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BENTHIC DIATOMS USED AS BIOINDICATORS FOR WATER QUALITY EVALUATION IN THE DRAINAGE BASIN OF THE ARIEŞ RIVER (TRANSYLVANIA, ROMANIA)

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Abstract: The present paper deals with the water quality evaluation at ten sampling sites on the Arieş River and eight sites located on its tributaries, based on Saprobic Index (SI), Diatom Biological Index (DBI) and Shannon-Wiener Diversity Index (H). The diatom samples were collected on 29 October 2008. The computed indices suggested evident differences in water quality according to the location of sampling sites and intensity of human activities, assessments sustained by the physicochemical parameters measured in the field. According to DBI values the upstream Arieş River exhibits good water quality, with the tendency to change into acceptable or mediocre towards its downstream courses. The waters of the tributaries are usually of excellent to good quality, except a few on the middle course of the Arieş River affected by the acidic mine waters of the mining areas of Abrud – Roşia Montană – Roşia Poieni – Baia de Arieş, as well as by household wastes. An outstanding case is the Valea Şesii rivulet where diatoms were almost entirely lacking. The Saprobic Index (SI) exhibited a growing tendency for organic loading in the Arieş River from upstream toward downstream. Its values indicated slightly polluted upper and middle courses and a rather polluted lower course, the later exhibiting moderately to heavily polluted water. The same tendency was valid for the tributaries, the upstream rivulets being slightly polluted, but the downstream ones moderately.

Keywords: benthic diatoms, water quality, Saprobic Index, Diatom Biological Index, Diversity Index

Introduction

The Transylvanian Arieş River located in the north-west of Romania, springs from the Bihor Mountains – the central massif of the Romanian Western Carpathians [2, 3]. The river is approximately 167 km long and discharges its water into the Mureş River downstream from the town of Luduş. The Arieş, the second largest tributary of the Mureş River, has a catchment area of 2970 km^2, two third of which covers mountainous regions, and only its lower course belongs within the Transylvanian Depression. The catchment area of the river is polluted throughout the year by mining, agriculture, zootechnology, household activities and increasing tourism [6, 7].

Increasing human settlements, through domestic life, agriculture and zootechnology, intensive grazing, and the wood and mining industries, has had the main impact on the upper part of the Arieş catchment area. Its lower part is complimentarily polluted by various chemical wastes resulting from the intense industrial activities in the nearby towns (Turda, Câmpia Turzii).

In spite of the fact that some sections from the upper and the middle region of the Arieş catchment area have been declared natural reserves [13], including ice caves, basalt columns, gorges with many interesting and unique landscape elements, intensive and careless tourism remains a permanent source of pollution (bottles, fire-sites, paper and plastic waste, etc.).

In the present paper the authors aimed to evaluate the ecological state of the streams from the Arieş River catchment area, to detect changes in the water quality of the main river and its tributaries, presumably altered by various pollution sources, based on the floristic composition and structure of the benthic diatom communities.

Materials and Methods

Benthic diatom samples from the Arieş River and its tributaries were collected on 29 October 2008 at 18 sampling sites, 10 distributed along the Arieş river course and 8 on its tributaries (Fig. 1). At the same time, some of the physicochemical parameters of the water were also measured, including: conductivity, salinity, dissolved oxygen, temperature and pH (Tables 1 & 2). The diatom samples were collected by scraping or brushing the surface of rocks, stones, gravel and other hard surfaces to remove the periphyton, and preserved in the field with 4% formalin. The diatom frustules were subsequently cleaned using standard methods (treated with nitric acid and repeatedly rinsed with distilled water, or just simply incinerated) and mounted in Colophony or Styrax. The diatom slides where examined under a light microscope with 100 X oil immersion lens (numerical aperture: 1.32), the taxa being identified according to standard key books. The Diatom Biological Index (DBI) and Saprobic Index (SI) were calculated based on the relative abundance and frequency of diatoms after counting at least 400 individuals in each slide. The steps employed for the calculation of DBI were those recommended by Prygiel and Coste [11] (see also Momeu and Péterfi [7]; Péterfi and Momeu [8]; Voicinco and Momeu [6]). The saprobic level of the water – or the saprobic index (IS) was calculated based on Zelinka and Marvan [14, 18].

Also calculated for each sampling site were the Shannon-Wiener diversity (H) and equitability (E) values.

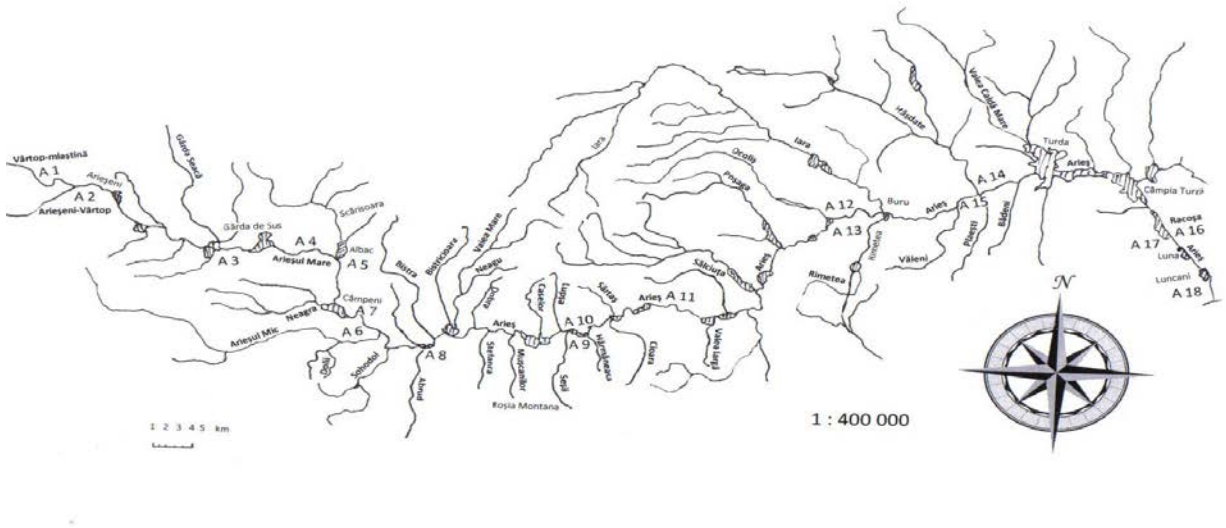

Fig. 1: Location of sampling sites in the Arieş River catchment area (10 sites situated on the main river course and 8 located on its main tributaries). A1 – Vârtop–mlaştină (Boggy area); A2 – Arieşeni–Vârtop; A3 – Gârda Seacă; A4 – Arieşul Mare upstream Albac; A5 – Valea Albacului; A6 – Arieşul Mic; A7 – Arieşul Mare upstream Câmpeni; A8 – Abrud rivulet; A9 – Pârâul Seşii; A10 – Arieş at Valea Lupşii; A11 – Brăzăşti; A12 – Valea Ocolişului; A13 – Arieş upstream confluence with Valea Ocolişului; A14 – Hăşdate; A15 – Arieş downstream confluence with Hăşdate; A16 – Arieş upstream confluence with Racoşa; A17 – Racoşa; A18 – Luncani.

Table 1: Physicochemical parameters of water in sampling sites located on the Arieş River

Number of sampling sites	Name of sampling sites	Water temperature (ºC)	Conductivity (µS.cm^{-1})	Salinity (mg.l^{-1})	Dissolved oxygen (mg.l^{-1})	pH
A1	Vârtop–mlaştină	8	13.22	6.62	13.46	5.1
A2	Arieşeni–Vârtop	8.3	15.74	7.9	13.15	5.3
A4	Arieşul Mare upstream Albac	7.2	11.29	6.6	11.68	6
A7	Arieşul Mare upstream Câmpeni	7.6	12.39	6.43	14.37	7.2
A10	Arieş at Valea Lupşii	7.7	7.16	4.9	9.12	7.6
A11	Brăzeşti	8.3	13.4	6.67	14.2	7.1
A13	Arieş upstream confluence with Valea Ocolişului	7	9.32	5.58	13.31	7.6
A15	Arieş downstream confluence with Hăşdate	8.1	12.13	6.1	14.99	8
A16	Arieş upstream confluence with Racoşa	10.2	8.55	4.61	9.8	7.8
A18	Luncani	2.5	13.46	6.48	9.1	7.5

Table 2: Physicochemical parameters of the water in sampling sites located on the main tributaries of the Arieş River

Number of sampling sites	Name of sampling sites	Water temperature (ºC)	Conductivity (µS.cm^{-1})	Salinity (mg.l^{-1})	Dissolved oxygen (mg.l^{-1})	pH
A3	Gârda Seacă	7.5	13.43	7.8	16.42	6.1
A5	Valea Albacului	6.8	13.93	6.7	16.15	5.8
A6	Arieşul Mic	7.4	6.62	3.69	13	6.5
A8	Abrud rivulet	7.2	13.67	7.53	12.7	6.4
A9	Pârâul Şesii	7.2	11.83	6.42	13.66	7.6
A12	Valea Ocolişului	8.3	13.56	7.67	13.4	8,9
A14	Hăşdate	5.8	12.22	6.34	18.04	8.2
A17	Racoşa	6.8	9.96	5.32	13.7	7.6

Results and Discussion

To explain properly the present findings concerning the diatom communities, one has to consider the main pollution sources acting in the Arieş river catchment area.

There are two major groups of aggressive polluting sources generated by human activities: one is mining, the second is forest clearfelling, the later being very intensive post-1990. Both sources markedly affect the ecological state of the streams in the Arieş River basin.

The oldest and the most aggressive of these is mining; the surrounding mountains are rich in auriferous and other non-ferrous metal deposits [10]. The acidic and toxic mine-waters affect and modify the physicochemical parameters of the stream water as shown by the measurement carried out in the sampling sites of the Arieş and its tributaries (Tables 1 and 2). Most evident are the low pH values in Abrud and Valea Şesii rivulets draining the mine-waters, decantation ponds and waste dumps located in the Roşia Montană – Roşia Poieni – Abrud area.

The second aggressive activity is recently intensified forest clearfelling. The activity of sawmills and wood processing factories at Gârda and Câmpeni generates large deposits of sawdust on the banks of the Arieş River and tributaries, affecting the water quality (e.g. pH of the water, see Tables 1 and 2).

Forest clearfelling on the other hand produces the erosion of slopes and river banks, landslips, forest destruction, floods [3, 13] and drifts in the drainage basin of the Arieş River. One should not underestimate too the impact of pollutants produced by agriculture,

zootechnology, households and tourism, which markedly affect the life of aquatic and terrestrial organisms and landscape.

The anthropogenic impact, by producing changes in physicochemical and geographical features, might potentially generate factors of natural risk: barren limestone areas, rock crashes, fall of stones, formation of debris layers [2, 9], and changes in water quality (low pH values, e.g. 5.1; 5.3) etc.

In recent years some positive changes have taken place, and some of the household waste deposits (e.g. Baia de Arieş) have been removed by local authorities. It is a good sign for this region, implying changes in human mentality and hope for a brighter future.

The ecological state of the streams belonging to the Arieş River catchment area is demonstrated by both Saprobic and Diatom Biological indices (Figs. 2, 3), correlated with the Shannon-Wiener diversity index.

The only sector of the Arieş River with low organic loading (water quality class I-II), namely with slightly polluted waters, seems to be the upper course or spring zone (Fig. 2). At the sampling sites situated on the middle course of the Arieş River the SI values indicated moderate organic pollution (water quality class II). On the lower course of the river the water quality ranged between moderately polluted and moderately to heavily polluted (water quality class II to II-III). In all investigated tributaries the SI values varied between 1.537 and 2.174 – that means slightly or moderately polluted waters. There is a generally growing tendency of organic loading in the tributaries (Fig. 3) from the Arieş spring area toward its confluence with the Mureş River. The only exception is the rivulet from Valea Şesii, heavily polluted by toxic mine-waters, where no living diatoms could be detected in the benthos.

Table 3: Saprobic Index correlated with water quality classes and water quality

SI values	Quality class	Water quality
$SI \leq 0.5$	I	Very clean waters
$0.5 < SI < 1.3$	I	Clean waters
$1.4<SI<1.7$	I-II	Slightly polluted, low pollution
$1.8<SI<2.1$	II	Moderately polluted
$2.2<SI<2.5$	II-III	Moderately to heavily polluted
$2.6<SI<3.0$	III	Heavily polluted
$3.1<SI<3.4$	III-IV	Heavily to very heavily polluted
$SI > 3.5$	IV	Very heavily polluted

The computed DBI values (Figs. 4, 5), correlated with water quality cases (Table 4), indicate that the Arieş River exhibited good quality water only in its spring area at site A1. Downstream in its upper and middle courses the water quality gradually changed into acceptable (sites A2 and A3) and mediocre (site A7) indicating stress from the growing household pollution. Further downstream the river has been recovered the quality of water, according to the DBI values, became acceptable or even good at Brăzăşti (site A11) and Arieş upstream confluence with Valea Ocolişului (site A13).

On the lower course of the river the water quality gradually decreases from acceptable (site A15) into mediocre, toward the confluence of the Arieş with the Mureş (site A18).

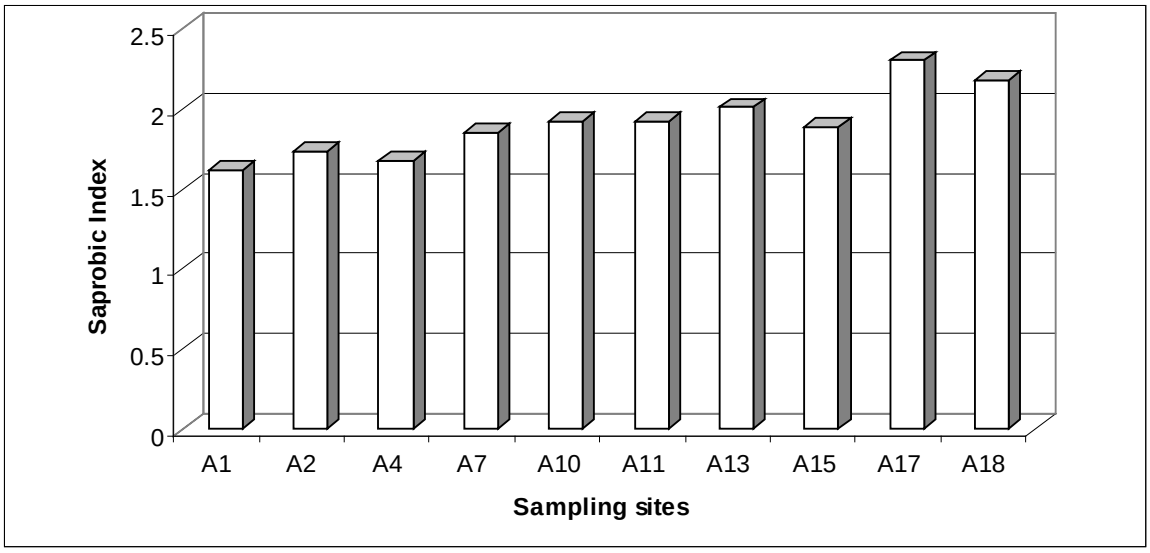

Fig. 2: Changes of the Saprobic index (SI) values on the Arieş river (Sampling sites: A1 – Vârtop–mlaştină; A2 – Arieşeni–Vârtop; A4 – Arieşul Mare upstream Albac; A7 – Arieş upstream Câmpeni; A10 – Arieş at Valea Lupşii; A11 – Brăzăşti; A13 – Arieş upstream confluence with Valea Ocolişului; A15 – Arieş downstream confluence with Hăşdate; A17 – Arieş upstream confluence with Racoşa; A18 – Luncani)

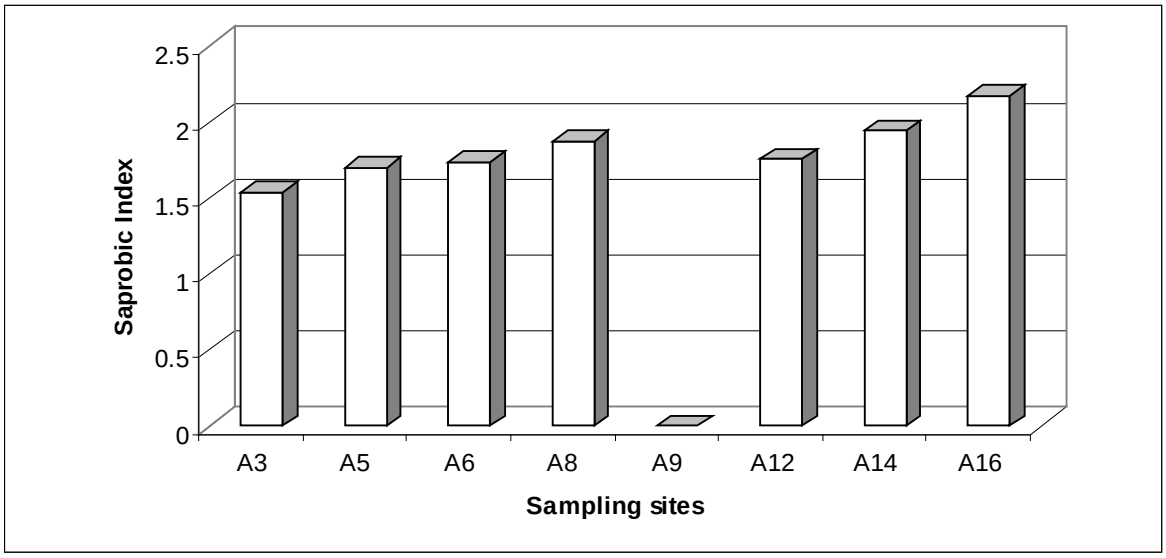

Fig. 3: Saprobic index (SI) values on the tributaries (Sampling sites: A3 – Gârda Seacă; A5 – Valea Albacului; A6 – Arieşul Mic; A8 – Abrud rivulet; A9 – Pârâul Şesii, no diatoms found; A12 – Valea Ocolişului; A14 – Hăşdate; A16 – Racoşa)

Table 4: Diatom Biological Index correlated with water quality classes

DBI	Water quality class
DBI<5	inferior
5≥DBI<9	mediocre
9≥DBI<13	acceptable
13≥DBI<17	good
DBI≥17	excellent

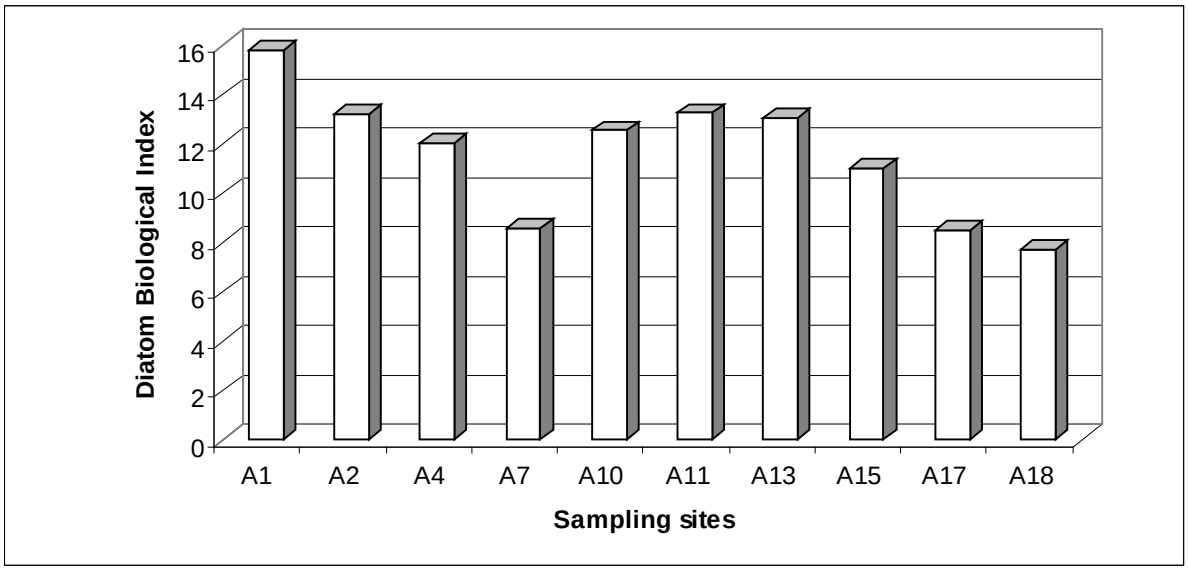

Fig. 4: Diatom biological index values (DBI) in different sampling sites on the Arieş River (Sampling sites: A1 – Vârtop-mlaştină; A2 – Arieşeni-Vârtop; A4 – Arieşul Mare upstream Albac; A7 – Arieş upstream Câmpeni; A10 – Arieş at Valea Lupşii; A11 – Brăzăşti; A13 – Arieş upstream confluence with Valea Ocolişului ; A15 – Arieş downstream confluence with Hăşdate; A17 – Arieş upstream confluence with Racoşa; A18 – Luncani)

The diatom biological index (DBI) values computed for the investigated tributaries (Fig. 5) ranged between 9.68 and 13.68, suggesting mostly acceptable but in single case good water qualities (site A12) at Valea Ocolişului rivulet. The DBI could not be calculated in the Valea Şesii (A9) rivulet, due to the total lack of benthic diatoms.

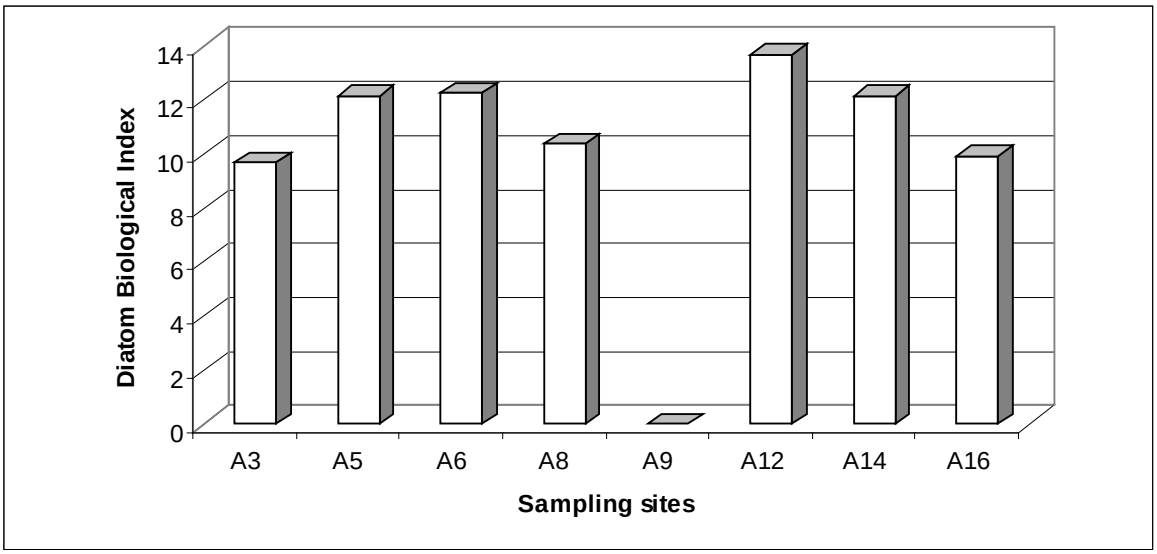

Fig. 5: Diatom biological index (DBI) values calculated for the main tributaries (Sampling sites: A3 – Gârda Seacă; A5 – Valea Albacului; A6 – Arieşul Mic; A8 – Abrud rivulet; A9 – Pârâul Şesii, no diatoms found; A12 – Valea Ocolişului; A14 – Hăşdate; A16 – Racoşa)

The present findings attest once more the validity of both biotic indices employed in the present investigations (SI, DBI) for the evaluation of ecological state in running waters. These data agree with earlier published records from the Arieş River [7, 16] and other Transylvanian streams [1, 4, and 17] or western European rivers [5, 11, 12, and 15].

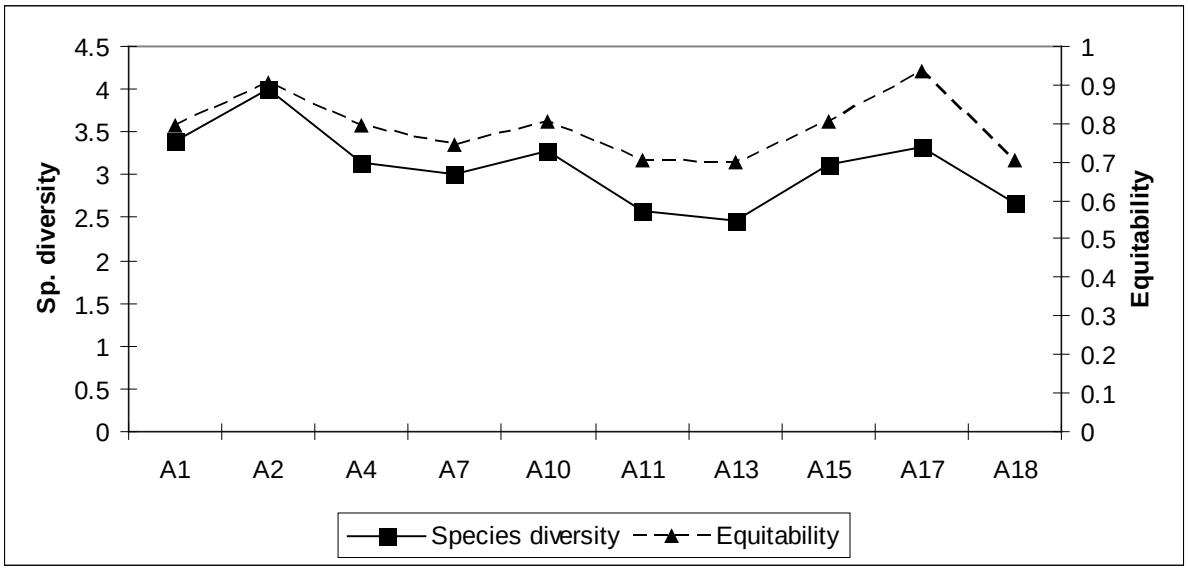

Fig. 6: Variations of Shannon-Wiener diversity index and equitability values in the Arieş River (Sampling sites: A1 – Vârtop-mlaştină; A2 – Arieşeni-Vârtop; A4 – Arieşul Mare upstream Albac; A7 – Arieş upstream Câmpeni; A10 – Arieş at Valea Lupşii; A11 – Brăzăşti; A13 – Arieş upstream confluence with Valea Ocolişului ; A15 – Arieş downstream confluence with Hăşdate; A17 – Arieş upstream confluence with Racoşa; A18 – Luncani)

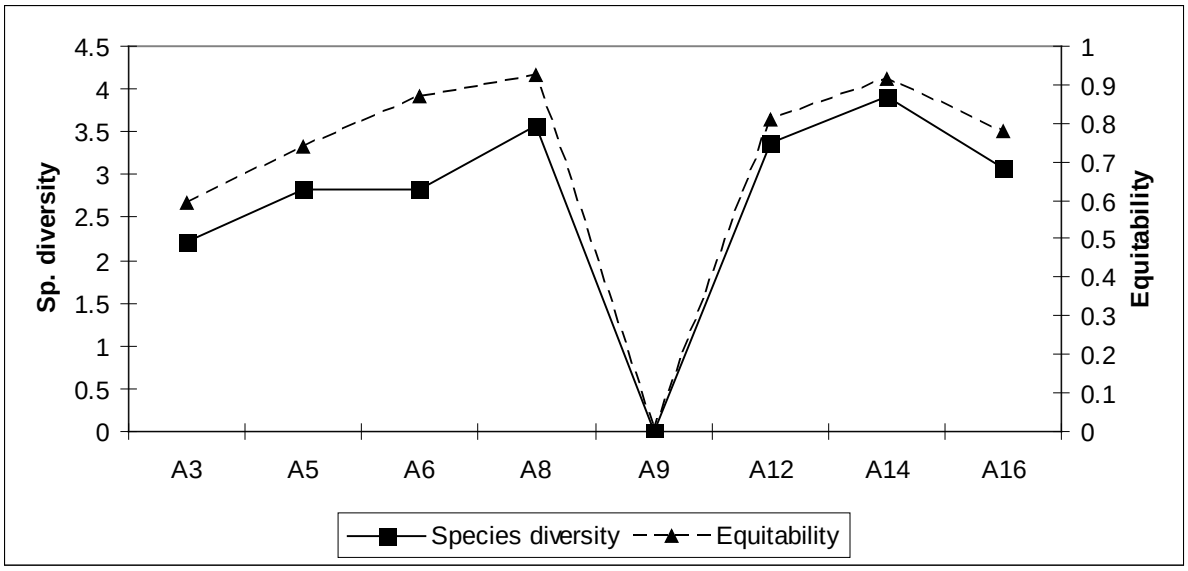

Fig. 7: Diversity and equitability of the diatom communities in the tributaries (Sampling sites: A3 – Gârda Seacă; A5 – Valea Albacului; A6 – Arieşul Mic; A8 – Abrud rivulet; A9 – Pârâul Şesii, no diatoms found; A12 – Valea Ocolişului; A14 – Hăşdate; A16 – Racoşa)

The Shannon-Wiener diversity and equitability values suggest also that the algal communities inhabiting the Arieş River and its tributaries are affected to different degrees by pollutants. The lowest diversity values are possibly means moderately to heavily polluted zones due to human impact. The total lack of algae at site A9 (Pârâul Şesii rivulet) is due to extensively toxic pollution caused by mine-waters draining into the stream. In the Arieş River the number of species exhibits a more or less decreasing tendency from upstream toward downstream with slight variations along its course. The highest diversity values were calculated for the Arieş River, at site A2 (Arieşeni-Vârtop), sheltering at least 83 species. The lowest value was calculated for

the Arieş river upstream of its confluence with Valea Ocolişului (A13) (Fig. 6), inhabited only by 35 species.

As regards the tributaries, the number of species is lower (about 40 taxa) in the tributaries, located upstream in the Arieş River and higher (up to 70 taxa) in those located on its middle and lower courses. The diversity and equitability increase from uphill toward downhill tributaries, with the highest at sampling site A14, located on the Hăşdate rivulet (Fig. 7).

Conclusions

- The natural ecological state of streams from the Arieş River catchment area is seemingly altered by local human impact (household, industrial, agricultural, zootechnological, woodworking wastes, etc.).
- According to the Shannon-Wiener diversity index, the Arieş River and its tributaries are affected by slight to critical pollution stress of various origins.
- The SI and DBI values suggest that the water of the Arieş River from the upper course toward its lower course, as well as of some tributaries, is affected first of all by organic loading.
- The Saprobic Index (SI) exhibited growing tendency of organic loading in the Arieş River from upstream toward downstream. Its values indicated slightly polluted upper and middle courses and rather polluted lower course, the later exhibiting moderately to heavily polluted water.
- According to DBI values, the upstream Arieş River exhibits good water quality, with the tendency to change into acceptable or mediocre toward its downstream courses.
- The waters of the tributaries are usually of excellent to good quality, except a few located on the middle course of the Arieş River, affected by the acidic mine-waters of the mining areas, as well as by household wastes (except the Valea Şesii rivulet, where diatoms were almost entirely absent).

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DIATOMEE BENTONICE FOLOSITE CA BIOINDICATORI PENTRU EVALUAREA CALITĂŢII APEI ÎN BAZINUL DE DRENAJ AL RÂULUI ARIEŞ (TRANSILVANIA, ROMÂNIA).

(Rezumat)

Lucrarea de faţă prezintă rezultatele evaluării calităţii apei din bazinul hidrografic al Arieşului pe baza a 10 staţii de prelevare din râul Arieş şi 8 din principalii săi afluenţi, pe baza indicelui saprobic (IS), indicelui biologic de diatomee (IBD) şi indicelui de diversitate Shannon-Wiener (H). Prelevările diatomologice au fost efectuate la 29 octombrie 2008.

Valorile indicilor calculaţi sugerează diferenţe sensibile în ceea ce priveşte calitatea apei, în funcţie de localizarea staţiilor de prelevare şi intensitatea activităţilor umane, constatări susţinute şi de parametrii fizico-chimici, măsuraţi la faţa locului. În concordanţă cu valorile IBD, calitatea apei din cursul superior al Râului Arieş este bună, cu tendinţa de a se schimba în acceptabilă şi apoi mediocră în cursul mijlociu şi respectiv inferior. Apa afluenţilor este de regulă excelentă sau bună, cu excepţia unora de pe cursul mijlociu al Arieşului, unde pare a fi afectată de scurgerile de apă de la exploatări miniere şi ape menajere din zona Abrud – Roşia Montană – Roşia Poieni – Baia de Arieş. Un caz ieşit din comun este pârâul din Valea Şesii, unde diatomeele lipsesc cu desăvârşire datorită toxicităţii apei.

Indicele saprobic (IS) indică pentru Arieş o tendinţă crescătoare a încărcării organice a apei de la obârşie spre vărsarea în Râul Mureş, bunăoară poluare uşoară în cursurile superior şi mijlociu şi moderată până la puternică în cel inferior. Aceeaşi tendinţă se constată şi în ceea ce priveşte afluenţii Arieşului, cei din amonte fiind mai slab poluaţi faţă de cei din aval care sunt moderat încărcaţi organic.

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