

THE IMPACT OF INDUSTRIAL ACTIVITIES ON SURFACE WATER QUALITY IN MUNICIPALITY BOR, SERBIA

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ABSTRACT: *Bigger part of the basis of industrial development consists of non-renewable mineral resources such as ores, non-metallic minerals and energy resources. The Republic of Serbia is among the countries with diverse and relatively rich mineral resources with significant copper ore deposits concentrated in Timok's igneous mass, ie. in the area of Bor and Majdanpek.*

Decades of exploitation and copper ore processing in the area of Bor and Majdanpek has significantly influenced on the environment through the degradation of large areas of land by depositing of huge amounts of mining waste and the appearance of mine waters in them. Mine waters appear in the form of leachate and natural resources, which contain heavy metals and sulfuric acid.

These waters pollutes nearby streams and small rivers, affecting the water quality of the Danube Basin.

Some of the physico-chemical parameters of mine waters as perennial pollutant of surface water flows are presented and analyzed in this paper.

Key words: *industry, environment, mine waters, heavy metals, surface waters*

Introduction

The Republic of Serbia has sufficient reserves of water to meet own needs, but only if they are rationally used and protected from contamination. The complex geological structure and favorable geological conditions produced considerable wealth in mineral and thermo mineral waters on the territory of the Republic of Serbia. It is estimated that in Serbia ground waters provides 70% of water demands for households and industry while in Vojvodina they are exclusive resource for water supply. Nowadays in Serbia, according to available statistics and estimates, the amount of water that are exploited for the public sector and individual water supply of the rural population is about 500 million m³ per year of groundwater [1].

Bor administrative district according to its natural characteristics is one of the most interesting geographic regions in Serbia. Reasons for such characteristics are:

- Geological structure of the field - in the middle of the territory igneous rocks are spread, while on the eastern and western part is the limestone massif.
- Morphology of terrain – mountain ranges that belongs to Carpathian-Balkan mountain system are separated with canyons and river valleys. The canyons of rivers in karst terrain are highlighted by beauty and biological significance.
- Hydrogeology – numerous of water springs on the the fringes of karst terrain, short torrential rivers, their sinks and dry river valleys are home to specific wildlife.
- Climate conditions that have specific characteristics at the sites of karst areas and canyons.

Intensive and long-term exploitation of mineral resources in Mining & Smelting Basin Bor in order to obtain copper and precious metals are greatly influenced on the quality of the environment and on the exhaustion of non-renewable natural resources. As an addition to the air and water pollution it has led to significant land degradation and huge amounts of solid waste generation [2]. Participation of preserved nature area in the total area of the Municipality is about 14% while the rest of 86% is under intensive human influence [3]. Utilization of renewable natural resources surrounding Bor is neglected.

Forests, waters, thermo mineral springs, biodiversity, different geomorphological landforms are values whose sustainable use parallel with development of new industries, offers the opportunity for economic growth of the region and the survival of the population.

Results and disscusion

Bor Administrative District, located in the Eastern Serbia on the area of 3506 km², comprises four municipalities: Bor (administrative center), Negotin, Kladovo and Majdanpek. According to the census of 2011th it has a total of 123 848 inhabitants. Town of Bor is known as the center of the largest copper mine in Europe whose exploitation began in 1903.

At first glance, the Bor district has exceptional hydrological potential. The river Danube flows on the northern border; Timok on the eastern and Pek on the western side (Figure 1) [4]. There are some small rivers and streams and several lakes like Đerdap I, Đerdap II and Bor Lake on its territory. However, water supply is a major problem in the Bor district for the following reasons:

- Danube River is a cross-border river whose quality cannot be managed by local communities.
- A large number of rivers are contaminated with wastewaters.

- Kriveljska and Borska River but also Timok are contaminated by mining, industrial and municipal wastewaters. Pek is also polluted by mine and municipal wastewaters. There are a number of other, smaller rivers whose natural composition is changed due to the economic activities in the territory of the District.
- Major changes in the abundance of groundwater sources and water flow in rivers.

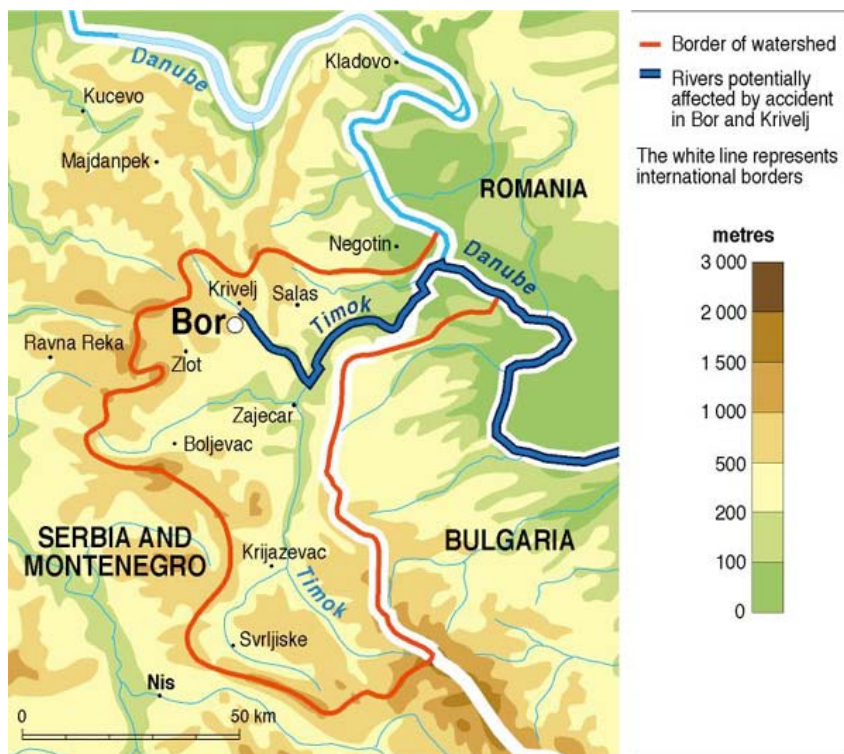


Figure 1. River Timok basin [3]

Industrial and urban development, if we look at the Bor district, was the fastest in Bor and Majdanpek. On the one hand, it has affected the wage growth of workers, but on the other hand very little attention was paid to environmental protection. During the long-term exploitation of copper ores a large amounts of wastewater has been released into surface waterways, causing pollution of water sources downstream of the copper mines in Bor and Majdanpek even nowadays. On the territory of the copper mine in Bor, the most important are Kriveljska and Borska River. Table 1 primarily shows the content of heavy metals in Kriveljska River downstream from the point of inflow of wastewaters from flotation plant and open-pit mine.

Table 1. Quality of water from Kriveljska River for the period between 2006 and 2013 [5]

Year	Fe, (mg/dm ³)	Cu, (mg/dm ³)	Cd, (mg/dm ³)	Zn, (mg/dm ³)	Ni, (mg/dm ³)	Suspended particles on 105°C, (mg/dm ³)	pH
2006	2.81	0.376	/	1.487	/	184.00	6
2007	0.195	0.611	/	0.17	0.015	203.75	6.12
2008	1.89	0.81	/	0.36	/	182.50	5.88
2009	24.45	15.70	0.0085	0.566	0.037	172.40	5.62
2010	455.40	168.14	0.033	13.04	0.25	250.33	5.78
2011	0.23	2.34	0.035	0.69	0.04	276.75	5.80
2012	18.19	6.62	0.016	0.41	0.041	460.90	7.215
2013	43.85	9.96	0.014	0.42	0.05	236.3	6.36
Legilastive limits	1.00	0.10	0.01	1.00	0.10	80.00	6-9

It can be seen from Table 1 that Kriveljska River is highly polluted with heavy metals as a result of mining activities in the area. It can be seen also, its perennial contamination with copper and iron ions. There is an increased acidity of water from Kriveljska River and a significant concentration of suspended particles that gives a characteristic yellow color of water.

Borska River is cut by Open pit in Bor. Their water are tapped and used for water supply of mining facilities in Veliki Krivelj. Downstream of Bor, a riverbed of Borska River remained without natural flow of water. Wastewater from mining and metallurgical facilities and households are being discharged into empty riverbed. Thus the empty riverbed of Borska River has become a collector of wastewaters from Bor. Borska River with Kriveljska River as a tributary is major polluter of Timok in their midstream. After the point of inflow, Timok becomes unusable for the population in coastal areas. Rivers downstream from mining and metallurgical complex and the point of discharge of sanitary waters are generally transformed into open wastewaters collector. They cannot be used for any purpose and present limiting factor of economic activities and livelihoods of villages on riverside. Leaching of accumulated flotation tailings on their banks produces contaminants which pollute groundwater in the area. Wastewaters from Bor are cross-border and regional problem. They jeopardize settlements near polluted rivers in Serbia and Bulgaria and affect water quality of the Danube. Solving this problem is important not only for Serbia but for the Balkan as well as for the use of Danube.

Conclusion

Copper production in Mining & Smelting Basin Bor was followed, from the beginning, by environmental pollution. In the past

years, insufficient attention and resources were devoted to wastewater treatment. As a result, there has been deterioration in the quality of water streams. Risk also represents the uncontrolled discharge of untreated wastewater into local streams and gullies, which jeopardizes groundwater resources. Water protection measures are rarely implemented. Regular chemical and physicochemical analysis of surface waters, ground waters and wastewaters are performed nowadays in copper mines in Bor and Majdanpek, but not their purification. Elimination of current surface water contamination could be achieved by collecting mine waters and their treatment, with possible valuation of copper. As a part of new copper smelter, a plant for wastewater treatment from Copper Smelter and Electrolysis plant is going to be built in order to eliminate further pollution of Borska Reka river by heavy metals and sulfuric acid.

Modern processes for acid mine water treatment, such as membrane techniques, requires capital investment which could be a problem. Such investments are missing in the times of economic crisis, especially in poorer areas. Without them there is no inclusion into modern European society and international legal obligations to protect environment could not be fulfilled.

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