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The effect of iron leaching on Arieş River ecosystem (Romania)

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Abstract. The effect of iron leaching was investigated on Arieş River ecosystem. Ten samples of water and ten of sediment from Arieş River were studied for their physicochemical, mineralogical and microbiological properties during the four seasons of the year 2008. The overall study showed high variations of the iron content in water samples more than the permissible limit recommended by Arieş Water Law No. 107/1996. A direct correlation between the inhibition of microbial development and the pollution degree of the sediment specific to each sampling point was observed. In its upper reaches, the river system is characterized by high contents of SO_4^{2-} as a direct result of acid mine effluents and the oxidation of sulphide minerals on mine dumps as well as inflows from settling ponds. Although continuous dilution by natural branch waters and natural water- rock interaction reduces the pollution to some extend, the total level of $SO4^{2-}$ remains above European averages. As compared to the values registered in unpolluted water, the Cu and Zn contents of River Arieş are 100 times higher than those admitted by law.

Keywords: iron bacteria, Arieş River, pollution, sediment, bacterial leaching.

Introduction

Due to its high abundance within the earth's crust, iron is ubiquitous in all freshwater environments and often reaches significantly higher concentrations in water and sediments than other trace metals (Livingstone 1963). Mining of Fe enriched ores, intensified forestry, peat production, and agricultural draining have increased the load of iron in many river ecosystems (Dahl 1963, Brown 1977, Boult et al. 1994). More recently, intensified draining of peatlands, forests and arable lands, as well as dredging of iron enriched river sediments, has increased the leaching of iron in many river ecosystems (Ahtiainen 1992, Palko 1994, Vuori 1993).

The formation of some sedimentary iron deposits has been directly attributed to microbial activity (Ewers 1983, Widdel et al. 1993). In spite of its importance very little is known about the microbial ecology associated with the mobilization of iron in nature (Amils et al. 2002). There is increasing evidence that iron may play a crucial impact on the structure and function of a river ecosystem (Vuori 1995).

Iron enters into the vegetal tissues constitution under the form of organic compounds. Under the fermentative processes fulfilled by some microorganisms, the organic compounds are mineralized and oxidised to ferrous state, to Fe^{2+}, that can be reutilised by plants. In this way, it is fulfilled a complete iron cycle in the nature (Amils et al. 2002).

The oxidation of Fe(II) is accelerated by trace metals, phosphate, fluoride and particles, including autocatalysis by fresh Fe oxides. Microorganisms greatly enhance the Fe(II) oxidation in acid streams (Davison & DeVitre 1992). The role of the iron on the rhizosphere is important, due to the small existent quantity this element stays at the base of a competition between plants and microorganisms, and between different microbial species, competition that creates some strategies of rapid absorption, that implies local acidification, chelation and reductive processes (Robin et al. 2008). In aerobic conditions and neutral pH, the ferrous iron is rapidly oxidized in compounds that at the level of the sediments are transformed into pyrite (Rickard 1969).

In most river waters, iron is predominantly transported in the particulate fraction (Burman 1983, Johnson & Thornton 1987, Davison & DeVitre 1992). The oxidized Fe particles in river water are removed by settling on the riverbed where they may be periodically resuspended, depending on their size and velocity of the current (Vuori 1995). In reducing sediment layers some of the Fe(III) oxy-hydroxides are reduced to Fe(II) (Vuori 1995). One part of this reduced Fe(II) diffuses upwards and is re-oxidized, while the other part is removed by the formation of authigenic minerals such as siderite, vivianite or iron sulphide (Davison & DeVitre 1992).

A high content of iron in the surface waters is indicative of pollution with industrial waste waters or with mining spills. Iron concentrations above 0.3mg/l change the organoleptic properties, prevent the use of these waters for technological purposes, and cause technical difficulties in using water for household needs by forming precipitates (Forray & Hallbauer 2000). Iron-hydroxide precipitates may drastically alter the physical characteristics of rivers receiving iron-rich runoff from acid sulphate soils disturbed by mining activities (McKnight et al. 1992, Boult et al. 1994).

When the water reaches a certain level of acidity, a naturally occurring type of bacteria called *Thiobacillus ferrooxidans* may kick in, accelerating the oxidation and acidification processes, leaching even more trace metals from the wastes (Xavier 1990). The environmental changes have a strong influence on the river dynamics, leading to river instability, and thus to changes in the erosion, transport and accumulation processes, in the sediments dynamic, heavy metal transport and geographical distribution throughout the river basin (Macklin 1996). Heavy metals accumulate in the sediments through complex physical and chemical adsorption mechanisms depending on the nature of the sediment matrix and the properties of the adsorbed compounds (Maher & Aislabie 1992, Ankley et al.1992, Leivouri 1998, Marin et al. 2010).

Previous researches have shown that problems with Fe load from mine field prevail decades after the abandonment of the mines (Boult et al. 1994, Gower et al. 1994). The hydrographic basin of Arieş River is situated in the northwestern part of Romania, in the middle of Apuseni Mountains. The Arieş River basin has an S form, a length of 131 km and an average width of 17.5 km (Ujvari, 1972). The study of Arieş River quality is a major current issue, regarding human health, as well as the flora and fauna. Pollution sources of the Arieş River are various, among them being the mining activity, the atmosphere pollution, house holding activity, as well as the anthropic influence. Another source of pollution is represented by waste dumps and settling ponds, which are usually placed near the Arieş River. Because of their position, the waste dumps are percolated by rainwater and the resulting water enters the phreatic and/or the surface water. During periods of heavy rain, the river level rises sufficiently to reach the base of waste dumps and thus, large amounts of barren gangue can also be transported into the river system contaminating the water. Further, the stability of the settling ponds can be affected, endangering the downstream areas (Forray & Hallbauer 2000).

The aim of our study was to realize a better understanding of the mechanisms by which the pollution of Arieş River affects the microbial population and activity in the river sediments. The present paper completes the enzymological research carried out on the same sediments (Bodoczi & Drăgan-Bularda 2008) and with a similar purpose Arieş.

Materials and methods

Microbiological analyses were carried out on water and sediments sampled from the Arieş River over the year 2008. The water and sediment samples were taken from the upstream and downstream of five major sampling sites in the following order: Abrud, Baia de Arieş, Sălciua, Turda and Luncani (Fig. 1). Sampling points were established taking into consideration the river's characteristics, the influence exerted by its tributaries and the pollution sources.

Water and sediment samples were taken seasonally, according with SR ISO 5667-6/97 and SR ISO 2852/94. Water samples were collected aseptically in 250 ml glass bottles. Sediment samples were taken from the riverbed at 50 cm from the bank following the removal of the first 5-10 cm of sediments. The water and sediment samples were placed in 4°C cooling boxes and immediately transported to the laboratory; no more than 9 hours elapsed between sampling and microbiological analysis.

The physico chemical analysis consisted in determination of some important parameters as: pH, sulphate $(SO_4)^{2-}$, and the presence of trace metals (iron, copper, lead, zinc) in the water samples. Water samples were filtrated through a 0.45 µm filter. pH was determined in the field at the time of sample collection using a calibrated portable pH meter. Sulphate, iron and lead concentrations in water samples were analyzed spectrophotometrically using standard methods. Zn concentration was detected by colorimetric method according to STAS 8314-69 and the total copper using the iodometric method according to STAS 3224-69. In iodometric determination of copper, iodides are oxidized into iodine in the presence of copper (II) ions which are reduced to cuprous ions.

Mineralogical composition of the sediment samples was established microscopically with chromatic objectives 4x (red), 10x (yellow) and 40x (blue) and a 10x ocular thus obtaining a 40, a 100, respectively, a 400 times magnification.

Assessment of iron reducing bacteria was performed through MTM (multiple tubes method) according to STAS 3001-91 (Cuşa 1996, Drăgan-Bularda 2000) on Optov culture media. The most probable number of bacteria was calculated according to the statistical table of Alexander (1965). After incubation at 25°C under aerobic conditions for 14-21 days, in each test tube were added 2-3 drops of α, α – dipiridil reagent.

There were considered positive those test tubes in which a pink colour appeared in 30 seconds, indicating the presence of Fe^{2+} resulted from Fe^{3+}.

The statistical correlation between bacteria implied in the iron cycle in Arieş River and some physico chemical parameters was established based on the application of two statistical tests: the ANOVA test of variances and the correlation coefficient test (r).

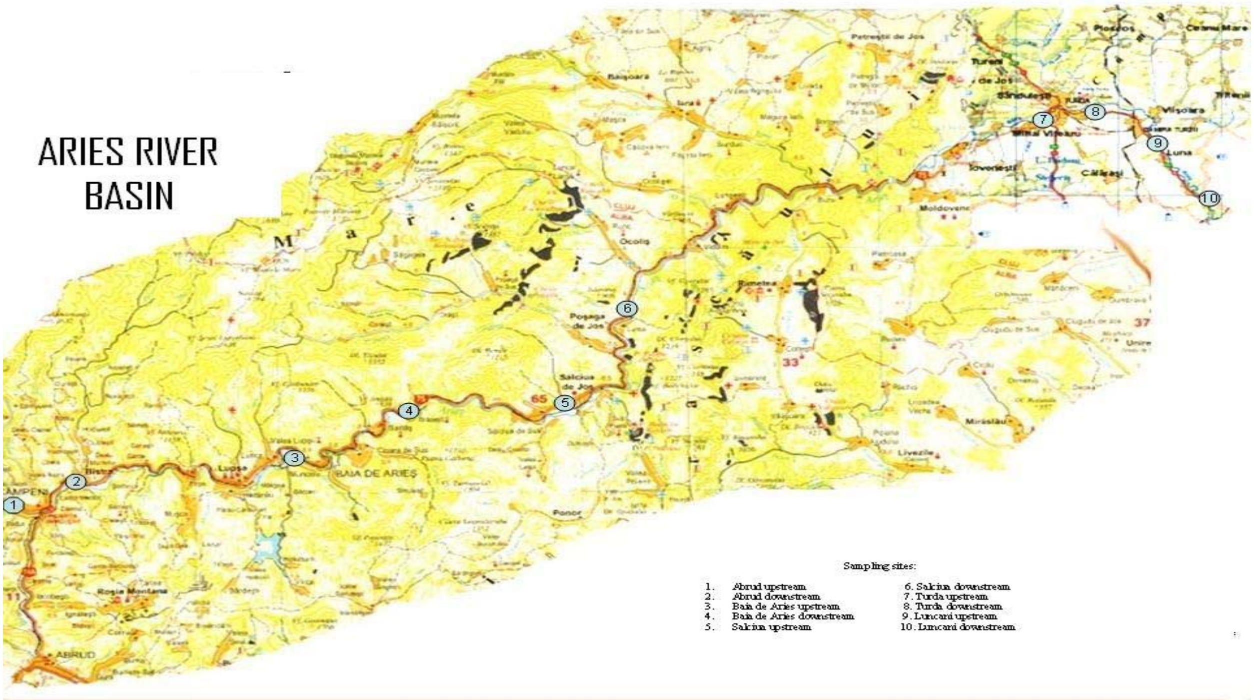

Figure 1. Map of Arieş River showing the sampling points (Bodoczi 2009)

Results and Discussion

The evaluation of water and sediment quality of Arieş River at the sampling sites was made based on the results of physicochemical, mineralogical and microbiological analyses with the goal of elaborating an original method for monitoring their quality. The presence or absence of an organism in an aquatic media is in close relationship with the biotic and abiotic factors of that environment (Zarnea 1994). On the other hand, the quality of freshwaters from source to outlet is increasingly affected by human activities, thus the conditions of existence for most of the aquatic organisms may be modified. Under these new conditions, an alteration of the initially established ecological relations between the community members can be observed, as compared to the situations encountered in other, similar, less affected ecosystems which we used as reference.

The concentrations of the measured chemical parameters from water samples are shown in Table 1. Heavy metals salts found in the water and in the sediments represent a very serious form of pollution for surface waters due to their toxicity and stability. They can induce disorders of the biological balance, with negative consequences over the various uses of water. Table 1 shows that the concentration values of heavy metals are lower in the upstream sampling points as compared with those registered in the downstream of the river. It can be affirmed that these elevated values are a consequence of the pollutants` accumulation as a result of mining activities.

Arieş catchments have the highest metal concentration from Apuseni Mountain. There are about 20 ore deposits, the most important ones being in exploitation at Roşia Montana and Roşia Poieni. Sediments are relatively more contaminated than surface waters in the Arieş River, particularly with Cu and Zn, whose concentrations increase downstream of the mining-affected tributaries, suggesting that the mines upstream act as a source of metals to channel sediments in Arieş River. Data collected from Arieş River have indicated that the degree of pollution is dependent upon the nature of mine waste, the hydrological link between mines and local rivers, and upon the local physicochemical environment (Forray& Halbauer 2000).

The sedimentary formations from Arieş River are diverse. In Abrud upstream they are represented by sandstones, laminated conglomerates and shales. Lithologically one can notice a predominance of conglomerates, macroconglomerates, sandstones, clays and limestones in flysch facies (Ianovici et al. 1976, Chira 2000).

Baia de Arieş has sedimentary formations represented by igneous bodies consisting of andesites, and by a predominance of quartz, kaolinite, mica, feldspar, gypsum and alunite. The magmatic products are accompanied by mineralized polymetallic Au, Ag and Cu which contribute significantly to the increase of the local and regional geochemical background, due to the large area of distribution and the alteration phenomena accompanying them (Ghergari et al. 1991).

At Sălciua sampling sites from lithological point of view the low terrace deposits are constituted of from clayey sands, sands with gravels and boulders and totally subordinated salty sands (Ianovici et al. 1976, Chira 2000).

Table 1. The values of some physicochemical parameters registered in the Arieş River water over the year 2008.

Sampling points	Physicochemical parameters	Annual mean upstream	Annual mean downstream
Abrud upstream and downstream	pH	7.3	7.2
	Sulphates (SO_4) mg/l	163.1	314.7
	Iron mg/l	0.26	0.39
	Copper mg/l	0.237	0.084
	Lead mg/l	0.001	0.001
	Zinc mg/l	0.643	0.835
Baia de Arieş upstream and downstream	pH	6.8	6.6
	Iron mg/l	0.073	0.25
	Sulphates (SO_4) mg/l	73.45	90.3
	Copper mg/l	0.008	0.018
	Lead mg/l	-	0.001
	Zinc mg/l	0.111	0.197
Sălciua upstream and downstream	pH	8.2	7.8
	Iron mg/l	36.4	0.23
	Sulphates (SO_4) mg/l	8.6	67.46
	Copper mg/l	0.006	0.003
	Lead mg/l	-	0.001
	Zinc mg/l	-	0.043
Turda upstream and downstream	pH	8	7.6
	Iron mg/l	0.35	0.40
	Sulphates (SO_4) mg/l	97.4	103.5
	Copper mg/l	0.010	0.019
	Lead mg/l	0.003	0.005
	Zinc mg/l	0.042	0.055
Luncani upstream and downstream	pH	8.0	7.3
	Iron mg/l	0.21	0.53
	Sulphates (SO_4) mg/l	103.05	132.45
	Copper mg/l	0.006	0.069
	Lead mg/l	0.00	0.00
	Zinc mg/l	0.043	0.086

The inferior basin of Arieş River (Turda and Luncani sections), as result of the selective erosion of the contact between the resistant formations of Mesozoic limestones and ophiolites and the Neogene sedimentary formations, was carved by the Arieş, whose valley was progressively enlarging. It consists of Sarmatian and quaternary sediments (sands, clays, gravels, volcanic tuffs) represented as terraces and meadows (Diaconu 1971, Popescu-Argeşel 1977, Ghergari et. al. 1991; Chira 2000). Due to their high content of highly soluble salts, they exert a strong influence on the chemistry of Arieş River in these sections.

The mineralogical composition of the studied sediment samples is presented in Table 2, and it can be observed that the diameters of mineral particles are mainly between 2 μm and 0.4 mm. Also, it has been observed that in all sediment samples the quartz is predominant and it was detected in high percentage. Hornblende and iron oxide and hydroxide are also present in all analyzed samples. At Turda and Luncani sampling sites there have been detected traces of opaque minerals.

Iron-reducing bacteria lead to iron reduction in the presence of organic substances (glucose) and at low redox potential in the medium (Ailiesei et al. 1999). Iron has an important role in the metabolism of animal and plants, but in high quantities it may determine an unbalance in the function of an ecosystem and may affect the existing organisms.

The numerical evolution of iron reducing bacteria in Arieş River is represented in Fig. 2. In the analyzed water samples, iron-reducing bacteria had densities between 10^2 and 10^4 cells/ml water. It can be observed a high numerical fluctuation of these bacteria from one sampling point to another (Fig. 2A). A high number of these bacteria were registered in Abrud and Baia de Arieş downstream sampling sites. This fact could be explained by the pollution of Arieş River as a consequence of confluence with the effluents of Abrud and Valea Sesei both containing mining spills derived from the mining tailings from the area: SM Cuprimin SA Abrud, respectively, SM Roşia Poieni.

Roşia Poieni represents Romania's largest cupriferous ore deposit and the second in Europe, possessing over 1 billiard tones of ore with a concentration of 0.36% Cu and 1.8% S. Roşia Poieni holds 64.5% of the national reserve of copper. Waste waters resulted here have a red characteristic colour induced by the high concentration of ferric iron maintained in solution due to the acidity of these waters. Also, a high number of iron reducing bacteria was registered in Turda downstream in the summer.

According to the literature (Corcheş et al. 2007, Lucaciu et al. 2010) the idea of bacterial leaching from mining dumps was adopted, that has as result the development of *Thiobacillus ferrooxidans* bacterial strains, water pH reduction and the enrichment of waters in Cu and Fe and other heavy metals (Cd, Zn, Pb, Mn) which finally get in the Arieş River leading to water degradation with negative effects over the water catchment's systems and the fresh water supplies from downstream of the river. Simultaneously, the water degradation may entail the possibility of aquatic flora and fauna destruction in those areas. Comparing the results obtained with those found in literature (Amils et al. 2002, Forray & Hallbauer 2000), a strong correlation between the activities aimed at reducing iron and sulphur contents in ecosystems that are characterised through high concentrations of heavy metals (Fe. Cu, Zn, Cd), can be observed.

The numerical evolutions of iron-reducing bacteria in the sediment samples are represented in Fig. 2B. Also, a numerical fluctuation of the iron-reducing bacteria (IRB) has been observed according to the sampling period. The iron-reducing bacteria were registered in lower densities in water samples than in the sediment ones (Fig. 2B), or they were even undetectable in some sampling sites, for example in Sălciua downstream in the winter. A progressive increase of

Table 2. The mineralogical composition of Arieş River sediments.

Sampling point	Principal mineral elements	Percentage (%)	Particles diameter	Predominant particle size
Abrud	Quartz	70%	2-80 μm	2-10 μm
	Orto-pyroxenes	8%		
	Iron oxides and hydroxides	20%		
	Feldspar	2%		
Baia de Arieş	Quartz	58%	0.01-0.4 mm	0.05-0.1 mm
	Hornblende, peroxides	30%		
	Iron oxides and hydroxides	2%		
	Biotite	10%		
Luncani	Quartz	72%	0.01-0.3 mm	0.01-0.1 mm
	Hornblende, peroxides	23%		
	Iron oxides and hydroxides	3%		
	Biotite	2%		
	Feldspar and opaque mineral trace	1%		
Sălciua	Quartz	65%	0.01-0.3 mm	0.05-0.1 mm
	Hornblende	30%		
	Biotite	2%		
	Opaque minerals	1%		
	Trace of iron oxides and hydroxides and chlorite	2%		
Turda	Quartz	87%	0.01-0.27 mm	0.08-0.2 mm
	Hornblende, peroxides	9%		
	Iron oxides and hydroxides	3%		
	Biotite and opaque minerals trace	1%		

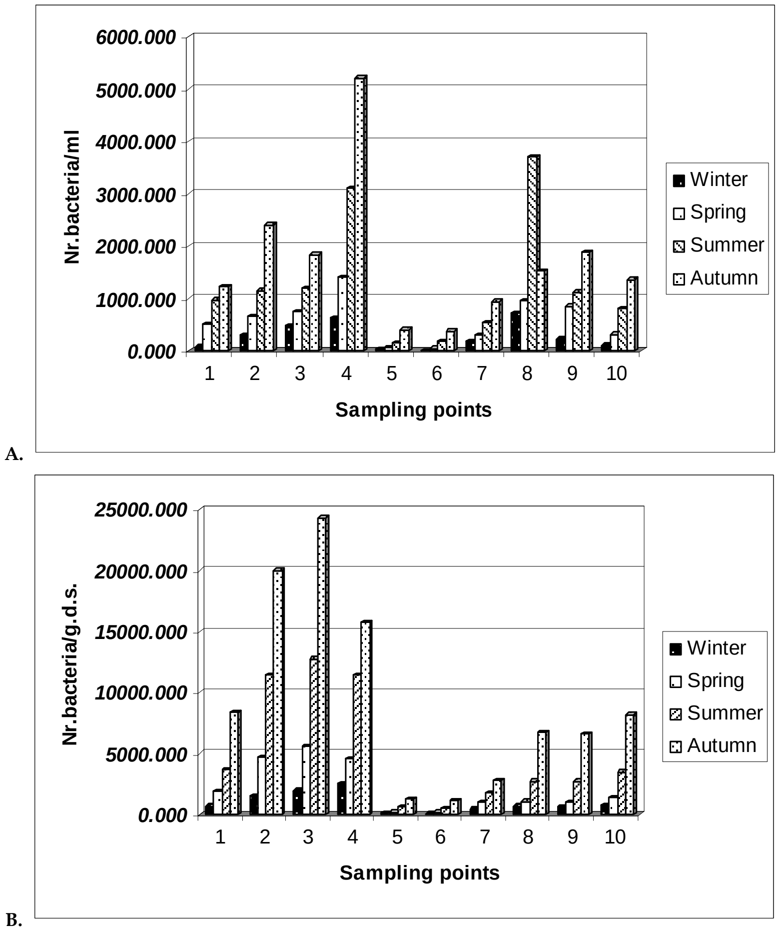

Figure 2. Numerical evolution of iron-reducing bacteria in Arieş water (**A**) and sediment samples (**B**) over 2008. (1 – Abrud upstream; 2 – Abrud downstream; 3 – Baia de Arieş upstream; 4 – Baia de Arieş downstream; 5 – Sălciua upstream; 6 – Sălciua downstream; 7 – Turda upstream; 8 – Turda downstream; 9 – Luncani upstream; 10 – Luncani downstream).

the number of bacteria can be observed from spring to summer, with maximum numerical density registered in the autumn in Baia de Arieş sampling points.

At the sediment levels the IRB registered different numerical densities according to the sampling seasons and sites. Best represented from the numerical point of view of iron-reducing bacteria was Baia de Arieş upstream, and the least represented was the Sălciua downstream sampling point.

The maximum value for the sediment samples was registered in autumn in Baia de Arieş upstream (24.292 bacteria/gram dry sediment- g.d.s.), and the minimum in Sălciua downstream (83 bacteria/g.d.s) in the winter. The numerical increases are correlated with the high quantities of iron and organic substances found in the water of the river in the upstream sampling sites.

According to the seasonal quantitative variation (%) of the iron-reducing bacteria it can be seen that the number of these bacteria increase progressively, from spring to summer in the water and in the sediment samples as well. These bacteria were more abundant in warm seasons with maximum numerical densities registered in the autumn. Comparing our results with those regarding Mureş River (Muntean et al. 2005) and Crişul Alb River (Filimon & Drăgan-Bularda 2004), it can be observed that in our study had been achieved highest values especially at the level of the sediment samples. Nevertheless, the registered values from our study are very close to those recorded in the case of the sediments sampled from lakes (Curticăpean & Drăgan-Bularda 2005).

Based on the results obtained, we may state that the circumstances of bacterial leaching phenomena in the upstream of Arieş River basin, as result of anthropic factors of risk, require monitoring (according to Law No. 645/2002 and 85/2003) and implementation of some prevention and intervention measures over the danger of pathogenesis induced by the bacteria-substrate interactions, which represent the main cause of water acidification and dumps instability (according to Law No. 466/2001). Also, it is needed an evaluation of the impact on the environment and prevention of some ecological disasters, according to Law 195/2005.

Apuseni Mountains represent a rich area in ore reserves, particularly pyrite. Because of the chemical or biochemical alteration of pyrite and other minerals, it was observed that from these deposits and abandoned mines come highly acidic „mining waste waters" and intense mineralization which overflowed in Arieş River determine the massive pollution of the water.

Even though sulphur metabolism has a great importance in aquatic ecosystems, iron seems to be the key element in these habitats (Pârvu 1999). Iron is not only an important substrate for bacterial communities that induce the iron oxidation processes, but it may also function as electron acceptor in anaerobic respiration, in the anoxic parts of the river.

The obtained correlation results (Table 3 and 4) show that the high iron concentration in the water of Arieş River has a strong influence on the bacteria implied in the iron cycle in these habitats. Thus, a positive and significant correlation from statistically point of view has been registered between the number of IRB and the iron concentration in Baia de Arieş upstream sampling point. Also, the number of IRB is positively correlated with other physicochemical parameters as: temperature, pH, CCO-MN, ammonia concentration ($p<0.05$) in Abrud and Turda upstream sampling points ($p<0.01$) and with nitrites in Abrud and Luncani upstream

Table 3. The coefficients of correlation between the number of IRB and some physicochemical parameters from Arieş River water over the year 2008.
(1–Abrud upstream; 2-Abrud downstream; 3-Baia de Arieş upstream; 4-Baia de Arieş downstream;
5-Sălciua upstream; 6-Sălciua downstream; 7-Turda upstream; 8-Turda downstream; 9-Luncani upstream; 10-Luncani downstream)

Sampling sites	T (°C)	pH	Dissolved oxygen (mg/l)	COD (mg O_2/l)	CCO-Mn (mg/l)	Ammonia (mg N/l)	Nitrates (mg N/l)
1	0.8999	0.2564	-0.8504	-0.8475	0.2961	0.9699*	-0.2515
2	0.6368	0.7167	-0.5415	-0.2803	0.5469	0.7131	-0.2935
3	0.7578	0.7617	0.264	0.5243	-0.4373	-0.1049	0.3575
4	0.7744	0.4031	0.5821	0.7197	0.6754	0.5652	-0.8608
5	0.5881	0.8326	-0.3679	-0.3206	0.8428	0.8398	0.6767
6	0.7463	0.00692	-0.0302	0.6072	0.0255	0.9736*	0.7283
7	0.6803	0.4524	0.00097	0.0967	0.3862	0.9159	-0.3529
8	0.8722	0.4378	0.5848	0.2272	0.3556	-0.3069	-0.2433
9	0.02039	0.358	0.5185	-0.0127	-0.7581	-0.1634	-0.3241
10	0.7633	-0.434	0.3984	0.8917	0.7852	0.946	0.6415

Sampling sites	Nitrites (mg N/l)	Total Fe (mg/l)	Sulphates (mg/l)	Cu (mg/l)	Pb (mg/l)	Zn (mg/l)
1	0.9806*	0.8756	-0.6992	0.3865	-0.928	0.8699
2	0.6414	0.5656	-0.0245	-0.5684	-0.6016	-0.2406
3	-0.3083	0.9901**	0.6329	0.0796		-0.8224
4	0.9182	-0.3688	0.2357	0.2295	-0.6421	0.5972
5	0.1619	0.0317	-0.4037	-	0.3373	
6	0.8124	-0.3674	-0.6228	-0.6097	-0.6097	-0.5053
7	-0.335	-0.694	0.9716*	0.8149	-0.7886	-0.7269
8	-0.7462	-0.4625	0.7074	-0.5088	-0.5521	-0.09749
9	0.9801*	-0.7558	0.8137	-0.0245	-0.7713	-0.3401
10	0.7008	-0.2369	0.5413	0.9378	-0.9018	0.05012

*$p<0.05$; **$p<0.01$

Tabel 4. The coefficients of correlation between the number of IRB and some physicochemical parameters from Arieş River sediments over the year 2008.
(1–Abrud upstream; 2-Abrud downstream; 3-Baia de Arieş upstream; 4-Baia de Arieş downstream;
5-Sălciua upstream; 6-Sălciua downstream; 7-Turda upstream; 8-Turda downstream; 9-Luncani upstream; 10-Luncani downstream).

Sampling sites	T °C	pH	Dissolved oxygen (mg/l)	COD (mg O_2/l)	CCO-Mn (mg/l)	Ammonia (mg N/l)	Nitrates (mg N/l)
1	0.6421	0.04353	-0.7439	-0.8375	0.3956	0.901	-0.6198
2	0.7378	0.7886	-0.4777	-0.1361	0.6641	0.7758	-0.2401
3	0.722	0.739	0.2209	0.4911	-0.4858	-0.1145	0.3779
4	0.8454	0.4761	0.6758	0.8119	0.7611	0.6746	-0.7828
5	0.7035	0.8137	-0.3614	-0.4633	0.8846	0.9132	0.6954
6	0.7728	0.7328	-0.4535	-0.5449	0.9376	0.9469	0.6167
7	0.7285	0.5147	0.07359	0.1688	0.4517	0.9423	-0.4159
8	0.6007	-0.2988	-0.6077	-0.3165	-0.7864	-0.04635	-0.2396
9	-0.1835	0.02729	0.2048	-0.0050	-0.5595	0.01366	-0.3828
10	0.6155	-0.3758	0.3271	0.7957	0.7908	0.9905**	0.7823

Sampling sites	Nitrites (mg N/l)	Total Fe (mg/l)	Sulphates (mg/l)	Cu (mg/l)	Pb (mg/l)	Zn (mg/l)
1	0.8115	0.5804	-0.6205	-0.00687	-0.7112	0.6289
2	0.7365	0.6757	0.119	0.6272	-0.6421	-0.0976
3	-0.3556	0.9825*	0.6385	0.1015	-	-0.793
4	0.948	-0.4096	0.3179	0.3217	-0.6602	0.7034
5	0.3138	-0.00582	-0.431	-	0.4596	-
6	0.3989	-0.1291	-0.3413	-	0.4587	-
7	-0.4027	-0.7392	0.9831*	0.7722	-0.7928	-0.7043
8	-0.164	-0.7983	0.5414	-0.4364	-0.261	0.0643
9	0.9174	-0.8916	0.8944	-0.08563	-0.5182	-0.5908
10	0.7286	-0.08677	0.4392	0.8783	-0.7949	-0.04592

*$p<0.05$; **$p<0.01$

sampling points ($p<0.05$). A direct correlation between the inhibition of microbial development and the pollution degree of the sediment specific to each sampling point was observed in the mountainous zone due to mining industry and on the inferior course due to urban wastes as in the case of other tested ecophysiological bacteria (Bodoczi & Carpa 2010). Negative correlations have been established in the case of the concentrations of dissolved oxygen, COD (mgO_2/l) and nitrites.

Conclusions

Iron-reducing bacteria have been present in each analyzed water and sediment sample, excepting those from Sălciua downstream sampling point where these bacteria have not been detected in winter. The registered bacterial densities show numerical fluctuations according to the sampling sites and the sampling seasons. Their numbers were by the order of hundreds in the water samples and by the order of thousands in the sediments.

The higher values registered in spring may be due to the increased temperature of water during this period and to the organic substance accumulation during the vegetation period. The maximum values were recorded in autumn due to the accumulation of organic substances by vegetal origin. The lowest values were registered in Sălciua upstream, in winter, for the water and sediment samples as well.

According to the horizontal numerical variation of the IRB it can be observed that the highest numerical densities were registered at the levels of the two tails of the river that may be explained through the correlation of these bacteria with the high concentrations of Fe ions in these areas. The high values of IRB on downstream of the river may be due to the accumulation of organic substances brought here by Racilor and Racosei effluents, both rich in waste waters resulted from households and industrial wastes. The number of IRB is positively correlated with some physicochemical parameters such as: temperature, pH of the water, CCO-Mn (mg/l), ammonia concentration ($p<0.05$) in Abrud and Turda upstream, and ($p<0.01$) and nitrites in Abrud and Luncani upstream sampling points ($p<0.05$). Negative correlation has been established with the dissolved oxygen content, the biochemical oxygen demand and the nitrites. A direct correlation between the inhibition of microbial development and the pollution degree of sediments specific to each sampling point was observed.

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