ENVIRONMENTAL IMPACT ASSESSMENT OF THE URANIUM MINING ACTIVITY IN THE BIHOR DISTRICT (BUCHAREST, ROMANIA)

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Abstract
The development of the uranium mining industry in Romania started in 1950. The exploitation of Bihor region, one of the most important metallogenic zones of the country, began in 1962. Uranium exploitation activities were ceased in 1995 due to the exhaustion of the ore deposits. Between 2001 and 2002, due to the entire mining zone closure, ecological rehabilitation and decommissioning was initiated. The proposed solutions, concerning terrain, equipment and buildings utilization were elaborated according to the guidelines of the Romanian Environmental and Nuclear Authority.

Introduction
The uranium ore deposit at Bihor was discovered in 1950. The next three zones with specific mineralization were identified:
- Valea Vacii- Valea Leucii zone, where complex nickel, cobalt and uranium sulphides mineralization dominates;
- Valea Ariesul Mic zone, where uranium, copper, lead, nickel and zinc mineralization dominates (Avram Iancu mine);
- Zona Valea Calului, where uranium mineralization dominates (Baita quarry).

In Figure 1 the mineralized zones and the perimeter of the Bihor mine are shown.
It has to be noted that uranium exploitation activities carried out during the last fifty years besides the significant benefits regarding industrial development of the area affected negatively the environment by changing the landscape of the mountainous areas.
The consequences of the mining workings were due to construction of ditches, opening-ups, pits, borings, coast galleries, yards, access pathways, dumps, diversion of some streams, contact beds etc. Another negative effect was the destruction of a significant part of the forested areas.
In order to research and exploit the Avram Iancu ore deposit hundreds of kilometres of galleries and other underground mining workings were constructed; these activities generated millions of tones of sterile or poor ore, stored in many dumps mainly on the banks of mountain creeks (Ariesul Mic. Dedesului, Dibarz, Crisul Negru) (Fig. 1).
Several exogenous factors continuously affect the materials (rocks and minerals formed under high temperature conditions) stored in dumps and other systems; these materials are subjected to additional transformations due to their adjustment to the new environmental conditions.
In the case of rocks and poor ore contained in the dumps, due to the temperature variation under the existing atmospheric and climatic conditions, transformations such as volume increase take place. In addition, alteration processes, which represent an opened cycle with a single direction evolution, are initiated. These alteration processes cause release and migration of several elements into dispersion media (water, sediments, vegetation) initiating thus environmental pollution.
Apart from these chemical processes, it is possible to measure increased values of gamma rate doses and radon concentrations on the surface of the dumps containing materials with elevated content of uranium and radium (Popescu et al., 2000).

Methods
In order to identify the pollution sources, namely dumps and mine waters, which due to their radioelement content, increase through different transfer pathways the effective dose for persons belonging to critical groups, the following investigations were carried out:
- In situ measurements of gamma rate dose performed by dividing the dumps surface in a sampling network consisting of squared surfaces sized either 5m ×5m or 5m ×10 m;
- Determination of radon concentration on the surface of the dumps and at the mouth of existing galleries;
- Sampling in dumps and lab analysis for U, Ra, As, Cu, Pb, Zn, Ni, Co and Mo (Dumitrescu et al., 1993);

▪ Water sampling from mines and creeks and determination of chemical and radioactive compounds.

The critical group represents the communities who live in the affected area's neighbourhood (AIEA, 1996).

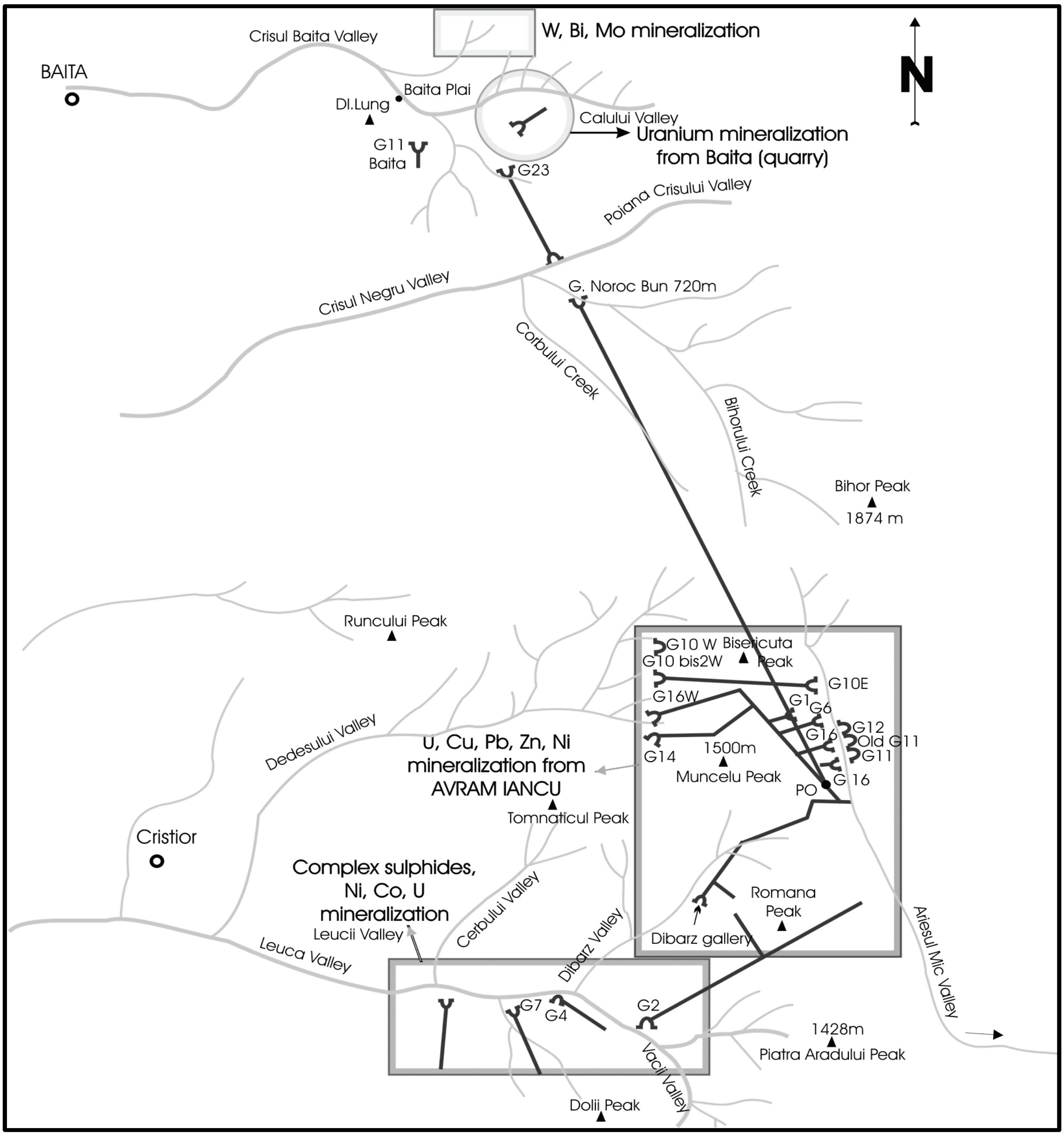

Figure 1. Types of mineralization at Bihor mining exploitation's perimeters.

Results and Discussion

1. Dumps characterization

In Table 1 the characteristics of the existing waste dumps in the Bihor zone are presented.

The total surface area of the dumps, consisting of sterile rock and crystalline schist, which is the dominating phase, is 75,460 m^2.

In terms of other elements, the composition of the samples was: Ni - 120 g/t; Mo - 4g/t; Cu-120 g/t; Co-150 g/t; Pb-40g/t; Zn-150 g/t; Cr-33g/t; As-100g/t.

No solubilisation or migration was seen in the dumps and therefore the water samples collected at the Ariesul Mic creek had low concentration of radioelements.

Table 1. Dumps characterization.

Pollution sources	Concentration			Gamma rate dose
	U g/t	Ra Bq/g	Rn Bq/m^3	µSv/h
Dump G_{10}	10	0.05	35	0.3
Dump G_{12}	4	0.03	40	0.45
Dump G_1	70	0.7	75	0.65
Dump G_a	15	0.047	25	0.25
Dump G_6	850	11.86	370	1.9
Dump G_{11}	12	0.1	50	0.55
Dump G_{13}	36	0.23	38	0.28
Dump G_{16bis}	150	1.25	145	1.02
Dump Poiana	145	1.44	80	1.85
Dump $G_{10\,W}$	750	6.01	560	8
Dump $G_{16\,W}$	350	3.73	180	2.10

2. Mine waters characterization

Due to the fact that mining activities were ceased during the last years no mine water generation was seen in most galleries.

The waters generated from the mining workings are flowing naturally to the surface, especially through the 720 m (Poiana) gallery.

The factors which are hindering flooding of the underground workings are the following:

- Mountainous landscape with sharp peaks, narrow tops and escarpments, which divert the flow of the water outside the boundaries of the ore zone;
- The low fragmentation of the metamorphic rocks decreases significantly infiltration of rain water in the underground mining workings.

The areas, where the metamorphic complex is fragmented by faults and cracks and thus increased flow rates of mine water are anticipated, are limited.

In Table 2 the mining works, which discharge mine waters in the environment, are presented.

Table 2. Mine waters characterization.

Mining works	Flow rate L/sec	Concentration	
		U mg/L	Ra Bq/L
G_{Poiana}	23	0.302	0.13
G_{12}	1.5	0.105	0.07
G_a	0.04	0.008	0.009
G_{11}	3	0.075	0.058
$G_{16\,W}$	2	0.015	0.01
G_{Dibarz}	2.2	0.005	0.004

3. Environmental impact

3.1. Pollution effect on hydrographic network

From the analysis of the data concerning uranium and radium content in all water samples the individualization of the following populations can be seen (Fig. 2):

- Population A - includes samples collected from the Aries and Crisul Negru springs representing the background: U – 0.003 mg/L, Ra – 0.004 Bq/L, and from the wells within the critical groups;
- Population B – samples collected from the Ariesul Mic creek at the beginning of the mining zone to the critical group – Tarsa village, at a distance of 9 km;
- Population C –samples collected from Crisul Negru creek beginning at the Poiana zone and ending at Vascau city;
- Population D – includes mine water samples.

If these results are superimposed on the sampling plan, it can be observed that only on the Crisul Negru creek exists a contamination “flag” (the pollutants content level exceeds the admitted limits for drinking water). A minor influence of the pollution sources is observed at the Ariesul Mic creek, but without exceeding the admitted limits for uranium and radium content. All the other elements exhibit concentrations below the admitted limits.

3.2. Pollution effect on soil and sediments
In order to assess the impact of radioactive contamination on nearby soils and sediments due to mine waters and dumps, the results were interpreted using discriminatory analysis (Fig. 3) by taking into account background values and migration processes.
Sediments sampled in the mine workings zone, at the Ariesul Negru valley, have an uranium content between 10 and 60 ppm while radium varies between 0.1-0.7 Bq/g; no unbalance between uranium and radium contents is seen (ellipse C), therefore contamination is due to mechanical transfer of ore particles from the dumps by rain water.
The same aspect is seen at the Crisul Negru creek near Poiana dump as well as downstream at a distance of about 0.5 km.
In the mud sampled in the galleries at Ariesul Mic creek valley the concentrations of uranium and radium are 30-100 ppm U and 0.1-0.25 Bq/g Ra respectively (Fig. 3 ellipse B).

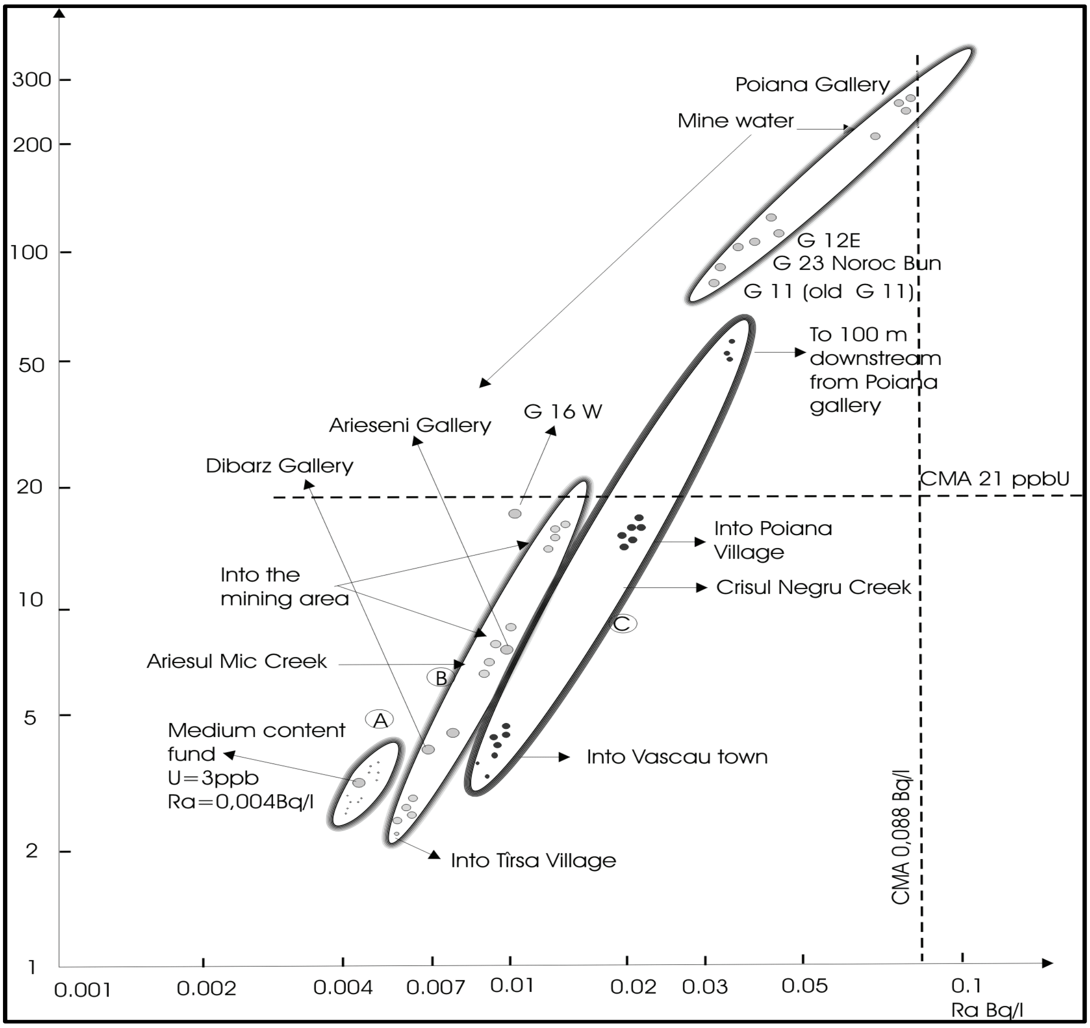

Figure 2. Uranium and radium distribution within the mine waters and the hydrographic network.

Conclusions

By taking into account the above presented data it can be seen that the limited pollution within the Avram Iancu mine basin is due to direct and indirect factors, namely:

- Rainy climate;
- High flow rates of rivers and slopes;
- "V" – shaped valleys;
- Neutral pH;
- Reduced U and Ra content in mine waters.

This is the general presentation of Bihor "landscape" concerning pollution sources and their influence on the environmental factors.

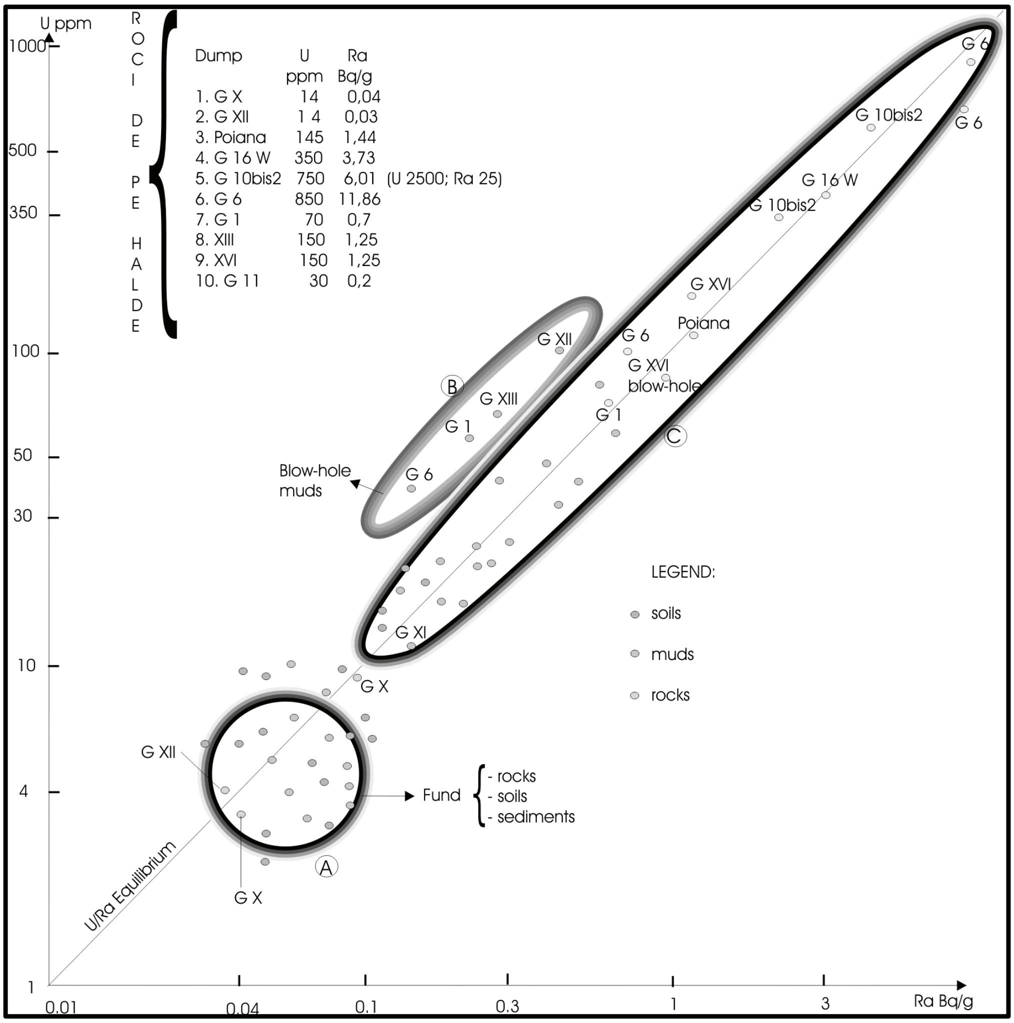

Figure 3. Uranium and radium distribution within soils, rocks and sediments.

Acknowledgements

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