ENVIRONMENTAL IMPACT AND RISK ASSESSMENT AT PRAID SALT MINE AND MEASURES TO REDUCE NEGATIVE ENVIRONMENTAL EFFECTS

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Abstract: *Given the importance of Praid salt mine both in terms of its contribution to salt production in Romania and to balneotherapy, tourism and leisure activities that take place underground, the paper assesses the environmental impact and risk generated by these activities based on the research of pollution sources and the use of data provided by specialized laboratories for the predominant quality indicators in this area. Finally, there are several measures to reduce and / or reduce the negative effects on the environment.*

Key words: *Praid salt mine, impact, environmental risk, mitigation measures*

1. Introduction

Praid salt mine is located on the territory of Praid village, 43 km from Odorheiu-Secuiesc municipality and 8 km from Sovata town, on the upper course of the Târnava Mică river. Access to Praid is provided by the asphalt road Tg. Mureș - Sovata - Praid and through the normal line railways Blaj - Praid. Also, the Praid locality is accessible by the county road from Gheorgheni (51 km), over the Bucin pass (alt. 1243m). The lands that are located on the surface of the exploitation perimeter and are used for mining activities, are the property of Praid salt mine (fig.1) /4/.

The object of activity of Praid salt mine is: research, exploitation and processing of rock salt, resulting from Praid salt deposit. In addition to this basic activity, Praid salt mine manages the underground treatment and visiting base (located on the level +402 m), the salt bath establishment in Praid, as well as other related activities.

A detailed analysis of the activity of Praid salt mine allows the identification of some aspects that represent sensitive points in the evaluation of the technical-economic efficiency and its sustainability, but also in the evaluation of the impact it has on the environment.

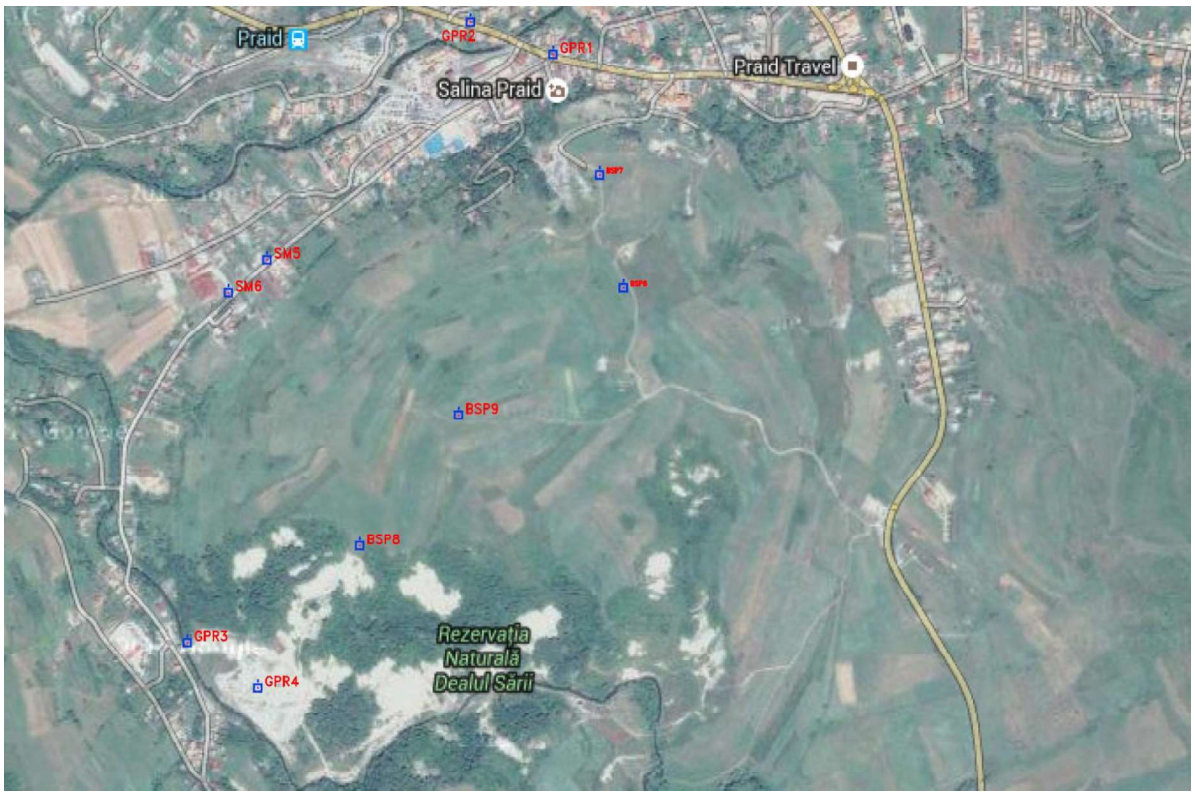

Fig. 1. *General view of the Praid area /4/*

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Like any other mining and salt mining activity, it involves imminent risk factors, generated by special working conditions, underground, primarily due to non-compliance of working technologies by mining operators.

Therefore, Praid salt mine must adopt a series of methods to prevent and combat pollution (such as the elimination of pollution at source), an efficient use of natural resources, comply with all national and European Community regulations in force, and the requirements other stakeholders (customers, non-governmental organizations, local authorities).

In general, the determining factor in achieving the above objectives is the investment in new technology and technology, namely the modernization of salt exploitation at Praid salt mine.

2. Sources of pollution

The entire mining activity at Praid salt mine produces, due to its specificity, multiple and varied negative effects on the environment, due to the existence of pollution sources. The most significant negative effects encountered at Praid salt mine are /3/:

- *changes of the relief / landscape*, manifested by changes in the landscape of the area from the southwestern part of the salt deposit, in the old enclosure, due to the landfill of salt on this perimeter in the past, but since 1994 the landfill in this area was stopped;
- *land degradation*, by the appearance in the southwestern part of the salt deposit of small suffusions at the surface of the land, due to the karst phenomenon, and in the southwestern and southern part of Salt Hill there are collapses in the form of large funnels in the form of amphitheaters, left over from past centuries, following surface exploitation;
- *pollution of running water from the surface* due to the existence of several sources of wastewater inside the salt mine:

- *domestic fecal wastewaters*, coming from the sewerage network of the salt mine and from related activities (shops, bars, salt baths), which until 2006 were discharged in Târnava Mică. Currently these waters are connected to the new sewerage system of Praid commune;
- *mine waters*, resulting from the pumped waters from the underground jumps and the natural drainage from the former Elisabeta mine, discharged to the salt baths and partially (from Elisabeta mine) directly into the Târnava Mică river;
- *treated wastewater from the car wash ramp*, inside Praid salt mine, discharged into Târnava Mică river, after the separation of oils and greases;
- *salt wastewater from the pool*, from the salt baths, discharged into the emissary Târnava Mică, through an open ditch;
- *rain waters*, from the platform of the salt mine and from the area of the above-ground fuel tanks, directed to a separator of sand and petroleum products, from where they are discharged into the river Târnava Mică;
- *hydrothermal water*, from the ACEX 401/1949 probe, which infiltrates the soil towards Corund brook.

- *negative influences on the atmosphere/air*, by discharging into the atmosphere the following pollutants:

- *exhaust fumes and shot gases*, resulting from the exploitation of salt as a result of salt removal operations, loading into dump trucks and transport with them, underground and on the surface, being discharged into the atmosphere, through the mine's aeration routes;
- *salt dust and powders*, resulting from the preparation, which are released into the atmosphere;
- *gases and powders*, resulting from the thermal power plant used to heat the socio-administrative platform, dispersed in the atmosphere through a chimney with a diameter of 500mm and a height of 10m.

- *negative influences on the flora and fauna of the area*; the area is partially adjacent to Praid Salt Mountain reservation, with an area of 2 ha. Following the extraction activity carried out by Praid salt mine, the terrestrial flora is affected in some places (in the areas with dumped earthy salt), a soil with a content of approx. 70 - 75% NaCl, allows only the fixation of some species that can grow in these extreme conditions (e.g.: Artemisia salina Willd., Salicornia herbaceea, Glyceria distans - Schur saline variety). The aquatic flora and fauna of the water of Corund brook and, implicitly, of Târnava Mică river is influenced especially in case of accidental pollution: excessive pumping, a low flow of the brook or in case of torrential rains, which washes a high amount of salt, especially in the area of Corund canyon in a relatively short time. The lands in the Praid area are agricultural, the predominant crops being potatoes, corn and orchards. As for the meadows, they have specific vegetation. There are also many hayfields, both on Salt Hill and in the surroundings, unaffected by salt exploitation operations. The evacuated pests do not affect either the crops or the spontaneous vegetation in the area;
- *noises and vibrations* spread in the environment, as a result of the activities carried out inside the salt mine, which may have in case of exceeding the allowed values a strong unfavorable action on people.

3. Impact of Praid salt mine activities on environmental components

Further, based on the values of some quality indicators of the environmental components, determined over a long period of time (1994-2019), by authorized laboratories, namely: the laboratory of hydrochemistry and hydrobiology Romanian Water RA-territorial branch Târgu Mureș and the laboratory of SC Wessling România SRL Tg. Mureș ***for waters***, the environmental protection laboratory of INCD INSEMEX-Petroșani ***for air and noise*** /5/, /6/, they established, following the statistical processing, weighted average values of these indicators that will be taken into account in assessing the impact of anthropogenic activities on the environment around the Praid salt mine area. In summary, these values are presented in Tables 1, 2 and 3.

3.1. Impact on air

The choice of pollutant collection points was made at several critical points inside the salt mine, measuring the emissions of NO_2, SO_2, CO and PM10 dust (Table 1).

Table 1 *Average concentrations of NO2, SO2, CO and PM10 pollutants*

Quality indicators	Sampling location	UM/h	C_{det} (values accepted in the impact assessment)	MAC (Cf. Law no. 104/ 2011)
NO_2	Adit -Inclined car run, main entrance	µg/m^3	**71,74**	**200**
SO_2		µg/m^3	**39,32**	**350**
CO		mg/m^3	**5,77**	**10**
	The gate behind the store		13,80	
	The gate opposite the swimming pool		26,50	
	Wood sawmill area		12,60	
	The main entrance, near the administrative headquarters		29,10	
PM10	Maximum accepted value PM10	µg/Nm^3	**29,10**	**50**

From the analysis of the values determined for the four indicators NO2, SO2, CO and PM10, included in table 1, it is observed that the values of the maximum allowed concentrations were not exceeded, according to the air quality law no. 104/2011.

3.2. Impact on water

The wastewater from Praid salt mine is mine and factory water.

From the multitude of data provided by the laboratory of SC Wessling Romania SRL Tg. Mureș, obtained following the systematic analysis of samples, a statistical processing of the values of the concentrations of quality indicators was performed, so that Table 2 displays the statistical averages of these concentrations. It is found that the values of concentrations of mine water quality indicators, in most of them, exceed the maximum permitted concentration (MAC).

Table 2 *Average concentrations of quality indicators for water*

Cr. no.	Quality indicators	UM	The average determined concentrations		Values accepted in the impact assessment C_{det}	Values maximum accepted, MAC
			Water wash pool filter	Mine water		
1.	**pH**	pH units	7,46	7,20	**7,20**	**6,5-8,5**
2.	**Fix residue**	mg/l	55025	251500	**251500**	**200000**
3.	**Suspensions**	mg/l	709	6047,5	**6047,5**	**350**
4.	**COD-Cr**	mg/l	1741	-	**1741**	**300**
5.	**Chloride**	mg/l	31975	205500	**205500**	**165000**

3.3. Impact on the soil

As no systematic chemical soil analysis has been performed at Praid salt mine, this environmental component will not be taken into account in the impact assessment.

The activities inside the salt mine require the occupation of a land area of 85,319.156m2 ≅ 8.6 ha, of which:

Total area (m^2) of premises (including buildings): 24,603.81 of which:

- ✓ Built area: 7.840
  made up of:
  - office building 406
  - social group building 321
  - materials warehouse 464
  - fuel depot 522
  - preparation plant 1.165
  - workshops 927
  - thermal power plant 100
  - outbuildings 3.935

- ✓ Access roads 1.892
- ✓ Transport area (inside) 10.279,81
- ✓ Parking spaces 4.592
- ✓ Air pit yard (Telegdy) 1.857,63
- ✓ Air raise yard 19.893,22
- ✓ The mouth of the adit 1.651,87
- ✓ Post-transformation yard 549,04
- ✓ Commercial spaces yard 1.877,36
- ✓ Kindergarten yard 405,43
- ✓ Salt bath yard 5.195,82
- ✓ Gh. Doja shaft yard 29.284,94
- ✓ Mine waste dump 1.165

3.4. The impact caused by noise

In order to establish the impact produced by the noise inside the salt mine, the authorized personnel of the Labor Protection Laboratory from INCD INSEMEX-Petroșani performed periodic measurements according to the specific standards. The analysis points were: store area, railways loading area, car ramp and opposite the swimming pool (table 3). It is found that the values of noise levels do not exceed the allowed limit if we report them all to industrial areas.

Table 3 *Noise level, static weighted average, L_{zsn}*

Cr. no.	Point of analysis	U.M.	The average of the measured values of Leq in the period 2012-2019	Accepted limit for industrial areas
1.	**Store area**	dB(A)	53,47	**65**
2.	**Railway loading area**		50,03	
3.	**Car ramp**		50,77	
4.	**Swimming pool opposite**		52,22	

4. Environmental impact assessment at Praid salt mine

4.1. Matrix environmental impact assessment /1/, /2/

In order to emphasize which of the environmental components will be most severely affected by an activity, the RIAM method (Rapid Impact Assessment Matrix) can be applied. It is based on a standard definition of the important evaluation criteria and the means by which quasi-quantitative values can be deduced for each of these criteria (represented by a concrete, independent note) (Table 4).

The calculation procedure for RIAM involves the following equations:

$$A_1 \cdot A_2 = A_t$$
$$B_1 + B_2 + B_3 = B_t \quad (1)$$
$$A_t \cdot B_t = SM$$

where: A_1, A_2, B_1, B_2, B_3 – evaluation criteria by RIAM method

A_t, B_t – grades obtained by multiplying, respectively, adding the values of the evaluation criteria

SM - average score for the analyzed factor

Table 4 *Criteria and evaluation steps by the RIAM method /1/*

Criteria	Scale	Description
A1 The importance of change environment (effect)	4	Important for national / international interests
	3	Important for regional / national interests
	2	Also important for the areas in the immediate vicinity of the analyzed area
	1	Important only for local conditions
	0	Without importance
A2 The magnitude of the change environment	+ 3	Significant major benefit
	+ 2	Significant improvement of the current / current state
	+ 1	Improving the current state
	0	Unchanged current status
	- 1	Negative change of fact
	- 2	Significant negative disadvantages or changes
	- 3	Major disadvantages or negative changes
B1 Permanence	1	No changes
	2	Temporary
	3	Permanent
B2 Reversibility	1	No changes
	2	Reversible
	3	Irreversible
B3 Addition	1	No changes
	2	Non-cumulative / unique
	3	Cumulative / synergiste

After obtaining the environmental scores, they are transformed into impact categories (CI), based on the conversion scale in Table 5.

Table 5 *Conversion of environmental scores into impact categories /1/*

Environmental score (SM)	Categories (Code)	Description of impact category (CI)
+ 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	Slightly positive impact
0	N	Lack of change / status quo / Not applicable
- 1 → - 9	- A	Slightly 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 Praid salt mine, the evaluation by the RIAM method is performed in table 6 based on the criteria and the conversion method presented in tables 4 and 5.

Table 6 *Evaluation by RIAM method*

Enviornmental component	Evaluation criterion					Environmental score, SM	Impact category, CI	
	A1	A2	B1	B2	B3		Code	Description
Air	3	-1	3	3	2	-24	**-C**	***Moderate negative impact***
Water	3	-2	3	3	2	-48	**-D**	***Significant negative impact***
Noise	2	-1	3	3	2	-16	**-B**	***Negative impact***

Conclusion: According to the RIAM method, it results that the impact of anthropogenic activities within Praid salt mine is slightly moderate to significant negative.

4.2. Integrated environmental impact and risk assessment

The integrated Environmental Impact and Risk Assessment (EIRA) procedure is an ideal mechanism used to estimate and establish quantitative values for quality parameters used in impact and risk assessment, both before the project and in the operational and post-project phase. operation of the project for which the environmental assessment is performed.

As a first step, the environmental components considered in the impact and risk assessment are established. Then the degree of importance (GI) is assigned to each environmental component taken into account, on a scale from 0 to 1, where the value 1 represents the greatest importance.

In calculating the importance, the calculation matrix method is used, finally obtaining the units of importance (UI) for each environmental component (see table 7).

For Praid salt mine, the degrees of importance of the environmental components were established as shown in table 7, according to which the units of importance were calculated (see the same table).

Table 7 *Calculation of the importance of each environmental component /2/*

Environmental component, CM	Degree of importance, GIi	Units of importance UIi = 1000·GIi/GI
Air	1,00	345
Water	1,00	345
Noise	0,90	310
Total	GI=ΣGIi=2,90	UI=ΣUIi=1000

The probability of an impact on an environmental component is determined according to Table 8.

Table 8. *Description of probability /1/*

Probability	Description	Probability (P)
Surely	it is achieved in 99% of cases	0,91-1,0
Almost sure	it could be achieved in 90% of cases	0,61-0,9
Probable	it can happen in 50% of cases	0,31-0,6
Unlikely	it sometimes happens in 10% of cases	0,05-0,3
Rare	may occur in exceptional cases, 1%	<0,05

The quality of a pollutant / quality indicator of an assessed environmental component (Q) is determined as the ratio between the maximum allowable concentration (MAC), according to the legislation in force, and the concentration determined in the environment (C_{det}), at a given time, for that pollutant / quality indicator /2/.

$$Q=CMA/C_{det} \quad (2)$$

The induced impact on each assessed environmental component (IM) is given by the relation:

$$IM=UI\cdot(\Sigma 1/Q_i)/n \quad (3)$$

where: $\Sigma 1/Q_i$ - the sum of the inverses of the values of the quality indicators / pollutants (i) of an environmental component;

n - the number of quality indicators / pollutants taken into account for an environmental component.

The risks associated with these impacts (RM) are determined in relation to:

$$RM=IM\cdot P \quad (4)$$

where: *P* - the probability of producing impacts on the environmental components.

The calculation of environmental impacts and risks generated by a given activity is centralized in Table 9.

Table 9 *The calculation of environmental impacts and risks*

Environmental component	Quality indicator	CMA[1]	C_{det}[2]	Q[3]	UI[4]	IM[5]	P[6]	RM[7]
Air	NO_2	200	71,74	2,78	345	**138**	0,9	**124**
	SO_2	350	31,32	11,17				
	CO	10	5,77	1,73				
	PM10	50	29,10	1,72				
	$(\Sigma 1/Q_i)/n$			0,40				
Water	pH	6,5-8,5	7,20	1,00	345	**1797**	0,9	**1617**
	Fixed residue	200000	251500	0,79				
	Suspensions	350	6047,5	0,06				
	COD-Cr	300	1741	0,17				
	Chloride	165000	205500	0,80				
	$(\Sigma 1/Q_i)/n$			5,21				
Noise	Store area	65	53,47	1,21	310	**248**	0,9	**223**
	Railway loading area		50,03	1,30				
	Car ramp		50,77	1,28				
	Swimming pool opposite		52,22	1,24				
	$(\Sigma 1/Q_i)/n$			0,80				

1 - maximum concentration allowed according to the national legislation in force, 2 - determined concentration, 3 - quality of the environmental component, depending on the indicator "i" from "n" quality indicators; 4 - the unit of importance obtained by the environmental component; 5 - the environmental impact calculated according to the "environmental quality" parameter, 6 - the calculated probability that the impact will occur on the environmental component; 7 - the environmental risk associated with each impact

The average values for the environmental impacts induced of the analyzed area as well as the risks related to the relations can also be calculated:

$$IM_{med} = \Sigma IM_j/m \text{ și } RM_{med} = \Sigma RM_j/m \quad (5)$$

where: *m* - the number of environmental components *j* analyzed.

The quantification of the environmental impact and risk, for each environmental component, will be done according to the classification given in table 10. Taking into account the classification in table 10, the following conclusions regarding the impact and risk of the activities carried out at Praid salt mine result, according to the EIRA method:

- according to **the air** environment component, *environment subject to the effects of industrial / human activities within acceptable limits with minor risks, must be monitored*;
- according to **the water** environment component *degraded, unsuitable for life forms with catastrophic risks, all activities must be stopped;*
- by component of environmental **noise,** *environment subject to the effects of industrial / human activities within acceptable limits with medium risks at an acceptable level, prevention and monitoring measures*

Calculating the average value for the three environmental components analyzed, we obtain an average impact **IM = 728** and an average risk **RM = 655**, which qualifies the area related to Praid salt mine as an *environment subject to the effects of industrial / human activities causing dangers to life forms, risks environments at an unacceptable level, control, prevention measures.*

Table 10 *The quantification of the environmental impact and risk /1/*

Environment impact	Description	Environment risk	Description
<100	natural environment, unaffected by industrial / human activities	**<100**	negligible / insignificant risks
100-350	environment subject to the effects of industrial / human activities within permissible limits	**100-200**	minor risks must be monitored
350-500	environment subject to the effects of industrial / human activities causing discomfort	**200-350**	medium risks at an acceptable level, prevention and monitoring measures
500-700	environment subject to the effects of industrial / human activities causing disturbances to life forms	**350-700**	medium risks at an unacceptable level, control, prevention measures
700-1000	environment subject to the effects of industrial / human activities causing dangers to life forms	**700-1000**	major risks, control and prevention measures
>1000	degraded environment, unsuitable for life forms	**>1000**	catastrophic risks, all activities must be stopped

5. Measures to reduce the negative effects on the environment /3/

5.1. Protecting surface objectives

- preservation of ceiling and floor pillars and floors;
- compliance with the dimensions, shape and coaxiality of the inter-chamber pillars, provided in the documentation of the approved operating framework methods;
- periodic monitoring, by topographic measurements, of the stability of the resistance elements (chambers, pillars and floors).

5.2. Prevention of landslides and landslides or dumps

- surveillance through geo-mechanical research and topographic measurements of the stability of the resistance elements;
- measures to ensure stability;
- execution of waterproofing and greening works of the perimeter.

5.3. Prevention of rush of waters and floods

The capture and discharge of water at Praid salt mine is regulated by the Water Management Authorization no. 258 / 20.09.2016 (valid until 20.09.2019).

- the sewerage of fecal-domestic wastewater from the surface is made through the sewerage network made of PVC pipes Dn = 200mm, which lead the waters to the communal sewerage system and the treatment plant of Praid;
- the collection system of fecaloid-domestic wastewater from the underground, is made in concrete and waterproof jumps from where through a pipe mounted in the coastal gallery these waters are sent to the sewerage network of Praid village.
- mine water sewerage:

- the water resulting from condensation on the aeration suites is collected in a basin of 10 - 20 m^3 and evacuated with electric pumps, having a capacity of $Q = 20m^3 / h$.
- the waters resulting from infiltrations are collected in underground basins of 80 - 2400 m^3 and are discharged by electric pumps with a capacity of 40 m^3/h. The evacuation of these salt waters is made in the Târnava Mică river.
- the hydrothermal water discharged by the wells ACEX401 / 1949, Q = 0.001 l / s, and F402 / 2010, Q = 0.43 m^3 / day is evacuated in Corund brook.

The works for the evacuation of the mine waters, infiltrated in underground, are a permanent activity of Praid salt mine, considering the fact that the affected area of the old mines is located in the immediately upper part of the new exploitation levels, in the vicinity of Corund brook.

- the evacuation of the ***rainwater*** afferent to the yard of Praid salt mine is done occasionally, directly in the emissary Târnava Mică, with a flow of approx. of $Q_{max.}$ = 420 l/s. The quality indicator for these waters is the content in petroleum products. Rainwater can be discharged into the emissary only without iridescence.

5.4. Other measures

- maintenance of the surface drainage system;
- the evacuation as soon as possible of the meteoric waters from the surface of the old mining platform;
- liquidation of small suffusion gaps by filling them with compacted clay;
- reopening of the old drainage galleries;
- maintenance of Elisabeta guarding trench, on Salt Hill;
- opening and filling the dissolution gap on the access road to Elisabeta pit.

6. Conclusions

Praid salt mine is one of the most representative salt mines in Romania, being known both for the production of salt that is delivered on the domestic and foreign market, but also for the balneotherapy, tourism and leisure activities that it performs to the general public.

The paper analyzing only the aspects related to environmental pollution generated by these activities and based on its own research, but also the data provided by the Saline management, conducted an environmental impact and risk assessment on the saline area using two methods MERI and RIAM.

The general conclusion is that the area related to Praid salt mine is an *environment subject to the effects of industrial / human activities causing dangers to life forms, medium risks at an unacceptable level, which require periodic controls, but also prevention measures.*

This state of the environment is mainly caused by the water component of the environment because the salt and rainwater are discharged directly into Târnava Mică river, and the hydrothermal ones into Corund brook.

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