IMPACT OF THE OPEN EXTRACTION OF ORES ON THE ECOLOGICAL STATUS OF SURFACE WATER

Daniela Zlatunova
Sofia University St. "Kliment Ohridski", Sofia, Bulgaria, daniela.zlatunova@mail.bg

Abstract: Assarel-Medet JSC mining and processing complex is the first, largest and leading Bulgarian mining company for outdoor mining and enrichment of copper and other ores. The detailed study of the Medet deposit was carried out in 1956-1962, which created the Medet mining and processing Complex/1964-1994/- the largest open - pit copper mine at that time in Europe and third in the world. At the end of 1968, the Assarel-copper deposit was opened. The hydrothermal copper deposit "Assarel" is of copper-porphyry type, located 12 km from the Medet deposit in the Panagyurishte ore region. It was formed in late chalk and the main ore minerals are chalcosine, pyrite, chalcopyrite, bornit and coveline, and the average copper content is 0.45%. After a detailed geological survey, on January 1, 1976 was established experimental-yielding section "Assarel". On the basis of the Medet mining and processing complex "Assarel" in 1986 was formed technological ore and enrichment plant "Assarel-Medet" the largest Bulgarian company for open-pit mining and production of copper ores. The most advanced technology is implemented high-performance equipment and unique company know-how. Assarel mine and the enrichment factory for the production of copper concentrate "Assarel" are two of the main production workshops of Assarel-Medet mining and processing complex. The modern infrastructure includes a water farm, a workshop for micro-biological leaching of copper, cyclic-flow technology for the transportation of mining, sorption installations and electrolysis of copper, modern treatment facilities and administrative and other buildings. It is 11 km northwest of the town of Panagyurishte and 90 km east of the capital Sofia.
Regardless of the most advanced technologies implemented, the negative effects of the discovered extraction on all environmental components – water, air, relief, flora and fauna are widely known. In this regard is the purpose of this publication, namely: to assess the influence of the mining enrichment complex on the ecological status of surface waters. In particular, subject of research is the rivers (Asrelska, Panova and Banska Ludayana) flowing through the territory of complex ecological polygon (CEP). CEP was built in 1988 and is the first company complex ecological polygon. It covers the Panagyurishte Srednogorie between the valley of the Topolnitsa River and the Panagyurishte Valley and has an area of about 147 km^2.
To assess the impact of the mining and enrichment complex on the quality of surface water, incl. of the ecological status, a monitoring network is established within the CEP. The quality of the river waters of the rivers Asarelska, Panova and Banska Luyana is observed at five points – two points reflecting conditionally – the natural conditions for the ecological status and three points giving information about the technogenic impact on the water of the mining complex. According to the normative documents, the classification of the ecological status of surface water is determined by biological and physico-chemical monitoring. The quality biological elements (QBE) include the composition and the abundance of aquatic flora and the composition and the abundance of invertebrate fauna, expressed by IPS Index and Biotic Index (BI). The hydrogen indicator as a physico-chemical element is used to support the biological elements. The main results of the study are related to the assessment of the ecological status of surface water under conditional-natural and technogenic conditions.
Keywords: outdoor ore production, ecological status, negative impacts.

1. INTRODUCTION

"Assarel-Medet", JSC mining and processing complex is the first, largest and leading Bulgarian mining company for outdoor mining and enrichment of copper and other ores. The detailed study of the Medet deposit was carried out in 1956-1962, which created the Medet mining and processing complex - the largest open - pit copper mine at that time in Europe and third in the world. At the end of 1968, the Assarel-copper deposit was opened. The hydrothermal copper deposit "Assarel" is of copper-porphyry type, located 12 km from the Medet deposit in the Panagyurishte ore region. It was formed in late chalk and the main ore minerals are chalcosine, pyrite, chalcopyrite, bornit and coveline, and the average copper content is 0.45%. After a detailed geological survey, on January 1, 1976 was established experimental-yielding section "Assarel". On the basis of the Medet mining and processing complex "Assarel" in 1986 was formed technological ore and enrichment plant "Assarel-Medet" the largest Bulgarian company for open-pit mining and production of copper ores. The most advanced technology is implemented high-performance equipment and unique company know-how. Assarel mine and the enrichment factory for the production of copper concentrate "Assarel" are two of the main production workshops of Assarel-Medet mining and processing complex. The modern infrastructure includes a water farm, a workshop for micro-biological leaching of

copper, cyclic-flow technology for the transportation of mining, sorption installations and electrolysis of copper, modern treatment facilities and administrative and other buildings. It is 11 km northwest of the town of Panagyurishte and 90 km east of the capital Sofia.

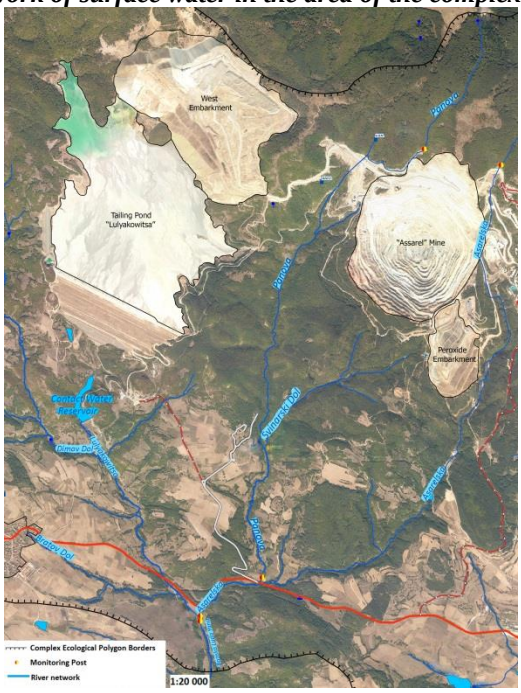
Regardless of the most advanced technologies implemented, the negative effects of the discovered extraction on all environmental components – water, air, relief, flora and fauna are widely known. In this regard is the purpose of this publication, namely: to assess the influence of the mining enrichment complex on the ecological status of surface waters. In particular subject of research are the rivers (Asrelska, Panova and Banska Ludayana) flowing through the territory of complex ecological polygon (CEP). CEP was built in 1988 and is the first company complex ecological polygon. It covers the Panagyurishte Srednogorie between the valley of the Topolnitsa River and the Panagyurishte Valley and has an area of about 147 km^2.

The studied rivers are characterized as semi-mountainous type of rivers. They belong to the catchment area of the cross-border Maritsa River. They fall in the Aegean catchment region, Ecoregion 7.

2. MATERIAL AND METHODS

To assess the impact of the mining and processing complex on the quality of surface water, including the ecological status, a monitoring network is established within the CEP.(Zlatunova, 2016, 2017, 2018, 2019) The quality of the waters of the rivers Asarelska, Panova and Banska Luda Yana is observed at five points – two points reflecting conditionally – natural conditions for the ecological status and three points giving information about the technogenic impact of the complex on surface water. (Fig. 1)

Figure 1. Monitoring network of surface water in the area of the complex ecological polygon (CEP)



Biological monitoring methods are used to assess the ecological status of surface water, which is in accordance with the requirements of the EU Water Framework Directive. (EUR – Lex, 2000*)* According to the normative documents (LEX.bg, 2014) the classification of the ecological status of surface water is determined by biological and physico-chemical monitoring. The quality biological elements (QBE) include the composition and the abundance of the aquatic flora and the composition and the abundance of the bottom invertebrate fauna expressed by IPS Index (EN Standard Store, 2007) and Biotic Index (BI). The assessment of the ecological status is carried out by a classification system which distinguishes 5 classes: "Very Good", „Good", „Moderate", „Bad"and „Very Bad". ((Ollis et al. 2006; Mugnai et al. 2008; Lavoie & Campeau 2010)

3. RESULTS AND DISCUSSION

Natural factors influencing the ecological status of the River waters

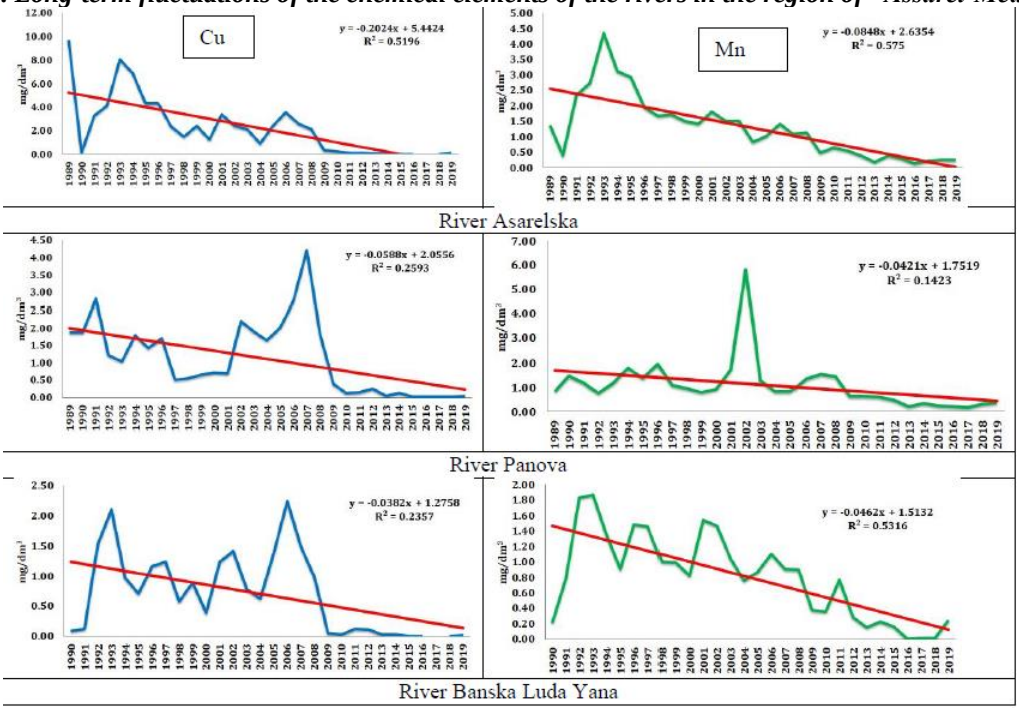
The catchment p, subject of the study, are built from highly indented mountain terrain with a complex geologo-tectonic structure. Lithological base consists of the Upper Creaseous volcanic rocks/Andesites, Quarz Andesites, Latites, Quartzlatandesites, Pyroclstites, etc./and sedimentary rocks. The cliffs of the Razlog volcanic complex, between the Asarelska and Panova rivers are tectonically the most rifted. Regardless of the Rift Systems and the volatilization processes, the hydrologic structures are weak aquiferous /with an average annual module of the underground runoff up to 5.0 – 6.0 l/s/km^2/and are drained from the low-water mostly drying springs. Only the springs fueled/nourished by deep underground water /e.g. Kavrakov Kamak – 16 l/s, ect./ are more permanent. Also, for the three investigated catchment areas are characteristic natural positive and polymetallic anomalous lithochemical fields (especially Cu, Mn, Mo, Pb, Zn, etc.), which are reflected also on the soil-chemical and hydrogeochemical environment. (Zlatunova, 2016) On the other hand, the large incline of the slopes and the disjointed valley network increase the intensity of the surface-running rain waters and their concentration in the main river bed. Therefore the pool is distinguished by a relatively large water-forming efficiency of rainfall, as well as the adjacent catchments of the Asrelska River, the river Mareshka and the River Lylikovitsa.

Technogenic factors influencing the ecological status of the River waters

The facilities of Mining and Processing complex "Assarel-Medet", JCS – Assarel Mine have significant anthropogenic impact on the ecological status of the river water(s), peroxide embankment, tailing pond " Lulikovitsa " (area 250 ha), West Embankment (184 ha), Contact water reservoir (15 ha). The road and construction infrastructure, as well as the route of the conduit also have effect. In the catchment area of Panova River, about 210 ha of forest areas were disturbed in total. The area of the absolutely disturbed/technogenised/ecosystems in the catchment area of Lulikovitsa are about 450 ha. (or 20.8% of the catchment area). These technogenic ecosystems transform heterogeneously water balance and water regime, as well as landscape-geochemical environment of the valley. The groundwater drained from the massif of the Assarel mine and entering the Panova/directly or through its left tributary River Svinarski Dol are risk technogenic factors for the state of the river. (Zlatunova, 2017*)*

As a result of the technogenic impact of the "Assarel" mine, the concentrations, for example, of the Cu and Mn elements in the river waters increased significantly during the period 1989 – 2009. For example, for the Asrelka River, a maximum value of 9, 73mg/ dm^3 (1989) was recorded; For River Panova – 4, 21mg/dm^3 (2007) and for Banska Luda Yana River – 2.24 mg/dm3 (2006). There is a significant trend of reduction after 2009, of the concentrations of these chemical elements. In recent years, in the predominant number of cases the concentrations correspond to the statutory annual averages, respectively 0.02 mg/dm3 for the indicator Cu and 0.0 mg/dm3 for the Mn indicator (Fig. 2).

Figure 2. Long-term fluctuations of the chemical elements of the rivers in the region of "Assarel-Medet", JSC



Ecological status of the river waters above the Assarel mine (conditional-natural environment)

In the conditionally natural aquatic environment of Panova River are found 14 taxon flint algae. Two of them (Fragilaria ulna and Encyonema minutum) are of high numbers, respectively 198.0 and 121.0. There are four of them in the range of 10 – 25. The other species have numbers – < 5. The value of the Diatom Index (IPS = 14.4) corresponds to the "good status" of the established qualitative and quantitative composition of the diatomic communities. 23 taxon flint algae are found in the waters of the Asarelska River. Two of them (Planothidium lanceolatum and Eolimna minima) have higher numbers, respectively 133.0 and 66.0. Nine of them are within the range 10.0 – 50.0. The others have numbers – < 10.0. The value of the diatom index (IPS = 14.7) corresponds to the "good status" of the established qualitative and quantitative composition of the diatomic message.

Both rivers (Asarelska and Panova) in terms of macrozoobenthos, evaluated by Biotic Index (BI) are in "good" ecological status. The BI of the Panova River is respectively between 3 – 4, and the Asarelska River – 4. It should be noted the significant number of individuals on the Asrelska River – 1199, while the Panova are only 195 individuals. More than twice is greater and the total number of taxons of the Asrelska River (25) compared to the Panova. (10) (table 1) It should be stressed that the described environmental condition, especially of the Panova, is influenced by the natural positive and polymetallic anomalous lithochemical fields/cu, Mn, Mo, Pb, Zn, etc./. They influence both the soil-chemical and the hydrogeochemical environment.

Table1. Status of river waters on biological quality elements (BQE)

	Above the "Assarel" Mine		**Under the "Assare" Mine**					
Years	**2016**		**2017**		**2018**		**2019**	
Indexes	**BI**	**IPS**	**BI**	**IPS**	**BI**	**IPS**	**BI**	**IPS**
River Asarelska								
Total number of individuals	1199	401	235	413	111	405	415	410
Total number of taxon	25	23	16	3	13	4	16	5
	4 Good	14,7 Good	3 Moderate	10,7 Moderate	3 Moderate	10,6 Moderate	3 Moderate	10,6 Moderate
River Panova								
Total number of individuals	195	417	15	413	348	402	106	400
Total number of taxon	10	14	6	3	16	5	15	1
	3–4 Good	14,4 Good	1 Very Bed	10,5 Moderate	2–3 Moderate	15,1 Good	3 Moderate	10,5 Moderate
River Banska Lujana Yana								
Total number of individuals	241	394	373	433	307	456	613	410
Total number of taxon	16	38	19	6	15	18	17	6
	3 Moderate	10,5 Moderate	3–4 Good	10,6 Moderate	3–4 Good	10,1 Moderate	3 Moderate	10,1 Moderate

BI – Biotic Index; IPS Index

Ecological status under the Assarel Mine (technogenic environment)

Under the Assarel mine in the waters of Panova River there is an extremely poor species composition – only two pioneering species of flint algae, which are very tolerant of contamination. These species are absolutely atypical for river type R5 and for the specific river areas surveyed. In the different years, between 5 – 10% of individuals are teratogenic (i.e., deformed with malformations). This is an indication of highly toxic river water pollution and extremely unsuitable conditions for the development of phyto-Entomis. Although the IPS index values correspond to a "moderate state", then the final score on the BQE Fitobentos is a "poor" environmental condition. This assessment was made taking into account the high percentage of teratology individuals and the lack of species diversity.

In the waters of the Asarelska River there is also an extreme poor species composition, which is atypical for river type R5, as well as for the specific conditions in the rivers surveyed. Over-domination of the very tolerant of dirt species (Achnanthidium saprophilum), which is not typical for the semi-mountain river, which visually looks in good condition. All Fragilaria Rumpens and Fragilaria gracilis are teratogenic (i.e., deformed, with malformations). This is a secure indication of toxic contamination due to the presence of heavy metals and/or toxic substances in the

water. The value of the IPS = 10.6-10.7 corresponds to a "moderate state" for the established qualitative and quantitative composition of the diatomic community, but without taking into account the presence of teratogenic individuals, as well as the very low species diversity (h = 0.15) and species wealth (only three species). With all this in mind, the final evaluation on the BQE Fitobentos is a "bad" environmental condition.

River Banska Luda Yana (Mechenska) is characterized by a poor species composition. Over-domination of the very tolerant of pollutions kind of Achnanthidium saprophilum, which is not typical in such high quantities for the semi-mountain river, which visually looks in good condition. All Fragilaria Rumpens and Fragilaria gracilis are teratological (i.e., deformed, with malformations). This is a secure indication of toxic contamination due to the presence of heavy metals and/or toxic substances in the water. Taking into account the extreme low species richness and species diversity (h = 0.12) and the presence of about 3% teratological individuals (i.e., deformed, with malformations), the final evaluation of the BQE Fitobentos is a "poor" ecological condition. There is toxic contamination.

Concerning BI, Panova and Asarelska rivers have a deterioration of ecological status, which from "good" changes to "moderate", and in 2017 for the Panova river to "Very bad". Only for Banska Luda Yana in 2017 and 2018, is taken into account the improvement of the ecological status compared with 2016, which is "moderately" changed to "good" biological status. In this case, the waters of the inflow of the river Banska Luda Yana – River Luliakovitsa, which in terms of chemical status is evaluated as "River achieving good" chemical condition, have favorable influence on the biological condition.

4. CONCLUSION

On the conditional – natural biological state of the rivers above the Assarel mine, the natural positive polymetallic and anomalous lithochemical fields / especially Cu, Mn, Mo, Pb, Zn, etc./ have influence. They determine the higher concentrations of heavy metals (Cu, Zn, Mn, etc.) in the river waters, which reflect on the species diversity and the species richness of macrophyte and macrozoobenthos.

Under the mine, the status of the BEQ of the Panova and the Asarelska Rivers is deteriorating and it is characterized as a "moderate" state. But due to the extreme low species richness and species diversity and the presence of teratogenic individuals (i.e., deformed, with malformations), the final evaluation on the BQE Fithobentos "bad" ecological condition. During the research period, only for the river Banska Luda Yana, in different years there has been an improvement in the state of BQE. This is due to the influence of the river Lulikovitsa, right tributary of the Banska Luda Yana River, which in terms of chemical indicators is classified as a river in a "good" chemical state. To improve the status of the BQE, it is necessary to maintain the Hp (hydrogen indicator) in the Normative Limits – (6.5 – 8.5). The concentrations of the Cu, Mn and Fe indicators in the waters of the rivers Panova, Asarelska and Lulikovitsa should not exceed the normative defined Annual Average Value. To control the outflow of acidic wastewater on the surface of the catchments. In this way, we will prevent the processes that would activate the release of heavy metals, which through surface streams can reach the river currents and cause toxic contamination.

LITERATURE

EN Standard Store (2007, June 29). *Water quality - Sampling - Part 1: Guidance on the design of sampling programmes and sampling techniques (ISO 5667-1:2006)*. Retrieved from https://www.en-standard.eu/search/?q=EN+ISO+5667-1

EUR – Lex (2000, December, 22). *Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy*. Retrieved from https://eur-lex.europa.eu/eli/dir/2000/60/oj

Lavoie, I. & Campeau, S, (2010).Fishing for diatoms: fish gut analysis reveals water quality changes over a 75-year period. *Journal of Paleolimnology*, 43, 121–130.

LEX.bg (2014 September, 23). *Ordinance N-4 for characterization of surface water. Promulgated, SG. 22 of the 5.03.2013*. Retrieved from https://lex.bg/bg/laws/ldoc/2135841270

Mugnai, R., Oliveira, R. B., Do Lago Carvalho, A. & Baptista, D. F. (2008). Adaptation of the Indice Biotico Esteso (IBE) for water quality assessment in rivers of Serra do Mar, Rio de Janeiro State, Brazil. *Tropical Zoology Journal*, 21, 57–74.

Ollis, D. J., Dalls, H. F., Esler, K. & Boucher, C. (2006). Bioassessment of the ecological integrity of river ecosystems. *African Journal of Aquatic Science*, 31, 205–227.

Zlatunova, D. S. (2016). Construction of complex ecological polygon in the region of „Assarel-Medet", JSC. Sofia, Sofia University.

Zlatunova, D. S. (2017). Construction of complex ecological polygon in the region of „Assarel-Medet", JSC. Sofia, Sofia University.

Zlatunova, D. S. (2018). Construction of complex ecological polygon in the region of „Assarel-Medet“, JSC. Sofia, Sofia University.
Zlatunova, D. S. (2019). Construction of complex ecological polygon in the region of „Assarel-Medet“, JSC. Sofia, Sofia University.