

Effects of water quality on mobilization of heavy metals in the mining area

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Abstract

The water heavy metals pollution of open and underground waterflows in mining areas, are very well documented all over the world. Movement of highly acidic water, rich in heavy metals, to the ground and surface natural water, may harmful effects on plants, animals and humans[1]. Wtare impacted by acid drainage, can be toxic to aquatic life, unsuitable for portable water uses, as well as for livestock watering or irrigation[2]. Due to that, in some countries water protecting systems are often obliged and usually regulated by law. Unfortunatelly in B&H, majority of these systems were devastated or broken down during the recent war, or even were not built in spite the existing regulations. In the mining areas water pollutions were detected (TSS, COD, TOC, acidity, heavy metals), as it was in the area of Banovići, North East B&H, with open coal mines.

Our interest was to study mobilization of heavy metals in the area of Gornja Višća (open coal mine Banovići) and to sugesst best solution for reducing the negative impact of open-coal mine overburden on water quality

Keywords: heavy metals, water quality, overburden, mining area.

Area of investigation

The area of Gornja Višća is one of the biggest open coal mine overburden area in B&H (about 8,6 km²), which is incoorporated in a rural countryside. On the native ground there are settlements, very often intersected by overburden pits and lakes, emerged during exploitation and now fullfilled with water. The ratio between coal and overburden is 1 : 12 (coeficient of loss 1,4 – 1,6), which reflects a fact that much bigger volume of overburden was realized comparing the native ground. The good indicator of natural disturbance is the area elevation peak: before the exploitation difference between the highest and lowest peaks was 53 m; now it is 120 m (205 qnd 325 m a.s.). During some 40 years of exploitation the coal mine has totally changed landscape.

Geologically the area belongs to rock masses of neogene and quartare (depth of some 800 m) followed by clay and clayey masses, which present lateral and ground hydrological barrierres to underground waters.

Hydrologically the area inclines to the river Oskova, the tributary of the main river in the region, river Spreča. The Oskova catchment area ranges 151 km² and some 12,8 km² belongs to the Višća region. In this area (Višća area) three small waterflows are present (Višća, Vodice, Brestovica) that are permanentlly changing their flows (special middle and down parts) caused by mine works. This is probably resulted in new water communications in the underground. Hydrological investigations showed that the average flow for the river Oskova was 2,50 m³/s (maximal 63,0, minimal 0,126 m³/s) with the draining coeficient (Vn/Vb) 0,55.

Approache

Field survey has showed that majory of water from the overburden area is draining away by waterflow Vodice, the small tributary of Oskova. An artificial lake in a pit is formed formed, supposed to be in connection with underground water of the area. We have focesed our investigation on these three water entities, including also soil-overburden quality investigations as an potential source of pollution.

Methods

Field investigation

Six sublocations of overburden and coal waste material, and four sublocations of natural ground were identified for soil-overburden sampling. The samples were obtained by standard rotary drilling up to 5 m (φ 128/101 mm). After definition of the litological profile, the „weakest“ zones were indentified in the cores (zones which by their heterogenity, porosity and permeability present the most possible way of fluid transport) and took as the sample. Two possible ways of transportation were identified and consequentlly two samples/core were taken at three boreholes (B-2, B – 8, B-9) in overburden region and at one in natural ground region (B-6). Also, there was place of mixing domestic waste and

overburden (B-10) that was presented as special case. All together fourteen samples were taken: nine from overburden (samples: 1,2,11,3,7,8,13,9,14), four from natural material (samples:4,5,6 and 12) and one (10) obtained by mixing of waste and overburden material.

Water sampling were made at five locations: two at the stream Vodice (source and down flow), two at the river Oskova (entrence and departure of the Višća area) and one at the lake. The sampling was done three times: period of low waters, period of middle waters and period of high waters. The period March to June was chosen for sampling. All together 15 samples were taken. The following parameters were done in situ: temperature, pH, CND, TSS, turbidity, CO₂, alcality, acidity and N-NO₂⁻.

Lab investigation

Soil samples were homogenized (< 2 mm) and analyzed on pH, organic matter, carbonate contents. The obtained aqua regia extracts were analyzed on Fe, Mn, Ni, Cr, Cu, Pb, Cd, Zn and As by AAS. Water samples were analyzed on Ca, Mg, K, Na, SO₄²⁻, Cl⁻, Fe, Zn, Mn, Cu, Cr, Ni, Cd, Pb, and As, also by AAS.

Results

Table 1 presents results of soil physical-chemical investigations

Table 1. Soil analysis: physical and chemical parameters

Borehole	Sample No.	pH	Org.matter %	CaCO ₃ %	Fe %	Mn ppm	Ni ppm	Cr ppm	Cu ppm	Pb ppm	Cd ppm	Zn ppm	As ppb
Overburden material													
B - 1	1	7,8	1,25	56,3	1,24	74,5	186	65	45,4	53,7	41,6	4,9	52,9
B - 2	2	7,8	0,10	11,4	1,99	41,7	21,4	126,1	18,5	43,5	76,1	4,4	29,0
	11	7,8	3,03	29,9	1,65	76,9	193,4	79,9	20,7	46,1	0,6	3,8	< 0,0
B - 3	3	7,7	1,47	11,0	2,10	38,9	195,9	41,5	58,2	54,7	175,3	11,2	< 0,0
B - 7	7	7,9	0,83	40,3	1,84	89,4	298,4	115,0	18,7	44,6	18,1	6,6	33,1
B - 8	8	7,7	0,63	21,3	1,32	44,2	117,0	69,7	14,3	36,1	18,7	10,9	< 0,0
	13	7,6	0,51	28,5	1,79	56,7	122,2	72,5	15,4	59,4	< 0,0	4,4	80,6
B - 9	9	7,9	0,53	20,5	1,59	58,7	135,5	74,7	15,1	36,9	< 0,0	4,3	43,0
	14	8,0	0,70	41,1	2,21	119,0	171,8	79,0	20,7	52,8	< 0,0	6,9	55,7
average		7,8	1,00	28,9	1,75	66,7	181,6	80,4	25,2	47,5		6,4	
Natural ground													
B - 4	4	7,2	1,57	4,2	1,89	70,3	84,9	61,4	19,9	51,9	158,2	5,2	< 0,0
B - 5	5	7,3	4,63	12,2	2,61	52,3	58,9	172,1	30,3	61,3	102,2	9,8	< 0,0
B - 6	6	7,3	1,51	1,1	1,47	40,5	50,1	32,0	11,9	36,7	30,8	6,9	< 0,0
	12	7,3	0,50	1,9	1,97	17,5	67,2	51,1	28,2	46,7	0,3	8,0	80,3
average		7,3	2,05	4,8	2,00	45,2	65,3	79,2	22,6	49,2	72,9	7,5	
Mixture of overburden and town waste													
B - 10	10	7,7	2,19	19,4	2,19	56,5	483,6	288,9	17,7	49,6	< 0,0	5,1	< 0,0

Table 2.: Water analysis: physical and chemical parameters

Parameters	Stream Vodice						River Oskova						Lake		
	upflow			down flow			upstream			downstream			I	II	III*
	I	II	III	I	II	III	I	II	III	I	II	III			
Temp.(°C)	11,1	13,0	13,5	10,4	12,5	14,9	7,6	14,2	13,8	7,8	14,3	14,3	9,8	16,6	19,6
CND, $\mu\text{S}/\text{cm}$	1562	1701	1789	729	996	1023	324	823	701	372	734	1077	741	1448	1114
Turb., NTU	15	6	4	4	0	3	24	12	18	21	33	122	7	12	3
pH	7,17	7,50	7,15	7,02	7,65	7,25	7,66	7,75	7,95	8,06	7,40	7,75	6,89	7,80	7,65
TSS(105°C)	1660	1712	2082	990	888	1164	364	802	996	441	1144	1594	1390	1356	1770
Ash, mg/l	1480	1412	1578	712	706	856	158	606	694	187	908	1280	1102	1128	1428
SO ₄ ²⁻ , mg/l	560	744	954	298	340	512	130	360	296	160	354	620	620	740	582
Cl ⁻ , mg/l	1,9	1,7	1,1	1,4	1,7	1,2	2,3	2,3	1,8	2,0	2,2	1,5	1,5	1,8	1,9
Ca, mg/l	300,8	294,4	319,2	155,2	149,6	97,6	54,4	111,2	123,2	62,4	153,6	159,2	158,4	163,2	215,2
Mg, mg/l	88,4	67,9	155,3	51,1	63,0	132,4	19,5	51,3	14,7	28,8	26,4	75,7	112,3	121,6	60,6
Na, mg/l	17,85	24,89	62,1	21,44	35,02	43,4	17,1	32,07	94,8	12,60	65,72	85,4	66,60	65,50	70,3
K, mg/l	1,86	5,16	5,16	3,80	0,83	3,64	2,86	3,80	3,70	2,32	4,64	4,43	5,78	5,68	6,88
Fe, ppm	0,36	0,24	0,18	0,53	0,04	0,09	0,68	0,74	0,36	0,23	1,46	2,48	0,08	0,02	010
Zn, ppm	0,02	0,26	0,21	0,06	0,13	0,16	0,14	0,12	0,05	0,06	0,14	0,21	0,16	0,12	0,14
Mn, ppm	0,03	0,02	0,02	0,04	0,09	0,18	0,04	0,01	0,09	0,09	0,05	0,03	0,07	0,09	0,02
Cu, ppb	26,1	31,0	37,1	26,1	25,1	34,0	23,4	29,1	31,4	24,2	28,4	33,1	25,2	29,6	34,1
Cr, ppb	16,9	43,9	55,6	22,2	37,6	52,5	25,3	33,5	49,2	27,9	33,4	49,9	19,5	45,2	55,8
Ni, ppb	2,5	1,2	5,1	2,7	5,4	2,8	1,4	2,6	3,1	4,2	3,1	3,7	3,4	4,8	3,1
Cd, ppb	0,12	0,10	0,12	0,24	0,11	0,10	0,14	0,00	0,06	0,10	0,00	0,00	0,13	0,14	0,11
Pb, ppb	17,6	12,1	11,8	13,6	8,4	12,4	14,2	12,4	14,1	7,5	10,6	7,8	12,8	10,6	13,6
As, ppb	0,00	0,00	0,17	0,24	0,16	0,18	0,10	0,34	0,24	0,12	0,00	0,31	0,26	0,00	0,01

I – first sampling period (low waters); II – second sampling period (middle waters); III – third sampling period (high waters)

Formation of overburden area totally changed physical and chemical matrix of waters in the Višća region. A very heterogenous material from inside the ground, now is at surface exposed to the atmosphere. Comparison of basic physical and chemical parameters of natural ground (up to 5 m deep) and overburden material, focus following findings: carbonate rocks, basic geological material of the region, are now at the surface, participating in average with 28,9 % (from 11 – 56,3%) contrasting some 4,8% (from 1,1 – 12,2%) in the natural surface layer. pH is consequently higher for some 0,5 units (in average for overburden 7,8 and for natural ground 7,3). Content of organic matter (expressed as humus) is almost 100% smaller comparing natural ground. All that influenced the availability of metals, determined in aqua regia extracts. The biggest influenced showed Mn and Ni, while it is difficult to make similar conclusions for other, because of the big heterogeneity of samples. It seems that there are no big differences in contents of Fe, Cr, Cu, Pb, Zn, Cd or As.

If the domestic waste is mixed with the overburden, the significant increase of available Ni and Cr resulted.

As we focused, the stream Vodice drained away majority of water from the overburden area. Quality of water reflects the first direct contact with overburden. Water is basic, more pronounced at the source. Comparing other two water entities (river and lake) this water is the most loaded in all three period of sampling, with the highest conductivity, TSS and ash; very high Ca and sulfate. Sampling downflow reflects gradual precipitation of sulfate, Ca, Mg, Zn, Cu and Pb.

River Oskova entrances area of Višće, less loaded comparing its content at the point when it leaves it: TSS, ash, sulfate, iron are much higher. The concentrations of all other measured parameters are in the same line: in average they are higher at the leave, except for Pb, Cd and As.

Lake's water has high TSS, ash, calcium, sodium, potassium and sulfate. Comparing water of stream and river, the content of Cr, Mn and Ni are a little bit higher while Fe and Pb contents are lower. Probably high contents of particles (TSS) are in connection with metal concentration, which are usually associated with them.

The presence of carbonate rocks prevent production of acid mine drainage, usually present when sulfide are mined. Probably some pyrite is present because there is high concentration of sulfate (gypsum is not present). In situ exposure of pyrite to air and water results in liberation of iron, and oxidation of sulfide to sulfate. We didn't find higher concentration of Fe in waters (probably precipitated as carbonate) but high concentration of sulfate are present in all three water entities.

Conclusion

Investigation of water quality of stream, river and artificial lake in the overburden area of open coal mine in B&H, has showed that there is strong impact of these activities on water quality. Thanks to the fact that basic overburden material is carbonate, alkaline by itself, possible acid draining and mobility of heavy metals are prevented. The impact is mainly limited to the high concentration of inorganic particles (high TSS, ash, CND), which physically lower light penetration, lower DO, and act physically on the system (but could present problem in some crisis situations).

In this conditions negative impact to the environment could be decreased by simple mechanical precipitation.

Literature

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