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CONFERENCE PROCEEDINGS CONTENTS

SECTION ECOLOGY AND ENVIRONMENTAL PROTECTION

CAPTURING OF ACID DRAINAGE MINE WATER FROM THE BUNARDZIK WASTE DUMP IN FUNCTION TO INSTALLATION FOR LEACHING OF COPPER AND PROTECTION OF THE ENVIRONMENT IN THE BUCHIM COPPER MINE, REPUBLIC OF MACEDONIA

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ABSTRACT

Acid mine drainage waters around the Buchim Mine were challenge for researchers and Buchim company itself, but of highest interest it was for the environmentalists. In several phases Buchim Mine was solving the problem of pollution around the mine, whhen definitely this environmental problem was solved with the construction of the copper leaching facility. Large quantity of material deposited at the Buchim Mine waste dump of around 130 Mt today represents source of drainage copper solutions that are captured by pipe lines net and end up into the copper leaching facility. In this complex system was enclosed newly formed Bunardzik waste dump, where at the moment are deposited approximately 23 Mt of waste material with around 0.11-0.12% Cu. Actually from this waste dump are leaching 15 to 20 *l/s* of solution with more than 380 mg l^{-1} copper, which through two precipitators and net of pipes delivers the solution to the copper leaching facility. This drainage system during the periods of decreased rainfalls provides complete capture od drainage water from the newly formed Bunardzik waste dump and western parts of the old Bucim mine waste dump. Our study confirmed that along the Bucimski Potok there are not passing contaminated or polluted surface waters.

Keywords: Drainage system, waste dump, water capture, pollution, Buchim Mine.

INTRODUCTION

Buchim Mine has been built more than 38 years ago on the well known porphyry copper deposit Buchim. During the four decades of continuous exploitation around the Buchim Mine was created surface waste dump were have been stored more than 130 Mt of material and more than 110 Mt material within the hydrotailling dam. These secondary landfills for years have been considered as basic sources of anthropogenic influences and contamination of air, soils and especially waters. For many years those influences haven’t been subject of serious scientific and practical studies, but however during last period they have been studied from few stand point according to the national and European standards for managing the secondary waste and environmental protection [1]. [2], [3], [4], [5], [6]. After that period studies around the Buchim Mine have been intensified and to longer distances in regards of running waters while it have been set monitoring points for particular hot spots around waste dump and hydrotailling dam with associated water drainage, ambiental dust monitoring, monitoring of soil contamination etc. Considering that issue have been completed some significant studies of soil contamination monitoring [7], [8] etc.

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Within this paper has been performed one compilation of an array of studies of waters that are draining the newly formed Bunardzik ore body mine waste dump, which have been added to an old waste dump mentioned above.

METHODOLOGY

Along newly formed Bunardzik ore body mine waste dump drainage system were sampled, analyzed and studied several localities such are: Precipitator 1 (in the immediate vicinity of the Bunardzik ore body waste dump), Buchimski Dol collector, UNDP dam (D_1) and Buchim Lake among several others that were studied occasionally (Figure 1).

Fig. 1. Google Earth map with locations sampled along the Bunardzik waste dump drainage system, Buchim Mine

1. Precipitator 1 (T-1); 2. Reserve/spare dam; 3. Buchim Creek collector; 4. UNDP dam; 5. Buchim Lake; 6. Waterfall after the Buchim Lake; 7. Dry riverbed after the outflow from the Buchim Lake.

Samples were collected during the continuous monitoring in 2013, 2014 an 2016 from the most environmentally threatening hot spots within the Buchim mine drainage system outlined below (Figure 1). Water was collected in polythene syringes, passed through a 0.45μm filter and transferred into polythene tubes. Water was acidified with 0.4 ml of 50% nitric acid. Conductivity and pH were measured in the field for all water samples. Samples were stored in a cool and dark place until they were returned to the laboratory analysis. Solutions were analyzed by ICP-AES at the Buchim Mine laboratory. A large number of analytes were determined but only those that are likely mining related and environmentally significant are presented and discussed here. The concentrations were compared to reference guidelines (Maximally Allowed Concentrations-MDK) to assess their significance.

ACID MINE DRAINAGE SYSTEM FROM THE BUNARDZIK WASTE DUMP

By the time we became aware that the mine wastes are the largest volume of materials handled in the world [9], and the generation of acidic drainage and release of water containing high concentrations of dissolved metals from these wastes is an environmental problem of international scale [10]. Acidic drainage is caused by the oxidation of sulfide minerals exposed to atmospheric oxygen. Although acid drainage is commonly associated with the extraction and processing of sulfide-bearing metalliferous ore deposits and sulfide-rich coal, acidic drainage can occur wherever sulfide minerals are excavated and exposed to atmospheric oxygen [11]. As we already know the consequence of the excavation of open pits, such is Buchim Mine itself, and other mining-related disturbances is that sulfide minerals previously isolated from the atmosphere are exposed to oxygen. Oxidation of sulfide minerals ensues. For example, pyrite oxidation and the factors affecting the kinetics of oxidation (O_2, Fe_3^+, temperature, pH, Eh, and presence or absence of microorganisms) have been the focus of extensive study because of their importance in formation of acid mine drainage [12], [13]. The oxidation of pyrite can occur when the mineral surface is exposed to an oxidant and water, either in oxygenated or anoxic systems, depending on the oxidant. The process is complex and can involve chemical, biological, and electrochemical reactions. In addition to formerly mentioned is that the open-pit mining result in the excavation of large volumes of rock to gain access to ore bodies. Rock of higher metal grade is processed, and rock below the cutoff grade is put to waste. Excess waste rock is deposited in waste-rock piles whose composition differs greatly from mine to mine because of variations in ore-deposit and host-rock mineralogy, and because of differences in the processing techniques and ore-grade cutoff values. In ours case, the Bunardzik waste dump (Figure 1; Figure 2), which was started in the second half of 2013, up to date contains 23 Mt of mine waste with an average of copper in the range 0.11-0.12% Cu. This new waste dump makes an addition to an existing (the old dump) of the Buchim Mine where has been deposited more than 130 Mt of ore waste. Draining waters are composed of meteoric waters flowing from upper parts above the mine waste pile (mine yard and Buchim village area) and passing through the mine waste, rain waters passing though the mine waste dump and flowing further downstream and ground waters infiltrating through the mine waste dump. Formerly mentioned Buchimski Dol and Buchim Lake are part of the drainage system/collector with channels around the location perimeter planned for the mine waste dump. This system collects part of draining waters from the mine waste dump and guides them to the Buchim Dol. Also, this gully constitutes of atmospheric waters redirected from open pit and ground waters under the mine waste. With the latest enhancements, waters at the bottom of open pit have been pumped into the pools for industrial water because they are unpolluted and can used again. They have been characterized by 30-45 mg/L), low pH value (3,6-5,5) and average flow of 15-20 l/s. For this study were made measurements that have shown increased values for sulphate ions (SO_4^{2-}), which probably is due to presence of sulfide ores in mine waste dump and occurrence of so called sulphate bacteria (Thiobacilusferioxidans). This bacteria represents the most common bacteria found in mine wastes [10]. Under certain conditions this acidophile aerobic bacteria increases the speed of oxidation of pyrit (oxidizes iron and inorganic sulfur compounds), which results in creation of sulfuric acid.

Fig. 2. Area of environmental interest, Buchim Mine

a) Newly formed waste dump of the Bunardzik ore body, Buchim Mine; b) Precipitator T-1; c) Outflow from the reserve/spare dam; d) UNDP dam; e) Buchim Lake; f) Dry riverbed of the outflow from the Buchim Lake.

This process and the presence of SO_4^{2-} point out to a possible local degardation of soil that have been in contact with waters.

RESULTS AND DISCUSSIONS

Analyses of surface water (Buchim Creek collector, Precipitator 1/T-1, UNDP dam D_1, Buchim Lake) and groundwater (V.I- and V.I-4) collected from the Bunardzik waste dump drainage area were performed in 2013, 2014 and 2016. Their alkalinity (pH), in 2013 and 2014, ranged 4.0 to 5.85 (Table 1). A distinctive feature of their chemistry is that for most samples Cu concentrations were several hundred times higher than those maximally allowed by national legislative (MDK; Table 1)

Table 1. Analysis results, March 2013

	Buchim Creek water collector	V.I-1	V.I-4	UNDP dam (D-1)	Merging of the Jasenov Dol stream and Topolnica River	MDK-3 class
Total dry matter at 105°C (mg/l)	1819	23426	7820	8615	6706	-
Total dry matter from filtrate at 105°C (mg/l)	1559	21227	6981	8581	6596	1000
Suspended matter (mg/l)	260	2199	839	34	110	30-60
Copper (mg/l)	1	380	1.6	140	95	0.05
Iron (mg/l)	< 0.01	12.9	<0.01	2.61	0.48	1.00
Consumption of $KMnO_4$ (mg/l)	4.74	17.54	10.58	8.06	7.27	5.01-10.0
SO_4^{-2} (mg/l)	935	5208	4725	5123	4385	-
Carbonate hardness (°N)	0.56	0.28	0.56	1.12	0.56	-
pH value	5.85	4	5.03	4.55	4.91	6.0-6.3

On the western margin of the open pit mine where was formed waste dump Bunardzik in the surface and sub-surface parts have been detected processes and products of copper bicarbonate and oxide minerals blossoming, which were prone to quick dissolving and drainage migration of copper that is reflected with increased copper concentration after first precipitating dam (T-1) in the adjacent vicinity of the waste dump (Table 1). These solutions then pass through another precipitator and reach the drainage system of the UNDP dam (D_1) from where by pipeline are transported to the ponds of the copper leaching facility in the vicinity (Figure 2; Table 1 and 2).

Table 2. Analysis results, September 2013

	Buchim Creek water collector	Precipitator (T-1)	V.I-4	UNDP dam (D-1)	Buchim Lake	MDK-3 class
Total dry matter at 105°C (mg/l)	35202	60834	29923	25059	28598	-
Total dry matter from filtrate at 105°C (mg/l)	34483	59089	29412	23050	27952	1000
Suspended matter (mg/l)	719	1745	511	2009	646	30-60
Copper (mg/l)	530	1040	6.2	49.0	310	0.05
Iron (mg/l)	11.2	20.0	0.19	1.31	1.95	1.00
Consumption of $KMnO_4$ (mg/l)	35.0	47.73	49.7	23.55	18.02	5.01-10.0
SO_4^{-2} (mg/l)	5385	5160	5439	5393	5420	-
Carbonate hardness (°N)	0.56	0.42	0.70	0.70	1.40	-
pH value	4.55	4.34	5.15	5.11	4.65	6.0-6.3

When there is a overflow from the UNDP dam, water with dissolved substances, where dominates copper, enters into the Bucim Lake. This lake is natural precipitator, but however during the wet season and increased rainfall, overflowing water from the Bucim Lake run through the Bucimski Potok and in such case represents pollutant for one part of the Damjan Field. However, such a scenario is very rare as can be seen from the Figure 2f, where after the construction of the copper leaching facility, this creek is mainly dry. Copper concentrations (as well as iron and some other parameters) in 2013, before (March, 2013) and after the start of building the waste dump (September, 2013) showed several times of magnitude higher values than allowed by MDK (Figure 3).

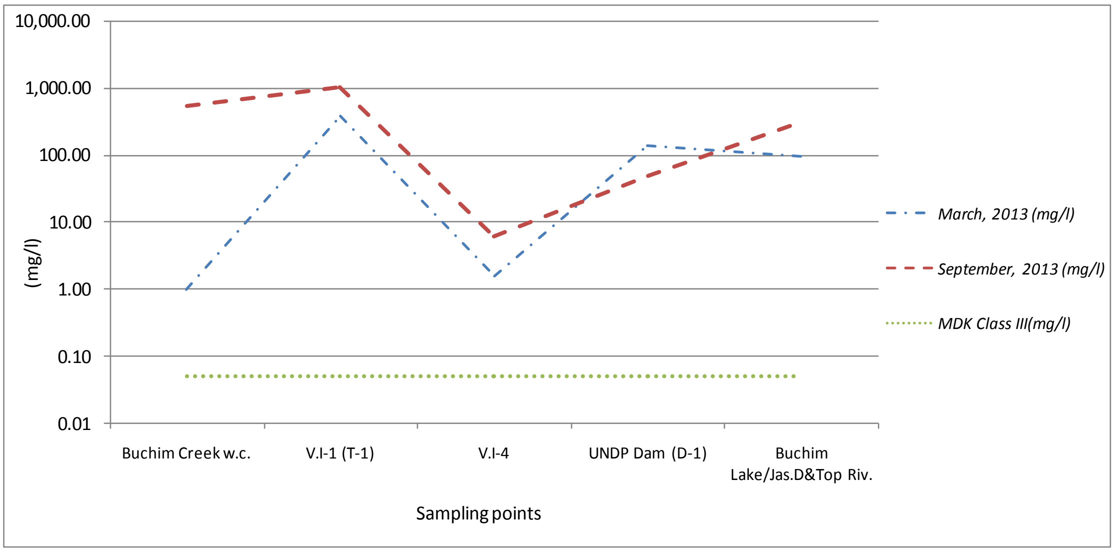

Fig. 3. Relation between copper analysis data in March and September, 2013 (vertical scale logarithmic).

Being highly intrigued by the eventual development and effects of the mine drainage system, we continued with the monitoring of the area in 2014 (Table 3) and 2016 (Table 4).

Table 3. Analysis results, May, 2014

	Buchim Creek water collector	**Precipitator (T-1)**	**V.I-4**	**UNDP dam (D-1)**	**Buchim Lake**	**MDK-3 class**
Total dry matter at 105°C (mg/l)	6074	3042	1024	3032	318	-
Total dry matter from filtrate at 105°C (mg/l)	5975	2955	1012	5678	310	1000
Suspended matter (mg/l)	230	99	78	153	136	30-60
Copper (mg/l)	385	58	2.5	6.3	3.4	0.05
Iron (mg/l)	11.8	18.0	1.2	1.85	2.1	1.00
Consumption of $KMnO_4$ (mg/l)	28.6	12.8	22.35	11.45	15.97	5.01-10.0
SO_4^{-2} (mg/l)	262	258	270	258	261	-
Carbonate hardness (°N)	0.41	0.48	0.55	0.59	1.20	-
pH value	4.8	4.1	5.4	5.77	6.58	6.0-6.3

As we assumed, effects of the system construction manifested in acidity reduction, all the sampling positions became more alkaline, while copper concentrations became from 2-20 times lower than previously, while the decrease of iron concentrations was not that drastic (Table 3 and 4). Mentioned decrease of the copper concentration, after the start of implementation of activities of the UNDP measures, was more drastic when plotted on the plot showing locations along that particular system (Figure 4).

Table 4. Analysis results, December, 2016

	Buchim Creek water collector	**Precipitator (T-1)**	**V.I-4**	**UNDP dam (D-1)**	**Buchim Lake**	**MDK-3 class**
Total dry matter at 105°C (mg/l)	5028	14837	4275	11775	16203	-
Total dry matter from filtrate at 105°C (mg/l)	4926	14512	4201	11693	15844	1000
Suspended matter (mg/l)	532	325	75	82	359	30-60
Copper (mg/l)	465	168.5	5.8	133.5	107	0.05
Iron (mg/l)	12.8	0.9	0.2	0.5	0.1	1.00
Consumption of $KMnO_4$ (mg/l)	35	11.98	12.46	10.48	9.62	5.01-10.0
SO_4^{-2} (mg/l)	3257	3757.8	2189	2699.4	2278.3	-
Carbonate hardness (°N)	0.47	0.33	0.63	0.38	0.68	-
pH value	4.56	4.22	5.63	4.26	4.25	6.0-6.3

Although copper concentration values were still above MDK values, this confirms the validity of activities applied (Figure 4).

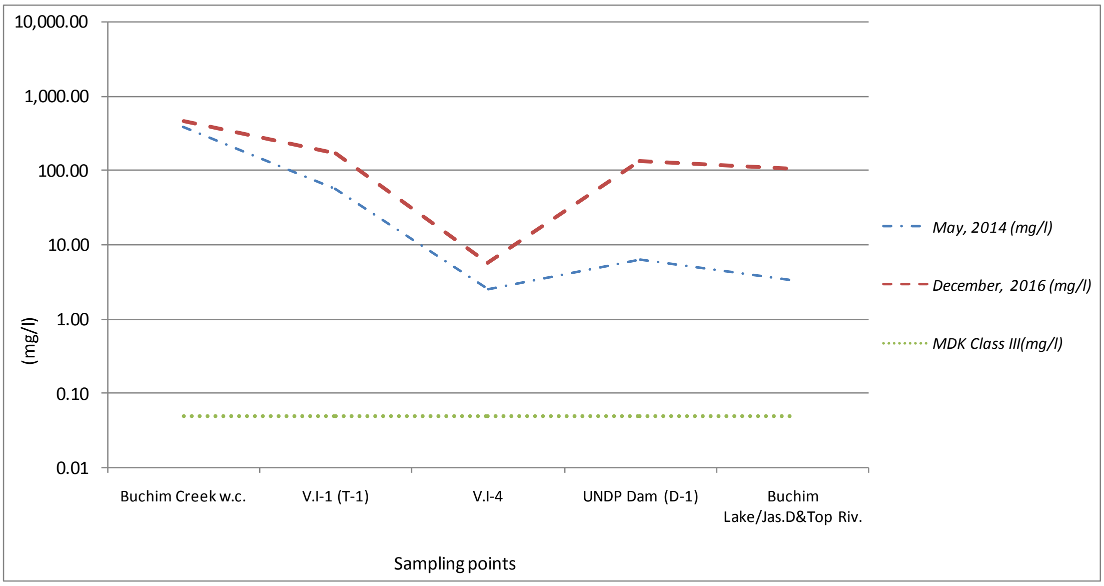

Fig. 4. Relation between copper analysis data in May 2014 and December 2016.

We are continuing with our monitoring and expect even better results, especially if bear in mind that as time goes by, the inherited deposited concentrations will be flushed away during the rainy periods of high water levels (see May vs. December; Figure 4).

CONCLUSION

By its production with open pit mine method, Buchim Mine represents potential pollutant of water, air and soils. Copper concentrations (as well as iron and some other parameters) before (March, 2013) and after the start of building the waste dump (Septe-mber, 2013) showed several times of magnitude higher values than allowed by MDK. Copper concentrations at ranged 1-530 mg/l Cu at the Buchim Creek water collector,

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58-1040 mg/l Cu at precipitator T-1, 3.4-310 mg/l Cu Buchim Lake, 2.5-6.2 mg/l Cu source water well 4. Recently built copper leaching facility in 2012, which encloses majority of surface and ground waters contributed significantly to a drastic decrease of pollution of surface and ground waters outside of the mine perimeter. At the newly formed mine waste Bunardzik at the moment there are deposited approximately 23 Mt of waste material with 0.11-0.12% Cu from where drainage about 10-15 l/s water solutions with above 380 mg/l Cu, which are completely captured through the pipeline net and driven to the copper leaching facility. This system leaves Bucimski Potok completely dry that causes the pollution to be at the lowest levels there. This monitoring will continue during the next period and we assume that its results will support our findings even more strongly.

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