R e p o r t

Impact of the *Ada Tepe* mine on the ecological status of Krumovitsa river

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Abbreviations

AA – Appropriate assessment

BI – Biotic Index

DPM – Dundee Precious Metals

EBRD – European Bank for Reconstruction and Development

EIA – Environmental Impact Assessment

EQR – Ecological Quality Ratio

MZB – Macrozoobenthos

NGO – Non-Governmental Organisation

EARBD – East Aegean River Basin Directorate

SEA – Strategic Environmental Assessment

TTN – Total Taxa Number

WFD – Water Framework Directive

Glossary of terms

Discharge – volume of water passing through a cross-section of the river in a unit of time. It includes any suspended solids, dissolved chemicals, or biologic material in addition to the water itself;

Hyporheic zone – the saturated portions of streambeds, banks, and floodplain containing water that originates from a stream and returns to the channel. They are characterized by a mixture of local and regional groundwater and stream water, and typically vary in extent and duration;

Interstitial – aquifer pores beneath river bed where most active aquifer-river water exchange occurs;

Refugium – an area in which a population of organisms can survive through a period of unfavourable conditions;

River blanketing – layer of suspended organic or inorganic solids on the top of river bed; prolonged exposure of river bed to river blanketing can result in river bed clogging

River bed clogging (colmatation) – infiltration and penetration of fine sediments inside of aquifer pores (insterstitial) forming a thin seal that disconnects surface water from hyporheic water by inhibiting exchange processes

Abstract

Ada Tepe is newly developed gold mine in the area of Krumovgrad (Bulgaria), officially set into operation in August, 2019. The development of the project was approved after long procedure amid an anti-mine campaign that resulted in significant reduction of exploitation area and usage of pollutants. The EIA imposed requirements to prevent environmental degradation and pollution through strict management of wastewaters and mining waste.

The present independent hydrobiological study on the impact of the mine on Krumovitsa river was conducted in the period 8th – 10th of October, 2020. The field study covered 12 km long

section of the river. Macroinvertebrate community was used as a primary biological quality element.

Discharge conditions were not suitable for proper ecological assessment because some river sections were dry, without any surface water flow. However, the visit took place during rain and erosional flows were registered, coming from the mining area and causing blanketing and colmatation of the Krumovitsa river bed. Such impact can disrupt water exchange between surface and hyporheic zone and can negatively affect macroinvertebrate community which is expected to be highly dependent on the conditions in the interstitial and hyporheic zone during the drought periods. The affected section was 2 km long. Upstream of the mining area, the river was in excellent ecological status and could be considered as a referent site. Presence of fish and signs of otter along the whole investigated section of Krumovitsa river is a positive sign, indicating that the river ecosystem is not heavily affected.

A list of recommendations is provided.

Introduction

Ada Tepe is the first newly developed mine in Bulgaria for the last four decades. It is located three kilometres south of Krumovgrad (Bulgaria), Eastern Rodope mountains. *Ada Tepe* is first out of six sections of the gold-containing mining field called *Khan Krum*. The international company, Dundee Precious Metals Inc (DPM), based in Canada, owns 30-year concession for the *Khan Krum* mining field.

The development of *Ada Tepe* is the first phase of the DPM concession activities and the only section that has passed successfully all regulatory procedures (e.g. Environmental impact assessment, Appropriate assessment as well as EIA procedure in line with the Convention on Environmental Impact Assessment in a Transboundary Context (1991 Espoo Convention)). Furthermore, DPM holds permits for searching and exploration of metal ores in another six gold-containing mining fields in Eastern Rodopes which fall within the boundaries of Natura 2000 Habitats Directive site Rodopi - Iztochni (BG001032).

Ada tepe is a conventional open-pit mine that uses methods like crushing, milling and flotation. It produces gold concentrate which is transported elsewhere for further treatment. Cyanide processing of the gold containing ores was excluded from the initial project due to its high environmental and human health risks. The investment project was approved by the Bulgarian state authorities after significant reduction of the project's exploitation area and the minimised usage of pollutants. Certain requirements are imposed on the project development in order to prevent environmental degradation and pollution through proper management of wastewater, industrial water and mining waste.

On 23th of August, 2019, *Ada Tepe* mine was officially set into operation.

This study aims to assess the current ecological status of the Krumovitsa river and possible impact on the river caused by the mine development and exploitation. The results will be reported to the investor, to the EBRD, to the state and local authorities, as well as to all other stakeholders (e. g. local people, environmental NGOs etc.).

This study is fully independent and, therefore, it can hopefully be considered to be a partial post construction monitoring of the performance of an enterprise. The *Ada Tepe* mine was financed by the EBRD and our study can be used for an assessment in line with the bank's own environmental and social policy.

Materials and Methods

The field work was carried out from 8th to 10th of October, 2020. The field study covered 12 km long section of the Krumovitsa river, starting 1km upstream from the confluence of Kesebir river and finishing 1,5 km downstream from the confluence of Elbasandere river. The mouth sections of the following tributaries were covered too: Kesebir, Buyukdere, Svinski dol, Golemiya dol and Elbasandere. These river stretches were first checked visually by walking along the riverbeds (Figure 1).

The assessment was conducted using benthic macroinvertebrates (macrozoobenthos, MZB) as a primary biological quality element. MZB samples were collected using standard hydro biological handnet (25x25cm, 500µm mesh size) complying with the BDS EN ISO 10870:2012 and BDS EN ISO 5667-1:2007. Adapted multi-habitat methodology (Cheshmedjiev et al., 2011) based on the standardized method EN 27828:1994/ISO 7828:1985 as well as on the multi-habitat approach of Barbour et al. (1999) was applied. The ecological status was assessed according to the criteria set in Ordinance N-4/14.09.2012 using the metrics "Biotic Index" and "Total Taxa Number". The methodology corresponds to Water Framework Directive (WFD, Directive 2000/60/EC) and the transposed legislation in Bulgaria (Ordinance N-4/14.09.2012, Water Act).

MZB samples were taken only from stretches where surface water flow existed (Figure 1). Dried stretches and those with isolated pools without surface water flow between them were not sampled as the metrics and methodology is not calibrated for stagnate waters and, therefore, any comparison of macroinvertebrate communities among those would not be correct.

The Krumovitsa river is R14 river type (sub-mediterranean small and medium-sized rivers in Ecoregion 7) and according to the relevant national legislation, for this river type fish-based indexes are not calibrated and adopted as an indicator for ecological quality assessment. Fish fauna existence and diversity was only visually observed – a non-standardized approach, easily applicable in the shallow transparent pools. Accidentally caught fish in the hand net, while sampling MZB using kick-net method, were photographed as an evidence for the species presence and released immediately after.

Results and Discussion

Most of the studied sections of Krumovitsa river and its tributaries were dry during the field visit. Therefore, it was not possible to collect enough MZB samples to assess the impact of the mine. Dried river sections where surface water flow did not exist are coloured in yellow on Figure 1 and those with flowing water are in blue. However, two MZB samples were still taken (Table 1). MZB sample from the flowing river section of Krumovitsa river downstream of the town of Krumovgrad was not taken due to obvious organic pollution caused by untreated wastewaters of the town.

Table 1. Locality of the sampling sites

Sample ID	Locality	Latitude	Longitude	Altitude
S_1	Krumovitsa, upstream of Kesebir	41.419272°	25.658426°	243
S_2	Krumovitsa, downstream of Kesebir	41.422987°	25.661461°	239

As a typical R14 river type, Krumovitsa river is characterised as rain-fed, with very high seasonal discharge fluctuations and absence of surface water flow during longer droughts (Lucarska 2015). The hyporheic zone is the region of sediment and porous space beneath and alongside the river bed, where shallow groundwater and surface water are mixed. The flow dynamics in this zone (termed hyporheic flow or underflow) are recognized to be important for surface water/groundwater interactions, as well as fish spawning and survival of some invertebrate species (Lewandowski et al. 2019). The wide sections in the Krumovitsa river valley accumulate deep alluvial deposits, where the hyporheic zone is especially well defined. In these sections of the river it happens that the hyporheic discharge reaches 100% of the total discharge during prolonged droughts. In these cases, the aquatic invertebrate fauna passes into its terrestrial stages or enters the interstitial spaces of the hyporheic zone. If stagnate pools are available, some animals (fish, crustaceans, dragonfly larvae etc.) can survive there. From the confluence of Buyukdere to the confluence of Elbasandere, Krumovitsa river forms very wide river valley, which is prerequisite for frequent absence of surface water flow during droughts.

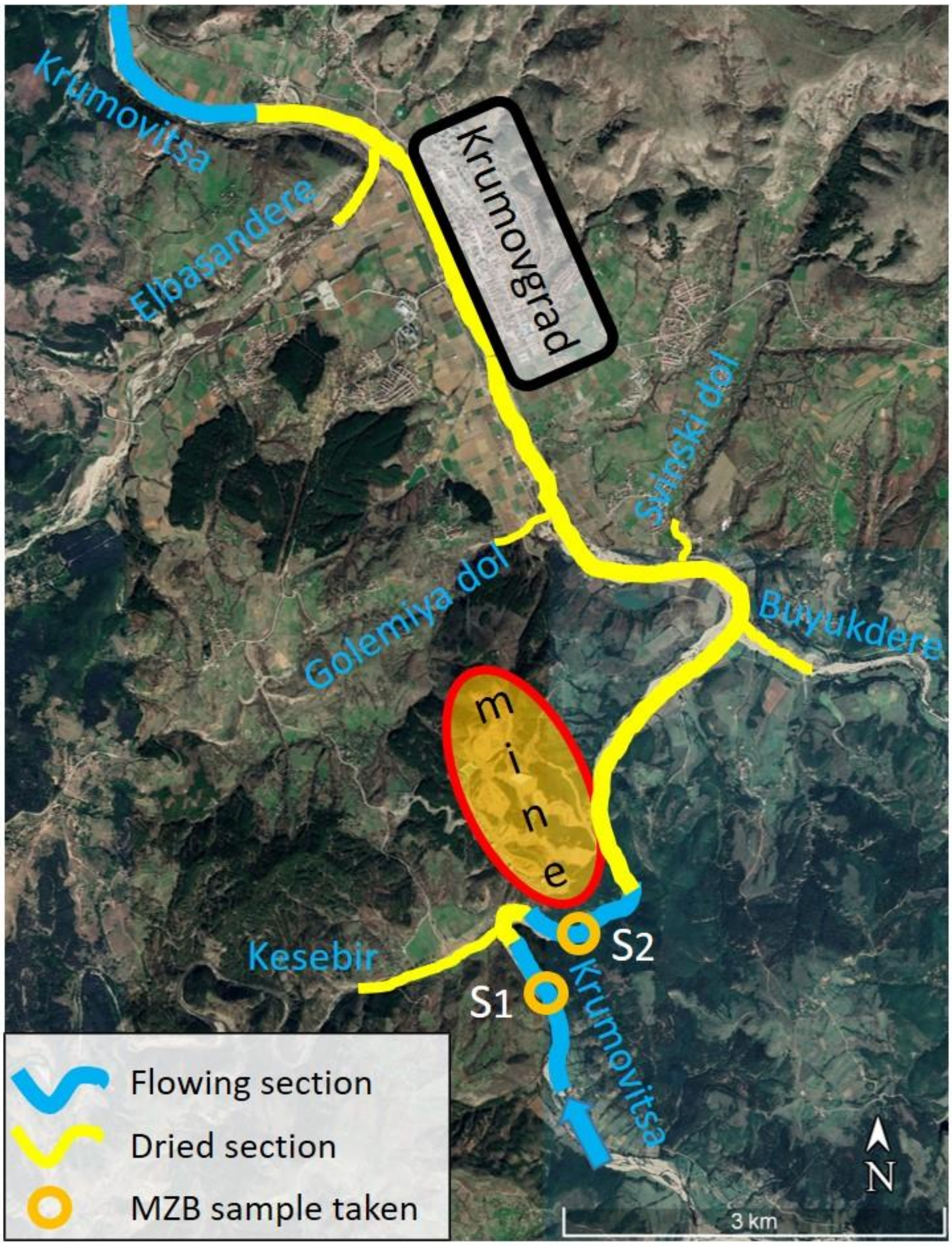

Figure 1: Map of the studied river sections.

A registered impact caused by mining activities, was so-called blanketing of the river bed accompanied by river bed clogging (colmatation). The field trip coincided in time with a moderate rainfall and turbid erosional water flows coming from the mining area and mouthing the Krumovitsa river bed were observed and documented (Pictures 4 and 5). The affected section of the river was approximately 2 km long. The impact was especially acute next to the mine and decreased with distance from the mining area. The observed riverbed clogging led us to the assumption that the erosional flows from the mine have not appeared recently, but their occurrence has started at least some years ago (the river bed clogging is time dependent process). These flows are even more visible on Google Earth satellite pictures from 2018 (Figure 2) taken during the construction phase of the mining project. Clogging is especially emphasized during low and extremely low water discharge conditions in the river bed due to almost 100% sedimentation of the erosional water flows coming from the mining area. The described negative impacts are visible on the pictures in Appendix 3.

Figure 2. Google Earth Satellite picture of Krumovitsa river and erosional flows coming from the mine area. Date of the picture: 22.07.2018 (during the construction period of the mine).

Fine sediment from erosional flows can cause clogging of water animal's gills, shading and reduction of visibility, loss of microhabitats and depending on the intensity and duration of exposure, it can cause direct killing (e.g. suffocation) or chronic inhibition of affected benthic organisms (Jones et. al. 2011, Ellis 1936).

Turbid waters naturally flow through the Krumovitsa river bed during high discharge condition and do not cause blanketing as well as do not result in colmatation. River bed clogging/colmatation disconnects surface water from hyporheic water by inhibiting exchange processes and reduces the recharge processes between surface- and ground waters (Brunke 1999). In some cases, MZB use interstitial as a refugium in order to protect themselves from risks that are threatening them at the substrate surface, such as floods, predators or droughts

(Lancaster et al., 1991; Lancaster, 1996). When the river bed is clogged, benthic invertebrate community is deprived of the shelters and food sources during dry periods or floods. Furthermore, when the interstitial zone is filled compactly with fine sediments, most of the water animals, the survival of which during unfavourable conditions depends on existence of interstitial zone, are not able to enter it (Mcclelland et al., 1980, Lancaster & Hildrew, 1993).

The EIA report states (page 185) that during construction phase the following measures should be prepared and undertaken to minimize the risk of surface flows contamination:

- *Construction of temporary drainage ditches for catching and diverting surface flows from the construction sites;*

- *Construction of temporary precipitators to collect water contaminated with undissolved substances (soil and subsoil material) for its purification, before its discharge into the river.*

The Figure 2 shows the erosional flows during the construction stage and brought us to the conclusion that these measures were either not taken, or were insufficient, or they did not work during the construction phase.

It is stated in the EIA report (pages 48, 82, 201/203, 287, 294 etc.) that during the operational phase all industrial, mining, surface and faecal wastewaters will be collected, precipitated and purified before they are discharged into the river. Numerous statements are leading to the conclusion that all kind of waste waters, including surface rainwater, will be captured, collected, purified, precipitated and reused or dumped through a pipeline into the river only after proper treatment. Our field observations showed that during rainfall a lot of erosional waters flowed directly into the river, right below the mining area in contradiction with the EIA recommendations and conclusions. The negative impact on the ecosystem has been discussed already. Therefore, additional measures concerning the surface waters from the mining area should be undertaken in due course.

MZB has leading importance for the ecological status assessment of rivers, because of its specific indicator values: relatively long life expectancy, low mobility, well-studied indicator role of individual taxa. The results of the taxonomical identification of the collected MZB samples are shown in Appendix 1. In total 38 taxa were found. The biodiversity was slightly higher in S1 (33 taxa) in comparison to S2 (29 taxa). The values of the Biotic Index (BI) were **4** for both sites. Ecological quality ratio was evaluated with **1** for both sites, corresponding to an *excellent* ecological status. The TTN index which has supporting importance to BI also confirmed the results, showing excellent ecological status for both samples. It can be concluded, therefore, that S1 and S2 are appropriate for referent sites, representing the natural ecological conditions in Krumovitsa river. It is of key importance for the impact assessment to locate and define referent stretches. The Kesebir river (the biggest tributary of Krumovitsa) which confluences the Krumovitsa river upstream of S2, did not change the ecological status of Krumovitsa river. The natural ecological condition of Krumovitsa upstream of the mine is prerequisite for further objective assessment of the impact of the mine.

More detailed analyse of the MZB samples demonstrates that the MZB community in the river is well adapted to extremely low discharge conditions and droughts. Species with perennial larval stage are missing, as well as the typical rheophilic ones. According to their life strategy and ecological traits, three basic ecological groups are dominating:

- animals that survive unfavourable periods entering the interstitial and hyporheic zone (*Leuctra sp., Caenis luctuosa, Ephemera danica, Psychomia pusilla, Plectrocnemia sp., Athericidae, Tabanidae, Limonidae, Tipulidae, Potamon ibericum, Hydrachnidia etc.*);

- animals that can survive in residual pools and are adopted to slowly flowing and stagnate waters (*Leptophlebia marginata, Psychomia pusilla, Plectrocnemia sp, Hydropsiche sp., Onychogomphus forcipatus, Caenis lucuosa, Limnius sp., Esolus sp., Hydraena sp, Micronecta, Baetis fuscatus, Chironomidae, Callopteryx splendens, etc.*);

- animals with relatively short life cycle in the water and terrestrial stage (*Ecdyonurus sp., Platycnemis pennipes, Simuliidae, etc.*).

Significant part of the MZB community in the river depends on the dynamic hydraulic connection and exchange between the surface waters and hyporheic zone, and on the conditions in interstitial spaces as well. This means that in the typical R14 river types, such as Krumovitsa, blanketing and clogging/colmatation are expected to have especially destructive impact on the MZB community. Moreover, it should be considered that the erosional waters coming from the mine can also contain toxic pollutants. Therefore, control of the erosional flows coming from the mine and further ecological studies, carried out on a regular basis, are highly recommended.

Regarding the ichthyofauna, the existence of fish was visually observed along the whole studied section of the Krumovitsa river in most of the pools left in the dry river bed. 6 species from the river section upstream the mine were registered. The pools downstream the mine were too turbid and only 3 species were recognised there. This does not prove that other species are absent, because the method used is selective and largely dependent on water transparency. In Appendix 2 the species registered for the aim of this study are listed and compared to those, caught during the AA study in 2010. Two species that are listed in Appendix 2 of the Habitats Directive were found – the round-scaled barbel (*Barbus cyclolepis*) and the balkan spined loach (*Sabanejewia balkanica*). The Balkan spined loach has not been registered in the Krumovitsa river upstream of Dolna Kula village (downstream of Krumovgrad) during the AA study and our observation indicates greater present importance of Krumovitsa river for the population of this rare species in that Rodopi - Iztochni Habitats Directive site. A positive observation was that otter excrement were registered several times along the entire studied river section, that assume existence of feeding recourses for this predator (Picture 16).

According to requirement III.20 of the Decision (18-8,11/2011) of the Ministry of Environment on the approval of EIA, DPM is obliged to conduct water quality monitoring and to report annually the results to EARBD, as well as to Greek Ministry of Environment. According to the water monitoring plan of DPM, the role of biological quality elements (phytoplankton, macrophytes, phytobenthos, benthic invertebrate fauna and fish) is neglected. The monitoring plan includes only 3 sampling sites for biological monitoring of surface waters and do not obtain a referent site upstream of the mine. This is in contrary to the WFD concept which considers biological quality elements as primary indicators while the physico-chemical ones (nutrients, oxygen condition, temperature, transparency, salinity and river basin specific pollutants) have supporting role in assessment of ecological status of rivers. An important disadvantage of the DPM water monitoring is that it is not sensitive to short lasting and emergency pollution that can cause dramatic deterioration of the ecological conditions, but can remain unregistered by the local people and the responsible authorities. Therefore, we suggest the role of the biological quality elements in the monitoring to be increased, especially macroinvertebrates which can register pollution or other negative impact that have already happened. Chemical and physical monitoring serves only as a snapshot of the pollution and it does not consider the reactions of riverine community to the external impacts.

Conclusions

The erosional flows coming from the mining area, causing blanketing and colmatation of the river bed, are a negative impact on the ecological status of Krumovitsa river.

Upstream the mine area, the river is in excellent ecological status and can be considered as a referent site. This is prerequisite for proper further assessment of the mine impact.

Macroinvertebrate community is well adapted to droughts and it is expected to be highly dependent of the conditions in the interstitial microhabitats and hyporheic zone.

The water quality monitoring of the investor neglects the importance of the biological quality elements and is not sensitive to accidental pollution.

Presence of fish and otter along the whole studied section of Krumovitsa river is a positive sign, indicating that the river ecosystem is not heavily affected.

Recommendations

1. Waste water management and monitoring needs to be improved by considering biological elements and introducing more monitoring localities.
2. Measures to prevent further discharge of erosional waters coming from the mining area and flowing into the Krumovitsa river right below the mine should be undertaken in due course.
3. The accumulated bottom sludge should be sampled and analysed for pollutants. Depending on the results, appropriate measures should be undertaken.
4. Similar independent study as this one should be conducted in the late spring or summer of the next year during more favourable water flow conditions. That would allow collecting of enough MZB samples for assessment of the impact of the mine on the ecological status of Krumovitsa river.

References

Barbour M., Gerritsen J., Snyder B., Stribling J. (1999). *Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish* (Vol. 339). Washington, DC: US Environmental Protection Agency, Office of Water.

Brunke M. (1999). *Colmation and Depth Filtration within Streambeds: Retention of Particles in Hyporheic Interstices*. Internat. Rev. Hydrobiol. 84 (2), 99-117

Cheshmedjiev S., Soufi R., Vidinova Y., Tyufekchieva V., Yaneva I., Uzunov Y., Varadinova E. (2011). *Multi-habitat sampling method for benthic macroinvertebrate communities in different river types in Bulgaria*. Water Research and Management, 1(3), 55-58.

Ellis M. M. (1936). *Erosion silt as a factor in aquatic environments*. Ecology 17: 29–42.

Jones J. I., Murphy J. F., Collins A. L., Sear D. A., Naden P. S., Armitage P. D. (2011). *The impact of fine sediment on macro-Invertebrates*. River Research and Applications 28: 1055–1071.

Lancaster, J. (1996). *Scaling the effects of predation and disturbance in a patchy environment.* Oecologia 107: 321–331.

Lancaster, J., Hildrew A. G. (1993). *Flow refugia and the microdistribution of lotic macroinvertebrates*. Journal of the North American Benthological Society 12: 385–393.

Lancaster, J., Hildrew A. G., Townsend C. R. (1991). *Invertebrate Predation on Patchy and Mobile Prey in Streams*. Journal of Animal Ecology 60: 625–641.

Lewandowski J., Arnon S., Banks E., Batelaan O., Betterle A., Broecker T., ..., Gomez-Velez J. (2019). *Is the hyporheic zone relevant beyond the scientific community?* Water, 11(11), 2230.

Lucarska S. (2015). *Characteristics of extremal water discharges in Arda river Basin for the period 200-2005.* Problems of the Geography, 1-2, Bulgarian academy of scienses, Sofia, pp. 198-206 (In Bulgarian)

Mcclelland, W. T., Brusven M. A., State N. C. (1980). *Effects of sedimentation on the behavior and distribution of riffle insects in a laboratory stream*. Aquatic Insects: International Journal of Freshwater Entomology 2: 161–169.

Mucha I., Banský L., Hlavatý Z., Rodák D. (2006). *Impact of Riverbed Clogging/Colmatation on Ground Water*. In *Riverbank Filtration Hydrology* (pp. 43-72). Springer, Dordrecht.

Appendix 1. Taxa composition and ecological status assessment of the collected samples.

Taxa	BI indicator group	Sample site	
		S2	S1
EPHEMEROPTERA			
Baetis fuscatus/scambus	C	62	70
Baetis muticus		11	
Caenis luctuosa	C	53	12
Ecdyonurus sp.	A	51	19
Ephemera danica	B	5	1
Leptophlebia cf. marginata	B	7	
PLECOPTERA			
Leuctra sp.	B	88	293
TRICHOPTERA			
Adicella reducta/filicornis	B		2
Cheumatopsyche lepida	C	146	123
Hydropsychidae Gen. sp.(puppae)		2	
Hydropsyche sp.		51	71
Plectrocnemia sp.	C	1	
Psychomyia pusilla	C		1
Rhyacophila sp.	C	1	1
ODONATA			
Calopteryx cf. splendens	B		2
Onychogomphus forcipatus	B	7	27
Platycnemis pennipes	B	8	18
COLEOPTERA			
Limnius sp.	C	2	12
Elmis sp.	C		5
Esolus sp.	C	24	75
Esolus sp. (imago)		19	23
Hydraena sp. (imago)	C	10	11
Limnius sp. (imago)		2	3
Helophorus sp. (imago)	C		1
DIPTERA			
Athericidae Gen. sp.	B	3	11
Chironomidae Gen. sp.	D	24	94
Limoniidae Gen. sp.	D	4	1
Psychodidae Gen. sp.	D		1
Simuliidae Gen. sp.	C	9	36
Tabanidae Gen. sp.	D	4	5
Tipulidae Gen. sp.	C		3
Diptera Gen. sp. (puppae)		3	7
CRUSTACEA			
Gammarus cf. komareki	C		1

Potamon ibericum	C	5	4
HETEROPTERA			
Micronecta sp.	C	5	7
HYDRACHNIDIA			
Hydrchnidia Gen. sp.	C	29	35
OLIGOCHAETA			
Oligochaeta Gen. sp	D	6	1
Total BI taxa number		23	26
Biotic index		4	4
EQR		1 (Excelent)	1 (Excelent)

Appendix 2. Fish species registered in the studied section of Krumovitsa river during the present study and during the AA study; Fishes at sites S1 and S2 were accidentally caught in the hand net, while sampling MZB using kick-net method. They were photographed as an evidence for the species presence and released immediately after

Fish species	Present study, upstream the mine[1] (N41.424578°, E25.655241°)	Present study, near Krumovgrad[1] (N41.467573°, E25.651633°)	AA study, 2010, near Krumovgrad	S1 Krumovitsa, upstream of Kesebir (N41.419272°, E25.658426°)	S2 Krumovitsa, downstream of Kesebir (N41.422987°, E25.661461°)
Barbus cyclolepis**	•	•	•	•	•
*Squalius orpheus**	•	•	•	•	•
*Gobio bulgaricus**	•	•	•		
*Vimba melanops**	•				
Cobitis strumicae	•		•		•
Sabanejewia balcanica	•			•	

The species in ***Bold*** *are included in Appendix 2 of Council Directive 92/43/EEC; * after the name of the species means that the species is endemic for the rivers in Aegean Sea basin; ** - endemic for Maritsa river basin;* [1]at this locations fishes were only visually registered without catching them.

Appendix 3: Pictures

Picture 1: Dry river bed of Krumovitsa river downstream the mine, blanketed by sludge and mud

Picture 2: Deep layer of fine muddy sediments in the river bed caused by erosional flows coming from the mining area

Picture 3: The blanketing is especially acute close to the mine

Picture 4: Formation of turbid water pools (from erosion flows) after rain

Picture 5: Upstream of this pool the river is not affected by the erosional flows coming from the mining area

Picture 6: Filled up interstitial spaces downstream the mine (left) and natural substrate upstream the mine (right)

Picture 7: The freshwater crab (Potamon ibericum) is typical for sub-mediterranean rivers and it is widespread along Krumovitsa river.

Picture 8: The orpheus dace (Squalius orpheus) and the round-scalled barbel (Barbus cyclolepis) are dominant fish species in Krumovitsa river

Picture 9: The balkan spined loach (Sabanejewia balkanica) together with the round-scaled barbel are included in Appendix 2 of the Habitats Directive

Picture 10: The bulgarian spined loach (Cobitis strumicae) is another endemic species (for the South-east Balkans) that inhabits the Krumovitsa river

Picture 11: Sampling site S2

Picture 12: Sampling site S1

Picture 13:The white-legged damselfly larvae (Platycnemis pennipes) is a relatively large predator that inhabit the river bottom

Picture 14: Stonefly larvae of family Leuctridae are the most numerous taxa in the samples and are among the animals which enter the interstitial during unfavourable conditions

Picture 15: The mayfly larvae Habrophlebia cf marginata is also entering the interstitial but can spend the draughts in the stagnate pools as well

Picture 16: Otter (Lutra lutra) excrements were registrated along the studied section of Krumovitsa river