THE ENVIRONMENTAL IMPACT AND RISK GENERATED BY THE EXTRACTION OF CONSTRUCTION ROCKS IN QUARRIES - CASE STUDY TURCOAIA QUARRY

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Abstract: *At present, in Tulcea County there are 50 quarries, of different sizes, that occupy a total area of 792 ha and which have as objective the extraction of useful rocks and building materials. Of these, 37 quarries are licensed to operate, the remaining 13 quarries need re-evaluations to obtain new authorizations, in order to be in compliance with the legislation in force. Porphyries are exploited from Consul, Cârjelari and Camena Hills; granites from Măcin, Turcoaia and Cerna quarries; limestone is exploited as building rock from Zebil, Bididia, Three Fountains and South Malcoci quarries; dolomite limestone from Mahmudia quarry is exploited for ArcelorMittal Galati; ornamental rocks (greasy limestone) from Baschioi and dolomite limestone of Mahmudia, Cârjelari and Codru Babadag quarries; basic rocks (used in road and railway construction works) are exploited from Niculiţel Hills area. Starting from this situation, the present study presents an impact and environmental risk assessment of the mining activity carried out in the largest quarry in the area, namely Turcoaia Quarry (at this moment the quarry is subjected to a re-evaluation process by the National Environmental Protection Agency in order to obtain an integrated authorization). For this purpose, based on the data provided by the activity holder, the environmental impact and risk generated by the extraction process is assessed using two procedures, namely the Rapid Impact Assessment Matrix (RIAM) and Integrated Impact and Environmental Risk Assessment (IIERA).*

Key words: *construction rocks, quarry, impact assessment, environmental risk, Turcoaia*

INTRODUCTION

The anthropic impact on the environment is multiple and significant and results from the unprecedented development of human society. At European Union level, environmental policy coordination has begun for more than 30 years, focusing on their preventive nature and on the application of the "polluter pays" principle, which should aim at avoiding pollution and stresses that this must take place in parallel and concurrent with economic and social development (LAZĂR AND DUMITRESCU, 2006).

The status of Romania, as a full member of the European Union, also meant the harmonization of the internal legislation with the European one, in this sense being transposed a series of directives and normative acts regarding the quality and protection of the environment, including those related to the environmental impact and risk assessment (LAZĂR AND FAUR, 2011).

Extractive industry, regardless of how it is performed, always leads to long term negative effects on the environment. The environmental component that suffers the most as a result of mining activities is land, and with it the entire ecosystem in the area. The most significant destructive effects of open pit mining are produced, both by the quarry and the associated waste deposits and tailings ponds (LAZĂR AND FAUR, 2013; NYARI ET AL., 2016)

The entire mining activity produces, due to its specificity, multiple and diverse negative effects on the environment, exemplified by: relief changes, manifested by the degradation of the landscape and displacement of the civil and industrial objectives in the exploitation areas; the occupation of large areas of land for the exploitation, dumping, storage of useful mineral substances, industrial installations, access roads, etc., which are thus totally

unusable for other purposes, for a long time, with effects on the local communities; land degradation, vertical and horizontal displacement of the surface, and slippage of the dumps, causing serious accidents; pollution of surface water and groundwater; hydrodynamic imbalance of groundwater; negative influences on the atmosphere, flora and fauna in the area; chemical soil pollution, which can affect for many years its fertile properties; noise and vibrations spread to the environment, with a strong unfavorable action.

These issues, summarized briefly in the above, are characteristic of all underground or surface mining.

MATERIAL AND METHODES

General description of the area

The Turcoaia - Iacobdeal exploitation perimeter is administratively located on the Turcoaia commune, Tulcea County, on the right bank of the Danube, about 64 km from Tulcea (figure 1).

Fig. 1. Location of Turcoaia quarry (***, 2017)

The major overall structure of the North - Dobrogea area is the result of hercinic orogenesis and eco - and neochimeric tectogenesis.

The massif, in which the Turcoaia quarry is located, is a granite body, in the center of which there are alkali microgranites and a granite with ribeckite and egirin, the latter having a gray color with rosary shades, with a hippidomorphic - granular structure, massive texture and irregular cracking. The granite is strongly cracked and altered, especially in the upper part of the massif (TIBA M.N., 2016).

The nearest watercourse is the Danube River with Măcin branch, about 2 km west of the quarry. From the hydrogeological point of view, the conditions from the area of the exploitation perimeter are favorable for the execution of the works, the area being arid, devoid of permanent underground bodies of water.

Macin Mountains are characterized by a pronounced temperate - continental climate with submediterranean influences in areas with higher altitudes and with obvious aridity influences in the southern part of the protected area. The average annual temperatures are of 10-11°C and average rainfall does not exceed 400 mm, the Măcin Mountains being the most arid mountains in Romania, the predominant winds in from north and northeast and they contribute to the lytic erosion.

The Măcin Mountains are characterized by a rich vegetation and flora, represented by over 1,770 plant species representing approximately 50% of Romania's flora that grows on

0.05% of the country's surface, of which 72 plant species are protected as rare or vulnerable and 27 species are endemic to the region.

Although the fauna of the Măcin Mountains has not been studied as much as flora, the studies performed are significant, highlighting a great diversity and the presence of rare species protected by international law.

Operational context

The area of land, of 130.58 ha, approved by Concession License no. 163/1999, includes the following subdivisions: the Turcoaia perimeter of exploitation (itself); access roads in the quarrying perimeter and for transporting aggregates; processing plant - crushing; conveyor belt network, sorting - washing plant; finished material warehouses - loading platforms; vehicle and machinery platform; warehouses and administrative premises; fuel and explosives storage facility (TIBA M.N., 2016).

Extraction technology

The preliminary production capacity for the next 10 years of the Tucoaia quarry was set according to the orders of the interested economic agents, averaging 1,750,000 tons per year.

The exploitation method to be applied is by transport to the external waste dumps, the extraction being carried out in descending steps, the blasting being carried out with the help of the explosives placed in the drill holes made with the Atlas-Copco drill.

The exploitation activity aims to extract the steps without interruptions, taking into account both the limits of the approved reserves in horizontal and vertical plane, as well as the limits of the exploitation perimeter. The material resulting from blasing operations is loaded with excavators with thermal engines (Caterpilar 365 Excavator; Caterpilar Excavator 385), in dumper trucks (Astra 25 t and CAT 775 50 t) and transported to the crushing plant for processing (Figure 2a) or in Gura Arman loading dock (figure 2b).

a b

Fig. 2. Crushing plant and loading Dock

In the Turcoaia quarry, the granite extraction activity is carried out as follows:

a. Opening the deposit - the deposit is opened from the top, the elevation + 305 m, to the bottom where the reserve volume was calculated, namely the +130 m elevation.

b. Preparing the deposit - the deposit is fully open, no preparatory work are required, the surface layer (the tailings layer) of negligible thickness is extracted with the useful rocks, being separated by pre-sorting operations.

c. The exploitation of the deposit - the exploitation activity takes place in the eastern part of the mining perimeter, namely the Manole Fountain area on the basis of the existing projects.

d. Processing - the preparation activity consists of crushing the rough quarry stone, obtained by blasting with explosives and sorting - washing the crushed mining products.

g. Depositing the waste material - tailings resulting from exploitation, as a result of technological losses, represents 3-4% of the total. It is temporarily stored in the area of the crushing plant, occupying approximately 800 m^2, and is latter used for the arrangement and maintenance of the quarry roads.

RESULTS AND DISCUTIONS

Description of the environmental impact

The impact on the environment is defined as a set of changes produced on the environment by a process, an activity or anthropic action. It is the synergistic effect of a disturbance over a given environment or environmental component (LAZĂR AND FAUR, 2011).

The impact on the atmosphere - based on the data provided by the activity holder, multi-annual average values for SO_2, NO_x, CO and dust concentrations were calculated which were considered to be representative for the assessment of the impact of Turcoaia quarry on the environmental component *air* (table 1).

Table 1.

Values of air quality indicators taken into account in the impact assessment

Air quality indicators	M.U.	Maximum Admitted Concentration (M.A.C.)	Values considered in the impact assessment C_{det}
SO_2	mg/m^3	350	125
NO_x		400	264
CO		10	14
Dust		50	43

The main pollutants and their sources are represented by:

- *combustion of liquid fuels (diesel)*, through the operation of the equipment and the means of transport which consume approx. 740 t/year of diesel evacuating directly into the atmosphere exhaust gases (SO_x, NO_x, CO, CO_2, COV, CH_4) and dust;
- *explosives blasting* for rocks exploitation (4 times/month) by emitting harmful gases (CO, NO_x) and powders from detonation of explosives and rock dislocation;
- *the extraction and processing of granite*, by loading, transporting, crushing and sorting the useful rocks, resulting in dust emissions.

The impact on water - table 2 presents the multiannual average values for the quality indicators determined in the perimeter of the quarry. Also the table presents the values used for the assessment of the environmental impact and risk generated by the Turcoaia quarry for the environmental component *water*.

Table 2.

Values of water quality indicators taken into account in the impact assessment

Water quality indicators	M.U.	Maximum Admitted Concentration (M.A.C.)	Values considered in the impact assessment C_{det}
pH	unit.pH	6.5-9.0	8.3
Suspensions	mg/dm^3	35	23
Extractible substances with organic solvents	mg/dm^3	20	9.3
Fixed residue at 105 ˚C	mg/dm^3	2000	291

The main polluting agents of water and the pollution sources in Turcoaia quarry area are as follows:

- *drinking and industrial water supply;*
- *drainage/sewerage system of rainwater*;
- *wastewater discharge* - domestic sewage from personnel and laboratory and wastewater resulting from the technological process at the granite aggregate washing-sorting plant.

The impact on land and soil - the main problem is the occupation of significant land areas, as can be seen from table 3.

Table 3.

Land occupation by Turcoaia quarry

Specification	Surface	
	m^2	ha
Granite mining perimeter	856.700	85,67
Manole Fountain perimeter (including temporary warehouses, loading bunker, administrative space)	68.661	6,86
The perimeter of the Turcoaia sorting - washing plant (including sorting facility, aggregated temporary storage, administrative site)	57.148	5,71
Iacobdeal perimeter (including explosive storage area)	212.542	21,25
Conveyor belts	1.400	0,14
The land area outside the mining perimeter (including historic tailings dumps)	90.000	9
Exploitation roads	6.168	0,617
Free land for construction and utilities	13.181	1,318
TOTAL	**1.305.800**	**130,58**

In order to be able to carry out the environmental impact and risk assessment by the two proposed methods, the area actually occupied and affected by the quarry and mining facilities was reported on the total concessioned area.

The impact of noise/vibrations - special problems in terms of noise pollution occur when the solid rock is dislocated by drilling and blasing works. When performing blasing works in quarries, the environment is affected in five ways, being subject to seismic waves, aerial shock waves, discarding pieces of broken rock from the massive, dust and gas.

From the analysis bulletins submitted by the activity holder, namely the emission bulletin no. F6/11936/24.08.2017 where the minimum value is of 58.7 db (A), the maximum value is of 63.3 db (A), resulting in an average of 61 db (A), (the average value does not exceed the maximum admitted limit by STAS, of 65 db.

The impact on biodiversity - to analyze the impacts of the exploitation activity, the biodiversity form the ROSPA0073 Măcin - Niculițel (which includes the Turcoaia quarry on the south-western boundary) has been analyzed and if the mobility of the flora or fauna elements in this area has the requirements or ecological or ethological motivation to interact with the environment in the Turcoaia exploitation perimeter.

Considering that no protected species and habitats have been identified at the site and in adjacent areas, a number of environmental impact mitigation measures have been established to maintain the integrity of the ecological functions of the protected area (area of Community interest).

The Rapid Impact Assessment Matrix (RIAM)

In order to emphasize which of the environmental components will be most affected by an activity, the RIAM method can be applied (GEORGESCU M., 2014). It is based on a standard definition of the important assessment criteria and the means by which quasi-quantitative values can be deduced for each of these criteria, represented by a concrete, independent score (table 4).

RIAM ensures a transparent and permanent record of the analysis process, while organizing the environmental impact assessment procedure, which leads to a considerable reduction of the Environmental Impact Assessment (EIA) execution time. The simple structure

of RIAM allows for rapid and accurate in-depth reconstruction and analysis of selected components. This flexibility makes the method a powerful tool both for performing and evaluating EIAs (PASTAKIA C.M.R., JENSEN A., 1998).

Table 4.

Criteria and steps of assessment by RIAM method

Criterion	Scale	Description
A1 **The importance of environmental change (effect)**	**4** **3** **2** **1** **0**	Important for national/international interests Important for regional/national interests Important for areas in close vicinity Important for local conditions Without importance
A2 **The magnitude of the environmental change**	**+ 3** **+ 2** **+ 1** **0** **- 1** **- 2** **- 3**	Major benefit Significant improvement of current state Improvement of current state Unchanging the current state Degradation of current state Significant disadvantages or negative changes Major disadvantages or negative changes
B1 **Permanence**	**1** **2** **3**	Without changes Temporary Permanent
B2 **Reversibility**	**1** **2** **3**	Without changes Reversible Irreversible
B3 **Cumulatitivity**	**1** **2** **3**	Without changes Non-cumulative/unique Cumulutative/sinergetic

The calculation procedure for RIAM involves the following equations:

$\mathbf{A_1 * A_2 = A_t}$

$\mathbf{B_1 + B_2 + B_3 = B_t}$

$\mathbf{A_t * B_t = ES}$

where:

A_1, A_2, B_1, B_2, B_3 – evaluation criteria for RIAM method;

A_t, B_t –scores obtained by multiplying, respectively, the aggregation of values of the evaluation criteria;

ES - environmental score for the analyzed component.

After obtaining the environmental scores, they are converted into impact categories (**IC**) based on the conversion scale in table 5.

Table 5.

Conversion of environmental scores in impact categories

Environment score (SM)	Category (Code)	Description of the impact category (IC)
+ 72 → + 108	+ E	Major positive impact
+ 36 → + 71	+ D	Significant positive impact
+ 19 → + 35	+ C	Moderate positive impact
+ 10 → + 18	+ B	Positive impact
+ 1 → + 9	+ A	Small positive impact
0	N	No impact
- 1 → - 9	- A	Small negative impact
- 10 → - 18	- B	Negative impact
- 19 → - 35	- C	Moderate negative impact
- 36 → - 71	- D	Significant negative impact
- 72 → - 108	- E	Major negative impact

For Turcoaia quarry, the assessment of the impact by RIAM method is done in table 6, based on the criteria and conversion mode presented in tables 4 and 5.

Table 6.

Environmental impact assessment by RIAM method

Environmental component	Evaluation criteria					Environmental score ES	Impact category CI	
	A_1	A_2	B_1	B_2	B_3		Code	Description
Air	2	-1	3	2	2	**-14**	**-B**	***Negative impact***
Water	1	-1	3	3	3	**-9**	**-A**	***Small negative impact***
Soil	1	-1	2	2	2	**-6**	**-A**	***Small negative impact***
Noise and vibrations	2	-1	2	3	2	**-14**	**-A**	***Negative impact***

Applying the matrix method for rapid assessment of the impact of pollution (RIAM) it was concluded that the environment of the area related to the activities of the Turcoaia-Iacobdeal quarry is ***affected from slightly negative to negative***.

Integrated impact and environmental risk assessment

An effective strategy to address concerns about the quality of environmental components and prioritization is the impact and risk assessment.

Impact assessment and environmental risk assessment is an important tool in the decision-making process and involves the collection of environmental quality data in general and the quality of environmental components (air, water, soil, etc.) in particular (ROBU B., 2005). For this purpose, the previous paragraphs presented analyzes of the environmental components that could be affected by the activities carried out in the perimeter of the Turcoaia-Iacobdeal quarry, but also outside it.

The Environmental Assessment System includes the estimation and quantification of environmental impacts assessed in terms of measurable units as ***units of environmental importance*** (**IU**). Environmental impact scores in environmental impact assessments are based on two components: ***magnitude*** of environmental impacts and ***importance***.

The quality of the assessed environmental component (**Q**) is determined as the ratio of the maximum allowable concentration (**MAC**), according to the legislation in force, and the concentration determined in the environment ($\mathbf{C_{det}}$) at a given moment for a particular pollutant.

$$Q = \frac{CMA}{C_{det}}$$

As a first step, the environmental components considered in the impact and risk assessment are established.

In the case of Turcoaia-Iacobdeal quarry: air, water, soil and noise-vibrations.

The ***importance*** of each environmental component taken into account, on a scale of 0 to 1, where 1 represents the highest importance, is attributed to the $\mathbf{C_{det}}$ values relative to **MAC**.

In order to reduce the degree of subjectivity in calculating ***units of importance***, the matrix method is used to obtain ***normalized scores*** and then ***units of importance*** for each environmental component.

The magnitude of environmental impacts depends on the environmental quality parameter. Thus, the ***impact*** induced on each evaluated environmental component (**IM**) is generally given by the product of the quality of the environmental component (**Q**) and the units of importance (**IU**) obtained by each environmental component.

$$IM = Q \cdot IU$$

For the case when a number m (j = 1 .... m) of environmental components is evaluated, each having a ***n (i = 1 ... n) number*** of representative quality indicators, the overall relation, expressing the induced impact on the environment can be written as follows:

$$IM_j = \frac{\sum_{i=1}^{n} Q_{j,i}}{n_{i,j}} \cdot IU_j$$

where:

IM_j - the environmental impact induced on the environmental component ***j***;

$n_{i,j}$ – the total number of quality indicators ***i*** and considered representative for the environmental component ***j***;

$Q_{j,i}$ - the quality of the environmental component ***j*** by the quality indicator ***i***;

$$Q_{j,i} = \frac{CMA_{i,j}}{C_{\text{det},i,j}}$$

$CMA_{i,j}$ - the maximum permitted concentration for the quality indicator ***i*** and, in accordance with national legislation, an indicator for the environmental component ***j***;

$C_{\text{det},i,j}$ - the concentration determined (analyzed) at a given time in the environment for the quality indicator ***i***, indicator for the environmental component ***j***;

UI_j - units of importance obtained by the environmental component ***j***.

Each environmental impact calculated by quality indicator "***i***" is associated with an environmental risk. Once the impacts on each environmental component have been quantified, the risks associated with these impacts are calculated as follows:

$$RM_j = IM_j \cdot P_j$$

where:

RM_j – the risk on the environmental component ***j***;

P_j – the probability of impact on the environmental component ***j***.

For the Turcoaia-Iacobdeal quarry, the degree of importance of the environmental components as set out in table 7 was determined, according to which units of importance.

The impacts on environmental components are estimated according to table 8.

Table 7.

The importance of each environmental component

Environmental component	**Degree of importance**	**Importance of each environmental component in relation with the others**				**Cumulated importance SI**	**Normalized scores SN=1/SI**	**Importance units IU=SNx1000**
		Air	**Water**	**Soil**	**Noise/ vibration**			
Air	**0,7**	1.00	2.33	0.88	2.33	6.54	0.153	**153**
Water	**0,3**	0.43	1.00	0.38	1.00	2.81	0.356	**356**
Soil	**0,8**	0.54	2.67	1.00	2.67	6.88	0.145	**145**
Noise/vibration	**0,3**	0.43	1.00	0.38	1.00	2.81	0.356	**356**
Total	**-**	-	-	-	-	-	1.000	**1000**

Table 8.

Probability of producing impacts on environmental components

Environmental component	Impact probability	Probability unit
Air	Rarely, it can happen in exceptional cases, 1%	**0.05**
Water	It is unlikely, sometimes, in 10% of cases	**0.1**
Soil	It is unlikely, sometimes, in 10% of cases	**0.3**
Noise/vibration	Rarely, it can happen in exceptional cases, 1%	**0.05**

Table 9 presents the calculation of environmental impacts based on the quality indicators set for each environmental component analyzed and the environmental risks associated with each impact taking the values for the unit of importance and probability from tables 7 and 8.

Table 9.

Calculation of environmental impacts and risks at the Turcoaia-Iacobdeal quarry

Environmental component	Quality indicator	MAC	C_{det}	Q	IU	IM	P	RM
Air	SO_2	200	125	1.600	**153**	**655**	**0,05**	**33**
	NO_x	400	264	1.515				
	Dust	50	43	1.163				
	Quality of the environmental component ΣQ/n			**4.278**				
Water	pH	6.5-8.5	8.3	0.904	**356**	**1251**	**0,1**	**125**
	Suspensions (MS)	60	23	2.609				
	Quality of the environmental component ΣQ/n			**3.513**				
Soil	Occupancy	-	-	-	**145**	**290**	**0,3**	**87**
	Quality of the environmental component ΣQ/n			**2.000**				
Noise/vibrations	Noise	65	63.3	1.027	**356**	**366**	**0,05**	**18**
	Quality of the environmental component ΣQ/n			**1.027**				

The classification of impacts and risks is given in table 10.

Table 10.

Classification of the impact and environmental risk

Environmental impact	Description	Environmental risk	Description
<100	degraded environment, improper for life	**<200**	major risks, preventive measures are required
100-250	environment seriously affected by human activities		
250-350	medium subject to the effects of human activities causing disorders	**200-350**	average life-threatening risks, prevention measures are required
350-500	environment subjected to the effects of human activities causing discomfort	**350-700**	average risks to an acceptable level should be monitored
500-1000	medium subject to human activity effects within acceptable limits	**700-1000**	minor risks but should be considered / monitored
>1000	1000 environment unaffected by human activities/natural quality	**>1000**	negligible/insignificant risks

Taking into account the values obtained in table 9 and the classification in table 10, the following conclusions regarding the environmental impact and risk generated by the activities carried out at the Turcoaia-Iacobdeal quarry can be highlighted:

- the environmental component air is subjected to the effects of human activities within acceptable/tolerable limits, preventive measures are necessary;
- the environmental component water is unaffected by human activities/possible hazard with major risks, preventive measures are necessary;
- the environmental component soil an is subjected to the effects of human activities causing disturbances to life forms with life-threatening risks, preventive measures are necessary;
- the environmental component noise/vibration, an environment subjected to the effects of human activities causing major discomforts, preventive measures are necessary.

Calculating of the mean value for the four analyzed environmental components gives an average impact of **IM = 641** and an average risk of **RM = 66**, which qualifies the area of Turcoaia-Iacobdeal quarry as ***an environment subject to the effects of human activities within tolerable limits with major risks, preventive measures being necessary.***

CONCLUSIONS

The present Impact Assessment Study has been conducted with the purpose of formulating a decision on the compatibility of the activities of the Turcoaia-Iacobdeal quarry with the environment, understood as a set of natural resources and human activities.

For the quantitative assessment of the impacts produced by the Turcoaia-Iacobdeal quarry activities, the values of the quality indicators of the four analyzed environmental components (air, water, soil, noises/vibrations) were used based on the data provided by the activity holder and by direct measurements. For this purpose, two methods for environmental impact and risk assessment from the quarry activities were applied, namely: Rapid Impact Assessment Matrix and Integrated Impact and Environmental Risk Assessment.

Through its activities, Turcoaia-Iacobdeal quarry has a ***minor impact*** on the environmental components, the health of the on-site staff, as well as the population in neighboring areas and beyond.

However, the author recommends to the holder of the Turcoaia quarry activity to quickly prepare and submit the necessary documents for obtaining the integrated environmental authorization, in the context of the expected tightening of the environmental protection legislation, given the relatively limited distance from certain objectives that enjoy a special protection regime.

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