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APPROACH FOR SOLVING ENVIRONMENTAL ISSUES AT ABANDONED MINING WASTES IN REPUBLIC OF SERBIA

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ABSTRACT – In Serbia exist numerous locations with larger and smaller quantities of mining wastes. Some of those wastes could be potentially characterized as "A" category wastes. One of the obligations of Republic of Serbia is harmonizing of national legislation with the EU Acquis Communautaire in the field of environment as a part of the negotiation process (Chapter 27). Regarding this fact, it was performed making of Cadastre of Mining Waste in Republic of Serbia with Consortium of German Companies PLEJADES GmbH and DMT GmbH & Co. KG with engagement of Mining and Metallurgy Institute Bor for implementation of all sites activities.

Keywords: Mining, Waste, Cadastre, Abandoned, Environmental.

INTRODUCTION

Mining industry in Serbia had a strong development during more than 100 years. Moreover, in Serbia exist archeological clues of mining activities from early V millennia BC (5400 BC) [1] on locality Rudna Glava which represent the oldest copper mine in Europe and probably world. Due to strong mining development in last few centuries, in Serbia exist numerous abandoned locations with larger or smaller quantities of mining wastes. According to EU Mining Waste Directive, mining wastes with potential for chemical and stability hazard is characterized as "A" category wastes [2].

One of the obligations of Republic of Serbia is harmonizing of national legislation with the EU Acquis Communautaire in the field of environment which is a part of the negotiation process for Chapter 27. Regarding this fact, Ministry for Mining and Energy of Republic of Serbia contracted and performed making of Cadastre of Mining Waste (CMW) in Republic of Serbia. The CMW project aims to support the sector of mining and environmental protection by developing and further improving the mining waste management system. The contracting authority for this project is the Ministry of Finance, the Department for Contracting and Financing of EU Funded Programmes (CFCU). The beneficiary of the project is the Ministry of Mining and Energy, and the project is implemented by a consortium of German companies PLEJADES GmbH and DMT GmbH & Co. KG which contracted MMI Bor for implementation of all sites activities including exploratory drilling, sampling, geotechnical testing and analyzing, chemical analyzing and interpretation of results. The CMW project began in 2017 and ends in early 2020. Total

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Project budget was 2.1 million EUR from which 90% was funded by the European Union and 10% by the Government of the Republic of Serbia.

METHODS

At the beginning of the CMW Project was performed initial consideration of potential abandoned mines sites based on available reports, historical data and Serbian map data. Based on this consideration was selected 250 abandoned Mining Waste Sites (MWS) for site visit. Site visits preparation included identification of accesses to abandoned mining sites and possible mining objects, preparation of rules for identifying of deterioration evidences, identifying of possible sampling locations, land usage, residential and industrial areas vicinity and similar data of importance.

Based on defined data which has to be collected during initial site visit, MMI Bor staff visited all 250 MWS and collected required data. One of the priorities during initial site visit was to confirm existing of Mine Waste Facilities (MWF) and indicate size and hazard potentiality. Collected data was a basis for the creation of Plan of Sampling and Exploration Works (PSEW). However, collected data was still not sufficient for selecting MWS for Detailed Sampling and Visiting Plan (DSVP) which has to be focused on Category "A" MWF.

Therefore, it was implemented Multi-criteria evaluation with Analytic Hierarchy Process (AHP) [3] which combines importance of collected parameters aiming on definition of MFW for DSVP. Based on this evaluation was selected 41 MWS for DSVP. The amount of waste in the selected sites accounts for 90% of the entire mining waste on all the visited abandoned mining waste sites (250 locations in total) [4].

DSVP included sampling of MWF by exploration drilling and test pits, sampling of surface waters and underground from installed monitoring wells. Collected solid and water samples were treated in MMI Bor laboratories with certified methods. Solid samples analyses included dry maters and solid leachate analyzes while water samples were analyzed on law defined limited parameters. Besides chemical analyzing, it was performed geotechnical sampling and testing objected on definition of stability hazards. All sampling points were recorded by licensed surveying company.

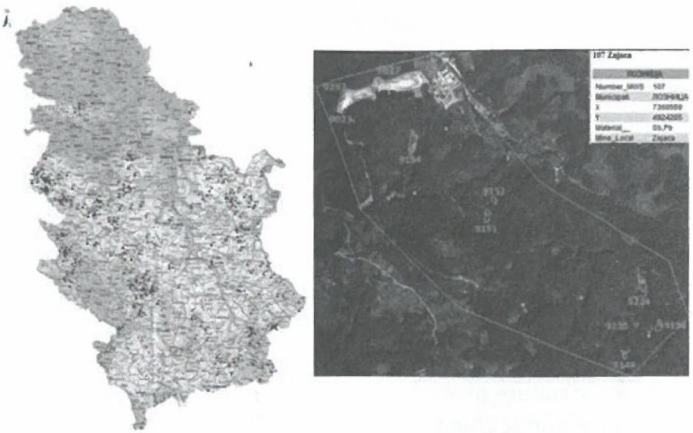
All of collected results from site activities and testing including three preliminary case studies will be part of CMW web application under administration of Ministry for Mining and Energy of Republic of Serbia.

RESULTS AND DISCUSSION

Preparation of MWS visits

Preparation included: Identification of access to the MWS; Preliminary identification of shafts, adits, open pits, processing plants, transport infrastructure and other facilities related to the exploitation in the vicinity of the MWS; Identification of evidence for deterioration of structural integrity, erosion, environmental pollution and other potentially adverse effects; Identification of potential sampling location; Identification of land-use in the vicinity of the MWS including location of residential areas, commercial and industrial areas and preparation of concept for field inspection of the individual

MWS. Map of selected 250 MWS (red triangles) for initial site visit in Republic of Serbia was presented on Figure 1a while on Figure 1b is shown example of prepared plan for visit of one MWS based on satellite imagery.

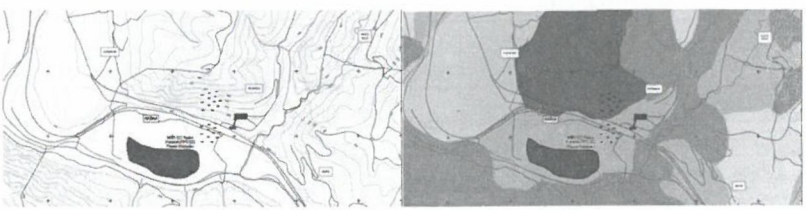


1(a) **1(b)**

Figure 1 (a) Map of selected 250 MWS for initial site visit in Republic of Serbia; **(b)** Plan for MWS visit based on satellite imagery

MWS visit and reporting

Reports from initial MWS visits included collected: General information (traffic, coordinates, mine elements, subsoil type); MWS geometry (lay-out, slope angles, inclination of base, volume estimation); Source potential (identification of type of deposited material, covering, etc.); Potential adverse effect and pollution (surface water management, seepage structures and rates, water treatment, erosion structures, slope failures); Potential receptors in the vicinity (waters, settlements, agriculture, nature areas); Verification of sampling locations and Photos. Figure 2 (a) and (b) shows example of map of MWS before and after the initial visit with included collected information's.



2(a) **2(b)**

Figure 2 (a) MWS map without collected data from initial site visit; **(b)** MWS map including collected data from initial site visit

Based on initial 250 MWS visit was also concluded:

- 63 MWS – without mining operations, No MWF
- 79 MWS – with mining operations but without mining waste or small

volumes of mining waste (≤ 50 m^3). 39 sites did not show any mining waste

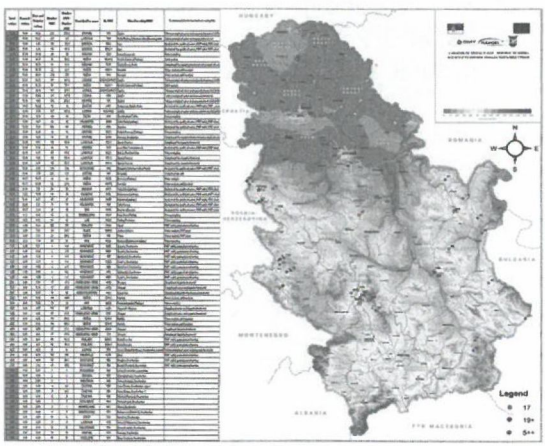
- 105 MWS – with large volumes of mining waste, totaling 215 MWF with individual vol. up to 3.5 mil.m^3
  - 35 of 215 MWF – present at 24 active MWS
  - 179 of 215 MWF – found at abandoned sites
- 3 MWS (127, 142 and 146) – without available data due to force majeure (access impossible)

Multi-criteria evaluation

Having on mind that DSVP should be objected on category "A" MWF collected data were analyzed with Analytic Hierarchy Process (AHP) which combines importance of collected parameters as follows:

- MWF area (m^2) (1 – Not at all important)
- MWF volume (m^3) (2 – Low importance)
- Vicinity of agricultural soil (km) (3 – Slightly important)
- Vicinity of nature protected areas (km) (3 – Slightly important)
- Vicinity of surface/und. waters (km) (5 – Moderately important)
- Vicinity of towns and settlements (km) (5 – Moderately important)
- Chemical hazard (6 – Very important)
- Stability hazard (6 – Very important)
- MWF toxicity (7 – Extremely important)

Results of Multi-criteria evaluation are presented on Figure 3(a) while map with locations of totally selected 41 MWS based on evaluation is presented on Figure 3(b).



3(a) **3(b)**

Figure 3 (a) Multi-criteria evaluation results (red hazardous – green non-hazardous); **(b)** Map of totally 41 selected MWS for DSVP

DSVP

Scope of site activities and laboratory testing are presented in following Tables:

Table 1 Sampling of solid and water samples

Activity	Specification	Unit	Total realized units
Test pit samples	0.2 x 0.2 x 0.2m	pcs	1465
Test pit samples	0.5 x 0.5 x 0.2m	pcs	67
Excavator samples	Depth 2m	pcs	245
Liner drilling	50-100mm	m	654
Install GWM-Well	Drilling and installation	m	96
Exist. GWM-Well	/	pcs	9
Surface water samples	/	pcs	107

Table 2 Water samples analyzing

Specification	Unit	Total realized units
pH, T, conductivity, redox (during sampling)	pcs	112
As, Pb, Cd, Cr(tot), Cu, Ni, Hg, Ti, Zn, V, Mo, Co	pcs	105
Total Fe, As	pcs	7
U	pcs	7
Sb	pcs	11
Sulfate	pcs	112
Flotation chemicals	pcs	17
Alkalinity	pcs	112

Table 3 Soil samples - dry matters

Specification	Unit	Total realized units
As, Pb, Cd, Cr(tot), Cu, Ni, Hg, Ti, Zn, V, Mo, Co	pcs	632
Total Fe, As	pcs	166
U	pcs	34
Sb	pcs	46
Asbestos	pcs	123
Mineral Phases (RDX)	pcs	108
TPH	pcs	10
PAH	pcs	10

Table 4 Soil samples - leachate

Specification	Unit	Total realized units
Leachate preparation	pcs	495
pH, conductivity, redox	pcs	495
As, Pb, Cd, Cr(tot), Cu, Ni, Hg, Ti, Zn, V, Mo, Co	pcs	380
Total Fe, As	pcs	163
U	pcs	16
Sb	pcs	15
TPH	pcs	10
PAH	pcs	10
Flotation chemicals	pcs	106
Alkalinity	pcs	482

Table 5 Geotechnical testing

Specification	Unit	Total realized units
Grain size distribution, fine grained materials	pcs	68
Moisture content	pcs	68
Atterberg Limits	pcs	13
Specific gravity	pcs	68
Undrained shear strength	pcs	68
Consolidation (Oedometer)	pcs	10

Total sampling points recorded by licensed surveying company – 1836 [5].

CONCLUSION

CMW Project was realized in very short time frame. 250 initial MWS for visits and later 41 MWS for detailed sampling and analyses indicate a strong and comprehensive organization and performing of all Project activities.

Defined approach for collecting data from site visits and laboratory testing and analyses ensured basis for implementation of Multi-criteria evaluation for determination of MWS priority for detailed consideration. Selected parameters and given importance indicators for Multi-criteria evaluation resulted with reliable results in determination of MWS priorities. Among selected 41 MWS for detailed sampling top three MWS with highest total and hazards ratings are Mine Zajaca near Krupanj, Veliki Majdan near Ljubovija and Lipa near Zagubica. During the CMW Project was collected huge amount of data, achieved results and information's and therefore it will be available on CMW web application.

Importance of performing CMW Project have to be considered as beginning of continual activities objected on solving of environmental and stability hazards on locations of abandoned mine locations all over Republic of Serbia. After the CMW Project, logical step forward is to start with planning of treatment of these locations. One possible way for continuation of those activities could be analyzing of methods for long term predicting of environmental performances on MWS. This approach should ensure basis for designing of measures for reduction of chemical and stability hazards on abandoned MWS.

ACKNOWLEDGEMENT

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