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POLLUTION OF AIR, WATER AND SOIL FROM INDUSTRIAL PRODUCTS OF THE EXPLOITATION AND PROCESSING OF COPPER ORE IN BOR

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ABSTRACT
In this paper is shown emission and immission of pollutants generated during the copper production in RTB Bor, which have direct and significant impact on air pollution. The paper also presents the characterization of industrial wastewater generated during the mining and processing of copper. Also is shown the chemical composition of the soil samples which were taken from several locations around Bor. The results of emissions measurements indicates that the concentration of sulfur dioxide and suspended particles containing heavy metals and metalloids often over the allowed limits. Industrial and mining waste water flows into the Bor River, making it one of the most polluted rivers in Europe. The results indicate the need of wastewater treatment prior to discharge into the Bor River. Flooding of polluted river leads to pollution of soil with heavy metals and metalloids.An additional effect of soil pollution are the pollutants from the air.
Keywords: pollution, monitoring, heavy metals

1. INTRODUCTION
Mining and copper production in Bor over the past hundred years has had a huge impact on the environment of the city and its surroundings. The biggest cause of air pollution in Bor and the surroundings are smelter gases generated in the smelting of copper concentrates which contain high concentrations of sulfur and heavy metals that multiple exceed allowed values.
Bor River in which the flow of sewage from the tailings, flotation and other facilities for the production and processing of copper is one of the most polluted rivers in the world [1]. The greatest impact on pollution Bor River have industrial wastewater generated during the copper production and acid mine waters caused by flushing deferred overburden from surface mining and flotation tailings with atmospheric waters. Acid mine water with a pH range of 3 to 4, containing Cu, Fe, Mn, Zn, Pb, Ni, Bi, Cd, etc., resulting from contact with solid industrial wastes with air and weather have is and that water pollute surrounding waterways.
The analysis of river sediments Bor River determined the concentrations of copper and other heavy metals exceeding the maximum permissible concentration prescribed by the legal regulations of the Republic of Serbia [2], which directly affects the pollution of the catchment area of the Timok River and Danube and represents an international environmental problem.
In this paper is shown the emission of pollutants and emissions that occur during the copper production in RTB Bor and directly the most significant impact on air pollution. The paper also presents the characterization of industrial waste water [3] and mine waste water. Also, the chemical composition of soil samples which were taken from several locations in surrounding of Bor is shown.

2. AIR POLLUTION

Industrial activities in Bor are the main cause of air pollution. Sources of air pollution in Bor and its surroundings are [4]:

- Mining: underground and surface mines, tailings and mining waste dumps
- Metallurgy: smelter
- Metal Processing Factory, Heating Plant, Transportation and other

Table 1 shows the results of measuring emissions of SOx, NOx and particulate matter from the major sources of pollution in Bor for a year [5].

Table 1. The most significant stationary sources of pollutants in Bor in 2010, t / year

	Izvor	SO_x/SO_2	NO_x/NO_2	Suspendovane čestice
1	Smelter - Concrete chimney (reactor and converter)	78365		289
2	Smelter - masonry chimney (stove flame)	3700		464
3	Sulfuric acid plant	2650		
4	Electrolysis – Jewelry plant			0.63
5	Electrolysis - Production of metal salts and galvanic preparations plant		0.34	
6	Heating Plant Bor	290	64	11
7	Heating Plant Bor - Boiler room Banjsko Field	12.10	1.07	0.35
8	Lime plant in Zagradje		1.06	37.84
9	Jama - ventilation shaft 4 - ore body Tilva Roche		5.73	17.98
10	Factory for equipment and parts - powered shotgun			1.24
Total		79717.10	72.20	822.04

The results indicated that 99.62% of the total measured SO_2 emissions is the result of the activities of RTB Bor, also 98.47% of the issued and suspended particles originating from RTB Bor. As for NO_x value of 90.12% is the result of activity Heating Plant.

The content of sulfur dioxide and particulate matter measured at four measuring points in Bor. The mean annual immission values for SO_2 and particulate matter are shown in Table 2.

Table 2 Average annual values for SO_2 and particulate matter in 2010. year.

Measuring point	Mean value $SO_2(\mu g/Nm^3)$	GVI ($\mu g/Nm^3$)	Pb ($\mu g/m^3$)	Cd ($\mu g/m^3$)	Ni (ng/m^3)	Cu ($\mu g/m^3$)	As (ng/m^3)	Hg ($\mu g/m^3$)
City park	182.2	125	0.1	0.008	0.4	1.17	4.57	0.18
Institute	94	125	0.1	0.007	0	0.92	38.2	0.01
Jugopetrol	101.6	125	0.1	0.005	0.0	0.75	20.6	0.05
Brezonik	97	125	0.1	0.008	0.2	1.01	20.0	0.05

**GVI – limit emissions SO_2*

Results of average annual emissions of SO_2 indicated that the values recorded in the city park above permissible limits. Also,concentration of arsenic and cadmium from prticulate matter are above the limited value.

3. WATER POLLUTION

Sources of water pollution in the area of Bor are:

- mine waste and drainage water originating from the active mine,
- drainage water from the flotation tailings which are no longer in function,
- old inactive mine overburden dumps
- City - urban wastewater, which is discharged without treatment directly into the Bor River.

These wastewaters directly pollute Bor and Krivelj River, which after the merger form the Bela River. The greatest impact on pollution Bor River have industrial wastewater generated in the production of sulfuric acid, copper electrolytic refining, production of copper sulfate and processing of anode slime. Table 3 shows the characterization of the composite samples of industrial waste water and mine waste water from the Robule accumulation [6].

Table 3 Chemical composition of industrial waste and mine water

Parameter	Industrial waste water	Mine waste water	MAC mg/dm^3
	The composite samples	**The Robule accumulation**	
Solid residue dried at 105 ° C g/L	23.58 – 238.24	484.00	
Suspended particles g/L	2.42 – 80.16	3.16	
H_2SO_4 g/L	2.25 – 10.47	15.67	
Sb mg/dm^3	<1	**352.50**	0,05
As mg/dm^3	**45 - 172**	<0.1	0,05
Cd mg/dm^3	1 – 11	<0.1	0,01
Cr mg/dm^3	<1	**430.00**	0.5
Co mg/dm^3	1-2	<0.1	2,0
Cu mg/dm^3	**123 - 1080**	1.20	0,1
Fe mg/dm^3	**3360 - 11690**	**61.80**	1,0
Pb mg/dm^3	2.8 – 5.9	**780.00**	0,1
Mn mg/dm^3	2,9 – 9,0	1430.00	
Ni mg/dm^3	4,3 - 62	**108.80**	0,1
Se, rastvorni mg/dm^3	**1 - 121**	0.68	0,01
V mg/dm^3	1.3 - 6	**140.00**	0,5
Zn mg/dm^3	**51 - 2197**		1
Ag mg/dm^3	<1	**23.40**	0,02
Hg mg/dm^3	0.001 – 0.014	<1	0,001
Cl^- mg/dm^3	17.47 – 131.72	0.001	
SO_4^{2-} mg/dm^3	16949 - 56013		

Based on the results shown in Table 4 can be concluded that most of the present heavy metals have multiple values who exceed the maximum allowable value.

Table 4 The chemical composition of the Bor River

Elements	Al	Sb	As	Cd	Ca	Cr	Co	Cu	Fe	Pb	F	Mn
mg/dm^3	15.2	0,91	1,2	4,86	207	0.0	72,1	354,4	3593	0,06	0,2	5575
Elements	Ni	Se	Na	V	Zn	Ag	Bi	Sr	Cl^-	SO_4^{2-}	Mg	Te
mg/dm^3	185,0	5,86	38,1	0,2	1079	0,0	0,01	1090	17,0	718	50,5	0,02

4. LAND POLLUTION

Hazardous elements present in the air directly affect the soil so as to accumulate on the surface due to the effects of atmospheric precipitation penetrate into the deeper layers of the soil.

Results of chemical analysis of soil from coastal areas of the river has been done and the results are shown in Table 5.

Based on the data presented in Table 5, it can be concluded that the some of sampled soil content the concentration of Cu, Pb, Zn, As, Cr above the limited value., and because of that the land from these locations classified as hazardous waste and are necessary preventive measures akording defined legal regulations.

5. CONCLUSION

Based on these analyzes present pollutants in air, water and soil have a significant impact on environmental pollution in Bor and its surroundings. The main sources of pollutants originating from activities taking place in the manufacturing process of copper in Mining and smelting company Bor. The results of measurements of emissions at the source of pollution and continuous air monitoring indicates that the concentration of sulfur dioxide and suspended particles that contain heavy metals and metalloids often exceeds allowable values.

Industrial and mining wastewater flow into the Bor river making it one of the most polluted rivers in Europe. This indicates that it is necessary to do a treatment of wastewater before discharge into the Bor river. Due to precipitation leakages and contamination of coastal rivers it leading to the concentration of heavy metals and metalloids in soil. The additional effect of soil contamination are the contaminants from the air.

All the pollutants present in the air, water and soil adversely affecting the food chain and therefore the entire living world.

Table 5 The content of heavy metals in coastal rivers in the direct area of responsibility Mining and smelting company Bor

Location	The sample	Pb,mg/dm^3	Cu,mg/dm^3	As,mg/dm^3	Zn,mg/dm^3	Ni,mg/dm^3	Cr,mg/dm^3	Cd,mg/dm^3
The land near the mine waste water from the pit Bor	1S	95	2580		377	25	17	3
	2S	105	675		277	34	13	2
	3S	69	2025		244	28	12	3
Land south of the mine Cerovo	4S	55	2715		171	28	12	3
	5S	45	1850		257	29	18	3
	6S	60	1650		183	31	10	3
Land from coastal of Ravna River	7S	325	4625		3013	36	104	2
	8S	197	1750		295	25	63	2
	9S	151	1810		287	29	48	2
Land from coastal of Bor River	10S	554	5625	110	672	30	114	4
	11S	704	5675	180	590	29	199	4
	12S	515	5900	123	580	30	163	4
Land from coastal of White River	13S	21	56		74	64	128	2
	14S	23	57		73	57	95	1
	15S	29	44		75	55	107	2
MAC, mg/l*		**5**	**25**	**5**	**250**	**20**	**5**	**1**

** According to the Regulation on categories, testing and classification of waste ("Sl.gl. RS", br. 56/10),*

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