Detailed technical design for acid mine water treatment in Novo Brdo Mine, Artana / KOSOVO

Nikolaus Linder[1], Michael Mackenbach[2], Jaromír Novák[3]

[1]*Fichtner Water & Transportation GmbH, Department Mining & Environment, Dreilindenstraße 84, 45128 Essen, Germany, Nikolaus.Linder@fwt.fichtner.de*
[2]*Fichtner Water & Transportation GmbH, Department Mining & Environment, Dreilindenstraße 84, 45128 Essen, Germany, Michael.Mackenbach@fwt.fichtner.de*
[3]*GEOtest a.s. , Šmahova 112, Brno 627 00, Czech Republic, novak@geotest.cz*

Abstract

In the past, Trepça Mining & Metallurgical Complex was the backbone of the economy of Kosovo with mining being Kosovo's premier industry. One of the mines belonging to the Trepça Group of Mines is the lead (Pb) and zinc (Zn) mine at Artana/Novo Brdo, located 22 km (38 km by car) east of Prishtina. Some mining operations still continue. There are large amounts of tailings and mine waste heaps at the site, and thus, acidic waters contaminated with hazardous substances are discharged into the Krivareka (aka Marevc) River (Aikaterini 2012).

The purpose of this project was to prepare the detailed technical design for the treatment of this acid mine drainage to neutralize the acidity and to eliminate the flow of heavy metals and other contaminants into the river. Thus, a significant source of heavy metal pollution in the area was to be eliminated.

GEOtest a.s. and Fichtner Water & Transportation GmbH, Department Mining & Environment were contracted by UNDP Kosovo as engineering consultants for the project. In a first phase, the Consultants collected and analyzed available data on geology, geography, hydrology, hydrogeology, land use etc., collected new data and performed all necessary surveys, laboratory tests, sampling and site investigations necessary to prepare a detailed technical design for an acid mine waters treatment plant.

The results of this first phase were crucial in order to determine the sources and the scale of the pollutants as well as the flow regime of contaminated water. This information was important to determine the remediation method, the most suitable location and the water treatment technology.

On the basis of these data, the Consultant made recommendations on the choice of the appropriate water treatment technology to assure the proper treatment of the acid mine drainage. Following the selection of the treatment technology in cooperation with the Client and Beneficiaries, the Detailed Technical Design for an active treatment technology was developed.

Key words: former mining, ecological improvement, dewatering, acid mine drainage

Introduction: location, relief, climate, AMD situation

In the past, Trepça Mining & Metallurgical Complex was the backbone of the economy of Kosovo with mining being Kosovo's premier industry. Today, with most processing plants being closed and limited exploitation of minerals taking place, Trepça Complex represents both Kosovo's greatest potential for economic recovery and the country's big environmental challenges resulting from former mining operations in Northern and Eastern Kosovo that have left toxic mining waste threatening tens of thousands of human beings in the area.

Artana mine complex is located in the eastern part of Kosovo, in the municipality of Novo Brdo (see Figure 1). It neighbors the municipalities of Gjilan, Kamenica, Prishtina and Lipjan. The municipality of Novo Brdo includes 33 villages (settlements) within an area of 204 km². Semi-urban settlements are Novo Brdo, Bostana, Llabjan, Koretishte, Pasjak, Kufce and Stanishor; other settlements are scattered in hilly-mountainous areas.

Figure 1 *Borderline KOSOVO and location of the municipality of Novo Brdo (Helvetas 2012)*

The relief in the area surrounding the mine complex is quite steep. The mine is located in a mountainous area under the highest peak with an altitude of 1,250 m a.s.l. The mine is situated in close vicinity to a valley, which leads to the Krivareka River valley. The highest elevation has adit V of the mine at 805 m a.s.l. The lowest point in the project area is the Krivareka River with an elevation of 664 m a.s.l.

The territory of the municipality of Novo Brdo is dominated by typical continental climate. However, due to the high altitude, some parts of the municipality are dominated by mountainous climate. The temperatures are lowest in January and highest during July and August. During the last 20 years, the average annual rainfall has been between 910 mm in 2002 and 540 mm in 2008.

The Novo Brdo Mine was currently reopened with small-scale mining activities and has four open adits. Two of the adits –adits V and VI - show outflows of acidic mine waters. The situation is shown in figure 2 and can be described in detail as follows: The outflow of acid mine waters from adit VI (figure 2 upper left) and the natural run-off from adit V partly contain acidic mine water from the upper mining levels (figure 2 upper right). The conflux of these two outflows as well as the discharge into a channel pipeline leading towards the main valley and discharging finally into the Krivareka River show the characteristic red colors of acidic mine waters.

The objective of the project was the treatment of the acidic streams from the adits V + VI in Novo Brdo Mine, Artana, in order to neutralize acidity and remove dissolved contaminants so as to comply with prevailing environmental standards. It had to be taken into consideration that the Trepça Group plans to increase the mining activities in the Novo Brdo area.

Scope of work

Fichtner and GEOtest were contracted as Consultant by UNDP Kosovo to evaluate the current situation and the requirements of an appropriate technical solution for the acid mine water treatment including a technical design for a water treatment plant. During the project, the Consultants evaluated all available geological, hydrogeological, meteorological and hydrological data, the spatial planning and the geology of the deposit as well as former and current mining operations.

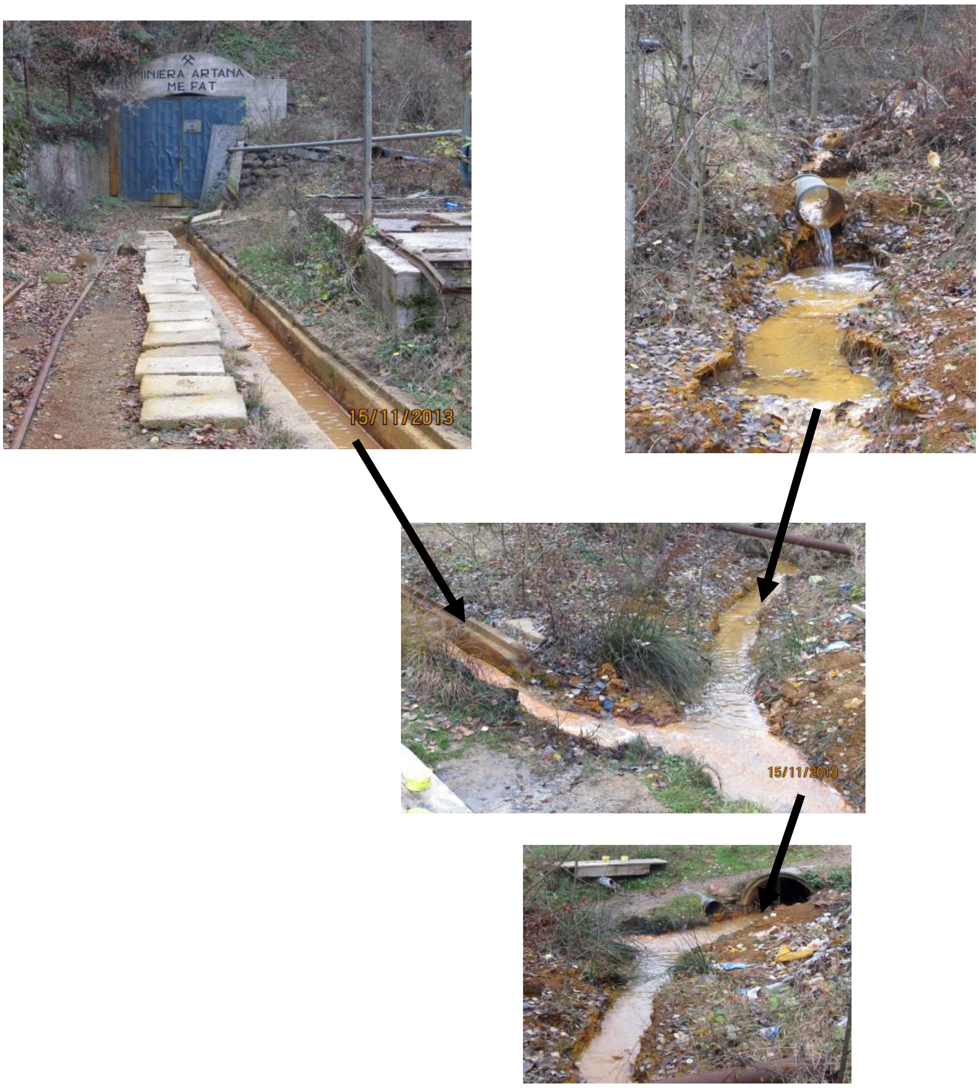


Figure 2 *Outflows and open creeks with acid mine waters*

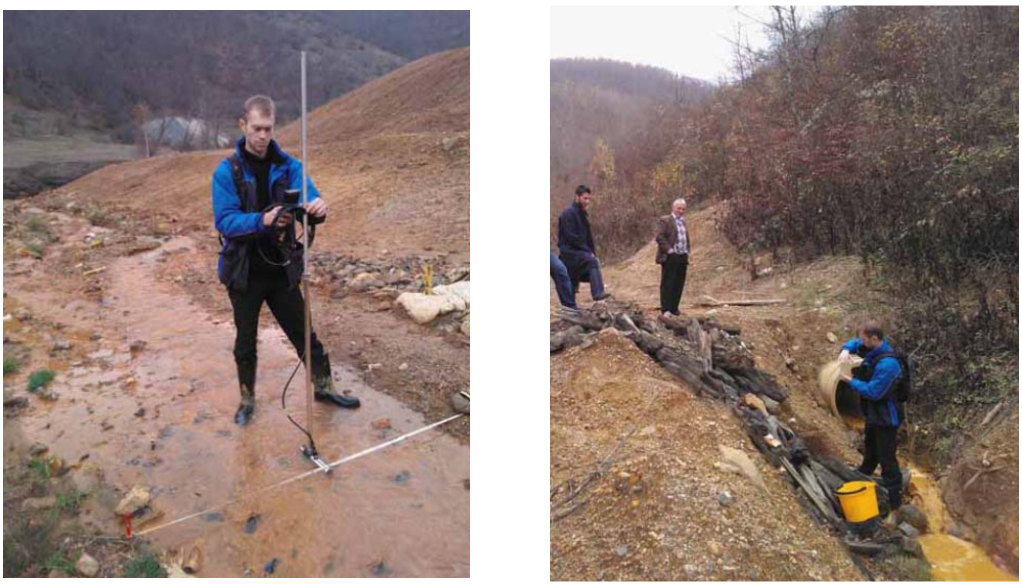


Figure 3 *Flow measurements with Acoustic Digital Current Meter OTT and sampling*

The team carried out a site visit with the following activities:

- Mapping of the mining area with all outflows of the mine, geology etc.
- Flow measurements of all surface water streams with Acoustic Digital Current Meter OTT (see figure 3)
- Water sampling (see figures 3 and 4)
- Investigations to identify an appropriate location for the treatment plant
- Discussion with the local authorities regarding planning and approval of a new treatment plant

Figure 4 shows the mining area with the sites for water sampling (red dots) and flow measurement (blue dots).

Figure 4 *Sampling and flow measurement locations*

All results of the first investigations as well as the water treatment scenarios were presented and discussed with the Client, different Ministries and Authorities, relevant stakeholders and the Trepça Enterprise Company as possible operator.

Results of the investigations

Flow measurements

The outflow from adit VI was measured at 11.8 l/s (pH 2.82). The outflow from adit V was approximately 0.05 l/s. From the point of discharge at adit V towards the confluence with water from adit VI, the water flows through a narrow valley of a length of about 630 m. Along this flow path, two small creeks additionally discharge into the stream. Close to the confluence of mine water outflow from shaft VI, this stream was measured with a total flow rate of 0.2 l/s (pH 3.17).

After the confluence of these two outflows, the stream of acid mine water continues on a flow rate of 12 l /s or 43.2 m³/h towards the Krivareka River. No additional discharge of acidic mine water into the stream could be observed.

The Consultants expect that the flow rate of contaminated mine water will be relatively constant, reflecting the main climatic trends during the year as well as former studies (MONTEC 2007 and Aikaterini 2012) that measured 35 to 50 m³/h for the mine water outflows in the same range. Outflow of acid mine water from adit VI is about 98% (11.8 l/s) of the total flow rate; from adit V it is about 2% (0.2 l/s).

The Krivareka River was measured downstream of the current discharge of acid mine waters with a flow rate of 69 l/s (250 m³/h).

Chemical content

The following table shows a short summary of the assay of the chemical contents of adit VI and the conflux of adits V+VI. Furthermore, the limits to be considered for discharge into the Krivareka River are listed:

Table 1 *Summarization of chemical contents available*

Parameter	VI*	VI**	V+VI*	V+VI**	Limits***
pH	2.82	2.9-5.6	2.85	2.86-5.6	6.0 – 8.5
suspended solids [mg/l]	245.0	152-362	179.0	140-252	-
Q [l/s]	11.8	9.98-14.05	12.0	-	-
Pb [mg/l]	< 0.05	0.05-0.23	0.103	0.01-0.34	0.2 – 1.0
Zn [mg/l]	72.07	65.3-110.0	66.74	28.6-85.0	0.5 – 2.0
Cu [mg/l]	0.961	0.01-1.0	0.267	0.01-0.75	0.1 – 0.5
Cd [mg/l]	0.15	0.01-0.16	0.141	0.01-0.18	0.01 – 0.2
Mn [mg/l]	54.6	47.8-86.0	44.3	14.0-61.0	1.5 – 2.5
Fe [mg/l]	222.0	44.4-306.5	175.0	23.3-224.8	2.0 – 5.0
As [mg/l]	0.47	0.62-0.67	0.358	0.25-0.51	0.05 – 0.2
SO_4 [mg/l]	1,670	604-1,622	1,437	400-1,310	150 – 250

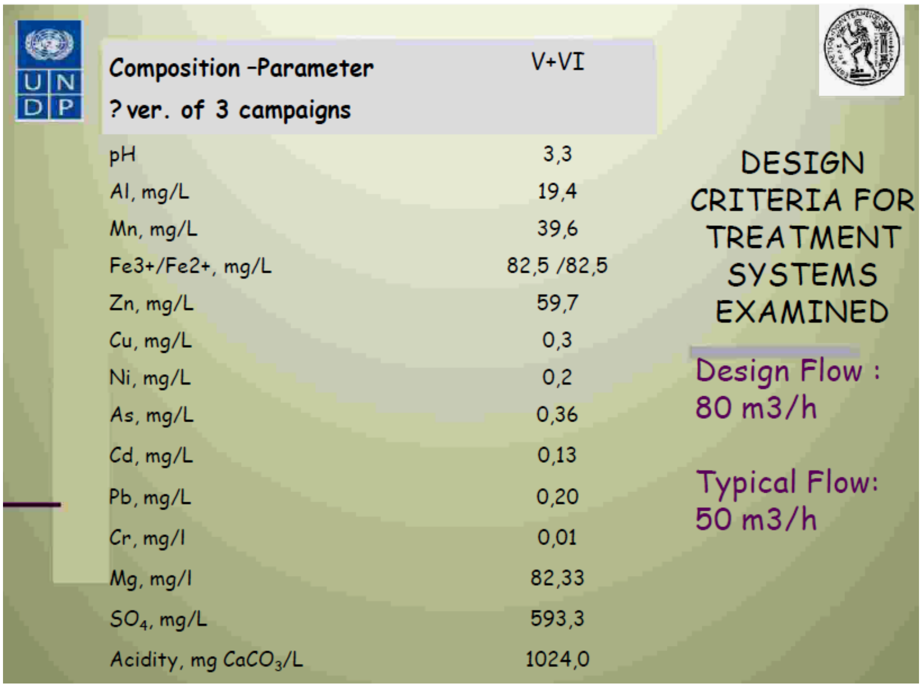
*: result GEOtest a.s.

**: min-max former investigations (MONTEC 2007, Aikaterini 2012)

***: Limits of discharge Category II – Category V (Kosovo 2008)

Methodology of the treatment plant

The UNDP and the former study elaborated by Aikaterini (2012) developed design criteria for the treatment system on the basis of the results of former investigations (see figure 5). Most of the former studies preferred a passive treatment system such as wetlands to reduce the technical effort and the OPEX for the treatment plant.



Composition -Parameter ? ver. of 3 campaigns	V+VI
pH	3,3
Al, mg/L	19,4
Mn, mg/L	39,6
Fe3+/Fe2+, mg/L	82,5 /82,5
Zn, mg/L	59,7
Cu, mg/L	0,3
Ni, mg/L	0,2
As, mg/L	0,36
Cd, mg/L	0,13
Pb, mg/L	0,20
Cr, mg/l	0,01
Mg, mg/l	82,33
SO_4, mg/L	593,3
Acidity, mg $CaCO_3$/L	1024,0

***Figure 5** Design criteria required by the Client*

On the basis of the results of the Consultants' investigation and the assessed quality of the acid mine water, resulting in increased acidity and heavy metal content, a passive treatment technology was not considered a sustainable solution. For a design flow rate of 80 m^3/h and considering the criteria for chemical content, an area of about 80,000 m^2 would be required for the implementation of a passive treatment system. Such an area is not available in the vicinity of the location. The only suitable area is close to the former flotation and processing plant in the main valley of Krivareka River (see figure 4) with an extension of approx. 30,000 m^2.

According to the limitation of space, the Consultants recommended a semi-passive or active treatment technology at an early phase of the project. The following parameters need to be considered when making a decision for semi-passive or active water treatment technology:

- Topography
- Available and useable hydraulic potential
- Range of flow rates in quality and quantity (Trepça Enterprise is planning further mining activities at the level adit VI. This could result in a quantitative and qualitative change of the outflows.)

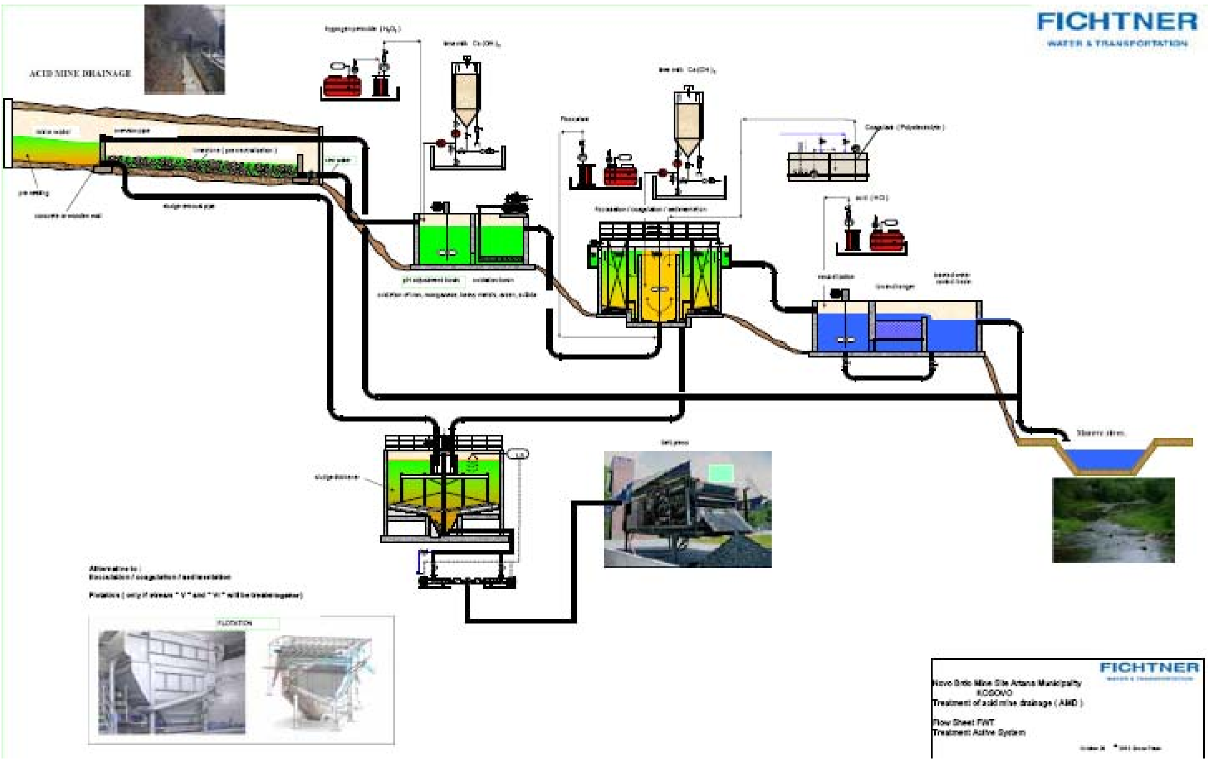
Finally, the Consultants recommended an active water treatment technology. It is highly expected that the quantity and quality of the outflows will change in future. In that case, a semi-passive treatment technology is not as flexible as necessary. The beneficiary and the stakeholders of the project followed this recommendation. Therefore, the detailed technical design considered an active treatment system.

Conclusions and recommendations

All activities, investigations and discussions suggest an Active Treatment Plant (see figure 7). The objective of the water treatment process is the purification of the acid mine water outflow of Novo

Brdo Mine, Artana, to fulfill the requirements applying to the discharge values (see table 1) and to follow the rules and regulations of the Government of Kosovo. On the basis of the results of the preliminary design, the following active treatment procedure was chosen:

- Step 1: Adjustment of pH-value for oxidation (target pH-value: 4 to5)
- Step 2: Oxidation basin (oxidation of iron, manganese, heavy metals, arsenic, sulfides)
- Depending on the specific water conditions, oxidation by atmospheric oxygen may not be sufficient. In this case, oxidation needs to be promoted by adding hydrogen peroxide (H2O2).
- Step 3: Pre-settling (suspended solids)
- Step 4: Flocculation / coagulation / pH-adjustment up to 8.5 to 9.5 (colloids, metals, arsenic, colloids, carbonate hardness) and sedimentation
- Step 5: Neutralization to pH 6.5 to 8.5 (discharge into river); this step includes an ion exchanger in series for polishing.
- Step 6: Sludge dewatering (thickener; dewatering)



- ***Figure 7*** *Technical design of an Active Treatment Plant*

It is recommended that the operator of the water treatment plant controls the treatment process on different stages of the process. Accordingly, it is proposed that an indicative analysis of the treated water is included at step 4. Monitoring of the final quality before final discharge could be added at step 5 to assess the performance of the system and to prove the successful removal of contaminants.

The dewatered sludge is a waste-product of the water treatment and contains heavy metals and other contaminants. Hence, the sludge must be safely transported and deposited on a proper waste disposal site.

The Consultant thus made the following recommendations:

- The requirements, permission and conditions of the final deposition of the dewatered sludge should be clarified by the Client prior to the tendering procedure for the water treatment plant.
- A contract between the operator of the water treatment plant and an operator of an appropriate deposit could be prepared by the Client.

Acknowledgements

We thank the United Nations Development Programme UNDP and the involved authorities of Kosovo as well as Trepça Enterprise for the good cooperation in the project.

Thanks to all colleagues at GEOtest a.s. and Fichtner Water & Transportation GmbH, who have contributed to the success of this project.

References

ADAM AIKATERINI (2012) Feasibility Study for the treatment of acid mine drainage (AMD) for the Novo Brdo Mine Site, Artana Municipality, Kosovo, Ref. no. 25252, Report II Final, UNDP, 184 p.

MONTEC (2007) Final Report Environmental Assessment and Remedial Action Plan (EARAP): Stan Trg/Stari Trg and Artana/Novo Brdo Mines, Kosovo, MonTec GmbH, 68 p.

HELVETAS (2012) Municipal Development Plan Novo Brdo, Kosovo, Swiss Intercooperation Helvetas, 366 p.

ZANE SATTERFIELD, P.E. (2005) Tech Brief Jar Testing, National Environmental Services Center (NESC), vol. 5, issue 1, 4 p.

GOVERNMENT of the KOSOVO (2008) Administrative Instruction for the limited values of the effluence that discharged on water bodies and on the system of public canalization, Kosovo, 14 p. and 6 appendices.