MINING WASTES IN BASIN BOR, SERBIA

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Abstract: *Mining and Metallurgical Basin Bor exists over one hundred years. During that period copper ore has been mined and processed by pyro metallurgical process, mainly for the rich copper ore. Flotation concentration process was introduced due to the decreasing copper grades in ore and started in 1930s. Since that time, mining production grew up generating large amounts of waste materials in form of solid, liquid and gas. They are all clearly visible all-around of mining area.*

This paper deals with flotation testing results preceded by an attrition step, on copper minerals and pyrite obtained under laboratory condition. Also, the main problems with other type of wastes were discussed and some recommendation for its further treatment was given in the paper. All proposed concept are based on sustainable development in this area and wider.

Keywords: *overburden, flotation tailings, flotation, copper minerals, sustainability*

INTRODUCTION

Mining of copper ore in Bor, Serbia, has over hundred years long history. During this period mining wastes (mining and flotation tailings) were generated with about 650 Mt solid materials, which, by geology estimation contains about 750.000 t of metal copper.

Compared to the area affected by mining of about 1,22 million m^2, areas affected by mining wastes are over 2,84 million m^2. Some data on areas of degraded terrain are given in table [1].

Table 1.

Data on terrain surfaces occupied by the open pit mines and overburden disposals and flotation tailings

Mine	Open pit mine	Overburden disposals	Flotation tailings	Sub Total
Bor	1.220.950	2.840.800	733.300	4.795.050
Veliki Krivelj	2.239.000	660.000	2.465.700	5.364.700
Total:	**3.459.950**	**3.500.800**	**3.199.000**	**10.159.750**

In addition to these areas that are directly affected by mining operations, the area of damaged and degraded agricultural land is estimated to over 25.000 ha. This represents about 60% of agricultural land in the municipality of Bor [2]. Smelting of copper ore with sulfur dioxide emissions have led to soil acidification, destruction of vegetation and erosion. The pollution of waters and watercourses are the most significant consequences of mining on the Bor's river, which is biologically almost completely destroyed, with significant concentrations of heavy metals. Also, the big problem is decades of consumption of drinking water for industrial production, reducing the abundance of existing natural water resources. In Figure 1, shows the appearance of Bor river, as a consequence of long-term leakage of wastewater from the flotation tailings.

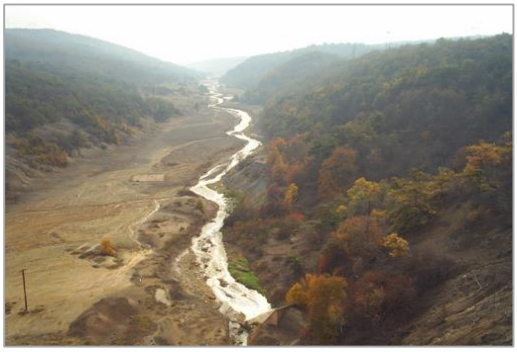

Figure 1. Landscape of river Bor

All these wastes have a damaging environment impact, but utmost has flotation tailings. The tailings consists of very fine dust, contaminated water, also very fine material leaking out from tailing pond in nearby rivers as well as valuable quantities of copper, gold and silver.

Old Bor flotation tailings are located near to Bor city center and therefore the main objective is providing recycling and dislocation process of flotation tailing to the location where will be no environment impact. By reprocessing of flotation tailings, metal copper and other valuable compounds will be produced and way possibility for self-financing of Bor's creek cleaning will be created. The flotation tailings reprocessing is consisted of following main steps: excavation, re-pulping, attrition, bulk sulfide and precious metals flotation, bulk concentrate treatment by selective flotation and newly obtained tailings disposed to the closed old open pit mine.

The extensive laboratory work was undertaken in order to obtain bulk flotation concentrate with high recoveries of above mention compounds. For example, copper recovery in bulk concentrate of up to 98% was achieved. Current activities are concentrated on copper minerals separation from pyrite from the bulk. Attrition technique is applied, rather than regrinding, in mineral liberation and cleaning of their surfaces prior to flotation. Attrition is much cheaper than grinding, and provides better results in flotation.

OLD FLOTATION TAILINGS

The are many ways of old mining wastes treatment depending on waste type, place and type of valuable components. The simplest way to solve those problems is reclamation of tailings and overburden surfaces by planting trees and grass without prior surface preparation [3]. Other authors propose desulphurization of tailings surface by froth flotation to the deep of 1-2 m, prior reclamation [4,5]. Those mentioned achievements have a primary goal to remediate waste surfaces and not take in account extraction of valuable compounds from the waste materials. Some investigation were undertaken at UB-Technical faculty Bor in order to recover useful compounds from old flotation tailings by froth flotation [6,7].

Old flotation tailings have most negative environmental impact such as surface degradation due to change of original land topography and damage to fertile soils, pollution of water and soil with heavy metals. Moreover, underground and surface waters in the vicinity of tailings pond can be contaminated by heavy metals such as lead, zinc, copper and arsenic, which have already been found in soil and plants in Bor region. In the case of a tailings dam failure there is the potential for a significant portion of the toxic material to run directly to the Bor's River and onward to the Danube River, with enormous environmental consequences to the entire region.

The main concept of our investigation is completely reprocessing of old flotation tailings by flotation and the residue material reject to old closed open pit mine (Figure 2) with economic effects. In Figure 2, overburden materials disposal from open pit mine "Veliki Krivelj" into the space of closed open pit mine "Bor" (left), is shown. This form of waste disposal is a permanent and sustainable solution for mining waste management, at present and in the future. In addition, this paper provides a new solution for disposal of tailing from the old flotation tailings in space of closed open pit "Bor", after its reprocessing.

Figure 2. Old closed open pit mine Bor

According to chemical analyses of tailings sample, given in Table 2, one can see significant copper contents. Copper is found mainly in sulphide form, (97,80 %) in total copper contents of 0,401 %. The pH of the sample was about 3,8 but the lower values can be found in dipper zone of tailings materials with values down to pH = 2. This is a typical characteristic for spontaneous chemical processes into tailing materials caused by sulphide oxidation. The average content of gold is 0.8 g/t and silver 2.4 g/t.

Table 2.

Chemical analyses of tailings sample

Element/ Compound	Contents (%)	Copper Distribution R_{Cu}(%)
Cu_{total}	0,41	100
$Cu_{sulphide}$	0,401	97,80
Cu_{oxide}	0,009	2,20
S	14,51	-
Fe	13,91	-
SiO_2	52,60	-
Al_2O_3	14,83	-
CaO	0,87	-

An extensive investigations on bulk sulphide flotation, were undertaken in Laboratory for mineral processing at the Technical faculty in Bor. The best results were achieved by applying attrition prior flotation in pulp preparation, flotation at pH of 10 and collector PIBX (potassium isobutyl xanthate). In that case, flotation recovery of copper was over 97 % and pyrite recovery was over 87 %. Copper and pyrite grades in bulk concentrate were 1,34 % and 42,74 %. respectively. Recoveries of precious metals such as Au and Ag have not been analysed in the initial phase of investigations, but it is believed that they follow sulphide minerals. Present investigations on these metals are in progress, as well as the further treatment of bulk concentrate.

OTHER WASTES

During the long period of exploitation of copper ore in the Mining basin Bor, has generated large amounts of waste. Mining and Metallurgy complex in Bor consists of three open pit copper mines (Bor, Veliki Krivelj and Cerovo) and a smelting plant for metallurgical treatment of copper concentrate. Of the three mines, two were closed (Bor and Cerovo) and only “Veliki Krivelj" is in operation. There are significant quantities of ore wastes around these mines that occupy large areas and have a negative impact on the environment.

OPEN PIT MINE BOR

Open pit mine Bor is the oldest copper mine in Serbia. The mining has ended and the mine was closed. This mine has left behind two stockpiles with overburden material and a flotation tailing pond. Overburden have been re-cultivated and the soil forested, Figure 3. Recultivation of these areas were designed to prevent erosion thereof and at the same time reduce the emphasis on acid solutions from them. Reclamation for the flotation tailing was planned in beginning by means of planting trees of various types as a short-term rehabilitation of its surface. In the future, the proposed processing of tailings and its relocation in the area of the former open pit Bor are planned. This process would be cost effective and the whole venture implemented in a profitable way.

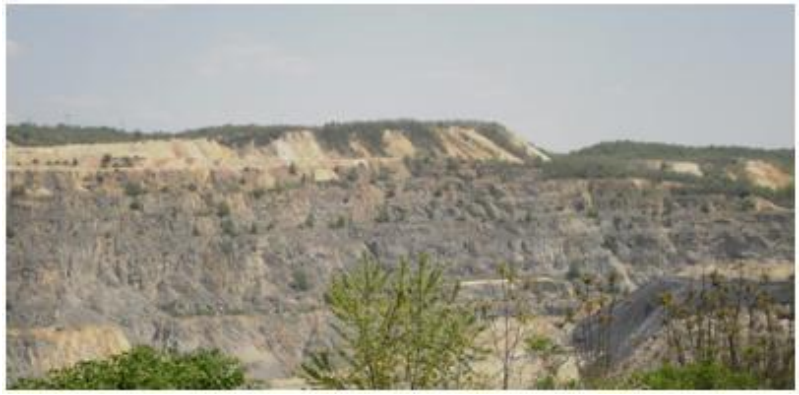

Figure 3. The origins of vegetation on open pit Bor overburden waste

OPEN PIT MINE CEROVO

Open pit mine Cerovo was closed as well as. This mine was opened in 1993 and was shut down after ten years of operation. In the vicinity of the mine, crushing and milling plant for treatment of copper ore was built. Milled copper was hydro transported to the flotation plant in Bor and processed there. At this mine there are overburdens waste ore. These overburdens have a large impact on water pollution because they contain copper oxide minerals that are easily dissolved under the atmospheric influence. There is a reception pond with the dam for acceptance of these solutions that are leaking from overburden heap, Figures 4 and 5. In addition, to build the dam, this problem has not been completely solved. In numerous occasion leakage of this solution into nearby waterways has occurred. In the Figure 4, one can see process of disintegration of overburden material by realizing the copper water-soluble compounds. The overburden waste heap with leaked water solution pond is presented on Figure 5.

Figure 4. Desintegration process of copper bearing minerals in the overburden on copper mine Cerovo

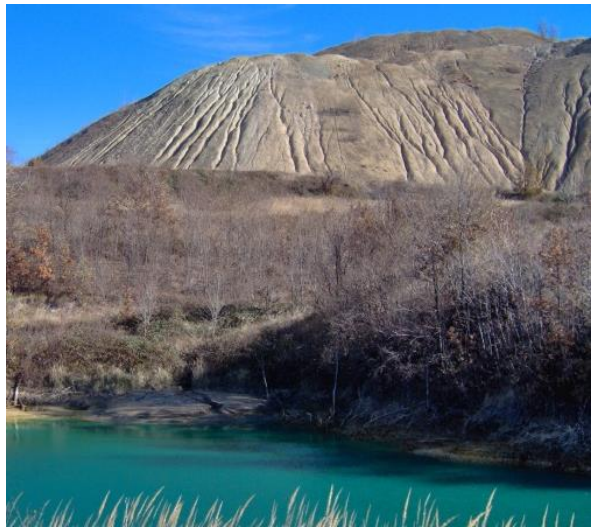

Figure 5. The overburden waste heap with leaked water solution pond

OPEN PIT MINE VELIKI KRIVELJ

This mine was open in 1982 and it is still operational. There are two areas with overburden and a flotation tailing in its vicinity. Overburden was deposited in two areas near the open pit. Now, this overburden are deposited into area of closed pit of mine Bor, as a permanent and sustainable solution, Figure 6. Flotation tailings from this mine is deposited in a special place, but a lot of problems with leaking of waste water solution are occurred, because underneath the tailings there is a tunnel through which passes nearby river. Now, the tunnel is under reconstruction.

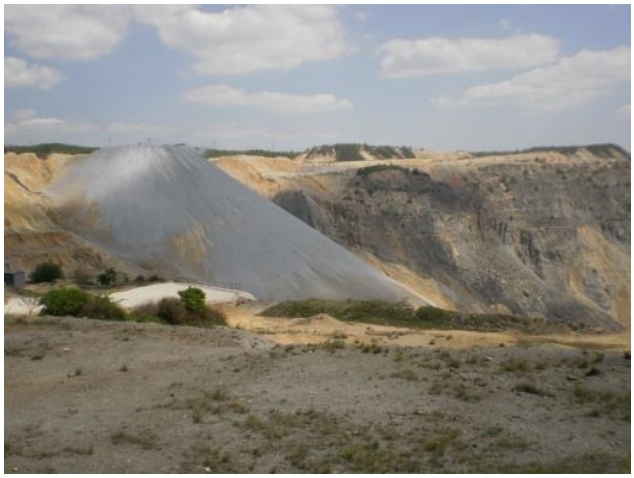

Figure 6. Deposition of overburden materials into area of closed pit of mine Bor

COPPER SMELTING PLANT

Metallurgical plant for processing copper concentrate has as long history as the Bor mine. From this plant two types of solid and gaseous wastes are produced. The solid waste is smelter slag and gaseous wastes are smoke and gases that carry large amounts of sulfur dioxide and other harmful components and aerosol. Smelter slag does not pose a grave danger to the environment because it dissolves very slow under the atmospheric conditions. Emission of gasses from the smelter has a great impact on the environment because it is disseminated over long distances. As is planned to build a new smelter and the introduction of modern metallurgical technology is expected to permanently eliminate this problem.

CONCLUSIONS

According to above presented, the following can be concluded:

Wastes in mining and metallurgy have a major impact on the environment because they occupy large areas.

In Mining and Metallurgy Basin Bor there are many problems associated with mining and metallurgical wastes, some of these are successfully resolved, and some are in preparation for solving.

There is a real possibility to obtain copper and other valuable compounds from tailings materials and at the same time obtain desulphured new tailings, which is less hazardous than the primary one.

There are possibilities for long term solutions of ecological problems by removing old tailing material and its relocation in the space of old open pit, after reprocessing.

This offer opportunity to clean existing tailings pond and down stream waterways. Prevention of acid mine draining from mine Cerovo overburden materials is the primary task for the near future.

According to recommendations from sustainable development principles, subsequent steps include long-term repair of all degraded areas especially revitalization of devastated river beds. The river valleys should again return to farming vegetables and other crops, which is a traditional form of agricultural production in Serbia. Solving problems of protection and rehabilitation of the environment, opens up opportunities for employment of many profiles of labor.

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