

# ENVIRONMENTAL IMPACT OF THE METALIFEROUS ORE MINING AND PROCESSING IN ROMANIA

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**Abstract** A sustained metal ore mining and beneficiation activity was developed in the past in Romania and it strongly impacted the environment as a whole and it occupied and damaged large surface areas of land as a result of the waste dump, tailings management facilities locations as well as of the erection of the industrial plants required for the production process.

The paper deals with the impact with the time of the mining industry on the territory as there have been built more than 350 waste dumps and 60 tailings management facilities.

There are shown the observations and measurements performed on site throughout the years and the works completed to enhance the stability and safety of such big waste and tailings deposits.

The final part of the paper deals with the concerns involved by the construction of a national complex system for environment monitoring mainly aiming at the tailings management facilities and waste dumps of the mining zones.

## Overview

There are many and various useful mineral deposits hosted by Romanian territory, such as: mineral fuels, ferrous, non-ferrous and rare metal ores, precious metal ores, non-metal substances, etc.

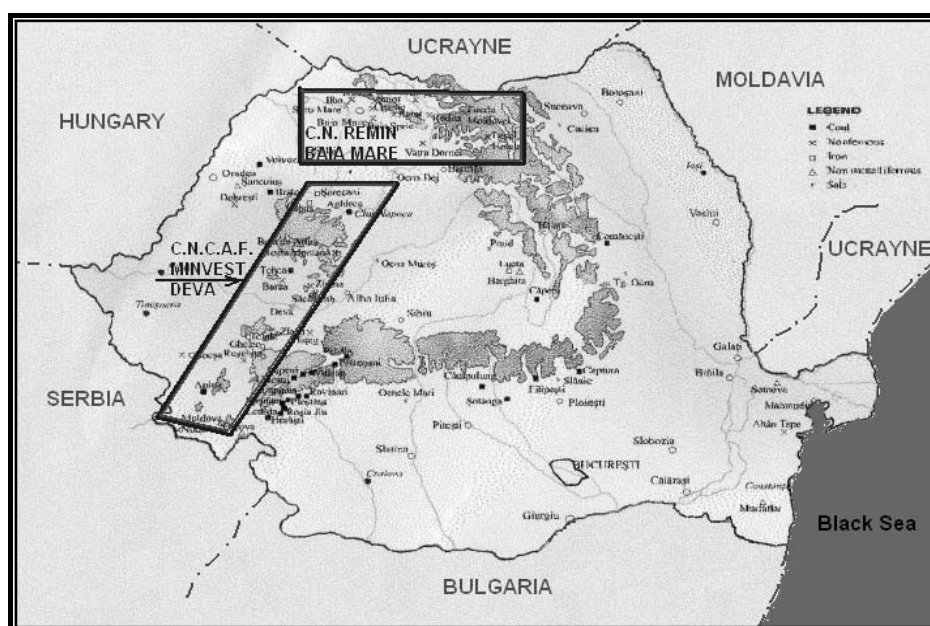
The mining and processing of the solid raw materials on Romanian territory have been developed since old times. The Romanian mining industry had been continuously developing until the last decade of the XXth century when it faced deep changes and adjustments to the transition to the market economy.

The most important metal ore deposits of Romania are located within the mountaineering areas of the North and West parts of the country, going from Bucovina to Maramures and Apuseni Mountains up to Moldova Nouă.

Until the year 1990 there were more than 40 mining exploitations and almost 30 processing plants operating in these regions and there were mined out more than 50 million tons per year of gold-silver, copper, base metal and iron-manganese ores (figure no.1).

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**Fig. 1** Map of ferrous and non-ferrous deposits of Romania

The conditions of the ore deposits of Romania are generally difficult and very difficult because of the complicated tectonics, small and medium reserves, thin layers and veins, low grades, deep mines, difficult hydro-geological conditions etc. Considering all these factors, only small scale exploitations were developed, but they had a strong and easily visible impact on the environment.

Classic methods and technologies were used for the opening, preparation and exploitation works within the activity of the ore deposit beneficiation in Romania.

In order to eliminate the subventions from the State budget and to render profitable the mining operations, even since the last decade of the XXth century, the Romanian Government decided to accelerate the closure process of some mines where the geological reserves were depleted and the geological and mining conditions were difficult incurring high and very high mining costs. A significant number of mines have been closed or under preservation so far as well as the activity areas of Bucovina, Maramureş, Munţii Apuseni and Banat where the geological conditions were difficult, the reserves were limited and they incurred high operating costs.

The review, preservation and closure processes of the Romanian mines is ongoing and only the profitable mines still remain in operation.

### **Mining industry and environment**

The mining industry has a significant impact on the environment during all the technological stages of the mining and processing processes. Regardless the method applied for an ore deposit

beneficiation, numerous physical and chemical operations are required and there result on one hand, the useful minerals and on the other hand, the waste material mined out with the useful mineral.

The useful minerals themselves of the crude ores existing in Romania, represent almost always low percentages of the total ore bulk mined out of the deposit and consequently, the solid waste tonnages resulted at the ore mining and processing are high and very high, and in addition to it there results waste material at the opening and preparation work, particularly at the open pit stripping works.

Besides the solid waste the mining industry is generating also liquid and gaseous residues which amounts are many times more significant than the solid ones.

Regardless their aggregation status these residues impact all the environmental factors: soil, air, water, flora and fauna.

### **Air and water pollution of the mining zones**

Throughout the entire period, when the mining activity was developed in a sustained manner with high production rates, the concerns for the air and water protection were permanent in the sense that the pollution and air and water impact had been investigated and there were implemented suitable measures to keep them within admissible value range according to the existing legislation both at national and European levels.

During the exploitation works and after their closure, the acid characteristic as well as the high mineralization rate and very high contents of Cu, Zn, Fe of the mine waters was noticed (figure no.2).



**Fig. 2** Acid drainage resulted at the old underground mines

Also, the huge amounts of used waters resulted at the processing plants were contaminated by metal ions, simple and complex cyanides, phenoles, xanthates, simple reagents, oils, etc. and had a strong toxic impact on the natural receivers and neighbouring areas.

It is to be underlined here that throughout the years, several technical accidents, ecological disasters occurred at the mines of Apuseni Mountains and Maramuresului Mountains and they caused the contamination of the river waters of the areas and of large surface areas with mining residues containing heavy metals and different

toxic matters with devastating impact on the flora and fauna of the region. There are to be mentioned the accidents which took place some years ago at the processing plant and tailings management facilities of Baia de Arieş, Gura-Barza, Certej, Baia Mare and Baia Borşa.

The most well – known accident which took place during the last years, was the one of S.C. Aurul S.A. Baia Mare, when on the 30th January 2000, there occurred a 25m burst of the starter dam from AURUL tailings facility and for about 10 hours, approximately 100,000 m<sup>3</sup> of water containing suspensions and cyanides was flowing out. As a result, there were contaminated with cyanide the river water courses of the zone, a large surface area of farming land and the phreatic cloth downstream the accident site.

This accident had serious consequences on the flora and fauna of the rivers from the area and serious trans-boundary implications.

### Land occupation and degradation

The mining industry projects occupy large surface areas which get damaged by the exploitation, waste dumping and useful mineral stockpiling as well as by the location of

constructions and installations required for the production development. At the same time, the mining industry is causing relief modification and relocation of industrial projects and human settlements. Under many circumstances, the land is damaged because of the subsidence events and sliding of dumps and tailings management facilities resulting in accidents with a serious and very serious impact.

Immediately after the year 2000, there were inventoried all the surfaces of Romania occupied by the mining industry for different purposes. On this occasion, a special attention was paid to the existing waste dumps and tailings management facilities and to their technical condition.

It was concluded that the metal ore mining and beneficiation operations in Romania occupied several thousands hectares of lands. Approximately half of the surface area is used for the production process development while the other half is affected by the residual product stockpiling, waste dumps and tailings management facilities.

The metal mining units administrated more than 350 waste dumps where a volume of 150 millions m<sup>3</sup> were stockpiled covering a total surface area of 700 ha (table no.1).

**Table 1** List of waste dumps of the metal mining of Romania

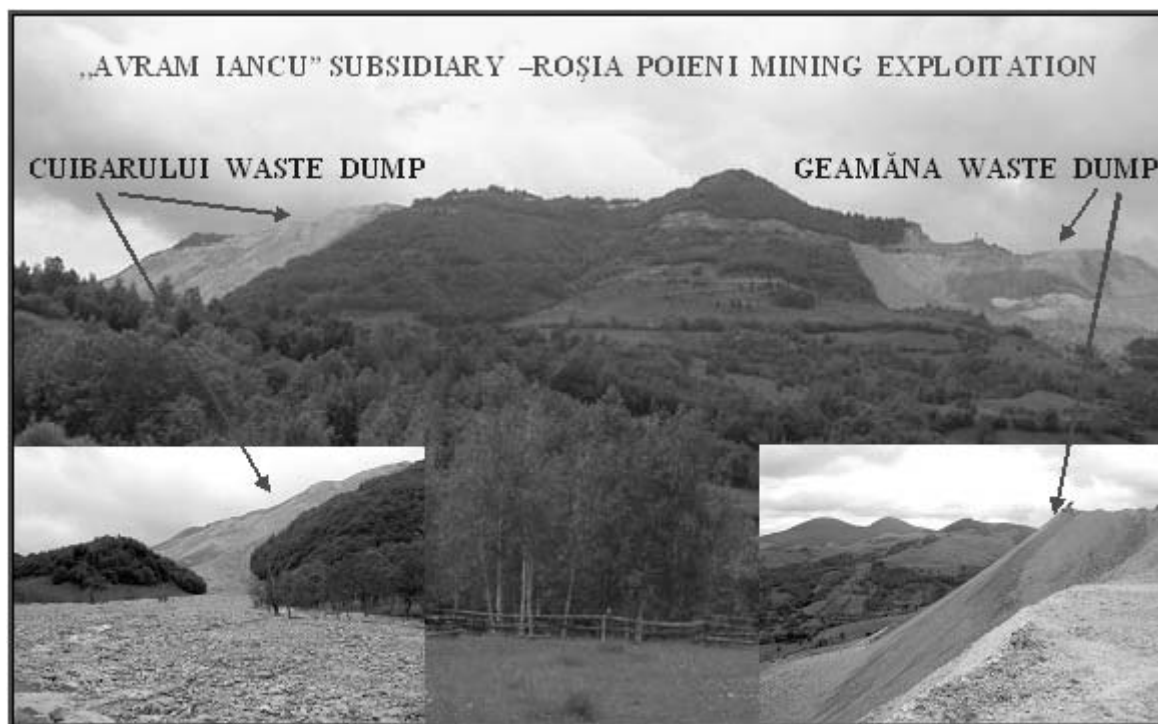
| No                            | Name of entity<br>Subsidiary/Mining<br>exploitation | Number of<br>mining<br>exploitation | No of<br>waste<br>dumps | Volume<br>stockpiled<br>(Mil m <sup>3</sup> ) | Occupied<br>surface<br>area<br>(ha) | Technical<br>condition<br>and stability |
|-------------------------------|-----------------------------------------------------|-------------------------------------|-------------------------|-----------------------------------------------|-------------------------------------|-----------------------------------------|
| <b>1.</b>                     | <b>C.N.C.A.F., MINVEST”<br/>S.A. DEVA</b>           | <b>21</b>                           | <b>179</b>              | <b>106,74</b>                                 | <b>417,25</b>                       | <b>Good ÷ Low</b>                       |
| 1.1                           | Devamin Subsidiary                                  | 9                                   | 78                      | 14,55                                         | 143,69                              | Good ÷ Low                              |
| 1.2                           | Avram Iancu Subsidiary                              | 4                                   | 32                      | 57,01                                         | 146,20                              |                                         |
| 1.3                           | Bălan Subsidiary                                    | 1                                   | 15                      | 1,66                                          | 25,63                               |                                         |
| 1.4                           | Moldova Nouă Subsidiary                             | 1                                   | 7                       | 32,05                                         | 84,07                               |                                         |
| 1.5                           | Other mining units                                  | 6                                   | 47                      | 1,45                                          | 17,66                               |                                         |
| <b>2.</b>                     | <b>C.N.,,REMIN” BAIA MARE</b>                       | <b>19</b>                           | <b>197</b>              | <b>48,10</b>                                  | <b>263,80</b>                       | <b>Good ÷ Low</b>                       |
| 2.1                           | Baia Mare Subsidiary                                | 8                                   | 60                      | 2,94                                          | 39,69                               | Good                                    |
| 2.2                           | Baia Borşa Subsidiary                               | 4                                   | 35                      | 1,31                                          | 25,37                               | Low                                     |
| 2.3                           | Rodna Subsidiary                                    | 3                                   | 23                      | 0,50                                          | 13,73                               | Low                                     |
| 2.4                           | Bucovina Subsidiary                                 | 4                                   | 79                      | 43,35                                         | 185,01                              | Low                                     |
| <b>TOTAL MINING COMPANIES</b> |                                                     | <b>40</b>                           | <b>376</b>              | <b>154,84</b>                                 | <b>681,05</b>                       | <b>Good ÷ Low</b>                       |

The biggest existing waste dumps of Romania resulted at the metal ore mining are at Roşia Poieni, Moldova Nouă, Roşia Montană, Teliuc Ghelar, Brad and Leşul Ursului, (figure no.3).

All these waste dumps are very high with high slope angles requiring continuous monitoring and maintenance because erosion events occurred at many of these dumps and they are impacted by the superficial and depth sliding events. As a result,

these dumps and many others are under permanent surveillance and observation particularly because there are roads, industrial objectives and even dwellings within their impact zone and all these could be affected by the slide events.

Several waste dumps of the mining zones constituted sources of construction materials or even they were exploited to recover the useful components.



**Fig. 3** General view of Cuibarului and Geamăna waste dump of E.M. Roșia Poieni - „Avram Iancu” Subsidiary

Further to the field analysis there resulted that more than 100 waste dumps require high capital investments for the levelling, stabilization and recultivation works so that they could be re-used for the economic purpose of the region where they are located.

So far, under the guidance of the Ministry of National Economy and of the National Agency of

Mineral Resources there have been performed levelling, slope reshaping works as well as the construction of intermediate berms at the major waste dumps to reduce the overall slope angles and for their stabilization by coevring them with topsoil layer and grass seeding or berm and slope afforestation (figure nr.4).



**Fig. 4** Waste dump slope arrangement:  
a) before rehabilitation works; b) after rehabilitation works

As a result of the metal ore processing in the plants there were built 64 tailings management facilities occupying a surface area of about 1,350 ha and stockpiling about 360 mil.m<sup>3</sup> of waste, table no.2.

The tailings management facilities are usually located on the river meadows of the exploitation zones, they are 20-30 m high and even higher and

occupy a tens of hectares each of them. These engineering constructions occur as relief shapes in contrast with the meadow relief.

The annual volumes of flotation tailings deposited in the tailings management facilities during the last years were most times over 5 millions tons, and the volume of water discharged in the emissary amounts to about 60 millions m<sup>3</sup>.

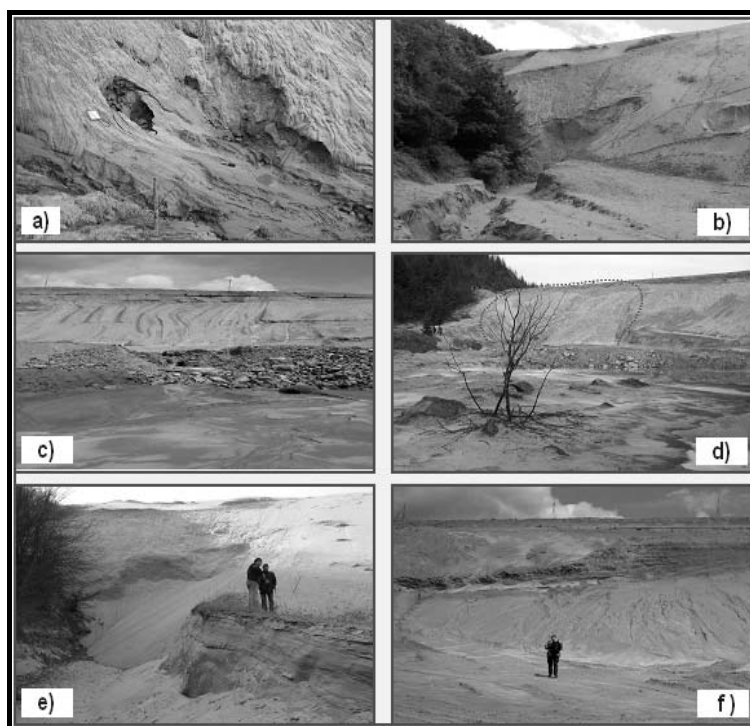
**Table 2** *Situation of TMF's of the metal ore mining exploitations of Romania*

| No                            | Name of the entity<br>Subsidiary / Mining exploitation | Number of<br>mining<br>exploitations | Total<br>number of<br>TMF's | Occupied<br>surface area<br>(ha) | Stockpiling<br>capacity<br>(Mil. t) |
|-------------------------------|--------------------------------------------------------|--------------------------------------|-----------------------------|----------------------------------|-------------------------------------|
| <b>1.</b>                     | <b>C.N.C.A.F. „MINVEST” S.A. DEVA</b>                  | <b>21</b>                            | <b>37</b>                   | <b>855,34</b>                    | <b>228,70</b>                       |
| 1.1                           | Devamin Subsidiary                                     | 9                                    | 18                          | 351,27                           | 64,80                               |
| 1.2                           | Avram Iancu Subsidiary                                 | 4                                    | 11                          | 272,02                           | 59,06                               |
| 1.3                           | Bălan Subsidiary                                       | 1                                    | 5                           | 111,05                           | 34,51                               |
| 1.4                           | Moldova Nouă Subsidiary                                | 1                                    | 3                           | 121,00                           | 70,33                               |
| 1.5                           | Other mining units                                     | 6                                    | -                           | -                                | -                                   |
| <b>2.</b>                     | <b>C.N. „REMIN” S.A. BAIA MARE</b>                     | <b>19</b>                            | <b>27</b>                   | <b>495,99</b>                    | <b>128,25</b>                       |
| 2.1                           | Baia Mare Subsidiary                                   | 8                                    | 11                          | 338,30                           | 77,02                               |
| 2.2                           | Baia Borşa Subsidiary                                  | 4                                    | 6                           | 63,57                            | 18,28                               |
| 2.3                           | Rodna Subsidiary                                       | 3                                    | 2                           | 19,30                            | 6,21                                |
| 2.4                           | Bucovina Subsidiary                                    | 4                                    | 8                           | 74,82                            | 26,74                               |
| <b>TOTAL MINING COMPANIES</b> |                                                        | <b>40</b>                            | <b>64</b>                   | <b>1.351,33</b>                  | <b>356,95</b>                       |

The tailings management facilities of Moldova – Noua, Bălan, Deva, Roşia-Poieni, Roşia-Montană, Certej, Baia-Mare, Cavnic, Baia-Sprie, Baia-Borşa and Tarniţa are the largest of the system and there are stockpiled huge amounts of tailings and consequently it requires a particular monitoring and permanent maintenance works.

### Preoccupations for improving the environment monitoring of the mining zones

After the accident of Baia Mare from 2000, of Romania, they proceeded with the field investigation of each tailings management facility verifying their technical condition revealing all the adverse geo – mining events such as: subsidence, overflowing, erosion, suffosions, seepage, and superficial and depth sliding events (figure no.5).



**Fig. 5** *Events recorded at the tailings management facilities: a) – seepage; b) – erosion; c) – ravines; d) – sliding limited in space; e) – overall sliding; f) – ravines, brakage and sliding events*

In order to perform the stability studies there were made geotechnical investigations of the material of the foundation ground, the rise dam and tailings facility beach. To this aim, there were

collected samples from different alignments for which the physical and mechanic properties were determined. Also, there was determined the perviousness of the material deposited in the

tailings facility and the capacity of eliminating the water from it.

For each tailings management facility there were made stability calculations based on different profiles which showed negative events. The methods based on curve and plane sliding surfaces were used. The results of the stability review confirmed the stability was high enough for each and every tailings facility.

Further the field observations under the coordination of the Ministry of Economy, through the General Directorate of Mineral Resources and the National Agency for Mineral Resources, there was proceeded with the closure and safety measures of the tailings management facilities which showed negative geo-mining events and of those involving high risks.

The most frequent works performed included: construction of guard channels to catch the torrents and block the run – offs from the valley sides, flowing out in the valleys from the base of the tailings management facilities, these works were necessary to enhance the stability of the heavy precipitations which could cause the dam burst, the tailings flowing and the serious damage of the downstream zones; reshaping of the main dams with overall slopes of 1:3 to ensure the tailings facility stability; main dam rises designing safety berms; reshaping of the slopes impacted by the seepage and material engagement; placing vegetal soil on top and then grass seeding or afforestation of the TMF reshaped slopes and beaches (figure no.6).



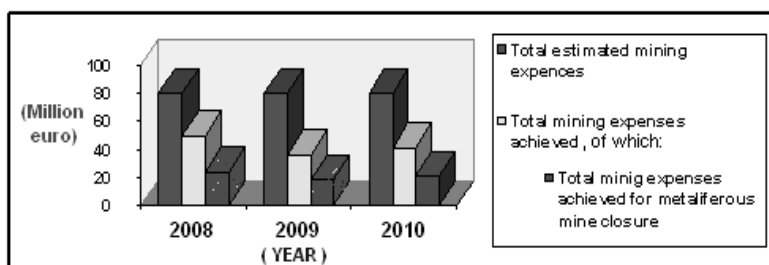
**Fig. 6** The dam and crest of wave of Herepeia TMF E.M. Deva „Devamin”Subsidiary:  
a) before the work completion; b) after the finalisation of the environmental rehabilitation works

Further on, it proceeded with the permanent monitoring of the tailings management facilities by controlling the hydrostatic water level of the tailings facility bodies using the piezometers and by controlling the deformations using the topographic landmarks which reveal continuously the sectors where the deformations are active or under stabilization. Also, in case of high risk tailings facility there were mounted and operated meteorological mini-stations.

In Romania, the preservation and closure process of the mines and non-profitable open pits

started in 1998 and it was developed in compliance with the Mining Law. The strategy of the mining industry regarding the closure and ecologization of the mining objectives provides that the process finalisation date is the year 2010 and to this aim, a budget estimate of about 80 millions Euro/year has been scheduled.

In Romania, the dynamics of the programmed / achieved investments funds for the closure and ecologization work completion during the last three years, is in accordance with the graphic of figure no.7.



**Fig. 7** Dynamics of the programmed and achieved investments for the execution of closure and ecologization works of the mining exploitations of Romania

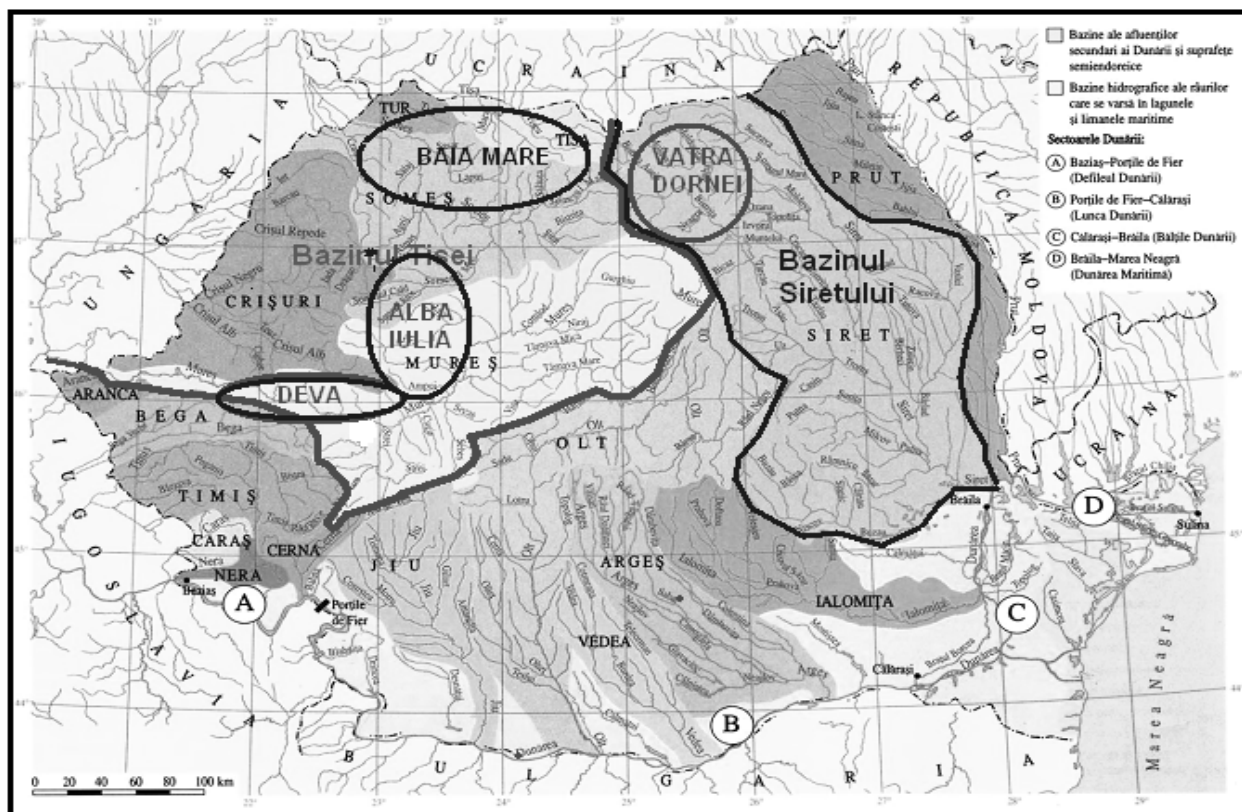
The works for the tailings management and waste dump safety were performed by Romanian companies, within the due time and at the set up

costs in strict compliance with the international procedures and mainly funded by the Romanian Government, which for some works, concluded

partnership agreements with the World Bank Group (BIRD) and the European Bank of Reconstruction and Development (BERD).

At present, in Romania, there is implemented the National Computer Assisted Monitoring System (SNIM), which aims at the improvement of the monitoring strategy of the tailings facility and waste dump stability as well as of all the environment components from the old and current

mining zones of the country. In a first stage, this „SNIM” system will monitor only the tailings facilities and waste dumps where there is a potential high risk of stability loss, from the C.N. „Remin” Baia-Mare and C.N.C.A.F. „Minvest” Deva mining companies and later on, it will be gradually extended to all the mining objectives of these companies and to the existing mining companies of Romania (figure no.8).



**Fig. 8** Zoning of mining objectives by water basins

So far, there have been undertaken the following steps regarding the overall design developed for this aim:

- Identification of the mining objectives and their classification depending on their risk rate which could cause mining accidents with severe impacts on the environment and even ecological disasters.
- The zoning of the potentially rich mining objectives of the Siret and Tisa river basins.
- There have been established four central laboratories for analyzing the environmental components, namely in Siret Water Basin at Vatra Dornei (Suceava county); and in Mures Water Basin at Abrud (Alba county), Baia-Mare (Maramures county) and Deva municipal (Hunedoara county).
- Putting into operation the Computer Assisted Monitoring System of Siret river basin at S.C. „MINBUCOVINA” S.A. - Mestecăniș station (Suceava county), which is carrying out the environment monitoring for the tailings facilities of

the Northern zone of the country. There already have been monitored the tailings management facilities of Târnicioara, Dumitreleu, Pârâul Cailor, Valea Straja, Poarta Veche and Dealu Negru, and then there will be integrated within this system other tailings facilities and waste dumps of the zone, too. For each tailings facility the following parameters are delivered to the Mestecăniș station: amount of infiltrated water; level of the underground water level; movement of the dam crest of wave; water pressure in the pores; quantity and quality of the dam leakages; seismic activity, meteorological conditions (rain, temperature, wind speed and direction, humidity); etc.

The connection to the National Computer Assisted Monitoring System, of the zonal monitoring system of S.C. „MINBUCOVINA” S.A.- Mestecăniș station (Suceava county), will be carried out immediately when the SNIM becomes operational.

Until the end of the year 2011 there will be also implemented the Computer Assisted Monitoring System which covers the Tisa river basin including three data collection centres in Baia-Mare, Abrud ( Cuprum head-office) and Deva municipal.

Each centre will include the followings:

➤ A fix laboratory where there will be processed the samples collected on field, there will be evaluated the analysis results and there will be introduced in the **monitoring – warning system**.

➤ A mobile laboratory performing the air, water and soil, sampling of each tailings management facility and waste dump. The samples will be preserved and transported for complex analysis to the fix laboratory. The mobile laboratory will be able to perform analyses on site and also will collect the data from the apparatus and devices mounted on field and which are not under GSM coverage (Global System for Mobile communications).

➤ A central information geographic system (G.I.S.) which will collect , record store and deliver the data in the SNIM (National Computer Assisted Monitoring System), to the central national unit of the National Agency for Mineral Resources and from there, to all the government institutions , **in order to draw their attention and warn them in order to get a rapid response in case of emergency**

In a future stage, SNIM will extend to all the country regions so that to cover and monitor all the mining objectives of Romania. At this stage, all the mines which could possibly cause accidents with severe consequences for the environment will be compulsorily under monitoring at national level.

The results of the monitoring performed by SNIM referring to different mining objectives will be accessed through internet by any person or interested institution of the country or from abroad and thus this information will become public.

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