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THE IMPACT OF MINING ACTIVITY UPON THE AQUATIC ENVIRONMENT IN THE SOUTHERN APUSENI MOUNTAINS

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ABSTRACT - In the Southern Apuseni Mountains, mining activities have taken place since Antiquity, leaving their marks upon the natural environment, the aquatic one inclusively. If the traditional technologies had a low impact upon the aquatic environment, the ones in the modern period have affected it up to the "dead water" level. It is about the disorganization of the hydrographical basins and especially about aggressive pollution of surface waters with some of the most toxic chemical substances such as cyanides, as well as by an increase in the contents of metallic ions, chlorides, sulphides, sulphates, suspensions and fixed residuum. The decrease in pH, and implicitly the acidification of waters, is also remarkable.

It must be mentioned that no systematic studies of the impact of mining activities upon the aquatic environment have been conducted in the area in the last years. In these conditions, the data about water quality have been taken over from the studies conducted by author between 1996 and 1998. The cause of the lack of concern in the field is no other but the cease in ore valorization activities in the majority of the mining objectives in the area. As none of the tailings settling ponds has guard canals, the direct pluvial waters and the ones drained from the slopes transport tailings with noxes which they subsequently discharge in the local pluvial network. In these conditions, both the quality of the mine waters which run freely into the emissary and of the ones that flow from the waste dumps remain mainly in the qualitative parameters analyzed and presented in the study.

Key words: the Southern Apuseni Mountains, mining activity, water pollution, risk, ecological rehabilitation.

1. SHORT DESCRIPTION OF THE HYDROGRAPHIC NETWORK

The analyzed territory is crossed by a dense network of *fluvial courses* which belong to the western group of rivers. As regards the density of the hydrographic network, it maintains at values of generally more than 0.8–1.0 km/km^2, with evident altitudinal oscillations. The highest densities appear at 1200–1400m high, at the level where the heaviest pluvial supply has a maximum frequency. Over 1400m, where the altitudinal nival supply begins to dominate and where the weathering processes intensify, the density begins to decrease. The decrease in density of the fluvial network at the subalpine level is due to the long freezing period, more than 150 days annually, as well as to the watershed effect, where the lack of a permanent runoff stream network is felt. The snow layer, which maintains itself six-seven months per year, has a protective role upon the relief, the runoff generated by its melting being of low intensity. In the lower areas, the slope deposits layer thickens sensibly and the heavy rains contribute to an intense fragmentation of the relief and, of course, to the creation of a dense running water network. The mantle-rock and the fissures in the parent rocks contain abundant phreatic waters which assure permanent underground supply even for the small rivers (Duma, S., 1998).

The running waters in the Southern Apuseni Mountains are included in the fluvial system of the Mureş and of the Crişul Alb (Fig. 1.), both of them discharging their waters into the Tisa and implicitly into the Danube.

The Mureş River, the longest of the inner rivers (761 km), is the main collector of the waters in the studied region. Moreover, the Southern Apuseni Mountains are also called the Mureş Mountains, especially because the river borders their eastern and southern side.

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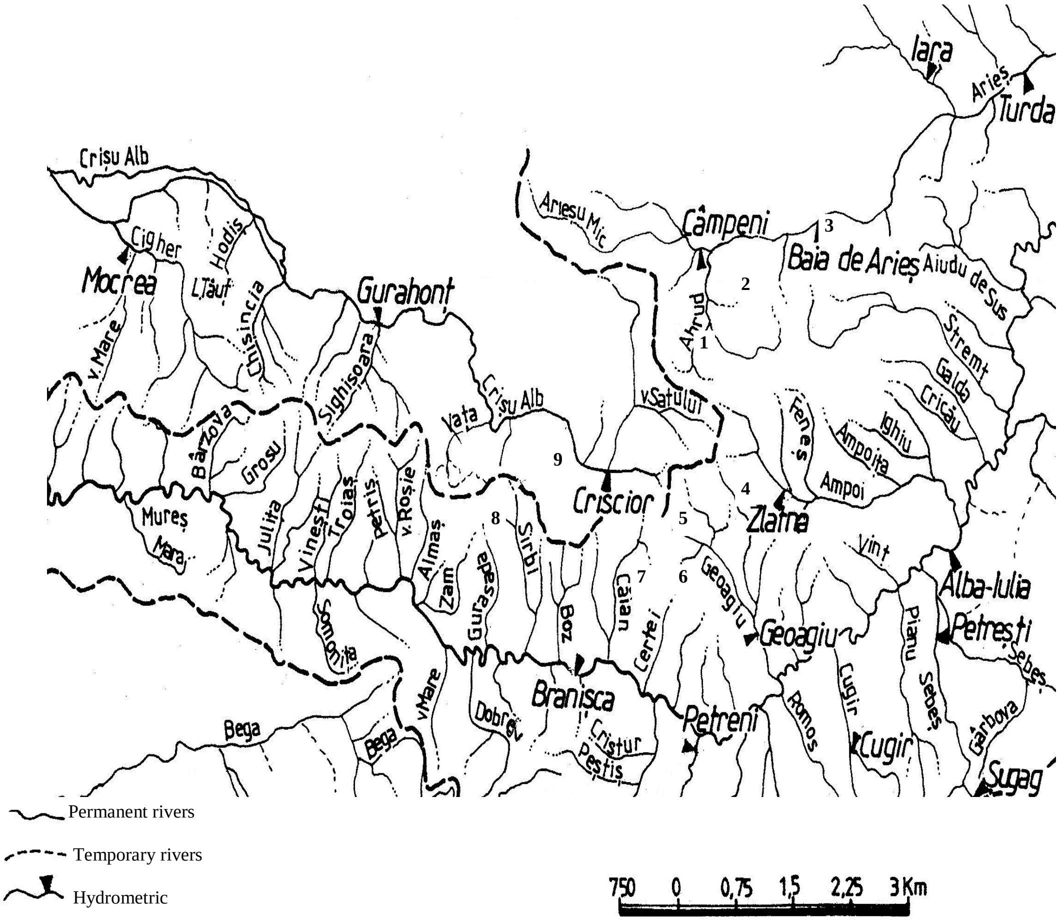

1-9 Zones of taking and analyzing water samples; **1**- Roşia Montană; **2**- Roşia Poieni; **3**- Baia de Arieş; **4**- Larga Mine; **5**- Haneş Mine, **6**- Certej- Săcărâmb, **7**- Troiţa Mine, **8**- Vorţa Mine; **9**- Barza- Brad.

Figure 1. *Hydrographic network in the Southern Apuseni Mountains.*

The Mureş has its origin in the Giurgeu Depression, at an altitude of 1,275m, the difference of altitude between its origin and its exit from the country being of 1193m. It has a mean slope of 1% and a sinuosity coefficient of 1.97, while the mean altitude of its hydrographic basin is of 613m. The mean discharge has an increasing dynamics from 9.87 m^3/s at Topliţa hydrographic post to 103.2 m^3/s at Alba Iulia post. This increase is a result of the water share brought by its tributaries the Arieş, Ampoi, Niraj, Târnava Mare and Târnava Mică rivers. From Alba Iulia up to its exit from the country, the Mureş receives its left-bank tributaries: the Sebeş, Cugir, Orăştie, Strei, Cerna and Dobra, and the right-bank ones: the Geoagiu, the Certej and the Căian, as well as other rivers of smaller dimensions, so that, at Brănişca post, it registers a discharge of 147 m^3/s and at Arad of 157 m^3/s. On the Mureş, the 1970 and the 1975 catastrophic discharges are known. In 1970, the maximum discharges of 2600 m^3/s and of 2180 m^3/s were registered at Alba Iulia and at Arad, respectively (Duma, S., 1998).

The main tributaries of the Mureş, from the Southern Apuseni, are the Arieş, the Ampoi and the Geoagiu.

The Arieş (Area = 3,005km^2; Length = 166km; Altitude of the river source = 1,108m; Altitude of the river mouth = 264m; Perimeter = 5m/km) crosses the massif on a distance of 30 km, forming four defiles between Sălciua and Lunca, one upstream the confluence with the Ocoliş, another one downstream Lungeşti and the last one between Buru and Moldoveneşti. In this place, a water aeration threshold was constructed (Fig. 2). At Moldoveneşti, the river exits the defile, the valley widens suddenly and the slope begins to decrease gradually. At Turda, the river has a mean annual discharge of 26 mc/s. Downstream Abrud, the Arieş receives, from the Metaliferi Mountains, a series of right-bank small rills such as the Ştefanca, the Muşca, the Seşei, which receive the waters from the Roşia Poieni, Hermăneasa and Cioara mining perimeter. The last flows into the Arieş next to the Baia de Arieş exploitation. A little downstream, at Sălciua de Jos, the Pârâul Huzii flows into the Arieş, as well as the Valea Morilor which flows at the contact of the Metaliferi Mountains with the Bedeleu Massif of the Trascău Mountains. The Abrud (Area = 229 km^2; Length = 22 km) is the most important right-bank tributary of the Arieş and is received at Câmpeni. It gathers the rills that flow radially around the igneous massif of Detunata, well-known for its basaltic columns. The Valea Cornii and the Valea Roşiei are among the most important tributaries of the Abrud, receiving the waters from the Roşia Montană mining perimeter.

Figure 2. *The Arieş River – water aeration threshold at Moldoveneşti.*

The Ampoi (Area = 579 km^2, Length = 57km, Altitude of the river source = 1,060m, Altitude of the river mouth = 219m, Perimeter = 15m/km) is an important right-bank tributary of the Mureş, receiving waters from the Trascău Mountains and from the Metaliferi Mountains and discharging them next to the city of Alba Iulia. It originates at the foot of the Dealul Mare, has a mean runoff gradient of 20–30 m/km and a relatively small hydrographic basin. Its mean discharges are of 1.33 mc/s at Zlatna and of 4.26 mc/s at Bărăbanț. Crossing different types of rocks, the river has eroded selectively, generating sectors widened in the soft rocks (Zlatna, Poiana Ampoiului, Meteş, Tăuți, Ampoița, Şard) separated by narrower corridors digged into ophiolites, conglomerates, or limestone. It has as left-bank tributaries: the Vâltori (Area = 41 km^2; Length = 12 km), the Feneş (Area = 61 km^2; Length = 16 km), the Ampoița (Area = 54 km^2; Length = 15 km) and the Ighiu (Area = 52 km^2; Length = 17 km). On the right bank, it receives the Valea Largă, which collects the waters from the Valea Largă Mine, the Trâmpoiele and the Galați valleys, etc.

The Geoagiu (Area = 326 km^2; Length = 48km, Altitude of the river source = 1,040m, Altitude of the river mouth = 197m, Perimeter = 21m/km) has managed by regressive erosion to penetrate into the core of the Metaliferi Mountains. It has its origins in the volcanic group of the Criscior Mountains, at about 1,000m high, flowing afterwards through the flysch deposits of Cretaceous age and through the eruptive ones. In the lower part of the basin, at the contact with the western crystalline schists, seven thermal springs, with temperatures of 29–31^{0}C, known since Roman times, appear on the fault line which crosses Geoagiu-Băi (Thermae Dodonae). Between Ardeu and

Glod, the Jurassic limestone core appears, cut perpendicularly by the Valea Glodului and then, by the Geoagiu, downstream Balşa. Among the right-bank tributaries, the Pârâul Porcului, the Gura Văii and the Valea Roşie have small dimensions, while the left-bank ones deserve to be mentioned: the Techereu, the Almăşel, which collects the waters from the Haneş Mine, and the Ardeu (Area = 51 km^2; Length = 23 km).

The smaller, direct tributaries of the Mureş, flowing from the Southern Apuseni, upstream Alba Iulia, are the following: *the Aiud* (Area = 182 km^2, Length = 26km, Altitude of the river source = 907m, Altitude of the river mouth = 241m, Perimeter = 25m/km), *the Râmeț* (Area = 229 km^2, Length = 48km) and *the Galda* (Area = 250 km^2, Length = 39km, Altitude of the river source = 1,120m, Altitude of the river mouth = 225m, Perimeter = 21m/km) from the Trascău Mountains, and downstream Alba Iulia: *the Vinț* (Area = 30 km^2; Length = 12km), *the Blandiana* (Area = 31 km^2; Length = 11 km), *the Băcăinți* (Area = 54 km^2; Length = 15km), *the Homorod* (Area = 32 km^2; Length = 13km), *the Boholt, the Certej, the Căian* from the Metaliferi Mountains. From the Zarand Mountains, it collects the waters of the *Boz, Sârbi, Vorța, Gurasada, Almaş, Troiaş, Julița, Bârzava, Milova* rivers, etc.

The Crişul Alb (Area = 4,240 km^2, Length = 234km, Altitude of the river source = 1,000m, Altitude of the river mouth = 87m, Perimeter = 41m/km), the main collector of the waters in the northern sector of the Metaliferi-Zarand Mountains, has a vigorous and picturesque course in this region, with numerous gorges and knicks. At Criscior, after 31 km from its source, the river descends to altitudes under 300m and receives the left-bank waters from the Valea Arsului opencast pit and at Brad the ones of the Luncoi and the ones from the Barza Mine. From this place to Ineu, on a length of 150km, the stream has an altitude fall of 187m and a gradient of 1.2m/km. In the Gurahonț Depression, the river gradient decreases under 1.0 m/km, producing strong braiding, then it deepens again in the eruptive, at Cociuba. Downstream this last narrowing, the river enters the gulf of Zarand, where the valley widens, receiving the aspect of alluvial plain. The first important tributary (the Valea Satului) is collected by the upper Crişul Alb on the left, having dimensions similar to the collector (Area = 107km^2; Length = 15 km). The rest of the left-bank tributaries, received from the Metaliferi and the Zarand Mountains, have similar dimensions: the Bucuresci (Area = 80 km^2; Length = 14km), the Luncoi (Area = 74 km^2; Length = 10km), the Vața (Area = 87 km^2; Length = 21km), the Sighişoara (Area = 156 km^2; Length = 16km), the Chişindia (Area = 102 km^2; Length = 20km). Downstream, there are a series of smaller rills (the Cleceova, Hodiş, Potoc and Gutul) and then, the most important hydrographic system in Zarand: the Cigher (Area = 670 km^2; Length = 58 km). Excepting the Cigher, all these rills flow into the Canalul Morilor, from where it discharges through outlets in the Crişul Alb.

In the analyzed region, there are also a series of *natural and artificial lakes*. The natural lakes are genetically integrated into the karst type, such as *Lake Ighiu* (Area = 5.26 ha; H_{max} = 9m), which is situated on the valley bearing the same name, in the southern part of the Trascău Mountains. This is the most typical dolina karst lake in Romania. Its morphobathymetric profile is typical for steep-slope dolinas. The maximum depth is registered in the whirlpool area, in the place where waters flow towards the lake emissary. The hydric regime is equilibrated due to the permanent and rich share brought by springs and by the slope runoff.

The anthropic lakes used to be in higher number in the past, but much more reduced in areas and with much more reduced eco-geographical influences, such as the "*hait*", used for wood transportation. The present anthropic lakes can be included into three categories: lakes for supplying water to the industrial and urban centres; lakes for mining needs and lakes for flood control. Of course, they are all useful both for recreation and for flood control. At Roşia Montană, the only lakes in the country arranged for gold ore washing in stamping mills are still preserved. These are: *Tăul Mare*, situated between Cârnic and Dealul Cuibarului; *Tăul Țarina*, near Văidoaia peak; *Tăul Brazilor* and *Tăul Anghel,* above the locality of Roşia Montană (near Cârnic Hill); *Tăul Țapului,* on the upper course of the Sălişte Valley (upstream the tailings settling pond), and *Tăul Cornii*, upstream the village of Corna.

In the same region, there are also two storage lakes for mining and recreation needs (*Făerag*, in the proximity of Deva, on the Certej Valley, and *Caraciu*, in the homonymous volcanic massif near Brad). In the Zarand Mountains, the *Tăuț* reservoir was built on the Cigher (Area = 240ha), with the purpose of controlling floods in the depression.

2. DEGRADATION OF HYDROGRAPHIC BASINS AND WATER POLLUTION THROUGH THE ORE EXPLOITATION AND PROCESSING ACTIVITIES

Through their specificity, ore exploitation and processing activities induce the systemic disorder state to the aquatic environment. This appears in the degradation of the hydrographic basins and in water pollution. The degradation of hydrographic basins implies their disorganization through excavations, stream blocking, water flowing underground, and through the acceleration of the sheet and the gully erosion. Water pollution appears as result of the introduction of noxious elements such as cyanides, metallic ions, chlorides, sulphates, etc. in the aquatic environment, as well as through the modification of pH (water acidification) and the increase in alluvial discharge.

As each hydrographic basin has its characteristics (area, discharge, hydric regime, gradient, etc.), as well as a certain peculiarity regarding the degradation and the pollution level, we found useful the presentation of these phenomena on hydrographic basins and on river groups.

2.1. Degradation of hydrographic basins and water pollution in the Arieş basin

The degradation and the pollution sources of the aquatic environment in the Arieş basin proceed from the mining objectives of Roşia Montană, Roşia Poieni and Baia de Arieş.

The main water collector within the Roşia Montană mining perimeter is the Valea Roşiei creek, in whose retention basin the Cetate opencast pit is also situated; within its area, the hydrographic network has been totally disorganized. From the opencast pit, the pluvial waters infiltrate into underground through the old mining works, washing this way the mineralization. They are collected at the level of the transport gallery from where they are discharged into the Valea Roşiei creek.

In the mine waters, exceeding values are registered for almost all indicators, including very noxious elements such as lead, copper, zinc and manganese, the pH level being very low (Table 1).

Table 1. *Water quality in the Cetate Mine (Roşia Montană).*

Quality indicators (mg/1)	Mine water	Admitted values for the water of the Roşia creek, downstream the mine water discharge (authorization no. 10/1991)
pH	2.6	6.5-8.5
Suspensions	40.0	25
Fixed residuum	6130.0	1200
CCO-Mn	80.0	25
Calcium	338.0	150
Magnesium	67.0	200
Chlorines	35.5	300
Copper	1.50	0.3
Lead	1.0	0.05
Zinc	43.6	1.0
Manganese	261.9	0.3

As result of this situation, the biota from the waters of the Valea Roşiei has totally disappeared, and because of the pollution of the phreatic level in the valley's small floodplain, wells have been partially abandoned.

Industrial water for the Gura Roşiei ore processing plant has been taken from the Abrud River through a water inlet placed 300 m upstream the processing plant, but downstream the discharge of the cleared waters from the tailings settling pond situated on the Sălişte Valley, a right-bank tributary of the Abrud.

The quality of the technological waters has been affected by the great quantities of impurifiers: suspensions, CCO-Mn, sulphates, iron, manganese, zinc, cyanides (Table 2).

Table 2. *The quality of industrial water and of the Sălişte Valley settling pond water* (*Roşia Montană).*

Quality indicators (mg/1)	The Abrud Valley industrial water	Cleared water, Sălişte Valley settling pond	Admitted values, according to C.G.A. M.11/88; STAS 4706/88
pH	6.0	5.5	6.5-85
Suspensions	75.0	58	25
Fixed residuum	612	980	1200
CCO-Mn	253	49.1	25
Magnesium	12.2	206	200
Chlorides	28.4	28.4	300
Sulphates	3194	485	400
Cyanides	0.014	0.018	0.02
Copper	0.17	0.11	0.2
Lead	0	0.16	0.2
Zinc	126	1.95	0.2
Manganese	7.5	335	0.2
Calcium	116	145	150

The industrial water, which has practically the qualities of the water of the Abrudel River, is also impurifier-laden water, a fact which justifies the disappearance of the aquatic biota and the contamination of the phreatic horizons in the Abrudel floodplain.

It is worth mentioning the contents of cyanides of the Abrud waters which is almost similar to the cleared water proceeding from the Valea Săliştei tailings settling pond. We mention the fact that the discharge of the Abrud is at least 20 times higher than the one of the Valea Săliştei (cleared waters). In these conditions, the contents of cyanides of the Abrud waters should be, because of dilution, 20 times lower. An elementary reasoning obliges us to make a reversed calculus from which it results a contents of cyanides of 0.36 mg/l, which is much more above the admitted one (0.02 mg/l) (Duma, S., 2008).

In the *Roşia Poieni* mining perimeter, the local hydrographic network, which collects the waters from the opencast pit and the mine waste dumps, is represented by the Valea Steregoi, Valea Ştefancei, Valea Şesei, Valea Muşca and Valea Fîntînilor, right-bank tributaries of the Arieş River, as well as the Valea Geamăna and the Valea Cuibarului, right-bank tributaries of the Abrud River. All these rills have been affected, in their areas of origin, by the works in the opencast pit, through the deviation of the runoff channels or through their filling.

During heavy rains, rills become real mudflows due to the very active sheet and gully erosion activated on the taluses of the opencast pit's and of the mine waste dumps' levels.

Once the ore has been uncovered, the diagenetic alteration phenomena have intensified, reason for which some depositions of copper carbonates, in green or blue colour (malachite and azurite), can be observed megascopically on the taluses in use, which are taken by the pluvial waters that flow into the Valea Muşca.

The analysis of the samples collected from the area of the opencast pit and of the mine waste dumps present very high exceeding values for all the water quality indicators, the pH and the contents of copper and iron registering alarming values (Table 3).

Table 3. *Water quality in the perimeter of the Roşia Poieni opencast pit.*

Water quality indicators (mg/l)	The Steregoi Rill, downstream the poor ore dump	Flows from the Geamăna mine waste dump	Flows from the Valea Cuibarului mine waste dump	Admitted values, according to STAS 4706/1988
pH	2.25	4.42	2.3	6.5-8.5
Suspensions	-	1360	-	60
Fixed residuum	9900	5600	6860	500
Copper	473.3	333	44.4	0.2
Lead	65.5	74.5	16.8	0.5

Oil products are another factor of surface waters pollution, their effects appearing on the Valea Muşca, in whose catchment area the motor depot is placed.

The phreatic level in the immediate proximity of the opencast pit has been disorganized due to discharges in the taluses of its levels. In exchage, phreatic pseudo-levels have appeared in the mine waste dumps, especially in the areas of contact with the natural slope.

The industrial water, necessary for the technological process of copper ore processing is assured from the Arieş River through the Gârda water- catchment, created downstream the confluence of the Arieş with the Abrud.

The drinking water for the ore processing plant and for the social convenience, for the blocks of flats inclusively, is taken from the water treatment station of the Mihoieşti reservoir, which supplies water also for the towns of Câmpeni and Abrud.

The quality of the water discharged from the two tailings settling ponds (Ştefanca and Şesei), present values exceeding the admitted norms for suspensions, fixed residuum, copper and lead, exceeding values which are lower than the ones in the Arieş River, upstream the confluence with the Valea Ştefancei (Table 4).

Table 4. *Waters discharged in the Valea Ştefancei tailings stettling pond (Roşia Poieni).*

Water quality indicators (mg/l)	The Arieş River, upstream the confluence with the Valea Ştefancei	Valea Ştefancei, upstream the confluence with the Arieş River	The Arieş River, downstream the confluence with the Valea Ştefancei	Admitted values STAS 4706/1988
pH	7.52	10.2	7.36	6.5-8.5
Suspensions	22	36	28	25
Fixed residuum	205	350	220	75
Calcites	30.46	80.16	36.85	150
Copper	2.67	0.228	1.135	0.2
Lead	1.31	0.584	1.89	0.2

The explanation consists in the fact that the Valea Ştefancei tailings settling pond no. 1 is preserved, while the tailings settling pond no. 2 is used only in case of damage. The waters of the Valea Ştefancei tailings settling pond no. 1 are copper carbonates laden-waters (malachite and azurite), resulted from the diagenetic transformation of the secondary copper sulphides (covellite and chalcosine), the presence of the copper carbonates modifying the pH, which is alkaline (10.2), and the colour of waters, which is green-bluish (Figure 3).

Figure 3. *The Valea Ştefancei tailings settling pond - malachite and azurite in the waters of the tailings settling pond.*

A similar situation, with exceeding values for all the quality indicators, appears for the waters of the Valea Şesei and, of course, for the waters of the Arieş River, downstream the confluence with the Valea Şesei (Table 5).

Table 5. *The water quality of the Arieş River upstream and downstream its confluence with the Valea Şesei.*

Water quality indicators (mg/l)	The Arieş River upstream the Valea Şesei	The Valea Şesei upstream the confluence with the Arieş River	The Arieş River downstream the confluence with the Valea Şesei	Admitted values STAS 4706/1988
pH	7.52	2.72	6.15	6.5-8.5
Suspensions	6	144	42	25
Fixed residuum	190	-	290	75
Calcites	36.87	-	48.1	150
Copper	1.47	27.1	6.5	0.2
Lead	1.88	195	7.9	0.2

The acid pH (2.72) of the waters of the Arieş River, upstream the confluence with the Valea Şesei, is generated by the share of acid waters collected from Roşia Montană and from the flows proceeding from the Valea Verde mine waste dump, situated on the Valea Cornii, a tributary of the Abrud.

In the *Baia de Arieş* mining perimeter, the local hydrographic network has been disorganized as result of stream blocking with mine wastes (Valea Hermăneasa and Valea Cioara) and with processing wastes (Valea Sartăş). The discharges of the rills in the mine area have decreased as result of the catchment of the phreatic horizons into the underground holes, a fact that led to an increase in mine water discharge to over 1900 m^3/day.

Mine waters are collected gravitationally into two basins which have a volume of 1140 m^3, with role in settling. The quality of the waters discharged in the Arieş River is influenced by their mineralization degree. Values exceeding the admitted values are registered for suspensions, fixed residuum, CCO-Mn, sulphides and metallic ions (Cu, Pb, Zn, Fe, Mn) (Table 6).

Table 6. *Water quality in the Baia de Arieş Mine.*

Water quality indicators (mg/l)	Settled mine water	Admitted values according to STAS 4706/88
pH	7.9	6.5-8.5
Suspensions	35.8	25
Fixed residuum	840	750
CCO -Mn	25.3	10
Sulphates	350	400
Sulphides	0.1	-
Cu	0.35	0.2
Pb	0.4	0.2
Zn	1.0	0.2
Fe	4.7	0.2
Mn	1.3	-

The industrial water for the ore processing plant was supplied from the Arieş River, while the used waters and the industrial waste were evacuated through pumping into the Sartăş tailings settling pond. The cleaning of these waters was done into a water treatment station placed downstream the tailings settling pond, station which did not function at the planned parameters. The qualitative indicators of the industrial water, of the non-cleaned used waters and of the cleared ones are presented in Table 7. Exceeding values were registered for CCO-Mn, metallic ions (Cu, Pb, Zn, Fe, Mn) and cyanides.

Table 7. *Technologic water quality in the Baia de Arieş ore processing plant.*

Water quality indicators (mg/l)	Industrial water	Non-cleaned water in the Sartăş tailings settling pond	Cleaned water from the Sartăş tailings settling pond	Admitted values STAS 4706/88
pH	7.8	7.7	8.7	6.5-8.5
Suspensions	35.6	68.5	40.5	25
Fixed residuum	488	684	580.5	750
CCO -Mn	18.9	51	44.2	10
Sulphates	83.9	502	447.7	400
Sulphides	0	0.04	0	-
Chlorides	28.4	28.4	142	250
Cyanides	0	54.5	0.75	-
Detergents	0.001	50	0	-
Cu	0.44	4.78	1.25	0.2
Pb	0.21	0.64	0.01	0.2
Zn	0.38	0.92	0.33	0.2
Fe	1.47	2.11	1.76	0.2
Mn	0.86	0.25	0.18	0.2

Even though the ore processing activity was ceased, data regarding the technological water quality have been presented as, from the Sartăş tailings settling pond, polluted waters are still flowing into the Arieş. During rain showers, more and more frequent nowadays, great quantities of tailings are transported into the waters of the Arieş. It must also be mentioned that the majority of the auriferous concentrates obtained at the units in the Metaliferi Mountains were processed through cyanidation at the ore processing plant in Baia de Arieş. This justifies the enormous contents of cyanides in the non-cleaned waters (54.5 mg/l) and very high contents in the cleaned waters (0.75 mg/l). As the norms for processing the concentrates were not always respected in a strict manner, we take the liberty to estimate that in the tailings settling ponds situated in this area there are dangerous quantities of cyanides.

If cumulated with the noxes discharged upstream from the Roşia Montană and Roşia Poieni objectives, the waters of the Arieş have become some of the most polluted waters in the country, a fact megascopically visible. In fact, the first signs of life in the waters of the Arieş appear only after the water aeration threshold at Moldoveneşti.

The high-impact pollutions produced in 1972 and in 1978 are worth mentioning, when, as result of the mine fires extinction, waters with a pH under 1.5 and with enormous loading of metallic ions were discharged into the Arieş. This had as result a catastrophic pollution of the Mureş River up to its flow into the Tisa River, a fact which represented also a dispute at diplomatic level between Romania and Hungary, followed by important financial compensation for damages paid by the Romanian state.

2.2. Degradation of hydrographic basins and water pollution in the Ampoi basin and in other small rivers on the south-eastern and southern border

The mining units that have affected aquatic environment in this area are Zlatna, Certej - Săcărâmb, Troița - Bolcana and Vorța.

In the *Zlatna* mining perimeter, the hydrographic network has been disorganized due to the construction of the tailings settling ponds on the course of the Valea Sfârci and on the Valea Mică and through the blocking of the Haneş and the Larga rills with mine waste dumps. The waters in the Larga Mine flow into the Ampoi River with a discharge of 100 m^3/day, while the ones in the Haneş Mine flow into the Almaş Valley (tributary of the Geoagiu River) with a discharge of 600 m^3/day. The mine water quality is also affected by the presence of great quantities of metallic ions (Cu, Pb, Zn, Fe, Mn) and by a very acid pH (see Table 8).

Table 8. *Mine water quality (Haneş+Larga).*

Water quality indicators (mg/l)	Waters from the Haneş Mine	Waters from the Larga Mine	Admitted values according to STAS 4706/88 for the 3rd class waters
pH	2.2	2.5	6.5-8.5
Suspensions	110	225	25
Fixed residuum	15830	1905	1200
CCO–Mn	1420	82.5	25
Copper	17.4	1.90	0.05
Lead	0.60	0.25	0.05
Zinc	720.5	25.6	0.03
Iron	1695	158	1.0
Manganese	830	20.8	0.8
Sulphates	9550	1250	400
Calcium	410	254	300
Magnesium	50	62.4	200

High exceeding values were also registered for fixed residuum, CCO-Mn, suspensions, sulphates, manganese and metallic ions (Cu, Pb, Zn, Fe). The discharges of the waters from the Haneş Mine and the concentration of polluting elements have increased once the collapsing cone of Stokul Meteşan was created (Haneş Mine).

Along the entire course of the Almaş Rill (tributary of the Geoagiu), waters have reddish colour, specific to the mine acid drainage which is locally called "galiță" (Figure 4), the effects being very alarming. The phreatic waters that receive water from the fluvial network have been polluted so that the water in the wells situated in Almaşu de Sus has become undrinkable, while the river waters cannot be used for animal watering or for domestic use.

Figure 4. *The Almaş Rill – acid mine water.*

The waters flowing from the tailings settling ponds of Zlatna register exceeding values for copper, lead, zinc, iron, manganese and cyanides.

In the *Certej – Săcărâmb* mining perimeter, waters are collected into the hydrographic basin of the Certej River, a right-bank tributary of the Mureş River. Thus, the mine waters run freely into the emissary, the ones from the Bocşa Mine into the Bocşa Rill, the ones from the Hondol-Băiaga Mine into the Certej River, and the ones from the Săcărâmb Mine into the Nojag Rill. In the perimeter of the Hondol-Coranda opencast pit, the hydrographic network has been totally disorganized and the waters from the opencast pit flow into the Băiaga Rill. The mine and the opencast pit waters are characterized by high contents of solid suspensions, fixed residuum, metallic ions (Cu, Zn, Fe, Mn) and sulphate ions (SO_4^{-2}). In Table 9, the lack of lead in the mine waters and the very acid pH of the waters flowing from the mine waste dump of the Hondol-Coranda opencast pit can be noticed.

Table 9. *The quality of mine and of opencast pit waters (Certej - Săcărâmb).*

Water quality indicators (mg/l)	Băiaga Mine	Bocşa Mine	Săcărâmb Mine	Exfiltrated from the mine waste dump of the Hondol-Coranda opencast pit	Admitted values according to STAS 4706/88 for the 3rd class waters
pH	7.11	4.76	5.31	2.80	6.5-8.5
Suspensions	299.0	740.0	229.25	785.5	25.0
Fixed residuum	2095.5	1847.0	1678.5	4409.0	1200.0
Ca	527	348.0	253.3	339.2	300.0
Mg	102.8	92.25	121.40	64.92	200.0
Fe total	0.09	3.90	0.59	302.78	1.0
Mn	7.30	36.54	39.29	150.40	0.08
Pb	No data	No data	No data	0.11	0.05
Cu	No data	1.95	0.43	15.62	0.05
Zn	4.64	55.39	50.88	246.0	0.03
SO_4	1388.0	1401.7	957.90	3427.0	400
CCO-Mn	29.33	33.04	30.01	57.47	25.0

The industrial water supply for the mining objective was done through pumping water from the Mureş River, at a discharge of 7000 m^3/day, while the tailings were deposited in the Mireş Valley and in the Valea Mealu.

The waters flowing from the Valea Mealu tailings settling pond present quality indicators characterized by exceeding values for suspensions, fixed residuum, metallic ions (Pb, Zn, Mn), SO_4, chlorine and cyanides (Table 10).

Table 10. *The quality of the waters flowing from the Valea Mealu tailings settling pond (Certej - Săcărâmb).*

Water quality indicators (mg/l)	Water flowing from the Valea Mealu tailings settling pond	Maximum admitted values	
		According to Dir. OGA nr.2/11.01.1994	According to STAS 4706/88 for the 3rd class waters
pH	7.30	6.5-8.5	
Suspensions	132.0	25	-
Fixed residuum	2376.0	-	-
CCO-Mn	20.2	-	1000
Ca	339.2	-	15
Mg	43.7	-	200
Fe total	2.0	-	100
Cu	0.09	0.095	1.0
Pb	0.01	0.084	-
Zn	0.73	0.04	-
Mn	5.60	-	-
Cd	No data	0.045	-
SO_4	1417.2	913	-
Cl	170.4	-	-
Cyanides	0.040	0.01	-

The water in the Valea Mealu tailings settling pond flows into the Certej Rill which also receives downstream, on the right, the waters from the Valea Mireşului tailings settling pond and which presents a neuter pH and a relatively high concentration of calcium ions (668 mg/l) due to the presence of lime in deposit. High concentrations of sulphate (1338.2 mg/l) are also reported, as result of sulphides decomposition. The waters of the Certej Rill have polluted through infiltrations also the phreatic levels in the floodplain, as it was established in the quality of well waters in the village of Bârsău, which, in certain periods of the year become undrinkable. This is explained by the fact that during rainy periods, in the Valea Mealu tailings settling pond, which has no guard channel, waters accumulate behind the dam forming a real lake. The waters in the pond frequently exceed the upper level of the dam and flow over under the form of some mud gullies, transporting enormous quantities of industrial sand which they discharge in the damage pond from where is received by the waters of the Valea Mealu and, afterwards, by those of the Certej and of the Mureş. In these periods, the Certej River becomes a mudflow, as 1997, when more than 50 ha of agricultural land were silted, the thickness of the depositions exceeding 10-15 cm.

In the case of Cetej, a damage with catastrophic characteristics also took place in the old settling pond, which also affected the aquatic environment, the one of the Mureş River, inclusively. The accident took place in the old settling pond, placed upstream the built-up area of Certej. Practically, this settling pond is known for the most severe accident in Romania produced by the collapse of a tailings settling pond. In the night of November 30, 1971, at about 4 a.m., the settling pond collapsed over the locality of Certej, causing the death of 99 persons and producing an undeclared number of physically-disabled persons, as well as great material damages. The catastrophic characteristics were given by the surprise element and by the rapidity the mud flowed from the settling pond. The breaking of the dam occurred with a real explosion (blast) and after a few minutes the mud flowed over the inhabitants' houses, over the blocks of the unit's personnel, demolishing it. The fluid extended on the Certej Valley up to the Mureş River, deteriorating through deposition large agricultural areas situated in the floodplain of the Certej Valley and of the Mureş River. No data were provided regarding the damages produced in the aquatic environment, the accident being of secret nature. However, we may assert that, in the settling pond, there were high quantities of cyanides and other flotation reagents.

The waters from the *Troiţa Mine* have a discharge of 420 m^3/day and run freely at the level of the Grimm gallery into the Bolcana Rill, a left-bank tributary of the Caian Rill that flows into the Mureş River, downstream the locality of Şoimuş. The quality of these waters is characterized by exceeding values for pH, fixed residuum, sulphates and metallic ions (Cu, Pb, Zn, Fe), as well as by a very acid pH (Table 11).

Table 11. *The quality of the waters from the Troiţa Mine and of those in the Căian Rill.*

Water quality indicators (mg/l)	The Caian Rill upstream	Water from the Troiţa Mine	The Caian Rill downstream	Admitted values according to STAS 4706/88 for the 3rd class waters
pH	8.09	2.78	8.02	6.5
Fixed residuum	400	3352	432	1000
CCO–Mn	9.47	8.95	7.35	15
Sulphates	83.9	2070.6	106.9	400
Pb	0.16	26.5	0.20	0.1
Cu	0.12	1.06	0.14	0.1
Zn	0.14	94.5	0.18	0.1
Fe	1.04	83.3	1.24	1

Mine waters have only little influence upon the water quality of the Caian Rill due to their low discharge value, as well as to the share of waters containing carbonates, which flow from the Crăciuneşti lime opencast pit and regulate the pH. Exceeding values are registered upstream, as result of the waters received from the Băiţa–Crăciuneşti Mine (in preservation) and from the Bolcana Mine.

The waters evacuated from the *Vorţa Mine* through the two flank galleries (Valea Heiuş and Pârâul Băii) are discharged into the Vorţa Valley, a rightârâul Băii gallery is of 10 m^3/day, while the discharge of those proceeding from-bank tributary of the Mureş River, in the Ilia area. The discharge of the waters proceeding from the P the Valea Heiuş is of 15 m^3/day. The quality of these waters is also characterized by the presence of metallic ions (Cu, Zn, Pb, Fe), but their influence upon the waters of the Vorţa Valley is insignificant due to the low discharges of the mine waters (Table 12).

Table 12. *The quality of the waters from the Vorţa Mine and of those in the Vorţa Valley.*

Water quality indicators (mg/)	The Pârâul Băii gallery	The Valea Heiuş gallery	The Vorţa Valley (downstream)	Admitted values according to STAS 4706/88 for the 2nd class waters
pH	8.45	7.6	8.65	6.5-8.5
Suspensions	140	68	40,0	-
Fixed residuum	784	892	320	1000
CCO–Mn	15	30	5.24	15
Sulphates	498.7	525	49.4	400
Cu	0.13	0.13	0.1	0.1
Zn	0.18	0.18	0.12	0.1
Pb	0.16	0.14	0.11	0.1
Fe	2.47	2.47	1.06	1.0

The Mureş River receives mine waters also from the geological research works conducted for rare metals and radioactive elements in the hydrographic basin of the Milova Rill. No information about the quality of these waters is available, as researches in the area were kept secret for a long time, and, after 1990, the geological research activities ceased. However, these waters are assessed to have been radioactively polluted as uranium minerals are known to be very water-soluble.

2.3. Degradation of the hydrographic basins and water pollution in the Crişul Alb basin

The Crişul Alb River collects the industrial waters from the former underground exploitations of *Barza* and from the *Valea Arsului* opencast pit. The Crişul Alb also receives the waters proceeding from the geological research works of Ciungani – Căzăneşti.

The Valea Arsului, in whose retention basin the Valea Morii opencast pit is also situated, has been hydrographically disorganized in the upper basin as result of excavating into its right flank and of obturating the Valea Cireşata basin, right-bank tributary of the Valea Arsului, through filling with the mine waste resulted from ore uncovering.

Both from the opencast pit and from the mine waste dump, during rain showers, great quantities of alluvia flow into the Crişul Alb.

The waters from the Breaza Mine have a discharge of 7170 m^3/day and are discharged into the Barza Rill, left-bank tributary of the Crişul Alb. Their quality is rendered in Table 13.

Table 13. *The quality of the waters from the Barza Mine.*

Water quality indicators (mg/l)	Mine waters	Admitted values according to STAS 4706/88
pH	2.82	6.5-8.5
Suspensions	440	25
Fixed residuum	4280	750
Cu	5.8	0.2
Pb	0.335	0.2
Zn	17.89	0.2
Fe	27.0	0.2
So_4	2140	-

The very acid character can be noticed, as well as the exceeding values for suspensions and fixed residuum, metallic ions (Cu, Zn, Fe) and SO_4.

Table 14. *The quality of the waters flowing from the Ribiţa-Curteni tailings settling pond.*

Water quality indicators (mg/l)	Cleared waters from the Ribiţa-Curteni tailings settling pond	Admitted values according to O.G.A. Agreement no. 354/78
pH	7.28	6.5-8.5
Suspensions	88	50
Fixed residuum	1718	1200
Cyanides	0.02	-
SO_4	310	-
Cl	12	-
Phenols	No data	0.02
Fe	0.25	0.10
Cu	0.011	0.30
Pb	0.005	0.05
Zn	0.133	0.5

The activity of ore processing in the *Gura Barza* ore processing plant was suspended. However, pluvial waters, which wash the tailings settling pond of Ribiţa-Curteni, present exceeding

values, two times higher than the admitted concentrations for iron and zinc, as well as for suspensions and fixed residuum. Exceeding values in rapport with the OGA Agreement were registered for cyanides as well, but they range among the norms admitted by STAS 4706/88 (Table 14).
No data about the waters proceeding from the geological research works of Ciungani-Căzăneşti is available.

3. EFFECTS OF THE MINING IMPACT UPON THE AQUATIC ENVIRONMENT IN THE STUDIED AREA.

The degradation of the hydrographic basins implied the exclusion from the agricultural (arable, pastures and hayfields) and forestry circuit of some large areas (Roşia Montană, Roşia Poieni, Hondol-Coranda, Valea Arsului, etc), as well as the silting of the riverbed, of the main collectors, inclusively (the Mureş and the Crişul Alb).

As regards water pollution, major values exceeding the admitted norms have been registered for pH, metallic ions and cyanides, all with direct and indirect effects upon biota.

Thus, very acid pH was recorded for the waters from the *Roşia Montană* (2.6), *Haneş* (2.2), *Larga* (2.5), *Troiţa* (2.78), and *Barza* (2.82) mines and for the waters flowing from the mine waste and the poor ore dumps from *Roşia Poieni* opencast pit (2.25 and 2.3). The acid pH determines the acid drainage called "galiţă" which consists in the production of sulphuric acid from the mineral sulphides that encounter air and water. The phenomenon is perceived through the brown-reddish water, determined by the presence of Fe^{3+} in suspension, and by the oozy, brown-reddish to deep red depositions, consisting of iron oxy-hydroxides and of other precipitation minerals. If the phenomenon is produced within a mine, it is called “mine acid drainage” and when it takes place within the mine waste dumps, as in the case of Roşia Poieni, it is called “rock acid drainage” (Popescu et al., 2007). The acid pH has direct negative effects upon the aquatic flora and fauna, as well as secondary effects such as the decrease of the oxygen contents, the increase of the carbon dioxide tension, all contributing to an increase of the toxicity of these waters which have become real dead waters (Duma, S., 2008).

High exceeding values of the contents of metallic ions were recorded for the waters from the *Cetate* Mine in *Roşia Montană* (1.50 Cu, 1.0 Pb, 43.6 Zn, 261.9 Mn, in mg/l), *Haneş* Mine (720.5 Zn, 1695 Fe, 830 Mn, 0.60 Pb, 17.4 Cu, in mg/l), *Larga* Mine (1.90 Cu, 25.6 Zn, 158 Fe, 20.8 Mn, in mg/l), *Săcărâmb* Mine (50.88 Zn), *Barza* Mine (17.89 Zn in mg/L) and *Troiţa* Mine (26.5 Pb, 1.06 Cu, 94.5 Zn, 83.3 Fe, in mg/l). In *Roşia Poieni*, high contents of copper were registered in the waters flowing from the mine waste dumps (473.3; 333; and 44.4 in mg/l). It was observed that, usually, the higher the contents of metallic ions in waters, the more acid the waters, so that their effects are synergetic. In the case of people, the consumption of lead-laden water produces memory disorders, hands paralysis and cancer, while in the case of children it affects the metabolic and the immune system and leads to a decrease in intelligence. Zinc produces epigastric and cardiovascular disorders, diarrhea, tremble, paresis (Taitner, 1988). In the case of animals, it produces digestive disorders (diarrhea), salivations, convulsions, paralyses of muscles and of larynx, tumefactions of articulations (Coman, N., 1991).

High contents of cyanides were recorded in the waters of the Sălişte Valley tailings settling ponds - *Roşia Montană* (0.32 mg/l), in the Sartăş tailings settling pond - *Baia de Arieş* (0.75 mg/l) and in the Valea Mealu tailings settling pond of *Certej- Săcărâmb* (0.040 mg/l). Fish are the most affected by the presence of cyanides in waters. For them, the contents of 0.03 mg/l HCN in waters are fatal (Witt et al., 2004). The consumption of cyanide-laden water produces headaches, vomiting, breathe disorders, tachycardia, coma, and, in the case of concentrations exceeding 300 mg/l, death (Taitner, I., 1998).

Certainly, there are also some other substances such as sulphates, chlorides, fixed residuum and suspensions that have negative effects upon the biota in the aquatic environment and upon consumers, but their effects are more reduced.

In order to reduce the toxicity of mine waters and of the ones flowing from the tailings settling ponds, the construction of some water treatment stations for each pollution source is needed, and the construction of some water aeration thresholds in the valleys’ riverbed is recommended since through water oxygenation their natural clearing is accomplished. The construction of some guard channels on the perimeter of the tailings settling ponds situated in valleys is also recommended, to receive the slope runoff, avoiding this way the transportation of industrial detritus and of noxes into the fluvial network. The construction of some concrete, contour channels is proposed for the tailings settling ponds situated in floodplains, with role in decanting the waters flowing from the taluses. The deposition of fertile soil and the fixation with forestry vegetation is recommended for the tailings settling ponds with ceased activity, a fact that will reduce substantially the discharge of nox-laden waters into the fluvial network.

The rehabilitation of the aquatic environment in the Southern Apuseni Mountains has to be done on the basis of some projects (programmes) that aim at the ecological reconstruction of all the environmental factors in the area.

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