BIOTIC ASSESSMENT OF AN AQUATIC ECOSYSTEM AFFECTED BY MINING ACTIVITIES

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In the region of the Apuseni Mountains, part of the Western Carpathians in Romania, metal mining activities have a long-standing tradition. Their activities caused impairments to the environment, such as acid mine drainage (AMD) resulting in long-lasting heavy metal pollution of waters and sediments.

The paper presents the biological analysis of an aquatic ecosystem in 9 control sections in order to assess the affected area by mining activities. The sampling for biological analysis was performed during two sampling campaigns: winter - February 2010 and spring - May 2010. The results of analysis for the biotic communities were according to the Norm concerning the reference objectives for the surface water quality classification (Order MMGA no.161/2006) and also, to the Directive 2000/60/EC which established a framework for community action in the field of water policy.

To achieve the objectives were sampled momentary storage compartments - water and sediment – in order to study the most representative biotic communities of the aquatic ecosystems (phytoplankton, zooplankton, benthic macro invertebrates) and to evaluate the contaminated sites by the distribution of pollutant substances in terms of biotic communities. This was choosen for captured important stages of life cycles and fluctuation fields of the main factors that influencing the control structure and functions of biotic populations. The analysis of the biotic communities in the all sampling site focused on the quantitative (numerical density, biomass, abundance after numerical density and biomass) and qualitative component (dominant species, indicator species).

The results of the study can be used by various stakeholders, mainly the mining company and local municipalities, in order to integrate them in their post-mining measures, thereby making them aware of the potential long-term impact of mining on the environment and on human health as well as on the local economy.

Keywords: environmental protection, surface water, phytoplankton, zooplankton, sediment, benthic macro invertebrates, pollution

INTRODUCTION

Metal mining is a long-standing human activity, which contributes indisputably to the progression of our civilisation and its economical growth. However, mining activities also result in apparent environmental impacts to waters, landscape and the atmosphere (**Younger, 1997**). They also influence strongly the economic wealth of the area and act on its social life. Both the environmental and socio-economic impacts of mining are well documented in numerous areas worldwide (**Boni et al. 1999**, **Balistrieri et al. 1999**, **Hudson-Edwards et al. 1999**, **Dold and Fontboté 2002**, **Espana et al. 2005**). Acid mine drainage (AMD) is the key impact to aquatic ecosystems which stems from mining of sulphide-bearing ore deposits (**A. T. Luís, et al 2009**). Water draining from mine workings, such as adits, open pits, tailings impoundments and mine waste deposits may turn acidic, caused predominantly by the oxidation of sulphide minerals associated with the ores extracted (**Vasile G. D, 2010**).

Without reliable information on changes in the quality of nature and the environment, and on the causes of those changes, decision-making cannot deal efficiently with these issues.

AIMS

The paper is based on research conducted in the Rosia Montana area in western Romania. This historic mining district located in west-central Romania in the Apuseni Mountains of Transylvania and covers an area of approximately 550 km^2. Gold mining at Rosia Montana can be traced back to approximately 106 a.d. at the beginning of the Roman occupation of Dacia. Sporadic mining activity continued in medieval times but accelerated during the period of the Austro-Hungarian Empire in the eighteenth and nineteenth centuries. During this time, there was an extensive mining and a network of underground mines covering several hundred kilometers was developed. Numerous man-made ponds were created in the surrounding area to provide adequate water supply. Historically mining activities at the Rosia Montana have led to extensive AMD problems in the streams surrounding the area (**Florea R. M. et al, 2005**).

The primary goal of the present research was to study the biotic/population – phytoplankton, zooplankton and/or benthonic components affected by mining activities – from the position of the systemic method and conception, in order to characterize the dynamics and role within the integrated aquatic ecosystems**.**

The study of the biotic associations that will be investigated was performed using methods and repetitive measurement of a specified set of variables at one or more locations over an extended period of time according to prearranged schedules in space and time (Figure 1). However, to be effective, a monitoring program must be more than just data collection: it also involves all other activities needed to present the results in an appropriate format to intended users, including analysis and interpretation of data (**P. Vos et al., 2000**).

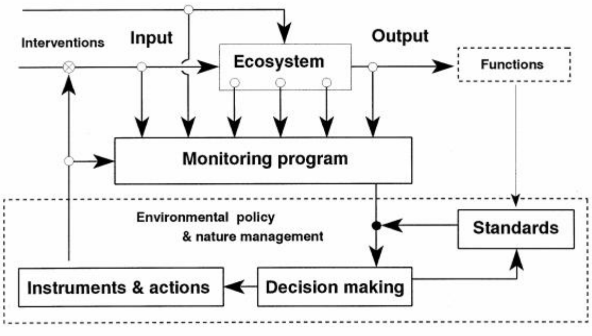

Fig. 1 - The role of an ecological monitoring program as part of a regulatory system (**P. Vos et al., 2000**)

To ensure the socio-economic sustainability is absolutely necessary to preserve a diverse and balanced capital structure and use of natural resources and services they produce within the limits of carrying capacity of its components (**Vadineanu A., Cristofor S., 1994**).

MATERIALS AND METHODS

Study area

The study area was in Transylvania, Romania, in the so-called 'Golden Quadrilateral', where important gold resources of Europe are concentrated. The mining activities in the region have led to extensive and high levels of pollution of the Aries and Abrud Rivers, ones of the main rivers in north-western Romania (Figure 2).

Fig. 2 - Abrud and Aries Rivers with its localization in north-western Romania

Nine stations (table 1) were established along the Abrud, Aries Rivers and its tributary – Foaies. The locations of the stations were chosen according to accessibility to the river, state of conservation of alluvia and to capture the important stages of life cycle and fluctuation fields of the main factors influencing the control structure and functions of biotic populations.

From each sampling station were collected in February and May 2010, 36 surface water samples for phytoplankton and zooplankton analysis, and 18 sediment samples for macro invertebrates analysis.

Table no. 1 – General information about the sampling stations along the studied area

Sample code	Sampling campaign	Sample type	Control section name	GPS sampling coordinates
0	*1*	*2*	*3*	*4*
1	February May	Surface water, sediment	Abrud River – at Abrud city	N46 15.326 E23 05.810
2	February May	Surface water, sediment	Abrud River – upstream Iaz Gura Rosiei	N46 17.562 E23 03.503
3	February May	Surface water, sediment	Abrud River – downstream Iaz Gura Rosiei	N46 18.238 E23 03.266

0	*1*	*2*	*3*	*4*
4	February May	Surface water, sediment	Foaies River– before confluence with Gura Minei	N46 18.213 E23 06.200
6	February May	Surface water, sediment	Foaies River– downstream of the confluence with Gura Minei	N46 18.308 E23 05.678
7	February May	Surface water, sediment	Abrud River – before confluence with the Foaies river	N46 18.502 E23 03.172
8	February May	Surface water, sediment	Abrud River – after confluence with the Foaies river and before Aries River	N46 18.760 E23 03.522
9	February May	Surface water, sediment	Aries River – before confluence with Abrud River	N46 21.595 E23 04.476
10	February May	Surface water, sediment	Aries River – after confluence with Abrud River	N46 21.779 E23 04.904

Determining the ecological status of aquatic ecosystems must be based on biological quality elements, considering the hydrogeomorphological, physical and chemical indicators pollutants that affect specific biomarkers (**Domitrovic Y Z., 2003**). The assessment of these elements mentioned above, can show the presence of natural conditions, minor alterations or extent of human impact, namely the quality status of water bodies (aquatic ecosystems) for a certain period of time.

Methods

The biological assessment methods - essential tools used to characterize aquatic biota were represented by: the saprobic system designed by Kolkwitz and Marson which listed the vegetal and animal organisms according to their sensitivity or tolerance of chemical compounds against decomposition of organic substances, naming them indicator pollution organisms and methods that focus on the presence / absence of benthos macroinvertebrates indicators of aquatic communities (**Stoica C. et al., 2010**).

Depending on the biological sample type were used special and adequate sampling equipment and the samples for analysis were preserved in 4% formaldehyde solution in order to assess the water quality status.

RESULTS AND DISCUSSION

The analysis of biological samples and interpretation of the results has been made in accordance to the Norm concerning the reference objectives for the surface water quality classification (Order MMGA no.161/2006) in order to establish the ecological status of water bodies: very good (I), good (II), moderate (III), low (IV), bad (V) based on biological quality elements, hydro morphological chemical and physic-chemical and to the Directive 2000/60/EC of the European Parliament and of the council establishing a framework for Community action in the field of water policy.

The analysis of the biotic communities in the all sampling site focused on the quantitative (numerical density, biomass, abundance after numerical density and biomass) and qualitative component (dominant species, indicator species).

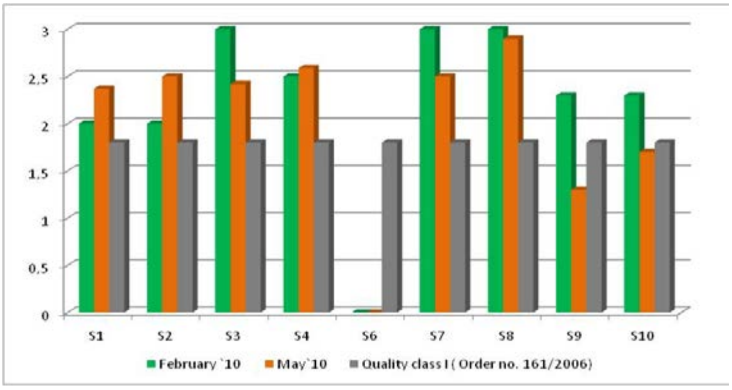

Fig. 3 - Saprobic index variation along Abrud, Aries Rivers and its tributary – Foaies

Following the analysis of samples taken along Abrud and Aries River control sections, the composition of phytoplankton was characterized by Bacillariophyceae species, like *Navicula cryptocephala (α), Diatoma vulgare (β-α), Navicula rynchocephala* (α *), Nitzchia filiformis (β , Achantes minutissima (o-β), Cymbella ventricosa (o-β) and Ceratoneis arcus (o).*

The dominant diatom, *Achantes minutissima* is abundant in a wide variety of habitats and conditions (**Beaver 1981**, **Verb, Vis 2000b**). It has a much wider range of tolerance to many environmental parameters than other species of Achnanthidium and is usually the only reported Achnanthidium species in AMD-polluted streams (**Ponader, Potapova 2007**). Some authors consider it a pioneer coloniser and characteristic of disturbed conditions (**Sabater et al. 1998**, **Sabater 2000**), capable of invading open areas due to changes in environmental conditions (**Peterson and Stevenson 1992**, **DeNicola 2000**). It is very common in pH below 5 according to **Van Dam et al. (1994),** but may exist in media with widely variable pH. Based on **Young (1976)** and **Verb and Vis (2000a),** it can survive in sites of very low pH (3.0 to 3.5). **Yoshiaki et al. (2004)** showed that relative abundance of *A.minutissima* had a raising tendency when Cu, Zn and Pb concentrations were high. Therefore, they concluded that *A. minutissima* was tolerant to heavy metals, probably due to its small size, and it could be used as heavy metal pollution bioindicator. In the present study, we can consider *A. minutissima* as neutrophilous and avoiding high metal concentrations.

The values of saprobic index induced to water body a « moderate » and « poor » environmentaly state, also were recorded the absence of phytoplankton comunity in S6 station (Foaies river– downstream of the confluence with Gura Minei) (Figure 3).

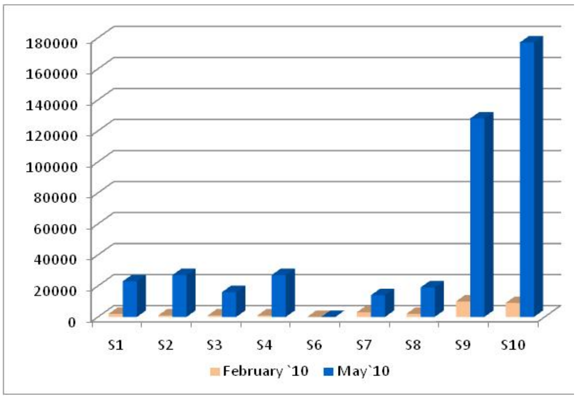

Fig. 4 - Average density variation of phytoplankton community along Abrud, Aries Rivers and its tributary – Foaies

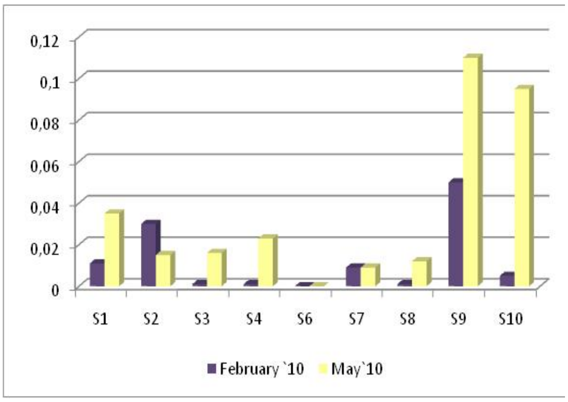

Fig. 5 - Biomass variation of phytoplankton community along Abrud, Aries Rivers and its tributary – Foaies

The highest numerical density values of phytoplankton were recorded in S9 and S10 (Aries River – before confluence with Abrud River and Aries River – after confluence with Abrud River) control section on May 2010 (128.000 ex. /dmc and 177.000 ex. /dmc), where dominated were oligo-betamesosaprobic diatom species. The lowest numerical density values were recorded in S2 (Abrud River – upstream Iaz Gura Rosiei) , S3 (Abrud River – downstream Iaz Gura Rosiei) and S4 (Paraul Foiesu – before confluence with Gura Minei) control sections (Figure 4). Concerning phytoplankton biomass, the maximum values were recorded in S9 (Aries River – before confluence with Abrud River) (0,050 mg/dmc) in February 2010 and (0, 11 mg/dmc) in May 2010 (Figure 5).

The zooplankton community, which is closely related to all other components of the biota (phytoplankton and benthos), is a sensitive indicator of the state of the aquatic environment, which allows including it in the system of monitoring of water objects. Structural characteristics, compared to functional, are more often used for diagnosis because of methodological difficulties in quantitative estimation of the latter (**Vandysh, O. I., 2004**).

In all along control sections, the zooplankton community were characterized by a poor species composition and low numbers (Figure 6), predominates the Rotifers species, aprox. 70 % followed by Copepoda and Ciliates species.

The zooplanktonic community of Abrud and Aries Rivers was dominated by the rotifers *Brachionus quadridentatus(β)* and *Keratella cochlearis (o-β)* and the ciliates *Chilodonella algivora (α), Carchesium polypinum (α)*, *Glaucoma scintilas (β)* and copepods *Tropocyclops prasinus (o)* in May 2010.

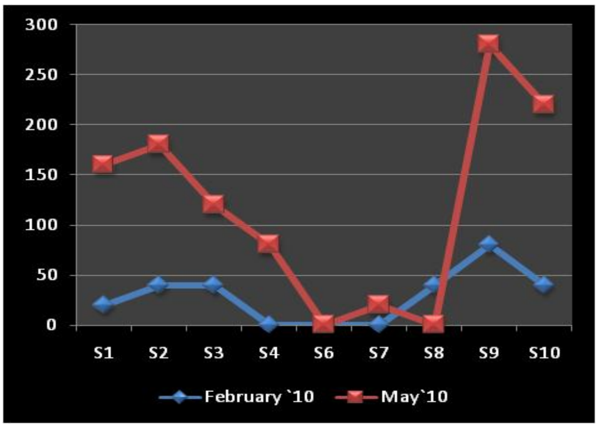

Fig. 6 - Average density variation of zooplankton community along Abrud, Aries Rivers and its tributary – Foaies

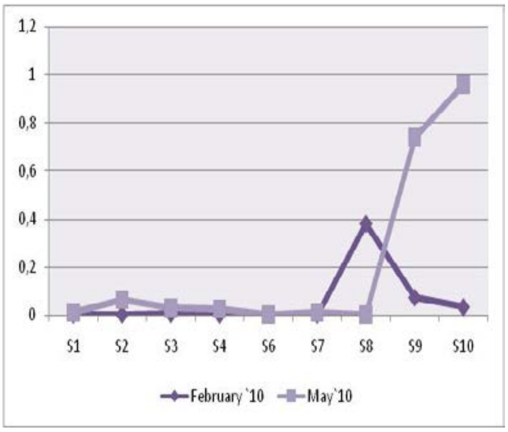

Fig. 7 - Biomass variation of zooplankton community along Abrud, Aries Rivers and its tributary – Foaies

The lowest values of zooplankton organisms and even their absence were recorded in **S4** (Foaies River– before confluence with Gura Minei), **S6** (Foaies River– downstream of the confluence with Gura Minei), **S7** (Abrud River – before confluence with the Foaies river) on February 2010 and in **S6** (Foaies River– downstream of the confluence with Gura Minei), **S8** (Abrud River – after confluence with the Foaies river and before Aries River) on May 2010.

The highest numerical density values (80 ex. /dmc) were recorded in S9 (Aries River – before confluence with Abrud River) on February 2010 and 280 ex./dmc in May 2010 sampling campaign (Figure 6). The maximum value of remanent biomass was recorded on May 2010 (0,74 mg/dmc) in S9 (Aries River – before confluence with Abrud River) and (0,96 mg/dmc) in S10 (Aries River – after confluence with Abrud River) (Figure 7).

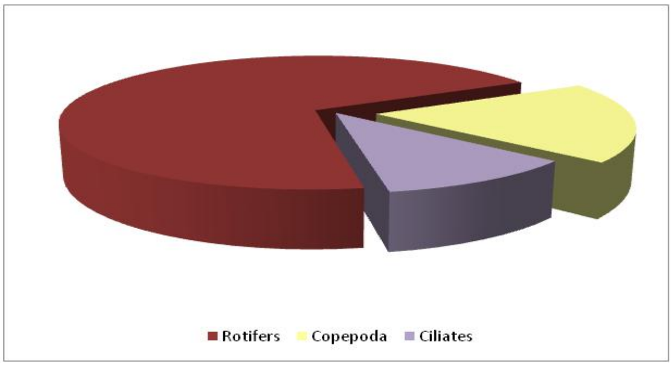

Fig. 8 – Dominant zooplankton groups in all control sections

Analysis of the most informative parameters of the zooplanktonic community indicated that its response to the mining pollution of the water body was expressed by the proportions (in percent) of the main taxonomic groups (Rotatoria, Ciliates, and Copepoda) in the total numbers and biomass changed, with the proportion of Rotatoria (which are most resistant to pollution) increasing and *K. cochlearis* becoming the dominant species (except in February 2010, which was related to seasonal variations) (Figure 8).

Referring to **benthic macro invertebrates** - those organisms that live on/or in the substrate of aquatic ecosystems, living freely or inside of own houses are affected by the human interventions on sediment include retaining and collecting the eroded soil and rock materials on the slopes of basins; damming the rivers for navigation and energy production purposes; dredging the bed material from the river channel for industrial use at a rate much higher than the bed load transporting potential of the river (**Moldovan, O.T. et al, 2011**).

The biological analysis in all sampling sites have aimed the quantitative component (numerical density, biomass remanence, abundance after numerical density and biomass) and qualitative (taxonomic composition, dominant groups) determination.

A total of 66 individuals from 3 invertebrates groups were recorded along all sampling sites in Faberuary and May 2010: *Oligocheta, Chironomida* and *Diptera.* Diptera larvae were the most rarely collected, occurring in only in two or three samples.

The analysis of the distribution of benthic macro invertebrates shows that the highest diversity (of taxonomical groups) was found at S 10 (Aries River – after confluence with Abrud River) (700 ex. / mp), while the lowest from S1 (Abrud River – at Abrud city) to S6 (Foaies River– downstream of the confluence with Gura Minei) (20 ex. / mp), even with their absence (S4, S7 on February 2010 and S3 on May 2010) (Figure 9, 10).

Macro invertebrates were affected by the changing environmental conditions in the area, as shown by the absence of organisms and lowest numerical density being severely depressed. Several factors might determine the community composition and thus the response of the indices. Those most likely to be responsible for this composition a priori are the natural longitudinal evolution of the rivers, seasonality and mining impact. Substrate type is a major factor in macro invertebrate distribution (**Wright et al., 1984**, **Richards et al., 1993**, **Ruse, 1996**) but its effect has been removed by selecting a homogeneous habitat. Coal mining usually leads to acid mine drainage caused by the oxidation of pyrite (**Evangelou, Zhang, 1995, Banks et al., 1997**), although it may sometimes be quickly neutralized resulting in a nonacidic discharge (**Younger, 1995**). These drainages and the rivers receiving them are characterized, in general terms, by elevated concentrations of some metals (mainly iron), sulfate and low pH.

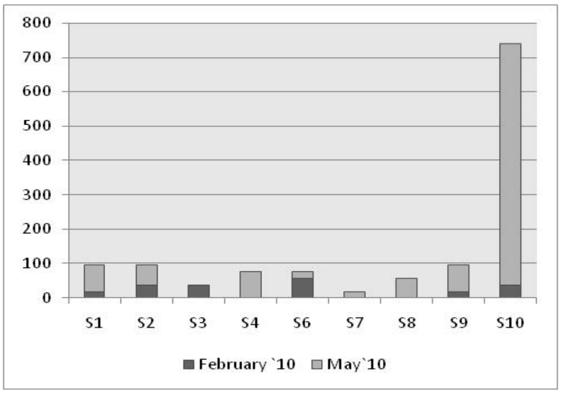

Fig. 9 - Average density variation of benthic macro invertebrates community along Abrud, Aries Rivers and its tributary – Foaies

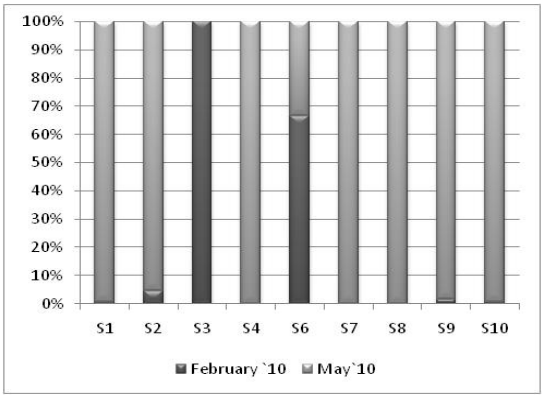

Fig. 10 - Biomass variation of benthic macro invertebrates community along Abrud, Aries Rivers and its tributary – Foaies

Pollution impact was investigated using invertebrate abundance and species richness, by emphasizing the changes in biological communities in each station in correlation to chemical composition of both interstitial water and sediments (**Garcia-Criado, F., et al, 1999**). The most polluted sites, located in the middle part of the studied transect, had less species and fewer individuals than the less polluted locations, although the extent of decline was dependent on the sensitivity of benthic macro invertebrates to pollution.

CONCLUSIONS

The results of these investigations enable to draw certain conclusions, important for the survey of the water quality, as well as for the direction of the necessary future investigations**.** The phytoplankton, zooplankton and benthic macro invertebrates biocenosis represent the trophic basis for aquatic ecosystems.

As the biological analysis indicated, the control sections examined, suffers the influence of human impact resulting in significant loss of biological communities and major disruptions of the aquatic ecosystem balance. The impairment of water quality was observed in those control sections located on Foaies and Abrud River by reducing the number of taxa of all biotic communities analysed. As a result of phytoplankton and zooplankton analysis in surface water samples and benthic macro invertebrates in sediments, water rate study fits in with the appropriate quality class IV in poor ecological condition, by saprobic index values with predominant betamesosaprobe, beta-alfamesosaprobe and alfamesosaprobe species.

The spatial and time evolution of the main physico-chemical indicators and quality induced by these states in the two sampling campaigns showed a concordance of the findings obtained by biological and physico-chemical analysis.

The results of the study can be used by various stakeholders, mainly the mining company and local municipalities, in order to integrate them in their post-mining measures, thereby making them aware of the potential long-term impact of mining on the environment and on human health as well as on the local economy.

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