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# THE STUDY OF MACROINVERTEBRATE COMMUNITY IN THE HEAVY METAL POLLUTED ARIEŞ RIVER (ROMANIA)

## 1.1. Introduction

Since ancient times human activity has exerted a significant effect on the environment, which impact seems to be continuous and gradually increasing. Today there is no natural environment that remains entirely untouched by man's activities.[1] However, according to Rakonczay,[2] 95% of the total surface of the Earth can be considered natural or only partially impacted. In spite of these contradictory opinions, serious and often irreversible effects are attributed to our actions.

This phenomenon can be observed in the case of aquatic ecosystems, too, which are threatened by habitat degradation caused by water diversion, channelization and damming.[3] Besides this, the pollution of surface waters has became a global problem.[4]

In each ecosystem a complex relationship can be identified among different species and between the species and their environment. Biological communities constantly respond to physical forces, chemical dynamics and ecosystem processes, which change minute-to-minute. It is extreamly easy to measure the decrease of dissolved oxygen downstream of a water treatment plant, the increase of sedimentation downstream of a construction site, pH value or conductivity. The real difficulty lies with estabilishing to what degree these changes affect the community and the ecosystem and how these changes interact with other physical, chemical or biological factors.[5]

A considerable disadvantage of the chemical analysis lies in the fact that it can reflect only the momentary situation, and it is impossible to analyze all the abiotic parameters of a river in a single survey. In this way similar results can be obtained by analyzing water samples from differently impacted courses. The chemical method treats water courses as simple channels omitting the relationship between habitat and community, therefore this method is not suitable for a more subtle assesment of water quality.[6]

In contrast, the biota are continuous witnesses of the river's state of health and are collectively sensitive to the whole range of potential pollutants.[7] Aquatic organisms show a higher taxonomic variety and are much more affected by the changes in the environment than the mainland ones, as the movement of their majority is limitated.[8] Macroinvertebrates are not only excellent, but one of the most reliable indicator organism[9] because various taxa are associated with different levels of water quality. Moreover, with their presence, absence, abundance they can show a graded response to a broad spectrum of types and degrees of disturbance. Similarly, they can be found in almost every type of water and their collection is easier than of any other aquatic organism.[10]

Habitat features structure the macroinvertebrate communities.[11] One of the most important factor is the type of the substrate. Detritivores (Oligochaeta, some Chironomidae) are characteristic of organically rich sediments, while mayflies (Ephemeroptera), stoneflies (Plecoptera) prefer the coarser substrates.[12]

The structure of benthic community shows not only different types of pollution but also the accumulation of heavy metals in the sediment. A decreased pH value contributes to the increase of the concentration of dissolved metals[13] by leaching them from the sediment thus facilitating the access to the toxic metals from the sediment.[14] Sites characterized by heavy metal pollution have a less diverse fauna with a greater abundance of the more tolerant species.[15] Mayflies and stoneflies are

[1] SCIAMA, Y. 2004.
[2] RAKONCZAY Z. 2001.
[3] MALMQVIST, B. – HOFFSTEN, P. 1999; FLEUITUCH, T. 2003.
[4] KÉKEDY NAGY L. – BOLLA CS. – SZABÓ G. 2003.
[5] NEDEAU, E. J. – MERRITT, R. W. – KAUFMAN, M. G. 2003.
[6] UJVÁROSI L. 2003.
[7] WALLEY, W. J. – GRBOVIC, J. – DZEROSKI, S. 2001.
[8] SÁRKÁNY-KISS E. – HAMAR J. – SÎRBU, I. 1997.
[9] BUBINAS, A. – JAGMINIENE , I. 2001.
[10] GEORGUDAKI-ILIOPOULO, J. et alii 2003; HAZELTON, P. 2003.
[11] KISS O. – SCHMERA D. – FEHÉR I. 2003.
[12] WEATHERHEAD, M. A. – JAMES, M. R. 2001.
[13] DENICOLA, D. – STAPLETON, M. G. 2002.
[14] CHERRY, D. S. et alii 2001.
[15] CARLISE, D. M. – CLEMENTS, W. H. 2003; MALMQVIST, B. – HOFFSTEN, P. 1999; NEDEAU, E. J. – MERRITT , R. W. – KAUFMAN, M. G. 2003; CHERRY,

extremely sensible to heavy metal pollution, the former being considered the most sensible organism of all.[16] Sites characterized by high Zn pollution are dominated by Chironominae (mostly Tanytarsini).[17] Along with the Oligochaeta, they can accumulate high concentration of Va, Mn and Ti besides the aboved mentioned Zn in their bodies. Aquatic Coleoptera (beetle) larvae are good bioaccumulators of Cr and Co, while Amphipoda (amphipods) easily accumulate Pb, Cu and Ni.

Macroinvertebrates also inhabit a vital position in the food chain of aquatic systems and therefore can be used to make estimates of the entire ecosystem health.[18]

The aim of this study is to determine the stucture of macroinvertebrate communities along the river, the change in their structure between the reference and impacted sites and successing sites, and to present a list of Ephemeroptera species that colonized the river during the research period.

### 1.2. Study area

#### 1.2.1. River Arieş

The River Arieş is the most important right bank tributary of the River Mureş, draining the central and eastern part of the Apuseni Mountains, the most extended and highest sector of the Western Carpathians.

Arieşul Mic has its source between the Curbăta Mare mountain (1849 m. above sea-level) and the Tăul Mare summit (1543 m. above sea-level), while the Arieşul Mare springs from below the Vârtop summit (1295 m. above sea-level). The two rivers are joined within a dam above Câmpeni, at Mihoeşti (550 m. above sea-level), thus forming the Arieş River.[19]

Its total lenght is 164 km and its drainage area exceeds 3005 km$^2$. Its multiannual discharge is of 19m$^3$/s at Baia de Arieș.[20] The tributaries are charecterized by relatively small average multiannual discharge, except for Iara and Abrud.

The yellow-reddish water of Abrud creek joins the trunk stream 2 km downstream of Câmpeni, maintaining its characteristic colour on a short distance on the right side of the river. Being the second largest tributary of the river with its 22 km lenghth and 229 km$^2$ catchment area,[21] drains the south-eastern and eastern flank of the Bucium, Roșia Poieni and Roșia Montană ore deposits.[22] Its typical colour is due to the iron oxy-hydroxides, both in suspension and in colloidal form.[23]

The largest tributary of Arieș, the 51 km long Iara, extends on a 390 km$^2$ are and is polluted by the Băișoara Mines.[24]

The hydrographic basin of the Arieș river shows a large variety of geological formations.[25] Every single rock or geological process, characteristic to the Carpathians, has had a permanent effect on this area.[26] Along the sedimentary and metamorphic formations, volcanic rocks with different chemistry from acid to basic can also be found. This large geological variety determines the complexity of the surface geochemical phenomena ocurring in this hydrographic basin.[27]

The climate of the Arieș Valley is moderatly continental. The average temperature in January is between -3–10, while in July, August it ranges between 10–20°C. The annual average rainfall decreases with the decrease of altitude (1400-560 mm).[28]

#### 1.2.2. Mining activity

Romanian mining history is characterized by several stages, which differ in the extractive techniques and the quantity of extracted ores.[29]

Mining has its tradition along the Arieș River. Rare metals were extracted even before the Roman times from the volcanic rocks of Apuseni Mountains and from the silty sediments of the Arieș River and its tributaries. A large number of mines were operating in the Roman period: Alburnus Maior, Bucium, Albac, Vidra, Băișoara, Făgetu Ierii etc.[30] After the historical documents from Roman times 720,000 kg of silver and 1,345,000 kg of gold had been extracted only from the Apuseni Mountains.[31] Following an interruption, the mining industry flourished again due to the modernization of extracting technology. Along with the industrialization in the 19$^{th}$ century, new mines and ore processing factories were established, which meant a permanent pollution source for the local freshwaters.[32]

For the time being, in the Apuseni Mountains there are seven active mines, 73 waste dumps of 243 hectares

D. S. et alii 2001.
[16] CHERRY, D. S. et alii 2001.
[17] CARLISE, D. M. − CLEMENTS, W. H. 2003.
[18] BODE, R. W. – NOVAC, M. A. 1995 in HAZELTON, 2003.
[19] POPESCU-ARGEȘEL, I. 1984.
[20] SERBAN, M. et alii 2004.
[21] POPESCU-ARGEȘEL, I. 1984.
[22] BIRD, G. et alii 2005.
[23] FORRAY, F. L. 2002b.
[24] POPESCU-ARGEȘEL, I. 1984.
[25] FORRAY, F. L. 2002b.
[26] POPESCU-ARGEȘEL, I. 1984.
[27] FORRAY, F. L. 2002b.
[28] POPESCU-ARGEȘEL, I. 1984.
[29] SERBAN, M. et alii 2004.
[30] POPESCU-ARGEȘEL, I. 1984.
[31] HAIDUC, I. 1940 in SERBAN et alii 2004.
[32] FORRAY, F. L. 2002a.

and 48 tailing dams covering an area of more than 1000 hectares.[33] In the Arieș Valley today the following mines are well-known: Roșia Poieni, the largest Cu mine of Europe, Roșia Montană, where 100–150 million tons of gold (1,9 g/t) and silver (10g/t) containing ore is supposed to be extracted.[34] Besides these, Baia de Arieș and Bucium mines are also important, where Pb and Fe are extracted, while in Mașca Băișoara and Iara mining activity is performed for Fe-ores.[35]

### 1.3. Materials and methods

Researchers from the Ecologics and Genetics Department of the Babeș–Bolyai University from Cluj-Napoca are analyzing the anthropogenic impact on the Arieș River by floristic and faunistic sampling and at the same time they intend to determine the physico-chemical characteristics of each site. When determining the sampling points, the existence of pollution sources were taken into account.

Sampling was carried out twice from 5 respectively 6 sites: in September 2005 and May 2006. At these occasions microbiological, phytoplankton and macroinvertebrate samples were collected. In order to show the presence of heavy metals and other pollutants, water and sediment samples were also taken. In each site water temperature, pH and conductivity was measured, moreover, the noticable changes in the water colour were also recorded.

Sampling of the macroinvertebrate community was performed with the help of Surber-sampler of $0.1m^2$ and 25 μ mesh size. Three replicates were taken from each site and then mixed. The collected samples were fixed in 3-4% formol, sorted into six groups (Oligochaeta - oligochets, Chironomidae - midges, Trichoptera - caddishflies, Ephemeroptera - mayflies, Plecoptera-stoneflies, Others, including Simuliidae - blachfly larvae, Coleoptera - aquatic beetles, Mollusca-snails, Blephariceridae - net-winged midges etc.) and then counted. They were preserved in 70% ethanol and mayflies were identified to the lowest level possible.

For the identification of macroinvertebrate groups, Croft's[36] guide was used while mayfly species were determined according to Bauerfeind[37], Bogoescu[38], Macan[39], Studemann et al.[40] and Ujhelyi[41].

Statistical data analyses was conducted using the software packages SPSS 9.0 for Windows. Kruskall Wallis test was used for the comparison of abundance data of all the sampling sites, while Mann-Whitney test was applied to realize a comparison between the abundance data of reference site and impacted sites, as well as succeeding sites both in the case of macroinvertebrate groups and Ephemeroptera. The existence of significant relationship between the community structure and physico-chemical characteristics were also tested with the use of Spearman rangcorrelation.

Shannon-Wiener and Simpson diversity were calculated and the results of the two-year research were also tested for determining the existence of significant differences with Mann Whitney test.

Applying the AQEM assesment system on the data referring to the mayfly community, sampling sites were classified according to their acidity.

### 1.4. Results

#### 1.4.1. Description of sampling sites

- AI reference site, situated 2.15 km below Mihoeşti Lake.

- AII is located below Câmpeni. The water has a rusty-red colour due to the inflow of the heavily polluted Abrud creek.

- AIII is situated below Gârde village, the distance between the sampling site and Mihoeşti Lake being of 17 km. Compared to the former site, the colour of the water looses from its intensity.

- AIV is situated below Baia de Arieş. The surface of stones is covered by a rusty-red coloured layer due to the mining activity. The colour of water is also changed, it is similar to the rocks.

- AV is situated 72.8 km downstream of the previous site, upstreams of the bridge from Buru, being polluted by the yellowish water of Iara and Râmetea creeks.

- AVI is situated near the petrol station of Hădăreni locality.

According to our observations, sampling sites have a stony, gravelbed substrate, fast flow velocity.

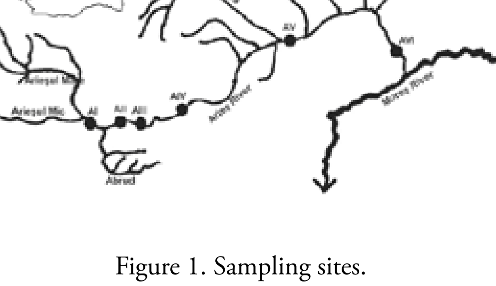


Figure 1. Sampling sites.

[33] FODOR, D. – BAICAN, G. 2001 in SERBAN, M. et alii 2004

[34] BIRD, G. Et alii 2005; FORRAY, F. L. 2002b.

[35] POPESCU-ARGEȘEL, I. 1984.

[36] CROFT, P. S. 1986.

[37] BAUERFEIND, E. 1994.

[38] BOGOESCU, C. – TĂBĂCARU, I. 1956.

[39] MACAN, T. T. 1970.

[40] STUDEMANN, D. et alii 1986.

[41] UJHELYI S. 1959.

The GPS coordinates and physico-chemical parameters of the sampling sites are summarized in the following tables:

| Sampling sites | GPS coordinates |
|---|---|
| A.I. | N46.36259973 E23.02653909 |
| A.II. | N46.37577474 E23.09266627 |
| A.III. | N46.37737870 E23.16576183 |
| A.IV. | N46.39102042 E23.28740001 |
| A.V. | N46.50735855 E23.60101998 |
| A.VI. | N46.46341860 E23.96332741 |

Table 1. GPS coordinates of the sampling sites.

| Sampling site | Parameters | | |
|---|---|---|---|
| | pH | Temperature (°C) | Conductivity (μS) |
| AI | 7.75 | 15.1 | 164 |
| AII | 8 | 17.3 | 237 |
| AIII | 7.82 | 16.7 | 219 |
| AIV | 7.11 | 16.8 | 296 |
| AV | 7.83 | 17.6 | 317 |

Table 2. pH, temperature, conductivity of water at the sampling sites (9.09.2005).

| Sampling site | Parameters | | |
|---|---|---|---|
| | pH | Temperature (°C) | Conductivity (μS) |
| AI | 7.12 | 11.5 | 155 |
| AII | 7.55 | 11.9 | 180 |
| AIII | 7.76 | 11.9 | 166 |
| AIV | 5.31 | 12.8 | 289 |
| AV | 7.15 | 13.6 | 302 |

Table 3. pH, temperature, conductivity of water at the sampling sites (28.05.2006).

### 1.4.1 Macroinvertebrate densities

| Sampling site | Number of ind./m$^2$ | | | | | |
|---|---|---|---|---|---|---|
| | Oligochaeta | Chironomidae | Trichoptera | Ephemeroptera | Plecoptera | Others |
| **AI** | 290 | 5690 | 420 | 170 | 787 | 190 |
| **AII** | 17 | 617 | 117 | 153 | 167 | 67 |
| **AIII** | 80 | 837 | 123 | 143 | 153 | 47 |
| **AIV** | 33 | 17 | 0 | 7 | 3 | 17 |
| **AV** | 0 | 857 | 50 | 63 | 10 | 17 |

Table 4. Abundance of macroinvertebrate groups at 9.09.2005.

| Sampling site | Number of ind./m$^2$ | | | | | |
|---|---|---|---|---|---|---|
| | Oligochaeta | Chironomidae | Trichoptera | Ephemeroptera | Plecoptera | Others |
| **AI** | 353 | 4940 | 443 | 730 | 107 | 723 |
| **AII** | 27 | 457 | 43 | 73 | 37 | 97 |
| **AIII** | 143 | 517 | 20 | 63 | 3 | 33 |
| **AIV** | 7 | 23 | 0 | 0 | 0 | 23 |
| **AV** | 40 | 410 | 23 | 153 | 7 | 180 |
| **AVI** | 20 | 63 | 3 | 17 | 0 | 7 |

Table 5. Abundance of macroinvertebrate groups at 28.05.2006.

As it is revealed in Table 4. and 5. as well as in Figure. 2 and 3., the reference site is characterized by huge densities of each group of macroinvertebrate organisms, which suffer a drastic decline at AII site due to the pollution transported by Abrud creek. Smallest density is observed in the case of Oligochaeta, the most common are Chironomidae, while the most sensible taxa occupy a middle place.

At AIII only in the case of less demanding organisms to water quality (Oligochaeta and Chironomidae) show a slight increase in abundance, the remaining groups either maintain the values attained in the previous site or decrease in number as it was observed in the case of Plecoptera and Trichoptera orders in 2006.

Along the river, the most drastic changes in abundance occur at the sampling site below Baia de Arieş, where not only the most sensible taxa dissappear (in 2006 besides the caddishflies, which were not present in autumn either, stoneflies and mayflies are missing, too) but the number of generally more tolerant Chironomidae and Oligochaeta is also decreasing.

Site V. gives us the impression, that the conditions are improving, however the not fully recovered community suffers a new decline at the last site.

Although the community tries to recover twice, at AIII and AV, it never reaches the abundance level of the reference site.

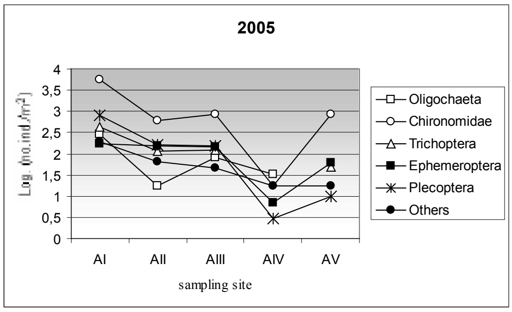


Figure 2. Change of abundance of macroinvertebrate groups along the Arieş River (9.09.2005).

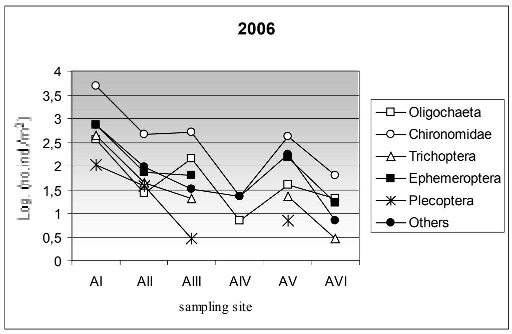


Figure 3. Change of abundance of macroinvertebrate groups along the Arieş River (28.05.2006).

### 1.4.2. Ephemeroptera species

| Family | Species | AI | AII | AIII | AIV | AV |
|---|---|---|---|---|---|---|
| Baetidae | *Baetis scambus* Eaton 1860 | 30 | 43 | 10 | - | 7 |
| | *Baetis sp.* Leach 1815 | 23 | 13 | 70 | - | 30 |
| | *Baetis vernus* Curtis 1834 | 50 | 37 | 23 | 7 | 20 |
| Caenidae | *Caenis macrura* Stephens 1835 | 17 | - | 17 | - | - |
| | *Caenis sp.* Stephens 1835 | - | - | 3 | - | - |
| Ephemerellidae | *Serratella ignita* (Poda 1761) | 20 | - | - | - | 3 |
| Heptageniidae | *Ecdyonurus alpinus* Hefti, Tomka & Zurwerra 1987 | 3 | - | - | - | - |
| | *Ecdyonurus gr.helveticus (zelleri?)* (Eaton 1885) | 13 | - | - | - | - |
| | *Ecdyonurus picteti* (Meyer-Dur 1864) | - | 3 | - | - | - |
| | *Ecdyonurus sp.* Eaton 1868 | - | - | 7 | - | - |
| | *Rhithrogena semicolorata* (Curtis 1837) | - | - | - | - | 3 |
| Leptophlebiidae | *Paraleptophlebia cincta* (Retzius 1783) | 3 | - | - | | - |

Table 6. List and abundance of mayfly (Ephemeroptera) species at 9.09.2005

| Family | Species | AI | AII | AIII | AIV | AV | AVI |
|---|---|---|---|---|---|---|---|
| Baetidae | *Baetis alpinus* (Pictet 1843) | - | - | - | - | 3 | - |
| | *Baetis rhodani* (Pictet 1843) | 10 | 3 | 13 | - | 20 | - |
| | *Baetis scambus* Eaton 1860 | 7 | 3 | 10 | - | 20 | - |
| | *Baetis sp.* Leach 1815 | 163 | 57 | 33 | - | 63 | 10 |
| | *Baetis vardarensis* Ikonomov 1962 | 7 | - | - | - | - | - |
| | *Baetis vernus* Curtis 1834 | 23 | - | - | - | 43 | 7 |
| Ephemerellidae | *Torleya major* (Klapalek 1905) | 3 | 3 | - | - | - | - |
| | *Serratella ignita* (Poda 1761) | 70 | - | - | - | - | - |
| | Ephemerellidae gen. sp. | 327 | 3 | - | - | - | - |
| Heptageniidae | *Ecdyonurus venosus* (Fabricius 1775) | 3 | - | - | - | - | - |
| | *Ecdyonurus sp.* Eaton 1868 | 3 | - | 3 | - | - | - |
| | *Heptagenia sp.*Walsh 1863 | 3 | - | - | - | - | - |
| | Heptageniidae gen. sp. | 23 | 3 | - | - | - | - |
| | *Rhithrogena semicolorata* (Curtis 1837) | 57 | - | - | - | 3 | - |
| | *Rhithrogena carpatoalpina* Klonowska, Olechowska, Sartori & Weichselbaumer 1987 | 13 | - | - | - | - | - |
| | *Rhithrogena sp.* Eaton 1881 | 20 | - | - | - | - | - |
| Leptophlebiidae | *Habrophlebia lauta* Eaton 1884 | - | - | 3 | - | - | - |

Table 7. List and abundance of mayfly (Ephemeroptera) species at 28.05.2006

16 species of 5 mayfly families were identified. The most abundant are the Baetis species, which prefer fast running waters and can be found along the entire river with the exception of AIV sampling site, in spring 2006. *Baetis scambus* and *Baetis vernus* form big populations, while *Baetis rhodani* is also abundant. It is important to notice the local apparition in small densities of *Baetis alpinus* (AV) and *B. vardarensis* (AI) in spring and at a single site.

From the 6 species of Heptageniidae only *Rhithrogena semicolorata* appears at two sites (AI, AII), the remaining species form isolated populations.

Crawling Caenidae are represented by a single species, at the reference point and at AIII site in autumn 2005. Likewise, crawling larvae, with high detritus characterized habitat preference, *Serratella ignita*, *Torleya major* and Leptophlebiidae species show a restricted distribution, appear only in the upper course of the river.

The list of Ephemeroptera species, which colonized the river during the research period, is presented in the Appendix.

### 1.4.3 Diversity of mayflies

Shannon-Wiener diversity ranges between 1.81–0 while Simpson diversity 0.81– 0. According to our expectations, species diversity is highest at reference site, reaching the lowest level possible at AIV, where in 2006 mayfly species lack from the scarce macroinvertebrate fauna.

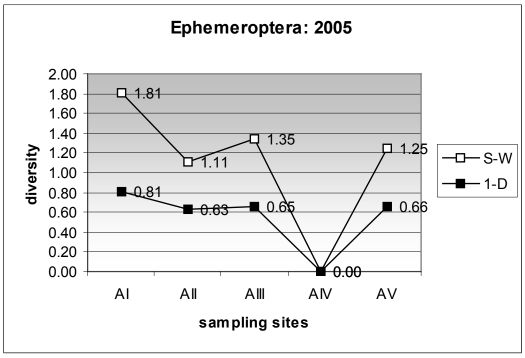


Figure 4. Diversity of mayflies (Ephemeroptera) along the Arieş River (9.09.2005).

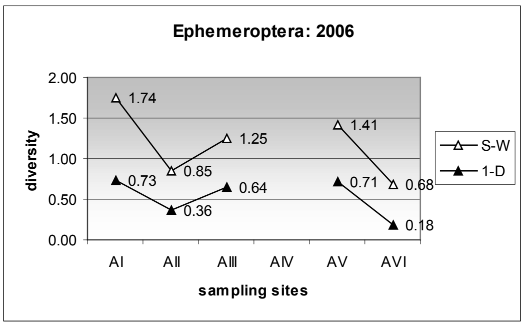


Figure 5. Diversity of mayflies (Ephemeroptera) along the Arieş River (28.05.2006).

**1.4.4. Classification of sampling sites according to their acidity using the mayfly species**

AQEM was developed by E.U. members for assessing the ecological state of rivers and besides other parameters, it uses the preference of species for different acidic conditions of water. This preference ranges between 1–5, 5 being the class of those taxae which occur in highly acidic waters.

According to the results of data analysis referring to the composition of the mayfly community, the sampling sites are members of the 2–5th acid class. In both years the sampling site below Baia de Arieş has got the worst qualification (5), according to which the water is characterized by permanent and serious acidification. In 2006 this site lacks any mayfly species, but as they were present in the previous year and upstream, it indicate the decrease in water quality with their absence. Other sites are characterized by relatively low acidic conditions of water.

Abundance, number of taxa and diversity also reflect the modifications in the habitat's acidity.

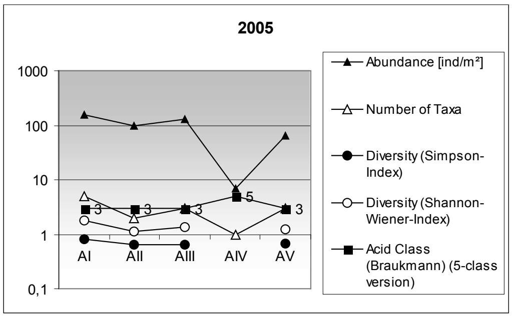


Figure 6. Change of acidity along the Arieş River (9.09.2005).

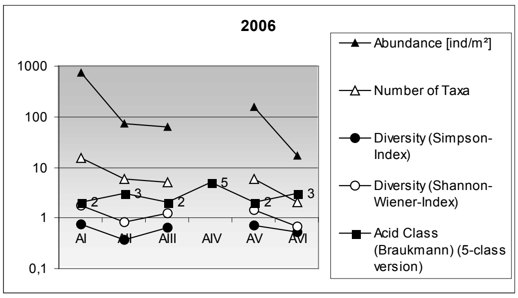


Figure 7. Change of acidity along the Arieş River (28.05.2006).

**1.4.5 Statistical analysis**

In both years the Kruskall-Wallis test shows a significant difference between the macroinvertebrate fauna of the sampling sites (2005: p=0.002; 2006; p=0.001). The Mann-Whitney test also revealed a significant difference between the density of macroinvertebrate groups of the reference and impacted sites in both years (p<0.041).

The comparison of successing sites was also made. In 2005 only the macroinvertebrate fauna of AIII–AIV (p=0.006), in 2006 all of them were significantly diferring from each other (p<0.041) with the exception of AII–AIII (p=0.699).

Comparing the conductivity, pH and abundance of show a significant correlation only in two cases: oligochets, caddishflies correlate with conductivity, namely with the dissolved material of their habitat water (p=0.037).

The statistical analysis of the data referring to mayflies also gives us valuable information regarding the changes between sites.

Kruskall-Wallis test shows a similarity between the autumn variables (p=0.056), being in contradiction with the spring ones, which identifies significant differences (p=0.000). The results of the comparison of the reference with impacted sites and the succeeding sites show significant differences only between AI–AIV in 2005 (p=0.010), but in 2006 the strong significant difference between the reference and impacted sites (p<0.007) was not strengthened by such differences between succeeding sites (p>0.079).

As in the case of macroinvertebrate groups, the mayfly species list and the diversiy of them was not significantly different in the 2 years (Shannon-Wiener: p=0.931; Simpson-index: p=0,662).

**1.5. Discussion**

The research on the macroinvertebrate fauna and the statistical analysis of the gained data contribute to the assesment of changes along the Arieş river. The specific physico-chemical features of the sampling sites all mark the biocenosis in a special way.

The significant differences between sampling sites revealed by decreased abundance and in the case of mayflies associated with decrease in number of taxa, loss of diversity, can be explained by the confluence of highly polluted tributaries. This is proved by the results of physico-chemical analysis of water samples taken from Abrud creek with 50 m before its confluence with the Arieş river showing high concentrations of particles in suspension (112.58 mg/l). The X-ray fluorescence analysis of the suspensions evidenced large iron concentrations and less amounts of copper, zinc, arsenic, lead and manganese[42] proving that heavy metals are transported by being adsorbed in the amorphous iron hydroxides and hydroxi-sulfates.[43] The influence of Abrud creek can be seen in the considerable loss of abundance (ten times less

[42] FORRAY, F. L. 2002a.

[43] FORRAY, F. L. 2003.

then before the confluence point) and a significant decrease in the mayfly diversity.

The situation is more dramatic below Baia de Arieş, where the more sensible taxa totally disappear: in spring not only the caddishflies dissappear but the mayflies and stoneflies are also missing from samples. Chironomids and oligochets are present only in extremly small number. The explanation of the situation also lies behind mining activity, as around Baia de Arieș waste dumps and settling ponds are situated near the Arieş River. Because of their position, the waste dumps are purged by rainwater and the resulting water enters the phreatic water and/or the surface water. During periods of heavy rains, the river level rises sufficiently to reach the base of the waste dumps. Thus, large amounts of barren gangue will also be transported into the river system. Furthermore, the stability of the settling ponds can be affected, endangering the downstream areas.[44]

The Brezești tailings locally pollute water with barium,[45] and at the same time they can be considered important sulfid-sources. The oxidation of these sulphides leads to the removal of soluble metal ions from the waste dumps under the effect of rainfall.[46]

According to the results of Forray & Hallbauer[47], the water at this site contains significant quantities of Ba (0.19 mg/l), Zn (0.213 mg/l), Cu (0.340mg/l), $SO_4$ (71 mg/l) and Br (0.21 mg/l).

According to the results of the statistical analysis in 2005, sampling points IV and V don't differ significantly from each other, both are characterized by poor macroinvertebrate communities. An explanation might be that the rains preceding sampling diluted the heavy metal polluted water, permitting the drifting organisms from upstream sites to remain alive. This shows a contradiction with the results of Forray[48], who claims that during wet periods the amount of transported Zn increased with up to 1100 times in Arieș river 200 m downstream from the confluence with Abrud creek, along with the concentration of other metals.

Our hypothesis about the provenience of site IV's macroinvertebrate fauna in 2005 is supported by Céréghino et al.[49], who conducted field observation upon *Rhithrogena semicolorata,* arriving at the conclusion that the increased discharge due to heavy rains drifts larvae downstreams. This is especially the case of young instars, which are not capable in maintaining their position in the increased currents.

The results referring to site V in 2006 emphasizes a significant improvement in the structure of the macroinvertebrate community, which – according to the relevant specialist literatutre - is due to the disparition of Ba, Zn, Cu and Br from water and a slight decrease in $SO_4$ concentration (57 mg/l) is also observed. Moreover, the Iara - draining Băișoara mines - doesn't raise significantly the pollution level of the Arieș due to its alcalinic characteristics.[50]

Comparing the heavy metal concentration of the Arieș with other Romanian rivers impacted by mining activity, it seems to be smaller,[51] although after Forray[52] it is 10, 100 even 1000 times higher than of non polluted ones. However, together with Abrud and Roșia creeks, the maximum values of Arieș can reach 3000 times those of normal ones.[53]

Analyzing the influence of Lăpuș creek – which is heavily polluted by non-ferrous metals, cyanides and fenols due to mining activities and ore processing plants – upon the macroinvertebrate fauna of the Someș River, Macalik[54] reached the same conclusion, after which pollution decreased abundance and proved to be fatal for metal-sensible taxa.

Bird et al.[55] highlights that Arieș represents a source of sediment-bound contaminant metals to the River Mureș, his findings being sustained by Sárkány-Kiss et al.[56] The later observed that after the inflow of the Arieș not only the N, P, K decreases in the Mureș River but the heavy metal concentration considerably increases, leading to a falling diversity.

Similar results were obtained by Malmqvist & Hoffsten[57] by comparing the fauna of heavy metal polluted Swedish streams: mayflies, caddishflies and stoneflies dissappeared from polluted sites, contributing to the decrease of diversity by 36%. Our results also show a loss of diversity with increasing pollution.

Decrease of abundance and diversity were observed by Carlise & Clements[58] in Zn polluted North American streams, Cherry et al.[59] in rivers polluted by Fe, Mn, Mg, Al, Nedeau et al.[60] in waters impacted by an industrial effluent. In the latest study the total amount of dissolved Fe and particulate Fe were 20 times higher in the effluent than in the upstream. The effluent

[44] FORRAY, F. L. – HALLBAUER, D. K. 2000.
[45] BIRD, G. et alii 2005.
[46] FORRAY, F. L. – HALLBAUER, D. K. 2000.
[47] FORRAY, F. L. – HALLBAUER, D. K. 2000.
[48] FORRAY, F. L. 2002b.
[49] CÉRÉGHINO, R. – LEGALLE, M. – LAVANDIER, P. 2004.
[50] FORRAY, F. L. – HALLBAUER, D. K. 2000.
[51] BIRD, G. et alii 2005.
[52] FORRAY, F. L. 2002b.
[53] BIRD, G. et alii 2005.
[54] MACALIK K. 2003.
[55] BIRD, G. et alii 2005.
[56] SÁRKÁNY-KISS E. – HAMAR J. – SÎRBU, I. 1997.
[57] MALMQVIST, B. – HOFFSTEN, P. 1999.
[58] CARLISE, D. M. – CLEMENTS, W. H. 2003.
[59] CHERRY, D. S. et alii 2001.
[60] NEDEAU, E. J. – MERRITT, R. W. – KAUFMAN, M. G. 2003.

always had a rusty-coloured appearance because of the iron hydroxides in suspension and the substrate was also covered with a layer of ferric hydroxide, showing similarities with the part of the Arieş below the inflow of Abrud and below Baia de Arieș. It is also Nedeau et al.[61] who mentioned that polluted sites have higher densities of oligochets, chironomids compared with metal-sensible taxae abundance. Grazing mayfly, caddishfly and stonefly species are extremly sensible to iron deposition as this inhibits the colonization and growth of diatoms and green algae that comprise an important primary food source for them. This can be observed in the case of the Arieş, too, the abundance of these organisms decrease after such a pollution and the diversity of mayflies too.

Species of Heptageniidae and Baetidae families are characteristic to mountain fauna[62] being especially sensible to Zn pollution, which increases predation pressure of stoneflies upon mayflies.[63] In our research Ecdyonurus species are the most abundant at the reference site, bellow it appearing in sporadic ways, but Baetis species are missing only from the most polluted site. This can be explained by Fialkovski et al.[64] who observed that *Baetis rhodani* and *B. vernus* can tolerate increased metal concentrations, moreover, bioaccumulate them proportionally with the concentration from water, at the same time prefer acidic waters.[65] But after Estonian data, priority is attributed to alcalinic waters. In the later case the water courses lack heavy metal pollution.[66] In contrast, *Baetis alpinus* can't tolerate acidic waters, they occur only in the upper course of rivers.[67] However, the present research was able to identify this species from the middle course, where due to the increased pollution it is present only in a small number, while the first two species were found in almost all sampling sites. Miesbauer et al.[68] also observed that metal concentration in mayfly larvae from the Heptageniidae family is significantly higher than in Baetide, thus concluding that the later ones are less sensible to heavy metal pollution. Furthermore, when compared to caddishfly larvae from the same site, the concentrations of Mn, Zn, Ba and Pb are significantly lower in Baetidae, whereas Heptageniidae exhibit higher Cu concentrations than caddishfly larvae. The differences in metal accumulation are most likely a consequence of species-specific feeding behaviour and thus different uptake of metals from their diet.

In the present study, Spearman rangcorrelation doesn't show significant relationship between the structure of macroinvertebrate community and pH, respectively conductivity with 2 exceptions. This is explained by Ujvárosi[69] as the physico-chemical parameters of a river constantly changes.

Weatherhead & James[70] observed that mayflies, stoneflies appear in the wave-washed parts of lakes characterized by coarse substrates, while oligochets, chironomids dominate the detrital habitat below macrophytes characterized by fine, organic rich sediments. After Găldean et al.[71], the mayfly distribution is determined by the type of substrate, $O_2$ concentration and availability of food sources. *Baetis rhodani, Rhithrogena semicolorata, Ecdyonurus venosus, Serratella ignita* prefers stony substrates. *Rhithrogena semicolorata* colonizes fast running waters, where it is more abundant than *Ecdyonurus venosus* but with the slowing velocity and increasing substrate stability *Ecdyonurus venosus* becomes the most dominant[72] of the two. This is sustained by our study too: at the reference site – which is characterized by fast running water – the *Ecdyonurus venosus* is present in 3 ind./$m^2$, while the density of *Rhithrogena semicolorata* exceeds 50 ind./$m^2$.

As the measured chemical parameters show only the momentary situation, long-term effects are better reflected by the structure of biota. Mayflies, like other organisms can accomodate to the local conditions to a certain extent. However, fatal changes in the habitat's condition can trigger the disparition of them when they are no more suitable for maintaining certain species' life. This is supported by the results of data analysis with the AQEM assesment system after which the site below Baia de Arieș enters the fifth acidic class. In 2005, when pH was 7.11, this site was colonized by a few *Baetis vernus* individuals. This species is capable of remaining alive in more acid waters but in spring 2006, when pH had fallen to 5.31, they are no longer present. AQEM uses a few mayfly species in the assesment, these are: *Baetis rhodani, Baetis vernus, Baetis sp.*, representants of the 3rd acid class's fauna, while the 2nd acid class is assigned to *Baetis alpinus, Ecdyonurus sp., Rhirhrogena semicolorata, Rhithrogena carpatoalpina, Rhithrogena sp*. These

[61] NEDEAU, E. J. – MERRITT, R. W. – KAUFMAN, M. G. 2003.
[62] HEFTI, D. – TOMKA, I. 1991.
[63] CARLISE, D. M. – CLEMENTS, W. H. 2003.
[64] FIALKOVSKI, W. et alii 2003.
[65] ZAMORA-MUNOZ, C. − SANCHEZ-ORTEGA, A. 1993.
[66] TIMM, H. 1997.
[67] ZAMORA-MUNOZ, C. − SANCHEZ-ORTEGA, A. 1993.
[68] MIESBAUER, H. − KÖCK, G. – FÜREDER, L. 2001.
[69] UJVÁROSI L. 2003.
[70] WEATHERHEAD, M. A. − JAMES, M. R. 2001.
[71] GĂLDEAN, N. – BACALU, P. – STAICU, G. 1995.
[72] MACAN, T.T. 1970.

species coloniozed the reference site, which in spring entered in the 2nd class. In this year at the site below Baia de Arieș we haven't found any mayfly species but as they were present above, with their absence indicate such a drastic change in the habitat quality, acidification of water, that induce the disparition even of the less sensible mayfly species. Abundance, number of taxa and changes in diversity correlate with the changes in water acidity, as they decrease with the increasing of it. Our results correlate with Howells'[73] after which at pH 6.0 or above and with moderate alkalinity, the macroinvertebrate fauna is usually rich in all species. In streams of pH 5.6 or above some taxa may be missing, absent or scarce. This is the case of mayflies, molluscs and crustaceans. Soulsby et al.[74] also observed in acidified Scotish streams (pH<6.0) that the relative abundance of Ephemeroptera is low while Plecoptera tend to dominate. In contrast, Ephemeroptera are more abundant in well-buffered streams where acid-sensitive species such as *Baetis rhodani* are present. The taxon richness and abundance of Trichoptera also tends to increase with the decreasing stream acidity. Stream microcosms with low pH contained significantly fewer individuals and taxa then control ones and the number of Ephemeroptera individuals decreased from 80.7% to 18.1% in the most acidic streams.[75]

### 1.6. Conclusion

The benthic macroinvertebrate samples collected along the Arieş River indicate a general decline in community sructure after the confluence with polluted creeks. Decrease in abundance is observed in each macroinvertebrate group, moreover, the more demanding orders to habitat quality (Ephemeroptera, Plecoptare and Trichoptera) totally dissappear from the macroinvertebrate fauna of the most polluted sampling site. A loss in diversity of mayfly species was also observed. Although the community tries to recover twice, never reaches the abundance and diversity level of the reference site.

The loss of either of the zoobenthic species impacts the whole ecosystem, as they represent an important loop of the aquatic food chain. In the same time, they accumulate heavy metals in their tissues, this contamination being concentrated in organisms higher up the food web and reaching its maximal level in top predators.

The high-rate pollution ocurring along the river decreases water usage, becoming unsuitable as water supply for the localities. Nonetheless, pollution also decreases the aestethic value of the region.

For a more subtle assesment of the anthropogenic impacts on the river it is neccessary to process all the taken samples, as well as to identify the remaining macroinvertebrate groups to species level. A further analysis of the macroinvertebrate fauna, sediment and water chemistry are also required.

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## Adatok a nehézfémekkel szennyezett Aranyos folyó makrogerinctelen faunájára vonatkozóan (Románia)

(Kivonat)

Az Erdélyi-Szigethegységben a bányaipari tevékenység hagyományos, a római időkre vezethető vissza, folyamatos, állandó szennyező forrást biztosítva a felszíni vizek számára. Jelen tanulmányban a nehézfémekkel szennyezett Aranyos folyó makrogerinctelen közösségének szerkezetét vizsgáljuk. A mintavétel két alkalommal, 5 illetve 6 pontról történt, 2005 őszén, valamint 2006 tavaszán. Eredményeink szerint a szennyezett mellékfolyók hatására megváltozik a közösség szerkezete, ami a makrogerinctelen csoportok, valamint kérészek abundanciájának és a kérészek diverzitásának hanyatlásában nyilvánul meg. Ismertetjük a kutatási periódus időszakában a folyót kolonizáló Ephemeroptera fajok listáját is. A mintavételi pontokat savasságuk szempontjából is jellemeztük.

## Contribuții la cunoașterea faunei de macrozoobentos din râul Arieş, poluat cu metale grele

(Rezumat)

În Munții Apuseni mineritul se practică încă din epoca romană, reprezentând o sursă continuă de poluare pentru apele de suprafață. În acest studiu analizăm compoziția faunei de macronevertebrate bentale din râul Arieş, poluat cu metale grele. Prelevarea de probe s-a realizat în septembrie 2005 şi mai 2006, din 5, respectiv 6 secțiuni. Conform rezultatelor obținute, în urma poluării cu metale grele se schimbă compoziția macrozoobentosului, ceea ce se reflectă atât prin scăderea abundenței grupurilor de macronevertebrate, cât şi prin scăderea diversității ephemeropterelor. Prezentăm şi lista speciilor de Ephemeroptera, care au colonizat râul în timpul cercetării. Secțiunile sunt caracterizate şi din punct de vedere al acidității.

# Appendix

| Family | Species | AI | AII | AIII | AIV | AV | AVI |
|---|---|---|---|---|---|---|---|
| Baetidae | *Baetis alpinus* (Pictet 1843) | - | - | + | - | - | - |
| | *Baetis rhodani* (Pictet 1843) | + | + | + | - | + | - |
| | *Baetis scambus* Eaton 1860 | + | + | + | - | + | - |
| | *Baetis sp*. Leach 1815 | + | + | + | - | + | + |
| | *Baetis vardarensis* Ikonomov 1962 | + | - | - | - | - | - |
| | *Baetis vernus* Curtis 1834 | + | + | + | + | + | + |
| Caenidae | *Caenis macrura* Stephens 1835 | + | - | + | - | - | - |
| | *Caenis sp*. Stephens 1835 | - | - | + | - | - | - |
| Ephemerellidae | Ephemerellidae Gen. sp. | + | + | - | - | - | - |
| | *Serratella ignita* (Poda 1761) | + | - | - | - | - | - |
| | *Torleya major* (Klapalek 1905) | + | + | - | - | - | - |
| Heptageniidae | *Ecdyonurus alpinus* Hefti,Tomka & Zurwerra 1987 | + | - | - | - | - | - |
| | *Ecdyonurus gr.helveticus (zelleri?)* (Eaton 1885) | + | - | - | - | - | - |
| | *Ecdyonurus picteti* (Meyer-Dur 1864) | - | + | - | - | - | - |
| | *Ecdyonurus sp*. Eaton 1868 | + | - | + | - | - | - |
| | *Ecdyonurus venosus* (Fabricius 1775) | - | - | - | - | - | - |
| | *Heptagenia sp*.Walsh 1863 | + | - | - | - | - | - |
| | Heptageniidae gen. sp. | + | - | + | - | - | - |
| | *Rhithrogena carpatoalpina* Klonowska, Olechowska, Sartori & Weichselbaumer 1987 | + | - | - | - | - | - |
| | *Rhithrogena semicolorata* (Curtis 1837) | + | - | - | - | + | - |
| | *Rhithrogena sp.* Eaton 1881 | + | - | - | - | - | - |
| Leptophlebiidae | *Habrophlebia lauta* Eaton 1884 | - | - | + | - | - | - |
| | *Paraleptophlebia cincta* (Retzius 1783) | + | - | - | - | - | - |

Table 8. List of the Ephemeroptera species which colonized the Arieş in autumn 2005 and spring 2006 (+ presence, - absence of the species).