Chapter

Risk of Slipping Industrial Landfills

Emilia-Cornelia Dunca and Sabina Irimie

Abstract

Due to the high rate of industrialization, urbanization and development of the road network, hydrotechnical constructions, etc., larger areas of agricultural and arable lands are affected, some of these being removed from the economic circuit. Due to the magnitude of the involved volumes, industrial waste has lately become a threat to all the components of the environment. In Romania, 90–95% of the total quantity of the produced industrial waste are stored, but only 24% of them have an environmental clearance certificate. The action of the climatic factors increases the risk of the occurrence of some landslides, which leads to the deterioration of the ecosystems and the risk of pollution, the loss of stability, the destruction of some historical objectives. Thus, the risk analyses represent the support for the decision-making process in taking solid measures, meant to lead to the limitation and diminution of the danger of slipping and losing the stability of these deposits. However, the implementation of the measures is based on a systemic model, supported by the concept of risk. This chapter presents the definition and classification of environmental risks, the risk assessment methodology and a risk analysis for waste in a mining area in Romania.

Keywords: risk, sliding risk, industrial waste, pollution risk and risk analysis, mining area

1. Introduction

The International Risk Institute emphasis's that "risk is part of our whole life" [1], therefore risk is a human concern, and as an object of study, it has been a component part of scientific research in various fields (socio-human, natural sciences and exact sciences). Due to this fact, the concept of risk has evolved through a variety of emerging theories. Starting from the earliest times, the representatives of different fields have tried to develop an algorithm for risk perception, assessment and management. Risk is unquestionably an ambiguous concept and very difficult to define. Up to present, there are numerous perceptions of risk, which depend on the taken perspective, context, situation, and application field.

The etymology of the term "risk" is not unambiguous either. Some authors grant it Arab roots, however most of them consider that the term comes from the Greek word—rock [2]. In French, "risqué" has two meanings: the first one is—to expose to it (the risk), and the second meaning—to bear something, to have a chance, possibility, opportunity, meaning which aims the positive favorable aspect, the possibility of success.

Although, in the case of the ecological risk, the delimitation and assessment of the positive aspects are carried out within the programs and actions for the restoration, improvement and conservation of the natural ecosystems and habitats, for improving the ecological situation of a region, for ensuring and improving the health and life quality of the population ([3], pp. 211–212). Simultaneously, the estimation of the risk negative aspects will affect the actions which can generate a possible high risk on the environmental factors, their ecosystems and biodiversity, the health and the life quality of the population ([4], p. 83). Most of the times, the environmental risks take a negative look: natural or technogenic disasters.

For the Romanian geographers [5], the environmental risk is a category of state, designating the relational conjuncture, which results as a consequence of the hazard assumption by those components of the geo-system which possess the capacity to perceive events ([6], pp. 10–16).

The environmental risk is defined by most specialists as the probable occurrence of an unexpected effect as a result of exposure to a disturbing factor. The notion of risk is related to the probability of unforeseen results or unpredictable consequences, derived from the decisions/omissions or actions of social groups [7].

Based on the analysis of the existing specialty literature, we propose to define *the environmental risk as the probability of a quantitative and/or qualitative deviation of the expected result which may occur following certain actions or inactions of the decision-maker and the magnitude of the losses or gains resulting from this variation*.

The probability of an event advancement is only a first component of the risk, the second being the size of the possible damage. Unlike danger, the risk cannot be analysed without assessing the consequences of the unwanted event occurrence. Therefore, risk represents the quantitative dimension of the danger, more precisely of the possible consequences, so the risk can be calculated by the formula:

$$R = PxQ \tag{1}$$

where R is the risk; P is the probability; and Q is the size of the losses, which can be of economic, social and ecological nature ([8], pp. 118–121).

Analyzing the specialized literature in this field, it can be observed that most of the classifications are made based on the criteria concerning these risk components. The existences of classifications according to the particularities of these two defining elements of risk are of great practical importance, especially for risk assessment and management.

Analyzing the criteria according to which the environmental risk classifications have been developed, one can see that they focus on the following aspects:

- The sources of risk (the subject of the action).
- Risk-generating action or inaction.
- The probability and the predictability of the risk, i.e., the occurrence of a deviant result from the expected one.
- The object of the possible impact.
- The consequences of the risk situation occurrence, which can materialize in profit or loss.
- The degree of sustainability and vulnerability to the risk (**Figure 1**).

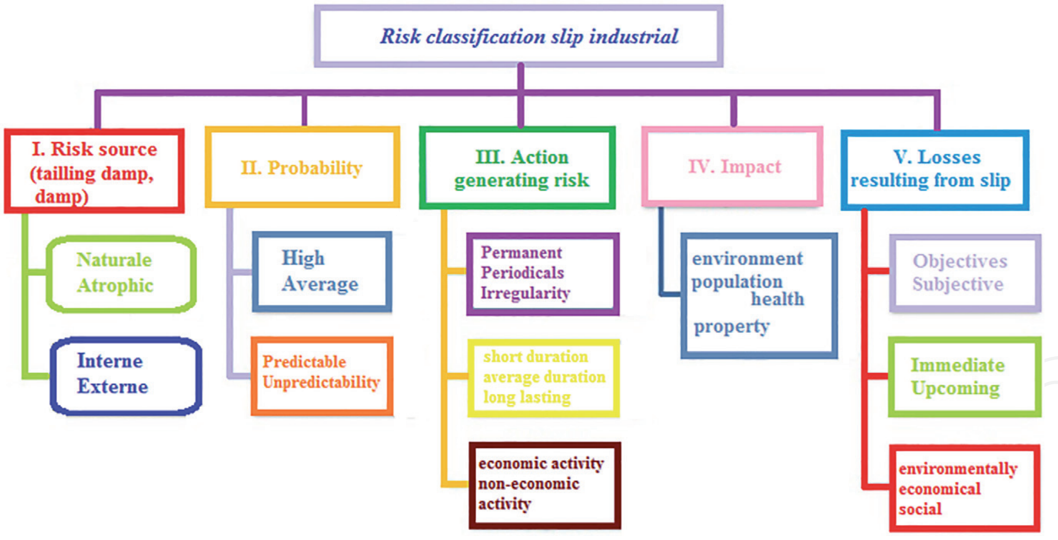

Figure 1.
Environmental risk classification. Source: authors.

In the classification regarding the sources of risk we find that depending on the type of the *source of risk*, there are approaches focused on the slide phenomena, which—in turn classify the risks according to their origin:

- Natural risks—generated by natural phenomena, such as earthquakes, storms, floods or droughts and so on.

- Anthropic risks—triggered by human activity.

2. Risk assessment methodology

In conducting risk analysis studies, reference benchmarks (indicators or indices) that can be used at different levels are required. It is obvious that the risk cannot be reduced to zero and therefore it appears as a value of the maximum importance to be the limit that can be borne by people in current activities.

Accident prevention through risk analysis involves a specific activity starting from the design stage through the application of qualitative and quantitative techniques and methods based on existing data and on systematic creative imaginative actions ([9], pp. 88–93).

The qualitative analysis has as a main objective the establishment of the list of possible hazards, and it makes possible the hierarchy of the events in the order of the risk and presents the first step in the methodology of performing the quantitative risk analysis.

There are two major categories of techniques in which a number of general components are distinguished (**Table 1**):

- Qualitative analysis used to identify hazards (Hazard and Operability Study—Hazop). Its main objective is to establish the list of possible hazards, making possible to rank the events in the order of risk and present the first step in the methodology of performing the quantitative risk analysis [6, 10, 11].

- Quantitative analysis used to assess hazards to decide how one should act in order to eliminate or reduce the risk (Hazard Analysis—Hazan) [12].

The order of application is from qualitative identification to quantitative analysis.

Hazop technique	Hazan technique
Identify hazards	Assess hazards
Preferred technique for use in every project	Selective technique: it is used especially for systems potentially exposed to major accidents
Qualitative	Quantitative
Made by a team	Made by one or two experts
Also called "But If?"	

Table 1.
Difference between Hazop and Hazan.

2.1 Qualitative analysis of the consequences

It is achieved through the classification into five levels of severity, an internationally accepted methodology and used in risk assessment studies [2, 13]. The five levels have the following significance (**Table 2**):

Crt. No.	Level	Effects
1	Insignificant	**Population:** insignificant injuries **Ecosystems:** some minor adverse effects on few species or parts of the ecosystem, on short term and reversible **Socio-political:** insignificant social effects without any concern for the community
2	Minor	**Population:** insignificant injuries **Ecosystems:** some minor adverse effects on few species or parts of the ecosystem, on short term and reversible **Socio-political:** insignificant social effects without any concern for the community
3	Moderate	**Population:** medical treatments are required **Economic:** reduction of production capacity **Emissions:** emissions within the target area withheld with external assistance **Ecosystems:** temporary and reversible damage, damage to habitats and migration of animal populations, plants unable to survive, air quality affected by compounds with potential long-term health risk, possible damage to aquatic life, pollution requiring physical treatments, limited contamination of soil which can be remedied quickly **Socio-political:** social effects with moderate concerns for the community
4	Major	**Population:** serious injuries **Economic:** interrupting the production activity **Emissions:** off-site emissions without harmful effects **Ecosystems:** death of animals, large-scale damage, damage to local species and destruction of large habitats, air quality requires "safe shelter" or decision to evacuate, soil remediation is possible only through long-term programs **Socio-political:** social effects with serious concerns for the community
5	Catastrophic	**Population:** death **Economic:** stopping the production activity **Emissions:** toxic emissions outside the site with harmful effects **Ecosystems:** death of animals in large numbers, destruction of species of flora, air quality requires evacuation, permanent contamination and on extended areas of the soil **Socio-political:** social effects with very high concerns for the community

Table 2.
Risk severity level.

2.2 Analysis of production probability

It is also achieved using the five levels, internationally accepted and used in different variants (**Table 3**).

2.2.1 Qualitative risk assessment

The level of risk as a product between the severity level (consequence) and the probability level of the analysed event is calculated [14].

Using the information obtained from the analysis, the risk of an event is placed in a matrix (**Figure 2**).

The extent of the risk analysis and the intensity of the prevention and mitigation measures should be proportional to the risk involved. Simple models of hazard identification and qualitative risk analysis are not always enough and therefore it is necessary to use detailed assessments. There are several methods for performing quantitative risk assessment [15]. The choice of a particular technique is particular to the analysed accident scenario.

Those accident scenarios are analyzed more thoroughly which, as a result of the qualitative analysis, are considered as potentially major, probabilities over 10^{-6}, i.e., they can occur earlier than 10,000 years and major consequences, so high risk above level 15.

Crt. No.	Probability	When can occur	Occurrence frequency
1	Rarely	Only in exceptional conditions	Probability of occurrence in 10^{12} years
2	Unlikely	It could sometimes occur	Probability of occurrence between 10^{8} and 10^{12} years
3	Possibly	It may sometimes occur	Probability of occurrence between 10^{6} and 10^{8} years
4	Probably	It can occur in most situations	Probability of occurrence between 10^{4} and 10^{6} years
5	Certainly	It is expected to happen in most situations	Probability of occurrence in a period less than 10^{4} years

Table 3.
Levels of the probability of producing risks.

				Consequences				
				Insignificant	Minor	Moderate	Major	Catastrophic
				1	**2**	**3**	**4**	**5**
Probability	Improbably	$<10^{-12}$	**1**	1	2	3	4	5
	Less probably	10^{-8} to 10^{-12}	**2**	2	4	6	8	10
	Possibly	10^{-6} to 10^{-8}	**3**	3	6	9	12	15
	Probably	10^{-4} to 10^{-6}	**4**	4	8	12	16	20
	Certainly	$>10^{-4}$	**5**	5	10	15	20	25

Figure 2.
The matrix of qualitative risk assessment and risk levels.

Methods are used to estimate the accidental emissions in the atmosphere and models of simulation of the dispersion based on which the severity of the possible consequences is evaluated.

Specific simulation methods are applied to assess the consequences of possible explosions or fires. The results of some simulation studies of the formation of breaches in the body of the tailings dam and the acid water collection pond are used to assess the consequences of such events.

The frequency diagram—consequences, FN (loss of materials or number of fatalities) centralizes the result of the analyses carried out in this way and it graphically presents the social risk specific to the project in correlation with the socially acceptable level of risk.

An overall assessment of the risk associated with the sliding of industrial waste will be made using the methodology of rapid environmental and health risk assessment developed by the World Health Organization.

3. Sliding of waste sterile dumps

The loss of the stability of the waste sterile dumps is determined by the following factors:

- The configuration and the physical-mechanical characteristics of the founding ground.
- The hydrodynamic particularities of the waters in the area and their interaction with the material from the dump.
- The geotechnical characteristics of the waste sterile material (porosity, internal friction angle, cohesion, cracking specifies, humidity, degree of compaction, etc.).

The probability of production is average, considering the compliance with the technical design criteria for the stability of the dumps, established for the specific conditions of the site and the characteristics of the material ([7], pp. 12–13).

The dumps will be monitored continuously, through visual control, through manual and automated topographic measurements, and the tailing will be carried out in stages, with the flatting and compaction of the deposited material. The severity of the accident can be major due to the large amounts of waste resulting from and deposited on the dumps and the fact that the sliding may cause damage to buildings on the site or access roads.

Waste dumps sliding after the completion of the deposits and carrying out the rehabilitation works have low probability and moderate severity, the associated risk being much lower than in the operating phase.

Geotechnical field investigations and studies of the physico-mechanical characteristics of the boulders and of the basic land have led to the conclusion that landslides can occur through boreholes. The risk of sliding slopes occurs in areas where the slope angle exceeds the interior friction angle of the welded rocks and on or through the base terrain if its slope is greater than the interior friction angle of the rocks.

The landslides of the industrial tailings deposits are a category of natural risk phenomena, which define the process of movement, the actual movement of the rocks or deposits on the slopes, as well as the resulting form of relief.

This slip process has three phases:

- The preparatory phase, of slow, incipient slip (preliminary processes).
- The actual slip (crossing the geomorphological threshold).
- Natural stabilization (balancing, post-processing processes).

From the geotechnical studies and the physico-mechanical characteristics of the boulders and the base terrain, they concluded that the risk of landslides may occur in areas where the slope angle exceeds the internal friction angle of the boulders and on or through the land base if its inclination is greater than the interior rubbing angle of the rocks.

As a result of the sliding large areas of agricultural land have suffered, constructions of villages or cities, roads, railways etc. are damaged, damage to industrial premises or to the area of hydrotechnical works are made. The masses of ground that can be moved can penetrate the banks of the rivers, causing the bottom to be raised or the partial or total obstruction of the drainage section.

The rocks that favor the sliding production the most are the "sensitive clays," spread in the regions that were covered with glaciers in the quaternary. They favor the movement of materials even on slopes of only 2–3°. That is why in the Northern countries of Europe, Alaska and so on, the landslides are frequent and large.

The most common landslides are recorded on slopes with moderate inclinations (10–30°) consisting of rocks with high shale, intensely fractured and altered.

In Romania, this type of process affected at the level of 1975 over 800,000 ha, some of which at about 250,000 ha with active landslides and 550,000 ha with stabilized landslides [16]. However, these expanded in the following years, especially until 1982. The landslides take large areas of slopes within the Sub-Carpathians (especially the curvature sector, where on certain areas they affect almost entirely the slopes), the Plateau of Moldova, the Transylvanian Depression, the Getic Plateau and even in the mountainous area (in the east of the Eastern Carpathians, in the sectors with high weight of clay shale, where the oil exploitation contributes to the disturbance of the slope balance by drilling, spills, vibrations. Example: the sliding in Zemes in 1992 moved out of work 47 oil wells, pipes, electrical networks, dwellings, the school).

The studies for the prevention of landslides and the fight against their negative consequences aim at the following stages:

a. Recognition of the areas affected by landslides and those susceptible to landslides.

b. Establishing the types, respectively the classification of the sliding.

c. Establishing the evolution stage.

d. Establishing the causes and mechanisms of movement in different types of rocks.

e. The mechanisms of movement in different types of rocks.

f. Knowledge of the way of intervention and of the technical works for stabilizing the lands.

(a) *The recognition of the areas affected by landslides and those susceptible to landslides* is facilitated by the observation of the specific micro-relief, by the mosaic appearance of the soils (unevolved soils) as well as by the presence of certain plant associations that indicate the varied ecological conditions determined by the newly formed soils.

The profile of the slopes has an irregular appearance, the surface deposits are kneaded in the form of sliding steps, mounds, waves, furrows, cracks, ridges, micro-depressions often occupied by water mesh or hygrophilous vegetation.

The main elements of a landslide are:

- The sliding slope or the detachment shaft, which is the area where the sliding material mass breaks.

- The body or mass of the sliding, which comprises the part of the displaced terrain, corresponding to the sector with chaotic micro relief, unfolded downstream by the detachment shaft.

- The front of the sliding, corresponding to the terminal part of the slide.

- The bed, the mirror or the sliding surface, representing the lubricated substrate, more or less smooth, on which the mass of material is moved down the slope.

(b) *Establishing the types, respectively the classification of the landslides* is made on the basis of several criteria: the geological structure of the slope, the way of affecting the slope, the characteristic morphology, the production time and so on. The most frequent and at the same time the most important through their consequences are the complex slidings, the interventions for their stabilization being very expensive. They are deep landslides, with generally old floods, with thicknesses exceeding 5 m, moving slowly on slopes, generalized on important areas of slopes.

The classification according to the depth to which the deposits are disturbed is very important, from this point of view there are three important categories:

- *Surface sliding*, up to 2 m thick, with the highest frequency and which usually represent reactivations of the old surfaces with sliding, but are also present on the slopes that have undergone a single cycle of mass movement processes.

- *Medium depth sliding*, with thicknesses between 2 and 5 m.

- *Deep sliding*, with thicknesses exceeding 5 m, with a slightly lower frequency, but which acquire a special magnitude where they occur.

The most dangerous are those which are deep, violent and rapid (with speeds of 2–3 m per hour), with disastrous consequences when they occur in inhabited areas: cracks in the soil, mounds, slope breaks, ditches, overturned vegetation, destruction of dwellings, roads and other economic objectives, etc.

A category of catastrophic landslides is represented by the sliding-crumbling, characteristic of the areas consisting of alternations of plastic rocks (clays or marls) and relatively hard rocks (hone) and even uncemented (sand, gravel). They are the result of the erosion affecting the base of the slopes, causing the breakage and collapse of the masses without support, together with their lateral pushing on those on the intensely moistened sliding bed. Moreover, the cutting of the slopes and excavations can lead to the triggering of such sliding, thus it is necessary to take into account the limit value of the slopes in relation to the type of rock.

According to a report of the inter-ministerial commission [16] for the inventory of industrial dumps, in Romania there are 1101 waste dumps, 994 of which are mining targets. Most are found in Suceava (224), Maramureş (180), Caraş-Severin (78) and Alba (66) counties. The problem is that only 247 of the 1101 dumps are owned by companies, the rest reaching over the years in the custody of local administrations.

Regarding the decanting ponds, there are 108, only 15 of which are operational. Most are in the counties of Maramures (15), Hunedoara (13), Harghita and Caraş-Severin (10). Many of them present a risk of sliding, especially in the seasons with heavy rainfall. Safety and environmental works have been started in many decanting ponds, but over time they have been interrupted even for years. On the other hand, where the greening was done many years ago, and the land was subsequently relocated, no monitoring was done, so no one knows what the current situation is.

Within the 556 mining objectives approved for closure since 1998, there are 78 decanting ponds with a total stored volume of 341.31 million m^3 and an area of approximately of 1770 ha, as well as 675 mining waste dumps, with a volume of 3101.92 million m^3 and an area occupied by about 9260 ha [16].

In Romania, one of the worst events of this type occurred in October 1971, when the tailings dam on the outskirts of Certejul de Sus, Hunedoara County broke down and the avalanche of toxic sludge killed 89 people and injured almost 100 others, most of the victims being children. The victims were buried in the waste of decanting ponds after the dam was broken or crushed by the debris of the blocks taken by the toxic avalanche. Over the 300,000 cubic meters of tailings lapped everything in their path, in only a quarter of hour. The wave of toxic sludge covered and destroyed six blocks, a home for single people and over 50 households. Almost half of the 89 victims killed by the disaster were students and preschoolers, and almost a quarter of them were women [16].

(c) *Establishing the evolution stage* leads to the differentiation of the active sliding (characterised by the fact that the process of moving the materials on the slopes is in progress), semi-stabilized sliding (characterised by an obvious reactivation potential) and stabilized sliding (old sliding, which does not present conditions for the movement retake).

(d) *Establishing the causes and mechanisms of movement in different types of rocks*. Within the natural causes which have already been mentioned, the strength characteristics of the rocks, represented by the angle of internal friction and cohesion, are of the utmost importance in the study of the dynamics of landslides. These can be determined with the Coulomb-Terzaghi equation:

$$\tau = (\sigma - u)\ \mathrm{tg}\varphi + c \tag{2}$$

in which τ = shear strength (tangential shear stress), daN/cm^2; σ = normal pressure on the shear plane, daN/cm^2; u = pore water pressure; φ = internal shear angle, degrees; and c = cohesion, daN/cm^2.

The water pressure in the pore (u) is determined by the formula $u = \gamma_a h_a$, in which γ_a is the specific weight of the water, and ha, the equipotential height taken in point a.

(f) *Knowledge of the way of intervention and of the technical works for stabilizing the lands*, it is known that the stability of a slope is conditioned by the existence of a balance between the forces of movement (represented by the multiplication between the mass of the material and the gravitational acceleration) and those that are opposed to the movement (the shear strength of the rocks that make up that slope). Therefore, the triggering of a sliding will start either due to the increase of the displacement forces or due to the decrease of the resistance forces.

The movement can occur by translation or rotation, and the displaced material may retain its original structure or may be completely destroyed.

Along with the natural causes, human activity can contribute to the triggering of sliding with disastrous effects, through improper use of the lands and carrying out works and constructions that do not take into account the degree of stability of the slopes.

3.1 Risk matrix for sliding of the industrial waste

The assessment of the risk of sliding of the industrial waste is a systematic technique of organizing the available information and knowledge based on a level of scientific certainty, in correlation with the necessary data and hypotheses; the technique objective is to facilitate the conclusions concerning risks, regardless of their nature ([17], pp. 73–77).

The risk assessment was carried out in accordance with "Order no. 184/1997 'regarding' the procedure for the achievement of environmental assessment" and according to which the risk is the probability of a negative effect occurring within a certain period of time ([17], pp. 73–77).

The risks of occurrence of industrial waste sliding phenomena which can have a major impact on the environment and population—for example, from the Brad mining perimeter they are:

- Loss of stability of the Cireşata Valley waste dump.
- Loss of stability of the Ribita decanting pond.
- Closure of the mining objectives in the area.
- Destruction of historical objectives.

The risk quantification is based on a simple classification system, a system in which the probability and severity of an event are classified as decreasing (**Table 4**).

The risk is calculated by multiplying the probability factor with the severity factor to obtain a comparative figure. This will allow comparisons between different risks. The higher the result is, the higher the priority that will need to be given in risk control.

The quantification of the relation between different economic, social, cultural and influence factors is presented in the risk matrix (**Table 5**).

The main purpose of assessing the risk of sliding of industrial waste is to help establish risk control. Risk assessment involves identifying the hazards and then assessing the sliding risk of the industrial waste they present, by examining the likelihood and severity of the damage that may arise from these hazards ([17], pp. 73–77).

The information regarding the assessment of the pollutants is given in the form of a checklist or matrix. The values of the sliding risk degree for the industrial waste

Probability classification	Severity classification
3 = high	3 = high
2 = average	2 = average
1 = low	1 = low

Table 4.
Risk quantification.

Crt. No.	Field	Influence factors	Probability	Severity	Risk
1.	Social-human	Population dependence on the objective	3	2	6
		Employment rate	3	2	6
		Health state	3	3	9
		Communications	3	2	6
		The risk of Social-human factors			27
2.	Aesthetic-cultural	Landscape effects	2	2	4
		Protected objectives	1	1	1
		Cultural settlements	1	1	1
		The risk of aesthetic-cultural factors			6
3.	Economic regional	Industrialization of the area	2	2	4
		The effect of the objective closure	3	2	6
		Current efficiency	2	2	4
		The risk of economic regional factors			14

Table 5.
The risk assessment matrix.

they present for the environmental, water, air and soil components are presented in matrix (**Table 6**). Environmental risk matrices in the mining perimeter of Brad.

The activity performed in the Brad area is 60% dependent on the mining industry. The reduction of activity in the mining industry has caused an acute shortage of jobs for the inhabitants of the area.

The environmental factor	The source of pollution	Procedure	Pollutants	Places affected by sliding of industrial waste	Probability	Degree	Risk
Water	Water that washes Morii Valley Quarry and Cireşata waste dump	Spillage and seepage under Cireşata dump	pH	The wells of the locals from the Morii Valley Quarry area The fauna and aquatic flora of the streams Emissary Crişul Alb stream by disappearing the aquatic flora and fauna	3	3	9
			Fixed residue		3	3	9
			Suspensions		2	2	4
			Heavy metals		3	3	9
			Sulphates		3	3	9
	Water of the Bucureşci stream	Spillage	pH		2	2	4
			Suspensions		2	1	2
			Heavy metals		3	3	9
	Water of the Barza stream	Mine water spillage	pH	Barza stream through the disappearance of the aquatic flora and fauna	3	3	9
			Suspensions		2	1	2
			Total ionic iron		3	3	9
			Heavy metals		3	3	9
		Total risk for the environmental factor “water”					84

The environmental factor	The source of pollution	Procedure	Pollutants	Places affected by sliding of industrial waste	Probability	Degree	Risk
Soil	Cireşata waste dump	Dispersion Exfiltration Anthropic Protosoil	Sedimentable powders Exfiltration under the dump Sterile	Forest fund	3	2	6
	Valea Blojului waste dump	Dispersion	Sedimentable powders	Forest fund	2	2	2
	Valea Morii quarry	Dispersion	Sedimentable powders	Forest fund	3	2	6
	Processing plant	Planning works	Ore processing	Agricultural fund	3	2	6
	Decanting pond Ribita	Planning works	Sterile sludge storage	Forest fund Agricultural fund	3	2	6
		Total risk for the environmental factor "soil"					26
Air	Crushing ore	Dispersion Propagation	Sedimentable powders Noise	Atmosphere Fauna Flora	3	2	6
	Ore transport Sterile transport Gurabarza processing plant (conveyor belts)	Dispersion Propagation	Sedimentable powders Noise	Atmosphere Fauna Flora	3	1	3
	Ore processing Gurabarza	Dispersion Propagation	Sedimentable powders Noise	Atmosphere Fauna Flora	3	1	3
	Cireşata and Valea Blojului waste dumps	Dispersion	Sedimentable powders	Atmosphere Fauna Flora	1	1	1
	Ribita pond	Dispersion	Sedimentable powders	Atmosphere Fauna Flora	2	1	2
		Total risk for the environmental factor "air"					15

Table 6.
Environmental risk matrices in the mining perimeter of Brad.

In conclusion, the quantification of the risk of slipping of the industrial deposits produced on the environment and the social domain was carried out through two risk matrices in which all the environmental components are analyzed.

The risk of slipping of industrial tailings deposits occurs in areas where the slope angle exceeds the internal rubbing angle of the rocky rocks and on or through the base terrain if its slope is greater than the internal rubbing angle of the rocks.

Risk assessment involves identifying the hazards and then assessing the risk of slipping the industrial deposits they present, by examining the likelihood and severity of the damage that may arise from these hazards.

Author details

Emilia-Cornelia Dunca[1]* and Sabina Irimie[2]

1 Environmental Engineering and Geology Department, Faculty of Mine, University of Petrosani, Romania

2 Management and Industrial Engineering Department, Faculty of Mine, University of Petrosani, Romania

*Address all correspondence to: emydunca@gmail.com

References

[1] Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances

[2] Băltianu D. Natural and Anthropogenic Hazards. Bucharest: Corint; 2001. p. 110

[3] Smith K. Environmental Hazards: Assessing Risk and Reducing Disaster. London: Routledge; 2001. p. 392

[4] Grecu F. Natural Hazards and Risks. Bucharest: University; 2004. p. 168

[5] Voiculescu M. Typology of Geographical Risk Phenomena. Oradea: Publishing House Oradea University; 1995

[6] Varnes DJ. Landslide hazard zonation: A review of principles and practice. In: Natural Hazards. Vol. 3. Paris: UNESCO; 1984. p. 63

[7] Cioacă A. Vulnerability assessment of lands affected by current geomorphological processes. In: AUŞMS-Geography-Geology. Bucharest: Publishing House University of Bucharest; 1997

[8] Cheval S. The current significance of the study of natural disasters. In: The Risk in the Contemporary Economy. Galati: Academica; 2002. pp. 118-121

[9] Raboşapca I. Considerations regarding the classification of environmental risks. ASEM. 2009; **6**(70):88-93

[10] Mac I, Petrea D. The Polysemy of Extreme Geographical Events, in Risks and Disasters. House of Science Book: Cluj-Napoca; 2002

[11] Stângă IC. Natural Risks. Notions and Concepts. Iasi: University Ed "Al. I. Cuza"; 2007. 112p

[12] https://www.theirm.org/what-we-do/what-is-enterprise-risk-management/

[13] Grecu F. Natural Phenomena of Risk. TUB, Bucureşti: Geology and Geomorphology; 1997

[14] Bogdan O, Niculescu E. Climate Risks in Romania. Bucharest: Romanian Academy, Institute of Geography; 1999

[15] Velcea V. Natural and Technogenic Risks. Sibiu: Faculty of Tourism Geography; 1995

[16] Report—Inventory and visual inspection of tailings dumps and tailings ponds in Romania. Ministry of Economy —Interministerial Commission for the national inventory of tailings dumps and tailings ponds. Reporting to the stage I no. 232.333/12.09.2017

[17] Dunca EC. Study on the Ecological Rehabilitation of the Affected Areas in the Brad Mining Perimeter. Petroșani: Universitas Publishing House; 2013. pp. 73-77