEIU[4], CARLA ENACHE [5]

Abstract: *In this work, a simplified method for risk assessment in one-way road tunnels for road transport of dangerous goods was documented. The transport of dangerous goods will continue to increase with the growth of the European Economic Areas together. For all modes of transport, but especially on the road, those dangerous goods transport operations that may pose an additional risk to the road users themselves, but also to the immediate environment (nature and population) will continue to grow. For this reason, appropriate risk analyses must be drawn up for the transport of dangerous goods by road to make it possible to assess these risks. All types of transport of dangerous goods by road are subject to ADR regulations. The objective of these regulations is to ensure safe transport and to minimise the risk of accidents involving injury to persons or the environment by applying technical and organisational rules. In this regard, in order to reduce the level of risk, the authorities could allow dangerous goods vehicles to transit through the tunnel at night and/or under escort, or an alternative route running completely in the open could be tested. The free movement of goods on European roads is a crucial factor in the development of markets in European countries, and the volume of goods transported on European roads is continually increasing [1]. To give a quantitative perspective, around 39 million goods vehicles were estimated to be on EU-28 roads at the end of 2013, with a rate of 77.8 goods vehicles per 1000 inhabitants. Among goods vehicles, dangerous goods vehicles are of relevant importance for safety both on roads and inside tunnels. Their circulation has been governed since 1957 by the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) [2]. In the light of this agreement, each contracting party may apply restrictions to the passage of vehicles carrying dangerous goods through tunnels. This is done by assigning a specific category to each tunnel: from A (no restriction) to E (all dangerous goods are prohibited). The tunnel category, which is based on the consideration that serious accidents in tunnels can be caused by explosion,*

[1] *National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petrosani, Department of Industrial Safety, G-ral V. Milea Street 32-34, Petrosani, Romania, vlad.lautaru@insemex.ro*
[2] *University of Petrosani, Universitatii Street 20, Petrosani, Romania, deni_t.2301@yahoo.com*
[3] *University of Petrosani, Doctoral School, Universitatii Street 20, Petrosani, Romania, claudiusandrei@yahoo.com*
[4] *University of Petrosani, Doctoral School, Universitatii Street 20, Petrosani, Romania, cipri_mci@yahoo.com*
[5] *University of Petrosani, Doctoral School, Universitatii Street 20, Petrosani, Romania, carla.enache91@yahoo.com*

release of toxic gas (or volatile toxic liquid) and fire, must be made by each competent authority in the country. However, many countries (e.g. including Italy) have difficulties in applying these restrictions due to geographical features, political and/or social implications, as well as problems of tunnel management on border roads. Therefore, in the absence of a specified category, a tunnel should be considered free for transit and dangerous goods vehicles. This means that legal responsibility for their circulation is assigned to the Tunnel Management Agency. For this reason, the relevant authorities need tools to make more appropriate decisions on restricting or prohibiting the passage of these vehicles through a tunnel.
In this regard, a quantitative risk analysis (QRA) carried out under the requirements of Directive 54/EC [4] published in 2004 (after the catastrophic tunnel fires that occurred in the early 2000s) was considered appropriate. In this Directive, for the purpose of identifying European safety standards for road tunnels, minimum safety requirements are reported and, in addition, it is stated when tunnels are open for dangerous goods that a risk analysis should be carried out to determine whether additional safety is required. measures should be implemented. Most risk analyses are based on an average value of the percentage of vehicles carrying dangerous goods. Indeed, the flow of dangerous goods is not constant, but may vary depending on the type of road containing the investigated tunnel, or peaks of dangerous goods volumes could be expected during the day. Therefore, in some cases, performing a tunnel risk analysis based only on the average value of vehicles carrying dangerous goods may not be justified. Given the above considerations, taking into account the variability of their traffic flow is within the scope of this chapter section.

Keywords: *risk analysis/assessment/management, simplified method, one-way road tunnels, transport of dangerous goods, modelling the consequences*

1. GENERAL INFORMATION ON RISK ASSESSMENT SPECIFIC TO THE TRANSPORT OF DANGEROUS GOODS BY ROAD

The transport of dangerous goods will continue to increase with the growth of the European Economic Areas as a whole. For all modes of transport, but especially on the road, those dangerous goods transport operations that may pose an additional risk to road users themselves, but also to the immediate environment (nature and population), will continue to increase. For this reason, appropriate risk analyses must be drawn up for the transport of dangerous goods by road to make it possible to assess these risks.

All types of transport of dangerous goods by road are subject to ADR regulations. The objective of these regulations is to ensure safe transport and minimise the risk of accidents involving injury to persons or the environment by applying general technical and organisational rules for the packaging, transport and handling of dangerous goods.

In addition to these safety regulations, the competent authorities of the Member States are allowed to apply certain additional provisions on their territory in the case of particular risks in certain locations. The relevant regulations can be found in Chapter 1.9, "Transport restrictions imposed by competent authorities". Due, among other things, to major accidents in Alpine tunnels in 1999 (Montblanc, Tauern) and 2001 (Gotthard) - which, incidentally, were not caused by the transport of dangerous goods - concern in some EU Member States about the transport of dangerous goods in trans-European networks has increased, particularly with regard to the transport of dangerous goods through road tunnels [15].

First, more detailed information on the scope outside tunnels and relevant requirements has been set out in Chapter 1.9.3 ADR: (a) Additional provisions or restrictions in the interests of safety for special structures such as bridges, combined transport or transhipment facilities; (b) Provisions for areas with special local risks (e.g. residential areas); (c) Special provisions for routes to be taken or for stopping and parking in special situations (extreme natural phenomena, disturbances, etc.); (d) Restrictions for the transport of dangerous goods on certain working days.

In all the above cases, unlike rail transport, it is not necessary for the competent authority to provide special evidence for the necessity of the measure. However, Chapter 1.9.4 states that measures according to 1.9.3 (a) and (d) must be notified to all ADR Contracting Parties.

Special attention is paid to road tunnels, especially considering that in the case of accidents involving dangerous goods in tunnel structures serious consequences (loss of life, traffic congestion, diversion through higher risk diversions, etc.) are to be expected. This is why in Chapter 1.9.5 ADR so-called "tunnel restrictions" are mentioned based on the assumption that three main risks emanate from dangerous goods and they are: Explosions; Release of toxic gases or volatile toxic liquids; Fires.

In addition, 5 tunnel categories A - E are defined with increasing restrictions, and if possible, the necessary classification should be carried out on the basis of risk analyses. This guide, however, does not deal with risk assessment in road tunnels; Directive 2004/54/EC of 29 April 2004 [15] already contains separate definitions in this respect. The subject of this guide is rather the scope of transport restrictions according to 1.9.3 (a), (b) and (d) of the ADR.

The objective of this chapter is to outline a more uniform approach to risk assessment for the transport of dangerous goods by road in ADR Contracting Parties and consequently to make individual risk assessments comparable.

As a result of the ADR regulations a high level of intrinsic safety has generally been achieved. However, ADR cannot guarantee absolute safety. A certain level of risk will always remain and therefore several European countries have already adopted their own assessment models for calculating risk, together with their own risk acceptance criteria. These methods and criteria are typically derived from national implementations of Council Directive 96/82/EC on the control of major-accident hazards involving dangerous substances (SEVESO II Directive, [16]), which excludes certain areas such as the transport of dangerous goods and off-site intermediate storage.

Examples of additional national regulations and standard methods for risk assessment and control related to the transport of dangerous goods by road are either very general compared to rail transport or deal with very specific questions, e.g. with collisions of road vehicles with structural parts of structures [17], with the transport of dangerous goods through tunnel structures [17] or with specific road sections [18].

Currently, there is no harmonised guide for risk assessment in the transport of dangerous goods by road. There is only a basic structure for road tunnels in the form of Directive 2004/54/EC [15], which however does not stipulate an explicit methodology for risk assessment.

Dealing with risk first requires defining technical terms to ensure a common understanding of the process. The use of terms is based on ISO/IEC Guide 73

"Vocabulary - Guidance for use in standards" [18] and ISO/IEC Guide 51 "Safety aspects - Guidance for inclusion in standards" [1], which apply to safety standards. In general, risks can be of a different nature, e.g. political, financial, technical or medical, positive or negative. In the context of this chapter, risk is only a transport safety issue and therefore the more specific safety definitions of risk-related terms in ISO/IEC Guide 51 are preferred. ISO/IEC Guide 73 is used to complement the list of definitions for risk management. Comments on the original Guide 51 and Guide 73 definitions are shown in brackets respectively:

-Risk: The combination of the probability (between 0 and 1) of injury occurring and the severity of injury ("combination" usually means "product", while additional factors such as risk aversion are part of the risk assessment process);

-Damage: physical injury or damage to human health or damage to property or the environment;

-Risk assessment: the general process of risk analysis and evaluation;

-Risk analysis: Systematic evaluation of available information to identify hazards (potential sources of harm) and to estimate risk;

-Risk estimation: Process used to assign values to the probability and consequences of a risk;

-Risk assessment: Process based on risk analysis to determine whether tolerable risk has been achieved;

-Risk criteria: Benchmarks by which the significance of risk is assessed;

-Risk treatment: The application of measures adopted to reduce risk;

-Risk management: The overall process of risk assessment, decision making, risk treatment and risk control;

-Decision criteria include in particular the treatment of risk and include social, economic and/or political risks and considerations (additional definition not part of ISO/IEC Guides 51 or 73);

-Decision: Selection process for risk treatment measures based on the decision criteria (additional definition not part of ISO/IEC Guides 51 or 73);

-Tolerable risk: Risk that is accepted in the decision phase on the basis of the decision criteria and which, in a given context, embraces in particular justifiable societal ideals;

The risk assessment process is based on risk criteria that have not yet been internationally standardised. Existing risk assessment criteria that have been developed in a national consensus relate to the risk assessment process ensuring its comprehensibility. In this respect, at least the following definitions are required for risk assessment:

-Individual risk: the risk that a person will suffer harm (also called "place-related risk", depends on location, the definition is not part of ISO/IEC Guides 51 or 73);

-Societal risk: Risk that all potentially involved persons will be harmed (probability density function (PDF) of individual risks or integral of this PDF, definition not part of ISO/IEC Guides 51 or 73);

-External risk: risk of injury to persons not involved in the transport or risk of injury to property not part of the transport system or infrastructure (also called "third party risk", unlike internal risk, definition is not part of ISO/IEC Guides 51 or 73);

-Perception of risk: How a stakeholder views a risk, taking into account their concerns;

-Stakeholder: any individual, group or organisation that may produce a risk or may be affected by a risk or perceive themselves to be affected by a risk. Note: the decision-maker is also a stakeholder;

-Risk aversion: additional factor for risk assessment to take into account a more negative perception of events with high potential for harm or events occurring beyond the influence of human beings or events with unknown risk etc. (see comment below, definition not part of ISO/IEC Guides 51 or 73).

It should be noted that using the definition of risk simply as a product of probability and harm can result in the same risk value from a high probability - low harm event as from a low probability - high harm event, although the perception of risk may be different. In order to take into account the different types of risk perception, an additional factor called "risk aversion" is used to assess risk, and depending on the risk perception, the risk assessment may also be limited to external risk;

-Quantification of risk: The application of the additional provisions according to Chapter 1.9.3 ADR is not linked to an obligation on the competent authority to provide evidence of the need for measures (unlike RID). In individual cases, however, it may be useful to provide information on the level of risk related to a particular transport route.

This relates, for example, to the selection of alternative routes in case of route restrictions, respectively:

1. Where no comparable alternative route is available, any restriction or measure required should be justified in accordance with the principle set out in the guidelines for quantitative risk assessment with reference to a tolerable risk level used in the Member State (which may be used at national level), the ALARA and ALARP principles, the stand-still principle (JOC) or the risk or decision criteria);
2. Where alternative routes are used, the risk analysis should justify why this route is considered to be more favourable in terms of risk, for example: a) usually on the basis of a qualitative comparison between routes if it is clear that the proposed restrictions lead to a significant improvement in safety; b) in other cases on the basis of a quantitative comparison of the risks inherent in the alternative routes.

- -Dividing risk assessment processes: The risk assessment process is divided into two different parts. The first part is the risk analysis which is necessary to quantify a particular risk related to the scopes outlined in chapter 1.9.3 (a), (b) and (d), which should be as objective and accurate as reasonably and practicable. This "scientific" part (risk analysis) is followed by an assessment of the calculated risk level, whereby if the risk level is below the tolerable risk level, the risk management process requires no further action, otherwise the decision making process and risk treatment must be implemented.
- -Uncertainty analysis: Risk analysis is always related to uncertainties of different origin. In order to use risk analysis as a basis for a risk assessment, the derivation (or at least estimation) of uncertainty levels requires particular attention. Uncertainty levels are of minor importance in cases where an analysed (estimated) risk is well below the tolerable risk level, provided that they remain

low compared to the tolerability margin. In cases where an uncertainty range substantially covers more than one area of the risk classification (e.g. tolerable/unacceptable), the recommendation is either to further reduce the uncertainty level of the analysis as far as reasonably achievable or to justify the appropriateness of the measures with particular attention to the uncertainty levels that have been established.

- -Risk comparison: in comparing the risks presented by two alternative routes based on an estimation tool, the uncertainty of the tool becomes less significant. What is more important in this case is to be able to estimate whether there is a significant advantage in using one or the other route, rather than to determine an absolute value of the level of risk. In this case, the risk estimation tool can contain only those elements of the estimate that have a low level of uncertainty and are relevant for estimating the risks of the routes in question. The other risk estimation parameters, especially those with too much uncertainty, should then be taken into account in the risk criteria that are not estimated by the tool participating in the risk management decision to be taken.
- -Required information: the documentation of a risk assessment must contain information on all work processes, either explicitly or as references to documents that are public or available on request. Transparent and detailed documentation of the risk assessment process is a basic prerequisite for understandable risk documentation.

Technical aspects of risk analysis

The outcome of the risk analysis part of the risk assessment process is information on the individual or societal risk of the transport situation under consideration. The risk analysis should derive the probabilities of accident scenarios and the potential consequences related to these accident scenarios. Therefore, the following sections cover the major aspects of scenario definition, statistical analysis and consequence analysis.

In order to understand the large number of potential accident scenarios, the first step of the risk analysis is to reduce the scenarios to a reasonable number of basic scenarios, including a grouping of hazardous substances.

All compounds or substances have their own pattern of chemical and physical properties (flammable, explosive, reactivity with other substances, toxic, radioactive, state of aggregation, etc.). Although the effect of a dangerous good is primarily the property of the material itself, circumstances also influence the effect that is experienced (e.g. temperature). To avoid the problem of describing thousands of compounds, a rigorous grouping is recommended. Both class (ADR) and hazard identification number (HIN) are suitable for classification and grouping.

A grouping of main substances that is too approximate should be avoided in order to reduce the uncertainty of the risk analysis and to ensure a reliable basis for risk assessment. In addition, the grouping of substances should take into account the potential sequence of events in an accident scenario, including consequences that may depend on additional parameters and circumstances. A coupled classification of scenarios and substances is therefore recommended.

The structure that is most suitable for the classification of accident scenarios and also for the calculation of risk itself is the event tree concept which is developed on the basis of a causal tree specifying the frequency of primary events in a systematic dimension comprising the basic elements: event, discharge location, quantity discharged, etc. Such a structure simplifies the calculation due to a clear overview and indicates the gradual process in the quantitative composition of the calculation. Figure 1 shows an example of an event tree. In order to optimise the classification of an accident scenario by event tree analysis, the absolute frequencies of all scenarios should also be considered, with emphasis on aspects related to the event tree structure and the derivation of quantitative values for conditional probabilities.

The risk analysis should also include the influence of the emergency services that in some cases the actual consequences of an accident, e.g. number of fatalities, are less severe due to the rapid and efficient intervention of the emergency services. Two examples are the prevention of a hot "BLEVE" (in a threatening domino scenario) and the well-organised evacuation of an area where a toxic gas has been released. Therefore, an assessment of the preparedness of emergency services is a parameter in the analysis of accident scenarios.

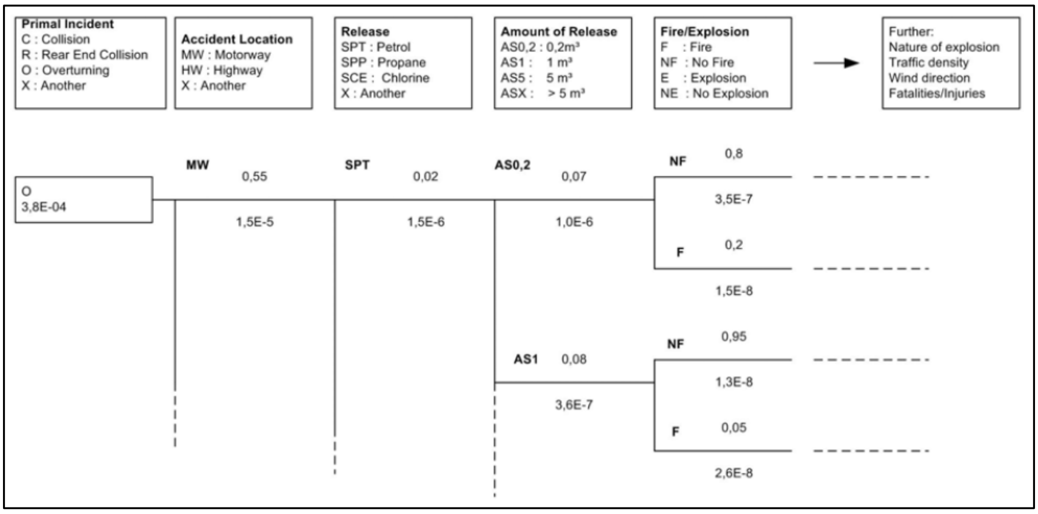


Fig.1.-Example of an event shaft section for a road tanker for flammable liquids

The following aspects need to be taken into account in event tree analyses for the transport of dangerous goods (either for scenario definition or for the risk analysis itself):

- Vehicles and traffic: Data on goods and vehicles must be collected to obtain information on potential branching in the event tree and on the probability of events and scenarios, respectively: Types of goods transported; Types of vehicles and tanks; Specific safety measures and transport time (day/night);
- -Road network: It is obvious that infrastructure must be considered in a risk analysis, despite the fact that the analysis focuses primarily on the vehicle and transport. The infrastructure includes the entire "system road network",

including intersections with other modes of transport (railway crossings, tunnels, bridges, safety installations, pipelines, etc.). Therefore, it is recommended to include an examination of the infrastructure and indicate the risk contributions. In this context, reference should be made to the special treatment of passages through tunnels in chapter 1.9.5. ADR. The information requested also includes: Type of road (open area, level section, road slope, population density of residential areas, bridge, one-way traffic, opposite traffic, etc.); Speed Limit; Safety installations (eg barrier barriers, traffic lights, overpasses); Tunnel passages; Railroad crossings.

- -Primary event: For a risk assessment in the context of ADR Chapter 1.9.3 only major accidents (and incidents with the potential to become major accidents) are considered. In this sense, the relevant scenarios are: Collision; Rear collision; Overturning; Collision with other objects (deer crossing, railway crossings); Fire (similarly to an explosion or toxic release, a fire must also be considered as a potential aftereffect of other primary events); Sudden tank failure. In a specific connection, influences such as vandalism, terrorism, storms, earthquakes and floods can also be significant, according to ADR 1.9.3 c. Most of these scenarios do not require further explanation. For example, the sudden tank failure scenario incorporates a variety of incidents with the sudden release of tank contents due to overpressure after breaching filling regulations or due to corrosion, embrittlement or fatigue of the tank material, etc.

Statistical data

For each type or scenario, an overall accident frequency based on the frequency of the initial event and the conditional probabilities of the failure shaft branches should be determined primarily from the corresponding national case histories. This task requires a large amount of accident data to cover all scenario branches even when the number of scenarios is already reduced by appropriate clustering. In order to obtain statistically significant information on conditional frequencies and probabilities, the requirements increase further in terms of number of accidents.

The number of dangerous goods transport accidents is quite low, which is positive for the human and environmental component, but limits the statistical significance of accident frequencies and conditional probabilities within the event tree branches. Therefore, when obtaining statistical data for the purpose of risk analysis, it is highly recommended to consider the following data: information from international accident databases and general freight transport accident data.

The applicability of these statistics to the individual dangerous goods transport scenario needs to be verified, based on the rationale of the assumptions established for their use.

Harmonisation of accident investigation and reporting through ADR section 1.8.5 will improve the basis for international accident statistics and detailed accident sequence analysis in the future. Systematic differences between national accident statistics due to differences in roads, vehicles, cargo quantity, minimum thresholds for defining accidents and other parameters should be taken into account. Particular attention should be paid to long-term trends in accident statistics due to improved safety levels.

Physical, numerical or statistical analyses of package performance under impact conditions can also serve as appropriate sources of information on the conditional probabilities of the event tree. Expert estimates should be avoided as far as possible in order to achieve an objective and reliable database for risk analysis and to ensure transparency of quality control.

Other data needed for statistical analysis of accident data are differentiated transport kilometres per year, commodity, route type, etc., in order to derive frequencies for each accident scenario. Information on the number of persons injured or killed with similar differentiation is needed to estimate the risk level of the whole transport of dangerous goods and to check the plausibility of the risk estimate for a specific location.

Modelling the consequences of the accident

The event tree shown in Figure 1 ends with the spillage and, if applicable, the burning of the main substance gasoline. For the determination of injury (e.g. fatalities and injuries), it is necessary to further trace the potential branching of the event tree. Factors affecting the conditional probability of a particular sequence of events following a hazardous substance spill depend on the accident site and its surroundings.

Relevant information thus includes: Population density in the area around the transport route (by time of day); Traffic density and likelihood of congestion (by season and time of day); Nature and use of surrounding buildings and other infrastructure; Accessibility of infrastructure to emergency services; Weather conditions (wind and temperature statistics); Topography.

Some parameters are only relevant for certain scenarios (e.g. wind statistics for toxic gas spills), while others are needed in all cases. Two geographical (topological) elements are crucial: firstly the distance to built-up areas, secondly the population densities in all parts of the immediate surroundings in a grid appropriate to the area of significant impact (e.g. 25 x 25 m to 100 x 100 m resolution).

The nature of the buildings is examined in order to estimate the protection against fire or explosion. Inventories of building types, including information on their use, are useful for calculating the presence of human beings (residential / industrial / commercial areas, schools, hospitals, etc.) In this respect, the relevant scenarios of impact on the human component and on the environment are: Explosion; Fire; Atmospheric dispersion of toxic substances; Water and soil contamination.

In order to deduce the consequences of the accident for each scenario, numerical or analytical models must initially be used to estimate the physical effects of each scenario (radiation, pressure, concentration of toxic substances, impact of waste). The models used for risk estimation should be checked in advance and compared with real scenarios or model benchmarks.

The degree of simplification inherent in physical models affects the validity and level of detail of the risk estimation process. Therefore, the choice of models and the number and quality of parameters to be included in the physical analysis should be kept consistent with the level of accuracy required for risk assessment. In general, the following types of injury or damage should be examined: Persons killed during or shortly after the accident; Persons injured; Damage to buildings and important structures; Environmental pollution related to the unloaded cargo.

As far as deaths and injuries are concerned, the damage to people must be estimated using statistical and physiological models based on estimated physical effects. These models assign figures for the probability of injury or death to physical effects such as, for example, exposure to radiation or toxic gases. There is still an unsatisfactory level of uncertainty in some of these models, depending on the type of consequences (e.g. probit functions for toxicity). Therefore, a considerable part of the level of uncertainty in risk analysis originates in the injury estimation.

The use of objective and transparent methods and the realistic inclusion of mitigation parameters such as evacuation or sheltering effects of buildings are indispensable for a proper risk analysis. The systematic use of pessimistic assumptions is counterproductive for a risk analysis, especially if it is carried out to establish an absolute level of risk to be compared with a fixed threshold. In the case of a comparative approach (using a particular instrument) this is less important, as more emphasis is put on the difference (gain) between one transport route and another. In all cases, consideration and discussion of uncertainty levels is part of the risk assessment process.

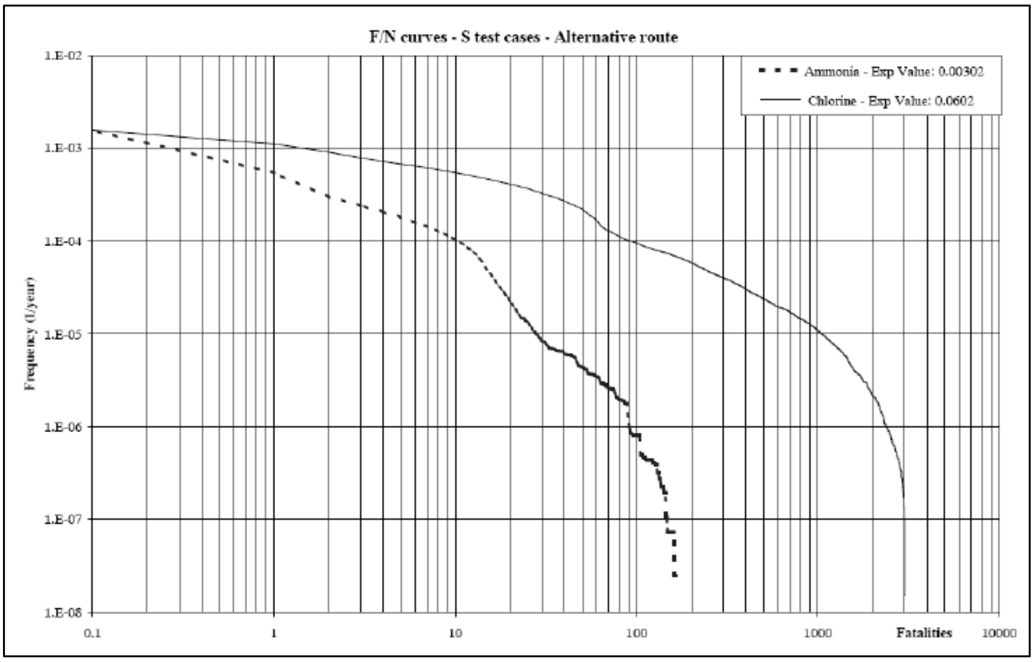


Fig.2.-Example of FN graph for the social risk of the main substances ammonia and chlorine for a road tunnel

Risk estimation

The risk estimation process includes the application of the event tree and physical and physiological models for the location under consideration. Calculated/estimated individual or societal risk values are assigned to all potential accident scenarios based on specific local data for dangerous goods transport capacity and route use. Following the simplified definition, risk is the product of injury and probability. However, presenting risk as a single probability of injury (e.g. probability of one death per year) is not common practice in risk analysis. Risk is normally considered as the likely frequency of injury (e.g. frequency of death), either in a spatial context or as a frequency distribution of the level of injury.

For systematic risk estimation, the transport route considered should be divided into different sections of standard length to make the risk values comparable with the risk criteria. A typical reference length for risk derivation (per year) is 100 m to 1 km.

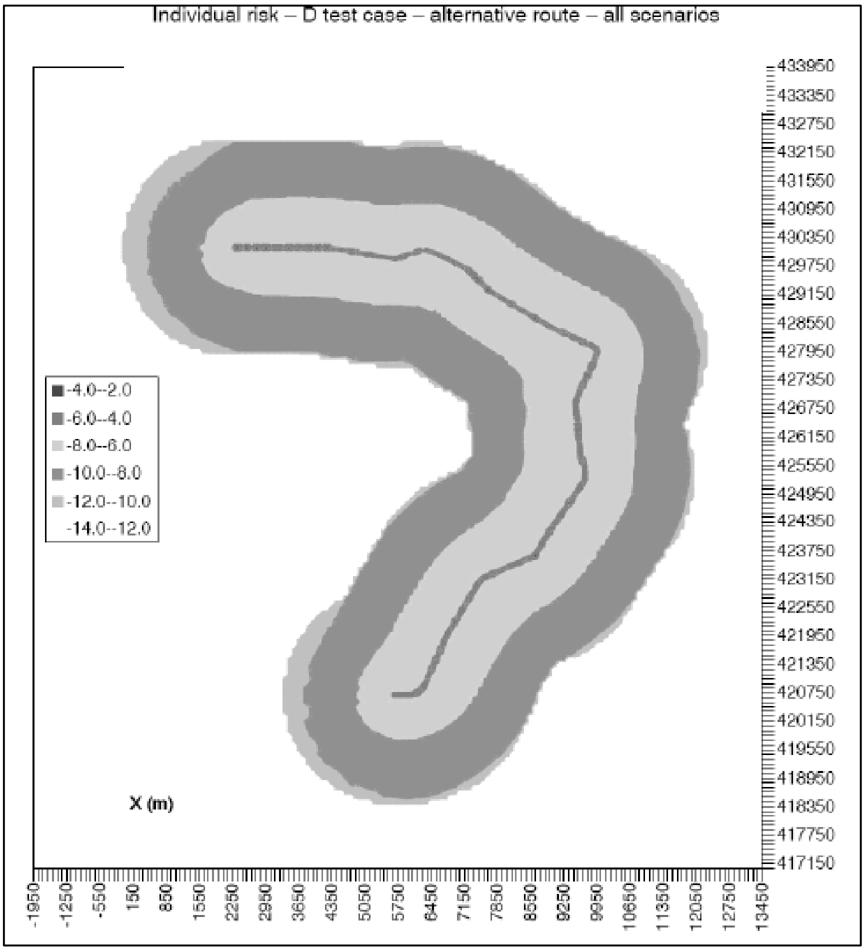


Fig.3.-Example of ISO risk graph of spatial distribution of individual risk (exponent for 10^n/year)

Risk assessment

At present, an ADR Contracting Party is free, under its national safety policy, to define target safety levels and to define measures in case of violation, as long as these provisions are not contrary to international regulations. So far, there is no uniform approach to risk assessment for the transport of dangerous goods.

Currently, ADR Contracting Parties also have different approaches to risk assessment at national level due to specific parameters. These differences relate to: the type of risk assessed (individual, societal, environmental); the level and form of acceptance and tolerability limits; acceptance and tolerability zones/categories.

Each type of risk needs a risk criterion to assess whether a risk is tolerable. These risk criteria should be checked for comparable types of risk (e.g. risks from industrial installations subject to the regulations of the SEVESO II Directive, [16]).

The ALARP (as low as reasonably achievable) principle applied in the UK defines an area of unacceptable risk which implies the need for risk treatment when the results of the risk analysis fall within this area. The adjacent tolerable zone with lower risk values leads to action according to the ALARP principle, while the acceptable zone with negligible (residual) and lower risk requires no action by the competent authority.

By way of derogation, the Dutch risk assessment approach does not contain an ALARP or a transition zone between tolerable and unacceptable risks, but for societal risk it takes into account an additional differentiated risk aversion due to different risk perception in an event: low-probability high-damage and a high-probability low-damage event [6]. It is also possible to limit the risk assessment to major damage and an additional ignoring of very low probability accidents (Fig. 4).

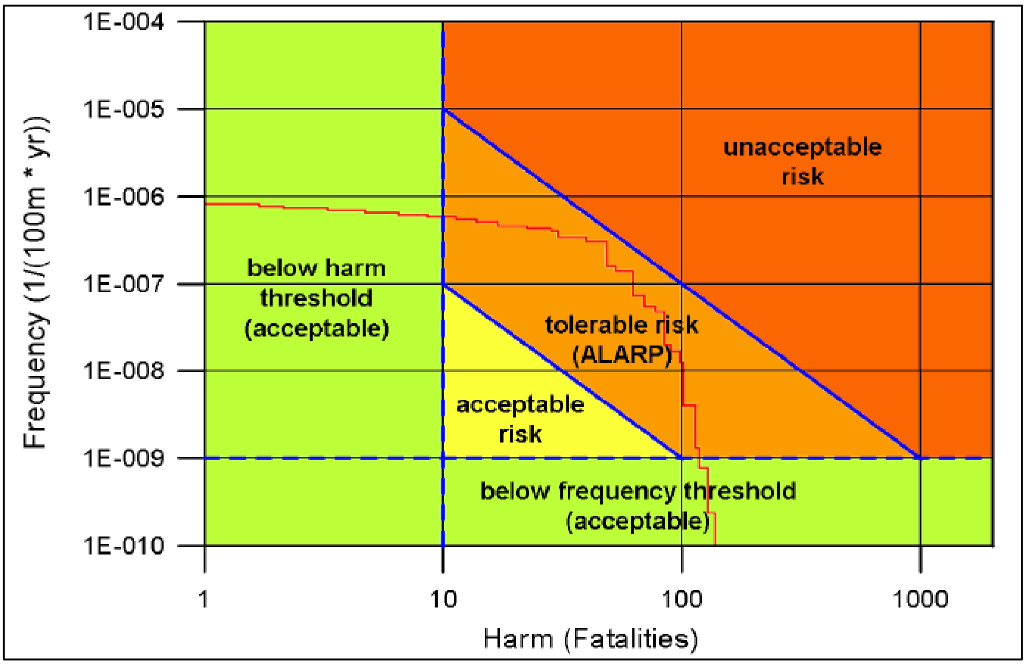


Fig.4.-Example of FN graph for societal risk with possible areas for risk assessment (presentation of arbitrary scaling principle)

The French GAMAB principle ("globalement au moins aussi bon" - globally at least as good) provides a possible evaluation principle for a qualitative risk analysis which, in a comparison of routes, would require at most the same risk for an alternative route compared to the existing route (stopping principle).

Several potential sources of uncertainty (accident statistics, physical and physiological patterns, time-dependent local parameters, etc.) have been highlighted above. For a useful risk assessment based on fixed risk criteria, it is fundamental to aim at minimising uncertainty, especially when restrictive measures are considered, and a transparent analysis and discussion of uncertainty in the assessment process is recommended for the understanding and acceptance of measures.

Risk management

Risk assessment provides information on whether or not a situation under analysis corresponds to a tolerable risk, and this assessment takes place independently of the risk analysis phase. With proper documentation of the risk assessment, a compliant description of the appropriate nature of the measures established can be provided. However, the documentation should also contain information on the selection of measures and in particular on the definition of decision criteria in addition to the risk assessment itself.

It is straightforward to use the same methods and models as for risk estimation to compare the effectiveness of different potential measures. The effectiveness of measures includes aspects such as risk reduction potential and cost to stakeholders. Adequate justification of measures increases the chance of their wide acceptance. It is also recommended to review the risk management process regularly to take account of changes in context or process.

Development of a simplified methodological tool for risk assessment in one-way road tunnels for the transport of dangerous goods by road

This section presents a simplified method for estimating the level of risk in unidirectional road tunnels. It provides the estimation of the risk level, expressed in terms of expected EV value, as a function of tunnel length (L), average daily lane traffic (AADT), percentage of both heavy goods vehicles (HGV) and dangerous goods vehicles (DGV).

The proposed method could help the relevant authorities in the field to make more appropriate decisions on traffic control strategies when the risk due to peak traffic volume hours, including especially dangerous goods vehicles, is considered to be excessive compared to normal standards.

In this respect, in order to reduce the level of risk, the authorities could allow dangerous goods vehicles to transit through the tunnel at night and/or under escort, or an alternative route running completely in the open could be tested.

The free movement of goods on European roads is a crucial factor in the development of markets in European countries, and the volume of goods transported on European roads is continually increasing (15). To give a quantitative perspective, some 39 million goods vehicles were estimated to be circulating on EU-28 roads at the end of 2013, with a rate of 77.8 goods vehicles per 1000 inhabitants.

Among freight vehicles, dangerous goods vehicles are of safety-relevant importance both on roads and inside tunnels. Their movement has been governed since 1957 by the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) [16]. In the light of this agreement, each contracting party may apply restrictions to the passage of vehicles carrying dangerous goods through tunnels. This is done by assigning a specific category to each tunnel: from A (no restriction) to E (all dangerous goods are prohibited). The tunnel category, which is based on the consideration that serious accidents in tunnels can be caused by explosion, release of toxic gas (or volatile toxic liquid) and fire, must be made by each competent authority in the country. However, many countries (e.g. including Italy) have difficulties in applying these restrictions due to geographical features, political and/or social implications, and problems of tunnel management on border roads. Therefore, in the absence of a specified category, a tunnel should be considered free for transit and dangerous goods vehicles. This means that legal responsibility for their movement is assigned to the Tunnel Management Agency. For this reason, the relevant authorities need tools to make more appropriate decisions on restricting or prohibiting the passage of these vehicles through a tunnel.

In this regard, we considered a quantitative risk analysis (QRA) carried out under the requirements of Directive 54/EC [17] published in 2004 (following the catastrophic tunnel fires in the early 2000s) to be appropriate. In this directive, in order to identify European safety standards for road tunnels, the minimum safety requirements are reported and, in addition, it is stated that when tunnels are opened for dangerous goods, a risk analysis should be carried out to determine whether the additional safety is required. measures should be implemented.

Most risk analyses are based on an average value of the percentage of motor vehicles carrying dangerous goods. Indeed, the flow of dangerous goods is not constant, but may vary depending on the type of road containing the investigated tunnel, or peaks of dangerous goods volumes could be expected during the day. Therefore, in some cases, performing a tunnel risk analysis based only on the average value of vehicles carrying dangerous goods may not be justified. Given the above considerations, consideration of their traffic flow variability is within the scope of this chapter section.

Various risk analysis models are used in different countries, respectively: in Europe, only for the risk analysis of vehicles carrying dangerous goods is widely used DG-QRAM (Dangerous Goods-Quantitative Risk Model) jointly proposed by PIARC (Permanent International Association of Road Congress) and OECD (Organization for Economic Cooperation and Development) with associated software developed by INERIS [18]. Also, applications of risk analysis can be found in: Ronchi et al. [1], Zulauf [135], Zhou et al. [3], Knoflacher and Plaffenbichler [4], Petelin et al.[5], Kyritopouolos et al. [6], Steiger et al. [7], Saccomanno and Haastrup [8], Hall et al. [9], Parson Brincherh off Quade & Douglas [10], Diernhofer et al. [11], Benekos and Diamantidis [12], and recently Caliendo and De Guglielmo [13,14].

According to the specialized literature, a quantitative risk analysis (QRA) applied to a bidirectional road tunnel was performed for different combinations of hourly traffic volume and percentage of heavy goods vehicles [13]. Thus, QRA was extended to the assessment of the level of risk in two-way road tunnels due to the transit of dangerous goods vehicles [14]. Moreover, a comparison was also made with an alternative route that runs completely outdoors. However, it must be said that these technical aspects were not investigated in the one-way road tunnels, a fact that determined the realization of the research approach through the results documented in this chapter.

Authorities in the field often have to make decisions about more appropriate traffic control strategies when it is expected that the level of risk due to traffic variability, during the day and/or week, could reach the threshold of intolerable risk. This could happen, for example, especially during the peak hours of the transit of dangerous goods vehicles. In this regard, a simplified method to quickly estimate the level of risk depending on both the geometry of the tunnel and the entity and composition traffic could support the authorities.

Traffic demand may vary by day of the week and/or time of day and at other given road locations, for example, especially at road intersections, where capacity is insufficient to meet demand congestion. Also, in these cases, Road Management Agencies need methods to support them in making quick traffic control decisions to avoid congestion.

As a result of the above, there are at least three main reasons that were the basis of the configuration of the simplified risk assessment method, respectively: (1) The need to quantify the effects on the level of risk in road tunnels due to the increasing flow of motor vehicles dangerous goods; (2) The importance of having a better understanding of the level of risk in one-way tunnels that are in accordance with Directive 54/EC; (3) The usefulness of design diagrams to ensure the rapid support of the authorities in the decision-making process.

Quantitative risk analysis

General concept

In general, two main groups of approaches belong to quantitative risk analysis (QRA), which are deterministic and probabilistic respectively. However, the probabilistic method as opposed to the deterministic method, which can only give accurate results if the exact input parameters are known, is generally considered to be the best tool. In fact, it takes into account the uncertainty associated with some parameters describing the process and assesses the long-term risk in more complex systems such as tunnels. A probabilistic method involves identifying hazards, estimating the probability and consequences of each hazard and quantifying risk as the sum of probabilities multiplied by consequences.

In addition, two appropriate approaches to risk assessment are also possible: a scenario-based approach, which is based on a risk assessment for each individual scenario that is assessed as relevant; another system-based approach, able to investigate a global system in an integrated process with the aim of obtaining the risk value for the whole system.

According to these distinctions, the QRA used in this chapter takes a probabilistic and system-based approach. The results are considered in terms of social risk (eg expected number of tunnel deaths per year). In particular, if F(N) denotes the frequency [1/year] of an event causing N or more victims (in terms of number of deaths), the social risk (SR) can be defined as follows:

$$SR=F(N) \times N \tag{1}$$

Social risk has:

i) a graphic representation by means of F/N curves in a bilogarithmic diagram;

ii) a numerical value, the expected risk value (EV), which can be calculated as an integral between 1 and 1. Regarding the risk level thresholds, it must be said that, according to Directive 2004/54/EC, each Member State he had to define his own limits for evaluating results.

Thus, we considered a maximum possible number of victims N in a certain period of time, according to the relationship:

$$EV = \int_1^{+\infty} F(n)dN \quad (2)$$

stating that the threshold values for intolerable risk are considered between 10-1 and 10-3, for N=1 and N=100 deaths; whereas the threshold values for tolerable risk are between 10-4 and 10-6, respectively, for N=1 and N=100 deaths; therefore, the ALARP region (as low as possible) is individualized by these limits. If the F/N curve is above the chosen safety limit (the intolerable risk threshold), safety measures to reduce the risk must be taken regardless of their costs. When the F/N curve is below the tolerable risk threshold, no additional safety measures are required. When the F/N curve is in the ALARP area, the implementation of additional safety measures should be justified by a cost-benefit analysis.

Brief description of the software

The software identified as useful for the purpose of this research is DG-QRAM. We have considered only 13 accident scenarios, as a comprehensive evaluation of the quantitative risk analysis for the transport of goods through tunnels requires significant simplifications. Two scenarios refer to fire caused by heavy goods vehicles without dangerous goods characterized by HRR (heat release rate) of 20 and 100 MW, for reference only; while the remaining scenarios consider fires, explosions or releases due to heavy vehicles carrying tank, bulk or cylinders of: liquefied petroleum gas (LPG), motor spirit, chlorine, ammonia, acrolein, refrigerated liquefied CO2. DG-QRAM takes into account: accident frequencies; consequences of incidents, escape and sheltering effects; and the effects of hazards (such as heat and smoke) on people. Also, a wide range of information must be entered as input: geometry, traffic, ventilation system, drainage, emergency evacuation, population density, etc. The results for each scenario can be reported both in terms of social risk via the F/N curve and also in terms of expected value (EV).

Tunnels studied

In this chapter, two types of one-way road tunnels in the design phase are analyzed, referred to below as type I and type II. Tunnel types are based on two key parameters: average annual daily traffic (AADT) per lane and tunnel length (L). In addition, these tunnels are supposed to meet the EU's minimum safety requirements (reported in the EU Directive). Figure 5 shows the cross section of the investigated tunnels.

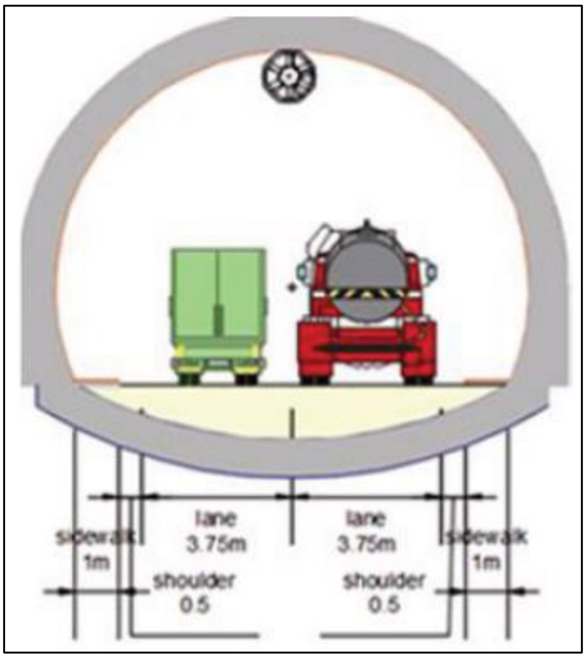


Fig.5.-Characteristics of the cross-section of the investigated tunnels

Table 1 - Description of the tunnels according to EU Directive 2004/54 with traffic on the lane of over 2000 vehicles. /day

	Length 1000 < L ≤3000m	**Length L >3000m**
Categories of tunnels	Type I	Type II
Length	2 km	4 km
AADT per band	5000 vehicle/day and 10.000 vehicle/day	
Percentage of heavy goods vehicles	20% and 30%	
Percentage of dangerous goods vehicles versus heavy goods vehicles	1%, 6%, 12%, 18% și 24%	
Longitudinal slope	1%	
Emergency exits	Every 500 m	
Lighting systems	Normal, safety and evacuation lighting systems	
Longitudinal ventilation system	Delivers via 8 - 1m diameter ceiling jet fans, 28m3/s air flow and 1200N thrust	Delivers via 13 - 1m diameter ceiling jet fans, 28m3/s air flow and 1200N thrust
Monitoring systems	CCTV	CCTV and automatic fire detection
Traffic signals	Before the entrances	Before the entrances and inside the tunnels

Type I and type II indicate, as summarized in table 1, two categories of tunnels widespread on European roads: length greater than 1 km, two lanes, no emergency lane and lane traffic of 5000-10,000 veh./ day. . Two percentages of heavy goods vehicles are considered for these tunnels: 20-30%. In addition, Table 1 also shows the percentages of vehicles carrying dangerous goods as part of heavy goods vehicles. Starting from an average value equal to 1% of dangerous goods vehicles, we assessed the impact on the level of risk in the tunnels mentioned above for the following other different percentages of dangerous goods vehicles: 6%, 12%, 18% and 24% .

Results analysis

The results are reported for the two types of tunnels described above: L= 2 km and L=4 km, respectively, with annual average daily traffic of 5000 and 10,000 vehicles/day per lane and for the two different percentages, respectively: heavy goods vehicles (%HGVs=20% and 30% respectively), according to the percentage of dangerous goods vehicles (%DGVs= 1, 6, 16, 18 and 24%).

Figure 6 shows the results obtained in terms of the expected risk value (EV) as a function of the percentage of dangerous goods vehicles (DGVs) with reference to the average annual daily lane traffic equal to 5000 veh/day (similar results were obtained for the annual average daily traffic per lane of 10,000 vehicles/day). It is interesting to note that the level of risk increases in a linear fashion with the percentage of DGV dangerous goods vehicles. However, when the percentage of heavy goods vehicles (HGVs) is higher (e.g. by moving from 20% to 30%), the level of risk increases more rapidly with HGVs (i.e. a larger gradient was found).

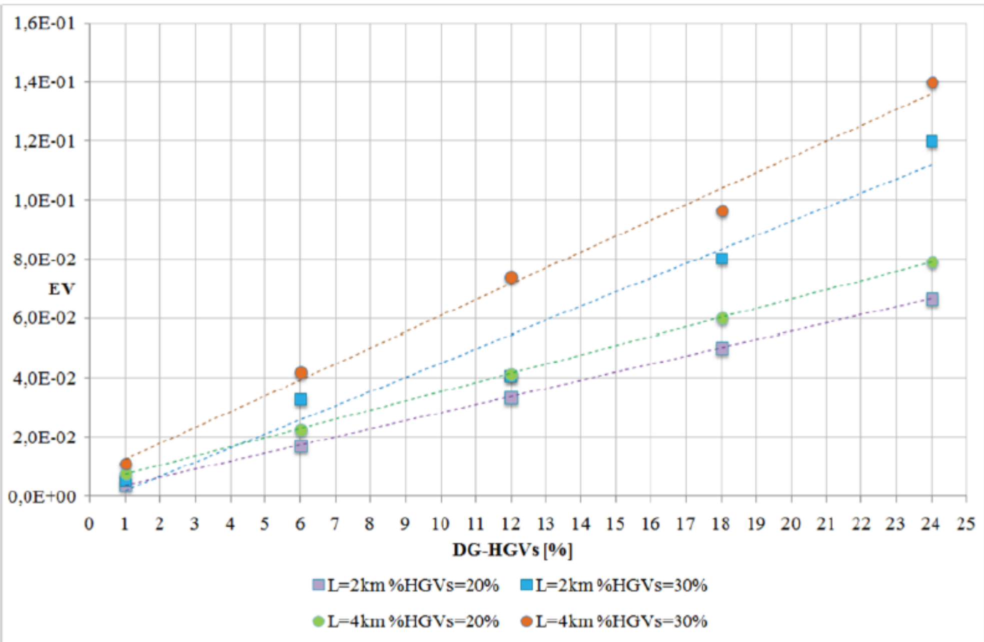


Fig.6.-EV values for different percentages of DG-HGVs
and AADT= 5000 vehicles/day per lane

It can also be added synthetically that, in almost all investigated cases, the FN curves were contained in the ALARP region, expecting the maximum value of the percentage of examined DGVs (24%) with the corresponding F/N curve reaching or partially exceeding the upper limit ALARP (ie, intolerable risk threshold). Therefore, safety measures must be implemented only when the percentage of DGV is equal to or greater than 24%; whereas, for DGVs lower than 24%, the implementation of additional safety measures should be justified by a cost-benefit analysis.

All the obtained results were organized in order to develop a simplified method in which the risk level expressed in terms of EV can be estimated in a short time according to: tunnel length (L), average daily lane traffic (AADT), percentage of heavy goods vehicles (HGV) and percentage of dangerous goods vehicles (DGV). In particular, a radar diagram is proposed as reported in Figure 7. This could be used by the relevant authorities for a quick assessment of the risk level and to choose more appropriate traffic control strategies to reduce the risk that may be caused by peak traffic hours, especially of HGVs.

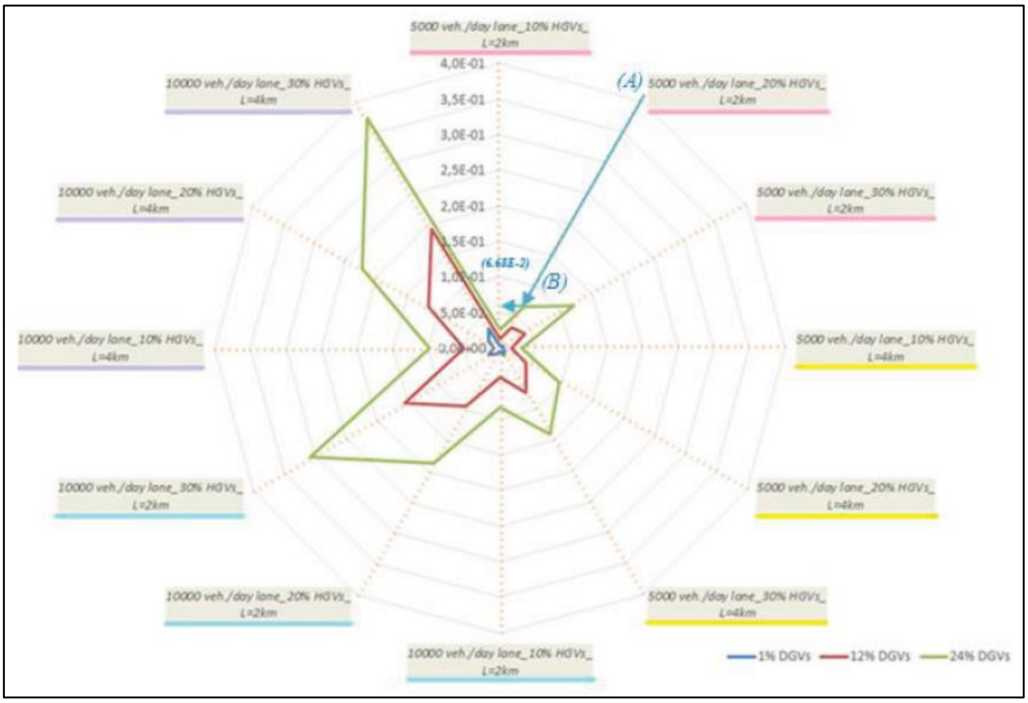


Fig.7-Radar diagram for a comprehensive representation of all risk values

Each of the four equal parts of the graph must represent constant values of both band and length AADT. Moreover, each quarter is characterised by the three different percentages of HGVs (10%, 20% and 30%). In the inner part, on the other hand, the three areas corresponding to EV values calculated for DGVs equal to 1%, 12% and 24% respectively are plotted in different colours. For example, for AADT per lane equal to 5000 vehicles/day with L=2 km and HGVs=20% (see point A in the graph), one can estimate for DGVs=24% a value of EV=6.0E-2 (point B). Obviously, for input parameter values that have not been investigated in this chapter, one can always use the above mentioned radar diagram by applying linear interpolations.

2. CONCLUSIONS

The transport of dangerous goods will continue to increase with the growth of the European Economic Areas as a whole. For all modes of transport, but especially on the road, those dangerous goods transport operations that may pose an additional risk to road users themselves, but also to the immediate environment (nature and population), will continue to increase. For this reason, appropriate risk analyses must be drawn up for the transport of dangerous goods by road to make it possible to assess these risks.

All types of transport of dangerous goods by road are subject to ADR regulations. The objective of these regulations is to ensure safe transport and to minimise the risk of accidents involving injury to persons or the environment by applying the general technical and organisational rules for the packaging, transport and handling of dangerous goods.

Currently, an ADR contracting party has the freedom, according to its national safety policy, to define safety target levels and to define measures in case of violation, to the extent that these provisions are not contrary to international regulations. To date, there is no uniform approach to risk assessment initiated by the transport of dangerous goods.

Currently, ADR Contracting Parties also have different approaches to risk assessment at national level due to specific parameters. These differences concern: the type of assessed risk (individual, societal, environmental); the level and form of acceptance and tolerability limits; areas/categories of acceptance and tolerability.

Each type of risk needs a risk criterion to assess whether a risk is tolerable. These risk criteria should be checked for comparable types of risk (eg risks from industrial installations subject to the regulations of the SEVESO II Directive).

The ALARP (as low as possible) principle applied in the United Kingdom defines an area of unacceptable risk that implies the need for risk treatment when the results of the risk analysis fall within this area. The adjacent tolerability zone with lower risk values leads to measures according to the ALARP principle, while the acceptable zone with insignificant (residual) and lower risk does not require any action from the competent authority.

By way of derogation from this, the Dutch approach to risk assessment does not contain an ALARP or a transition zone between tolerable and unacceptable risks, but for societal risk it takes into account an additional differential risk aversion due to the different perception of risk in a event: low probability and high damage and a high probability and low damage event. It is also possible to limit the risk assessment to major damages and further ignore accidents with a very low probability

This chapter presents a simplified method for estimating the level of risk in one-way road tunnels, which have characteristics in accordance with the European Directive 2004/54/EC.

The results, expressed in terms of expected value (EV) of risk, show how the level of risk is positively associated with tunnel length (L), average daily lane traffic (ADT), percentage of both heavy goods vehicles (HGV) and dangerous goods vehicles (DGV).

The method developed can help the authorities in charge in taking more appropriate and timely decisions on traffic control strategies before the risk due to peak hours of traffic volume, including especially HGVs, can reach the threshold of intolerable risk. In this respect, to reduce the level of risk, the relevant agencies could implement low-cost safety measures, i.e. they could allow DGVs and/or HGVs to transit through the tunnel at night and/or under escort, or an alternative route could be provided that runs completely in the open.

However, it has to be said that some provisions of the Directive, cannot be modelled in the current version of DG-QRAM. This leaves it to the risk analyst to account for the potential effects of parameters that cannot be modelled in the risk analysis.

REFERENCES

Bibliography

[1] **Ronchi E., Colonna P., Berloco N.** *Revizuirea codurilor italiene de securitate la incendiu pentru analiza evacuărilor tunelurilor rutiere: Avantajele și limitările utilizării modelelor de evacuare. Știința siguranței vol. 52, februarie 2013, paginile 28–36.*

[2] **Zulauf C.** *Evaluarea riscurilor pentru tunelurile rutiere: evoluții curente. a 6-a ed. Graz, Austria: International Conference Tunnel Safety and Ventilation, 2012. Disponibil la: http://lampx.tugraz.at/tunnel2014/history/Tunnel_2012_CD/PDF/5_Zu auf.pdf, Accesat 31 martie 2015.*

[3] **Zhou JB, Chen H, Yan B, Shi X, Li XW.** *Evaluarea riscurilor privind siguranța exploatării în tunelurile de autostradă: O abordare de evaluare utilizând mai mulți indici de siguranță. Journal of Transportation Safety & Security, 2014; 6(2):93–116.*

[4] **Knoflacher H, Pfaffenbichler PC.** *O analiză comparativă a riscurilor pentru anumite tuneluri austriece. A 2-a Conferință Internațională Tunel Safety and Ventilation, 2004 Graz (Austria).*

[5] **Petelin S., Luin B., Vidmar P.** *Metodologia de analiză a riscurilor pentru tuneluri rutiere și rute alternative. Journal of Mechanical Engineering 2010; 56: 41-51.*

[6] **Kirytopoulos K., Rentizelas A., Tatsiopoulos I., Papadopoulos G.** *Analiza cantitativă a riscurilor pentru tunelurile rutiere care respectă reglementările UE. Journal of Risk Research 2010; 13(8), 1027-1041.*

[7] **Steiger M, Norghauer N, Day JR.** *Analiza cuantificată a riscului sistemelor de ventilație din tunelurile rutiere: ventilație longitudinală simplă portal-la-port versus sisteme locale de extracție a fumului. A 5-a Conferință Internațională Tunel Safety and Ventilation 2010, Graz (Austria).*

[8] **Saccomanno F, Haastrup P.** *Influența măsurilor de siguranță asupra riscurilor transportului de mărfuri periculoase prin tunelurile rutiere. Analiza de risc 2002; 22(6): 1059-1069.*

[9] **Hall R., Knoflacher H., Pons P.** *Model cantitativ de evaluare a riscurilor pentru transportul mărfurilor periculoase prin tuneluri rutiere. Road Magazine 2006, 329:87-93.*

[10] **Parson Brickerhoff Quade & Douglas,** *Studiu de analiză a riscurilor pentru camioanele cu materiale periculoase prin tunelurile memoriale Eisenhower/Johnson. Raport final pentru Departamentul de Transport din Colorado, 2006.*

[11] **Diernhofer F, Kohl B, Horhan R.** *Evaluarea riscului transportului de mărfuri periculoase în tunelurile rutiere austriece. Al 4-lea Simpozion Internațional pentru Siguranța și Securitatea Tunelurilor, Frankfurt pe Main, Germania, 17-19 martie 2010; http://www.ilf.com/fileadmin/user_upload d/publikationen/53_Risk_Assessment_Transpo rt_Dangerous_Goods.pdf*

[12] **Benekos I., Diamantidis D.** *Despre evaluarea riscurilor și acceptarea riscului transportului de mărfuri periculoase prin tunelurile rutiere din Grecia. Safety Science 91 (2017) 1-10.*

[13] **Caliendo C., De Guglielmo M.L.** *Analiza cantitativă a riscului bazată pe impactul fluxului de trafic într-un tunel rutier. Jurnalul Internațional de Matematică și Calculatoare în Simulare, Vol. 10, p. 39 45. Nord Atlantic University Union, 2016.*

[14] **Caliendo C., De Guglielmo M.L.** *Analiza cantitativă a riscurilor privind transportul mărfurilor periculoase printr-un tunel rutier bidirecțional. Analiza riscurilor, voi. 37, No. 1 Wiley Online Library DOI: 10.1111/risa.125942016. 2017.*

[15] *** * *,** *Eurostat, Statistical Explained. Transport rutier de marfa pe tip de marfa. Noiembrie 2016. Disponibil la: http://ec.europa.eu/eurostat/statisticsexplained/index.php/Road_frei ht_transport_by_type_of_goods*

[16] *** * *,** *Națiunile Unite. Acordul european privind transportul rutier internațional al mărfurilor periculoase. Vol. I si II. New York/Geneva: Publicația Națiunilor Unite, 2014.*

[17] *** * *,** *Parlamentul European și Consiliul. Directiva 2004/54/CE. Jurnalul Oficial al Uniunii Europene. L.167, Bruxelles, aprilie 2004. [5] PIARC. Analiza de risc pentru tunelurile rutiere. Comitetul Tehnic PIARC C3.3 Operațiunea tunelului rutier, 2008. Disponibil la http: www.piarc.org.*

[18] *** * *,** *INERIS. Transport de mărfuri periculoase prin tuneluri rutiere. Model cantitativ de evaluare a riscurilor (Versiunile 3.60 și 3.61), Ghidul utilizatorului 2005 și Manual de referință.*

[19] *** * *,** *Legea 126/1995 privind regimul materiilor explozive cu modificările și completările ulterioare și Normele Tehnice de aplicare*

RECOMMENDATIONS FOR SELECTION OF PLANTS FOR BIOLOGICAL RECLAMATION OF MINES AND QUARRY DAMPS IN KRYVBAS

IRINA ANTONIK [1], *VALERY ANTONIK*[2*]

Abstract: *A brief description of the agrochemical properties of the soils that make up the dumps of overburden rocks of quarries, sludge storage facilities of processing plants and waste rocks of mines is given. It was noted that the soils in the dumps and sludge dumps are represented predominantly by rocks of deep horizons, contain trace elements of many metals and have absolutely no organic components, nitrogen and phosphorus. A substantiation of plant species for biological reclamation (greening) of man-made objects consisting of iron ore mining and enrichment waste has been carried out. It is recommended to plant seedlings of poplars (Pópulus), maples (Acer), acacia (Robinia), pine (Pinus) as well as oleaster shrubs (Elaeagnus) and amorpha (Amorpha) directly on the rock with local excavation of holes on horizontal and slightly inclined areas of dumps. Landscaping of steep slopes (30-40°) and the surface of sludge storage facilities is proposed to be carried out by stimulating natural self-overgrowth by applying (including by hydraulic method) a mixture of seeds of perennial grasses, trees and shrubs along with mineral fertilizers and humus of organic substances. The surface of sludge storages, due to the high degree of salinity and "cementation" of the substrate, before planting plants, requires obligatory soiling with a layer of at least 200 mm of chernozem or a mixture of chernozem with loam, followed by planting of xerophyte plants: meadow brome (Lolium pratense), straight brome (Bromus erectus Huds)), rye – triticale (Triticosecale).*

Keywords: *dumps, sludge dumps, soils, plants, stimulation, overgrowing*

1. INTRODUCTION

The ultimate goal of restoring disturbed lands of quarries and mines is biological reclamation of sanitary and hygienic direction, which is designed to fix the dust-forming soil layer by planting plants. The disturbed lands of mining enterprises are mainly represented by dumps of waste rocks and substandard ores, various embankments and

[1] *Krivoy Rog State Pedagogical University, Krivoy Rog, Ukraine, ira067108kr@gmail.com*
[2] *Scientific and Research Mining Institute of Krivoy Rog National University, Krivoy Rog, Ukraine, viantonik096@ gmail.com*
* *Corresponding author: Antonik Valery Ivanovich, PhD (Biological), leading researcher at the Research Mining Institute of Krivoy Rog National University, Krivoy Rog, Ukraine (5th Microdistrict Zarechny, building 73, apt. 44, Krivoy Rog, 50081, tel. +38096 2501416, viantonik096@gmail.com).*

sludge dumps. Physical and chemical properties of rocks forming these technogenic structures determine the degree of biological suitability of substrates for plant growth. There are four groups of such suitability of rocks, namely: suitable (fertile and potentially fertile), hardly suitable, conditionally suitable and absolutely unsuitable [1]. The first group of rocks consists of chernozem, clay, loams or sandy loam. The second group is the main part of dump bulk and contains few plant food elements and has unfavorable mechanical composition, but is partially suitable for planting. The third group consists mainly of rocks, which are not suitable for planting without creating local zones of life-giving substrate. Absolutely unsuitable soils in terms of physical properties include coarse rocky soils, and in terms of chemical properties – strongly acidic, strongly alkaline and saline soils.

The rocks of waste rock dumps obtained as a result of mine development works usually have the following mineralogical composition: granites (up to 2%), martite jespilites (up to 21%), hematite-martite hornfels (up to 42%), quartz-sericite-chlorite schists, hematite–talc schists (up to 33.5%) and loams (up to 1.5%). Granulometric composition is dominated by large fractions, gravel and crushed stone (65-80%), and sand and dust make up from 8 to 12%. Chemical composition of waste rocks is characterized by significant amount of silica, soluble iron and oxides of aluminum, calcium and magnesium, which in principle are useful trace elements for plant life. The reaction of aqueous extract of the rocks is close to neutral and they have a medium to high degree of water absorption. Thus, the rocks forming the mine dumps belong to the second group of soils, i.e. they are conditionally suitable for plant growth [2]. The quarry overburden dumps formed from the surface layers of the first group of soils are usually ranked as soft rock stockpiles and are subsequently used for land reclamation processes. The overburden rock dumps belong to the second-third group of soils and consist mainly of schists, granites, nonmetallic or oxidized quartzites.

Slurry storage facilities are places where solid residues (“tailings”) from the enrichment of iron ore raw

materials accumulate, which in the form of an aqueous suspension (pulp) is transported by slurry pipelines from the concentration complexes and washed onto special alluvial maps (beaches). The content of the solid fraction in the pulp is 4-6%; Particles ranging in size from 0.001 to 3-5 mm predominate. Mineral composition of the “tails” (%): magnetite – 1.8; magnetite + hematite – 1.0; carbonates – 17.0; silicates – 6.0; Fe hydroxides – 5.3; quartz – 64.2; calcite – 3.9; apatite - 0.3; other impurities - 0.7. The water from the pulp is sodium sulfate-chloride, mineralization up to 15 g/l [3]. The embankment of sludge storage facilities at enrichment plants is usually formed by overburden rocks of quarries, and the alluvial maps of the “tailings” (waste) of the enrichment are represented by the fine fraction of the fourth group of soils with high salinity.

There is a large number of works on the technology of biological reclamation of dumps and the substantiation of plant species for landscaping sites for storing waste from mining and mineral processing [4-18]. Most authors propose to carry out preliminary excavation of the surface of coal and iron ore mine dumps with soft rocks (including slopes), followed by planting seedlings of deciduous or coniferous trees and shrubs [10;17]. It is proposed to use various types of tree and shrub species characteristic of the biocenoses of the corresponding regions (maples (Acer), ash (Fraxinus), poplars (Pópulus), as well as handicrafts: oleaster (Elaeagnus), elderberry (Sambucus), rose hips (Rosaceae), mackerel (Cotinus), caragana (Caragána) and others [5; 7-9; 13-14]. The successful use in landscaping of dumps of plants - oligotrophs of the mountainous Crimea and, first of all, Crimean pine (Pinus nigra) [18]. In the process of landscaping steep On the slopes of dumps, there is known experience in the use of herbaceous plants (sandy sainfoin (Onobrýchis arenária); Lessing's feather grass (Stipa lessingiana)) [11-12]. During the biological reclamation of sludge dumps, it is most often recommended to use sodding of the surface with herbaceous plants - saltworts, including southern reed (Phragmites australis) and black sea grass (Leymus racemosus) [10;16]. The disadvantage of all technologies for preliminary earthing of the surface of dumps, the area of which can be hundreds of hectares, is the high labor intensity and cost of such work, as well as the need for a large amount of fertile soil (with an earthing layer thickness of 0.5 m, for every 100 hectares of dump area, 500,000 m3 of soft soil is required soils). In addition, excavation of steep slopes of dumps and sludge dumps is not very effective, since usually soft rocks are easily washed away by water flows of sediments. Of the variety of plants that are recommended for landscaping man-made objects, in practice it is difficult to decide on specific species for planting on horizontal and inclined surfaces of dumps and tailings of iron ore enterprises.

The purpose of this work is to optimize technology and specify plant species for biological reclamation (greening) of man-made objects consisting of waste from iron ore mining and processing.

2. METHODOLOGY

One of the key issues of biological reclamation is the soil-plant relationship. During mining, geological strata move and deep rocks, which differ in mineral and chemical composition from zonal surface soils, appear. Therefore, plants settling on these soils find themselves in edaphic conditions that are unusual for their life. The success of artificial plantings during biological reclamation requires the selection of plants that are most capable of surviving in specifically harsh conditions, when there is a combination of soils depleted in nutrients, moisture deficiency and scorching rays of the sun, and in sludge storage areas also the salinity of the substrate.

Observations show that rocks on the surface of dumps, under the influence of atmospheric factors, weather over time with the formation of up to 40 - 50% of the fine fraction, therefore, we successfully carried out work on horizontal, slightly inclined areas and gentle slopes (angle up to 18%) of 3-5 year old dumps for planting plants directly on empty rocks without continuous excavation of the surface. Using the technology we have developed, holes 30x30x30 cm are made for planting seedlings of trees or shrubs (using a drill hole or manually with a shovel). 8 kg of potentially fertile soil (low-productive chernozem, loess-like loam or a mixture thereof) and 0.15 kg of nitrogen-phosphorus-potassium mineral fertilizer (nitroamophoska) are added to each of the planting holes. As an alternative to mineral fertilizer, the final product of processing municipal solid waste (vermicompost) or solid sludge from municipal sewage treatment plants can be used. In this case, the planting holes are filled with a mixture of potentially fertile soil (up to 7-8 kg) with the specified biologically active substances (up to 2 kg). After planting a plant seedling, the remaining space of the planting hole is filled with excavated waste rocks (size 0.1-3 mm, at least 40%) and a hole is formed on the surface for carrying out work on caring for the seedling (watering, loosening, etc.). Approximately 1.8 tons of low-productive chernozem or loess-like loam and 68 kg of nitroamophoska are needed per 1 hectare of plantings.

We also recommend using a proven rational planting scheme, the essence of which is to reduce the number of plant seedlings per unit area without reducing the effect of landscaping. This is achieved by increasing the distance between row plantings of woody plants to 5 meters, and in rows - up to 3 meters (for coniferous plants) and up to 5 meters (for deciduous plants). This planting scheme, on the one hand, provides greater living space for the development of each plant, and on the other hand, it allows for the intensive development of young self-seeding or root-sprout shoots of the mother plant, which achieves significant savings in money and effort for green construction activities.

Greening of steep slopes (up to 35-40°) is particularly difficult in biological reclamation of dumps of waste rocks and substandard ores. Usually, the surface of the slopes of new dumps is represented by large fractions of rock mass, and only after 12-15 years under the influence of atmospheric factors the fine fraction is formed by weathering, which creates more or less favorable conditions for plant growth. It is during this period that self-overgrowth of dumps can occur by seeds of grass, trees and shrubs spontaneously carried by the wind, birds or animals. Attempts to speed up the process of greening slopes by covering their surface with a layer of soil are not successful due to the great technical complexity, high cost and low efficiency. In this case, we recommend using technology with the greatest success the technology of stimulating the natural self-overgrowth of slopes of any age by sowing their surface with a mixture of seeds of grass, trees and shrubs along with mineral fertilizers and vermicompost (for example, sludge from sewage treatment plants). Sowing is best carried out by the hydraulic method using standard hydroseeders [19], which form a flow of hydraulic mixture over a distance of 30 - 50 meters. Since the surface of dumps, especially new ones, is represented by soils of the third group, the addition of fertilizers and humus to the hydraulic mixture of seeds makes it possible to create local places of life-giving substrate between the pieces of rock for the initial growth of plants.

3. RESEARCH RESULTS

Taking into account the agrochemical properties of the rocks forming the dumps of Krivoy Rog, our own experience in carrying out land restoration work and the analysis of known methods for reclamation of dumps of mining enterprises in Krivoy Rog [6; 14-17], a list of plant species that are most suitable for the biological reclamation of stored production and enrichment wastes has been substantiated iron ore raw materials, taking into account the requirements of minimizing work on preliminary mining and technical preparation of the territory. Under these conditions, on rocky waste rocks (limestones, stony quartzites, shales with an admixture of clay), sanitary and hygienic reclamation measures should primarily contribute to the creation of green spaces of a mixed type (woody, shrub and herbaceous plants).

In this case, for planting it is the best to use those plant species that grow in natural biotopes adjacent to the reclamation zone. In conditions of Kryvyi Rih such plants should include Acer negundo(also known as the ash maple), Acer platanoides (also known as the Norway maple), Acer tataricum (also known as the Tatar maple), Robinia pseudoacacia (also known as white acacia), different types of Populus, Ailanthus altissima (also known as tree of heaven), Pinus nigra subsp. pallasiana (also known as the Crimean pine), Pinus sylvestris (also known as the Scots pine), and the shrubs: Elaeagnus angustifolia (also known as the Russian olive), Tamarix tetrandra (also known as tamarisk), Amorpha fruticosa (also known as amorpha bushy). In case of early spring planting and favorable conditions with watering, these plants can grow up to 60 cm in the first year, and subsequently up to 80-100 cm per year.

For the purpose of phytomelioration of the surface of waste rock dumps, as well as for the conservation of dumps of temporarily substandard ores, it is recommended to sow cereals and legumes perennial grasses in a mixture with complex mineral nitrogen-phosphorus-potassium fertilizers at the rate of 200 kg of a mixture of seeds and 200 kg of fertilizers per 1 hectare of area . The tested composition of seeds should include xerophytic plants such as meadow brome (Lolium pratense), stokolos erect (Bromus erectus Huds), sage (Sālvia officinālis), yellow brome (Melilotus officinalis), sainfoin (Onobrychis arenaria), blue alfalfa (Medicágo satíva) .

To stimulate self-overgrowth of steep slopes of dumps by hydroseeding their surface, the seeds should include the above-mentioned perennial cereals and legumes, as well as seeds of trees (acacia, poplar, maple) and shrubs (amorpha, tamarix, etc.). The technology for stimulating self-overgrowth of dumps makes it possible to reduce the time for landscaping by 2-3 times. The described technology of hydroseeding with the addition of fertilizers and humus can also be used for landscaping the slopes of multi-tiered sludge storage facilities consisting of highly saline soils of the third group. At the same time, it is recommended to include halophyte plants in the composition of seeds at the first stages of biological reclamation: (for example, European saltwort (Salicornia europaea), hill saltwort (Salsola collina) and only after 3-5 years can sowing be carried out with perennial cereals and leguminous grasses. Drained " beaches" of sludge dumps in Saint Petersburg with high salinity of the substrate and "cementation" of the surface can be subjected to phytomelioration only after preliminary soiling with chernozem or a mixture of chernozem and loam with a layer of at least 20 cm. The most successful use of xerophytes of meadow brome (Lolium pratense) as ameliorants in these conditions direct stole (Bromus erectus Huds), rye - triticale (Triticosecale).For landscaping the beaches of sludge dumps, it is also recommended to use halophyte plants, for example, horned swede (Suaeda corniculata), coastline (Aelúropus), sea plantain (Plantago maritima), seaweed (Suaeda maritima), etc.

3. CONCLUSIONS

Based on the presented materials, conclusions are made:

- when choosing plants for biological reclamation of disturbed lands in Kryvyi Rih, preference should be given to those species that grow naturally in natural biotopes adjacent to the reclamation zone;

- it is necessary to use those plants that successfully vegetate on "poor" soils, are oligonitrophilous and drought-resistant;
- when landscaping the slopes of dumps and dams embanking tailings by sowing the surface using a hydraulic method, in addition to plant seeds and mineral nitrogen-phosphorus-potassium fertilizers, an organic substrate (for example, specially prepared sludge from sewerage treatment plants) must be added to the composition of the hydraulic mixture;
- it is recommended to introduce seeds of cereals and legumes of perennial grasses, seeds of trees and shrubs into the mixture of seeds to stimulate the natural self-growth of dumps (the most successful are the seeds of white acacia and amorpha bush);
- when landscaping dry beaches of sludge dumps, it is recommended to use seeds of halophyte plants.

REFERENCES

[1] **Derzhavnyj Standart Ukrajiny**: DSTU 7906:2015 (2015) Zakhyst dovkillia. Prydatnist rozkryvnykh ta vmishchuvalnykh hirskykh porid dlia biolohichnoi rekultyvatsii zemel. Klasyfikatsiia. Vvedenyi z 01.07.2016. - K.: Natsionalnyi universytet bioresursiv i pryrodokorystuvannia (NUBiP) Ukrajiny

[2] **Dolina O.O. and Smetana O.M.** (2014) Territorial structure and classification gruntov Krivorizky iron ore basin. Bulletin of Dnipropetrovsk University. Biology. Ecology. VIP. 22 (2).- P. 161–168.

[3] **Smetana O.M., Smetana N.A.** (2006) Solevoye sostav khvostokhranilishch of Krivbass // Bulletin of Krivorizky Technical university. Collection of scientific works, Vip. 12.- Krivy Rig,, P. 281-285.

[4] **Koptieva T S and Denysyk B G** (2021) Quarry and dump landscape systems of Kryvorizhzhia. XX-th International Multidisciplinary Scientific GeoConference. Surveying, Geology and Mining, Ecology and Management – SGEM 2020. Bulgaria.Albena, - P. 665–670.

[5] **Safonova GS and Reva SV** (2009) Colonization of iron ore dumps of Krivbass by higher plants. Visnyk of Dnipropetrovsk University. Biology. Ecology Vol. 17, N 2. - P. 87–94.

[6] **Maltseva I.A., Baranova O.A.** (2014) Vodorosli of technogenic ecotopes of iron ore production // Algology..- National Academy of Sciences of Ukraine. Institute of Botany im. M.G. Cholodnogo. T. 24, No. 3. – P. 350-353.

[7] **Shkuta S.I.and Pavlenko A.O.** (2018) Shrub component of vegetation on the dumps of Krivbass. Ecological research of forest biogeocenoses of the steppe zone of Ukraine": mat. II MNC. – Dnipro. – P.37–38.

[8] **Korshikov I.I., Krasnoshtan O.V. and Pasternak G.A.** (2012) Species diversity of woody plants on industrial dumps of the steppe zone of Ukraine //Visn. Dnipropetr. holding Agrarian University No. 2.-P.24-28.

[9] **Komisar I.O.** (2005) Primat robinii in the otvalnich usloviyach proizrostaniy -Materials of the IV International Conference: Problems of ecology and ecological lighting. - Krivy Rig: Etude-Service, - P. 113-116.

[10] **Savosko V. M.** (2011) Melioration and phytorecultivation of lands / V. M. Savosko. – Krivyi Rih: Publishing house "Dionysus". – 288 p.

[11] **Masyuk N.T., Uzbek I.Kh.** (1971) Cultivation of sandy sainfoin on dumps // Plants and industrial environment. – K.: Science. Dumka, 1971. - P. 153-157.

[12] **Mitsik L.P., Likholat Yu.V. and Okhrimenko A.A.** (2003) Method obrazovaniy derna on technogenic krutih otcosach otvalov// Newsletter of the Dnipropetrovsk National University.- Series: Biology, Ecology. -VIP. 11. – T. 2- P.119-124.
[13] **Kumar S.R. Arumugam T., Anandakumar C.R., Balakrishnan S. and Rajavel D.S.** (2013) Use of plant species in controlling environmental pollution- A Review. Bulletin of Environment, Pharmacology and Life Sciences.. Vol. 2 (2).- P. 52–63.
[14] **Nowak D.J., Hirabayashi S., Bodine A. and Greenfield E.** (2014) Tree and forest effects on air quality and health humans in the United States. Environmental Pollution.. 193. R. 119–129. DOI: 10.1016/j.envpol.2014.05.028
[15] **Schiop S.T., Hassan M.A., Sestras A.F., Boscaiu M., Sestras R.E. and Vicente O.** (2015) Identification of salt stress biomarkers in Romanian Carpathian populations of Picea abies (L.) Karst. Plos one. 10 (8). P. 14–22. Doi: 10.1371/journal.pone.0135419.
[16] **Kucherevsky V.V., Mazur A.E. and Dotsenko A.N.** (1989) Opyt biologicheskoy fiksatsii pylyashchikh poverkhnostey. sushchestvuyushchikh khvostokhranilishch // Mining Journal. – No. 7. – P. 56-57
[17] **Shapar A.G. Skripnik O.A., Bobyr L.F.** (2005) Activation of self-healing of degraded lands of Krivbass // Newsletter of the Dnipropetrovsk State Agrarian University - No. 1. – P. 15-18.
[18] **Mikhailenko I.L. and Smetana O.M.** (2013) Usloviya sushchestvovaniya yeli obyknovennoy, sosny krymskoy, sosny obyknovennoy i mozhzhevel'nika kozach'yego v sostave zelenykh nasazhdeniy Krivogo Poga. Nutritional bioindication ecology.. VIP. 18, no. 2. - .P. 170-178.
[19] **Antonik V I, Bugriev S V, Shchokin V P, Antonik I P, Shtanko L O and Ivaschenko V A** (2022) Method stimulating natural landscaping of steep slopes of dumps mines and quarries (Ukrajina MPK: A01B79/00) patent N 151 336 published 07/06/2022, Bulletin No. 27.

INDEX OF AUTHORS

INSTRUCTIONS FOR AUTHORS
PAPER TITLE TNR 14p bold

Author 1 Surname, Name [1], Author 2 Surname Name[2] TNR 12p bold

Abstract: *5-15 lines, TNR 10p italic*

Keywords: *4-7 key words, TNR 10p italic*

1. INTRODUCTION, TNR 11p bold

Body text, 11p normal, paragraph first line 12.5 mm.

2. TITLE HEADER, TNR 11p bold

2.1. Subtitle header, TNR 11p bold italic

Body text, 11p normal, paragraph first line 12.5 mm.

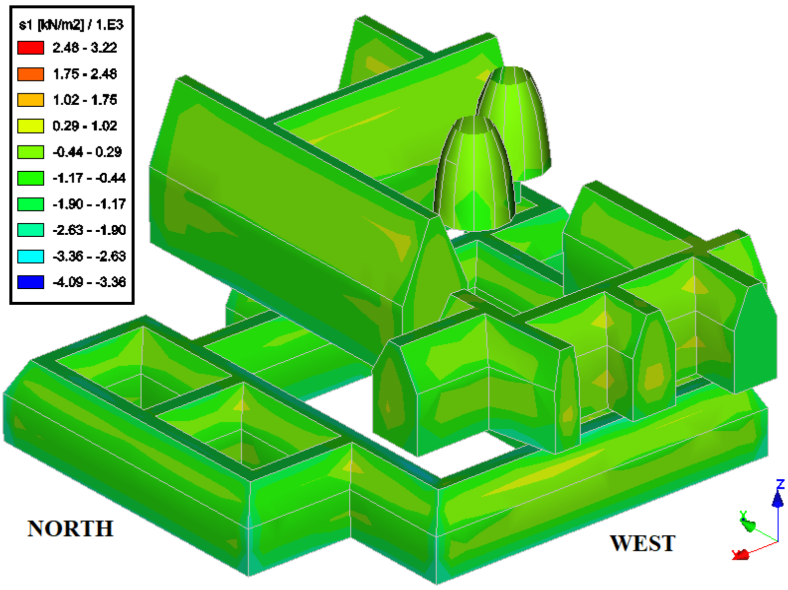


Figure 1. Figure title 10p TNR

[1] *Author 1 title, afiliation*
[2] *Author 2 title, afiliation*

Table 1. Table title 10p TNR

Heading 1	**Heading 2**	**10p TNR bold**		
Content 1	Content 2	10p TNR		

Formula, TNR 11p alignment right (1)

2.2. Subtitle header, TNR 11p bold italic

Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm.

Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm.

Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm.

Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm.

Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm.

3. CONCLUSIONS

Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm. Body text, 11p normal, paragraph first line 12.5 mm.

4. REFERENCES

[1]. Author, Paper title, Publisher (year) – TNR, 10p

Do not insert page numbers