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DISTRIBUTION OF THE QUALITY PARAMETERS ($CaCO_3$ and SiO_2) IN THE CARBONATE DEPOSIT (LIMESTONE AND CHALK) SPASINE - BRDJANI NEAR UGLJEVIK

Abstract

For the needs of desulphurization of flue gases, the Mine and Thermal Power Plant Ugljevik have found the necessary absorbent (limestone) in the immediate vicinity. The deposit of carbonate mineral raw materials (limestone and chalk) Spasine - Brdjani is defined by detailed geological exploration in which the sodality in distribution the main quality parameters ($CaCO_3$ and SiO_2) is observed.

Keywords: *flue gas desulphurization, detailed geological explorations, quality parameters, distribution*

INTRODUCTION

The Thermal Power Plant Ugljevik, installed power of 300 MW, uses the brown coal as a fuel for the production of electricity that is exploited by the open pit Bogutovo Selo. The brown coal of the deposit of Bogutovo Selo is characterized by the increased sulfur content (5-6% S). By the coal combustion, as one of the flue gases, sulfur dioxide is released; whose concentration in the air exceeds the allowed limit. From the aspect of environmental protection, primarily the air pollution, the process of flue gas desulphurization (FGD) in the dependent company Mine and Thermal Power Plant has become inevitable. After providing the financial resources for these activities, a Conceptual Study was developed in which one section explores the possibility of supply the limestone (absorbent) for the mentioned process and where it is proposed to find the solution in the surroundings of Ugljevik, known for the presence of a huge carbonate massif.

After this, the preliminary explorations have begun, which in the end resulted in a fact that it is completely justified to conduct the detailed geological explorations.

Taking into account a number of important factors (level of exploration, distance, density, connectivity with the open pit and landfill, transport, etc.), a commitment was to perform the detailed geological explorations at the site Spasine-Brdjani which is close to the Mine and TPP.

The explored area is 1x1km. Detailed geological explorations were carried out in two phases on a larger surface with the aim to separate the deposit segments with the good quality indicators that were pre-set. Already after the first phase of the exploration where the net of drill holes was 160x160 m, it was noticed that the essential parameters of the quality were better in the northern part of the deposit. Then, in the second phase, the dense network was used to reexplorate this part of the deposit. The results justified the needs, so in the end, the area of the deposit with the good quality indicators was defined, which significantly exceeded the required quantities of car-

**Jantar Group d.o.o., Belgrade*
***Mine and TPP Ugljevik*

bonates (absorbent) in reserves, but provided the possibility for leveling the quality as well as the possibility of starting the exploitation in the best part of the deposit.

All exploration works, types of tests, as well as the subsequent separation of the ore bodies that are not only expressed to their geological differences and specificities, but also the qualitative characteristics that determine them, have been designed and processed, that is, analyzed in a function of carbonate similarity for the FGD process.

The Ugljevik Mine and Thermal Power Plant is located in the northeastern part of the Republic of Srpska at the place where the Semberija plain passes into the hills of the Majevica Mountain, about 20 kilometers from the town of Bijeljina.

GEOLOGICAL STRUCTURE OF THE DEPOSIT

Based on the data of exploratory drilling and field geological mapping, it has been found that the explored deposit is mostly built by the Badenian chalk and limestone (M_2^1), and Sarmatian limestone (M_2^2) as an interesting mineral resource, and from an economic point of view the productive area and quartar formation (Q): eluvial-deluvial sediments of insignificant thickness, which for these reasons are not shown on the geological map.

Badenian chalk and subordinate limestones (M^1_2)

The deposits of the Badenian chalk and limestone were deposited over the Upper Badenian massive and laminated marls. This is a clearly defined unit that is mostly built by three lithologically different members (ore bodies): dusty, compact and solid chalk that is often permeated by layers to the sandy limestone.

Dusty chalk M_2^1 **- krd(p)** is in the surface, whereby changing the color and con tent of calcium carbonate gradually shifts from gray marls into this article, characterized by the fact that "the content of silicon in limestones with depth is increased, due to the presence of siliceous spicules sponges in the older parts of the explored profiles" (Vrabac, 2014). It contains lithotamian, shellfish: *Corbula* cf. *gibba* Olivi., *Venus cf. Multilamela* (LAMARCK), *Tellina* sp., *Martinottiella* sp., *Xestoleberis* sp. and spicules *Spongiae*, as well as a very large association of benthic foraminifers and ostracodes. Thickness of this type of chalk reaches 30 meters.

Compact chalk M_2^1 **- krd(к)** is made by lithotamian limestone (calcarettes) with shall fish *Flabellipecten cf. besseri* (ANDRZEJOWSKY), *Lucinoma cf. borealis* (LINNE), *Amphistegina* sp., *Elphidium crispum* (Linne), *Planostegina* sp., *Hydrobia* sp., *Turitella* sp., *Xestoleberis* sp., and fragments of Ostrea sp., many remains of microcxfauna foraminifera, ostracoda, coral and *briozoa.* The largest thickness of this type of chalk is 30.2 m.

Solid chalk M^1_2 **- krd(č)** was not found in any drill hole. However, it was discovered in sections of human-made activity (open pits) in the far western part of the exploration area. It is a variety of chalk, extremely solid, from which the blocks are made as a fundament, or bearing parts of residential buildings.

Lower Sarmatian limestone, chalk, sandstone and clay (M22)

Deposits of the Lower Sarmatian (ore body) lie, most likely, concordant on the Upper Badenian in a greater part of the field. The boundary is noticeable because the Lower Sarmatian limestones are deposited over the Upper Badenian deposits of chalk, which is a correctness found both in the drill holes as well as in the field.

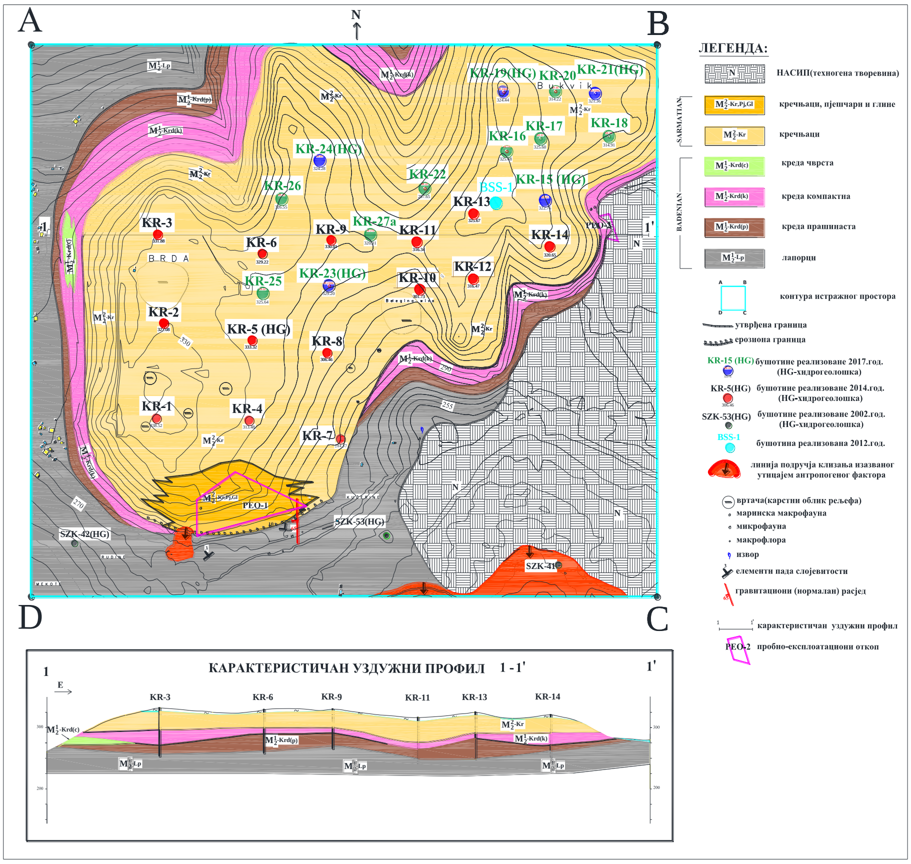

Figure 1 *Geological map of the deposit (R≈1:10 000)*

The older portion of the Lower Sarmatian is made of make Mohrensternia layers while the younger part of the Lower Sarmatian is proven by molluscs *Poliaptes cf.tricuspis* (EICHWALD), *Obsoletiforma absoleta cf vindobonensis* (LASKAREV), *Cardiidae*, *Modiolus* sp., *Granulolabium* sp., *Gibbula cf. picta* (EICHWALD) and *Hydrobia* sp (Vrabac,S. 2014).

It was observed that the Lower Sarmatian mollusks are preserved in the form of prints eyelids and molds, while largely preserved mollusks are present in the Cretaceous sediments of the Upper Badenian.

Quaternary deluvial-eluvial sediments (Q)

These rocks are represented by the surface clays and clays with the limestone debris whose thickness reaches almost 15 meters.

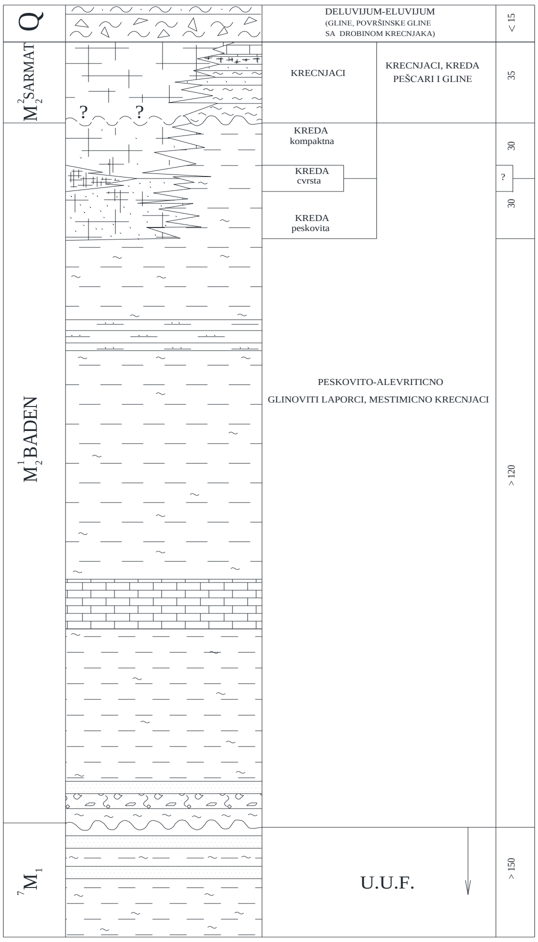

Figure 2 *Litostratigraphic column of the Badenian and Lower Sarmatian sediments*

It can be said that the carbonate rocks, generally, mild (up to 10 degrees) fall to the north-northeast, making a mild monoclinic structure, too.

Geological explorations of the deposit

Methodological observations of the field explorations of the deposits were done by the geological mapping of the field, exploratory drilling, and development of trenches and open mining works.

Detailed geological mapping has selected the prospective members of the carbonate series of sediments, defined for practical reasons as the ore bodies. The results of laboratory tests have fully confirmed this determination of the ore bodies, because they, apart from the geological ones, also possessed the characteristic qualitative parameters in which they differed.

Thus, under the carbonate raw materials, in geological terms, they include:

- sediments of chalk (ore body 3 - dusty to sandy chalk, ore body 2 - compact chalk - lithotamian limestone),
- as well as the deposits of hard, compact Sarmatian limestones (ore body 1).

During explorations, the 27 exploratory drill holes, 26 exploratory trenches and two test-exploitation excavations were carried out. The total of 1,066 partial and 212 complete tests were tested from the laboratory testing for the purpose of testing the quality of mineral raw materials.

In addition to these, the test of grain size distribution, factors of looseness and cohesion, determination the physical-mechanical and deformation characteristics, determination the volume mass, petrographic, difractometric and paleontolo-gical tests, reactivity, Bond index, Mn, Zn, Cu, Co and Cr metals were analyzed and realized the experimental technological tests.

The activities that preceded the phases of detailed geological explorations and which included the calculations of coal combustion, theoretically calculated and measured values of the emission of harmful gases, obtaining a corrective factor, and finally the measurement of flue gases (degree of flue gas flow and amount of pollutants (2012) are shown in Table 1:

Table 1 *Designed requirements regarding the quality of absorbents (Main Desing of construction the FGD plant)*

	Unit measure	Range	Designed
$CaCO_3$	wt-%	85 – 100	< or = 94.0
$MgCO_3$	wt-%	< 2	< 2
SiO_2	wt-%	< 5	< 3
Fe_2O_3	wt-%	< 1	< 1
Other	wt-%	difference to 100	difference to 100
H_2O	wt-%	to approx. 10%	
Bond index	Wi	3.0 – 10.0	5.0
Particle size (delivered)	Mm	max. 20	max. 20
Reactivity	--	Be determined by the contractor	
• Only as information	Titration of HCl at a constant pH value after 3 minutes	> 50%	

The basic parameters of quality were:

- Available Ca or reactivity
- Low content of inert elements
- Impact on the quality of obtained product
- Impact on wastewater treatment
- Particle size/grain size (less = better)
- Special grinding facilities depend on the limestone grindability (Bond Working Index)

Considering the content of inert elements, the same must be below 5%. Particularly important is the share of MgO. Namely, a part of MgO is inert, especially if it is in the form of dolomite, but a part is soluble, and the presence of MgO ions in solution improves the process, so that the content of this element of 0.8-2% I spreferred. The other inert components such as Al, Si and Fe adversely affect the sulfur recovery process so that their presence should be in the following limits: Al_2O3 0.4-0.8%. SiO_2 0.8-1.5%. Fe_2O_3 0.1-0.7%.

Analyzing the obtained quality parameters ($CaCO_3$, $MgCO_3$, SiO_2 and Fe_2O_3) and their synthesis, the appropriate maps were made for each of these parameters, as well as for each mining body separately.

DISCUSSION

It was immediately noticed that the percentage share of calcium carbonate rises to the north and that it has the highest (most favorable) values for each analyzed package (ore body). As it increases, the values of the other three parameters are reduced.

The values of the quality parameters for $MgCO_3$ i Fe_2O_3 are below the above designed units of measure, although they clearly decrease from the middle of deposit to the north. Due to these reasons, these parameters are not the subject of more detailed analysis.

The percentage content of $CaCO_3$ directly depends on the consumption of carbonates in the FGD process and the amount of gypsum produced, and from SiO_2 the abrasive effect in the plants for absorbent preparation.

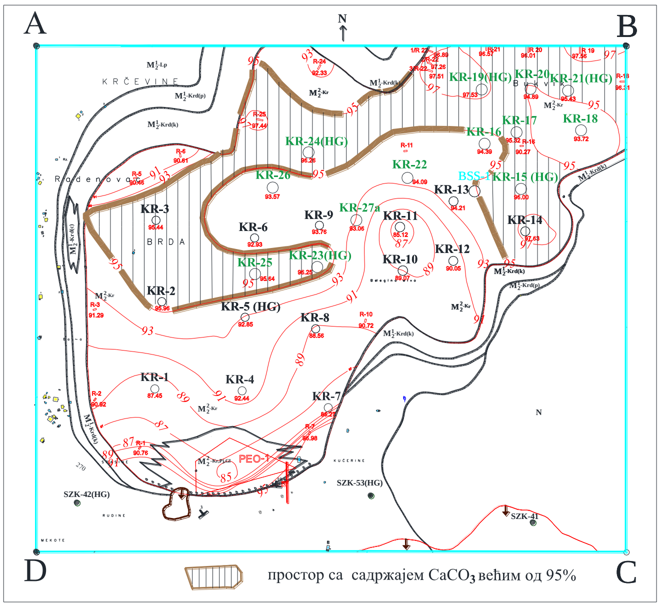

Figure 3 *Contour of the $CaCO_3$ quality for the Sarmatian limestone (ore body 1)*

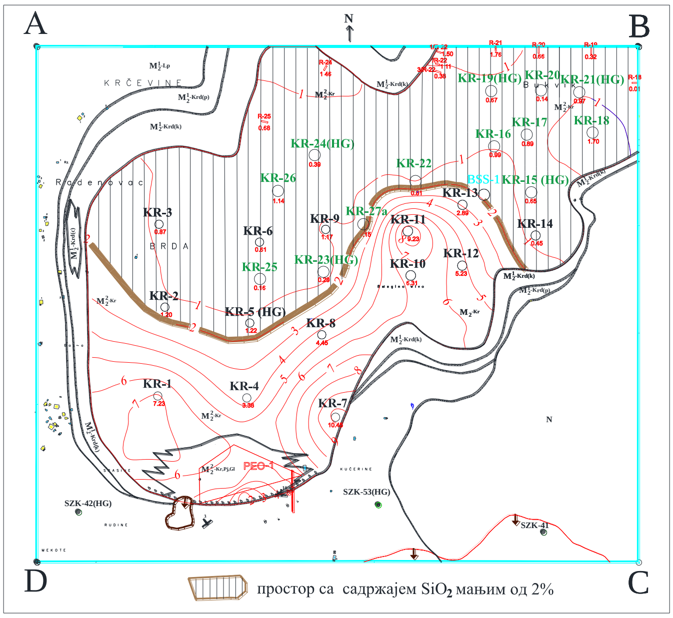

Figure 4 *Contour of the SiO_2 quality for the Sarmatian limestone (ore body 1)*

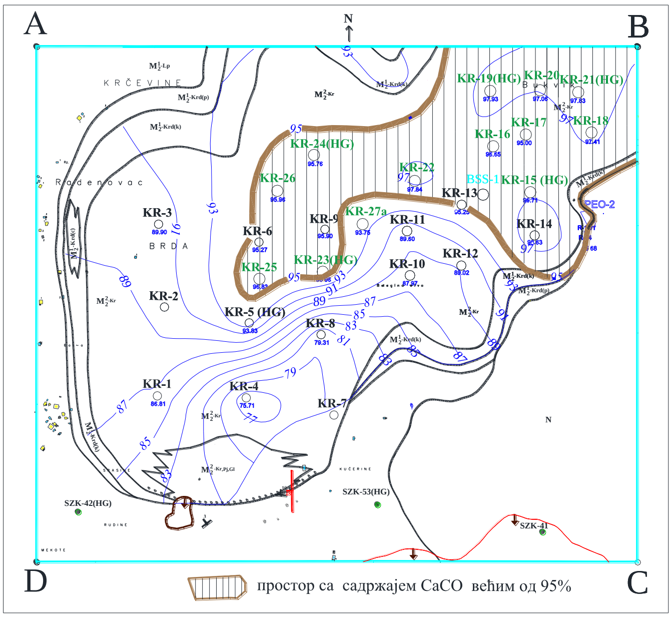

Figure 5 *Contour of the $CaCO_3$ quality for the compact limestone (ore body 2)*

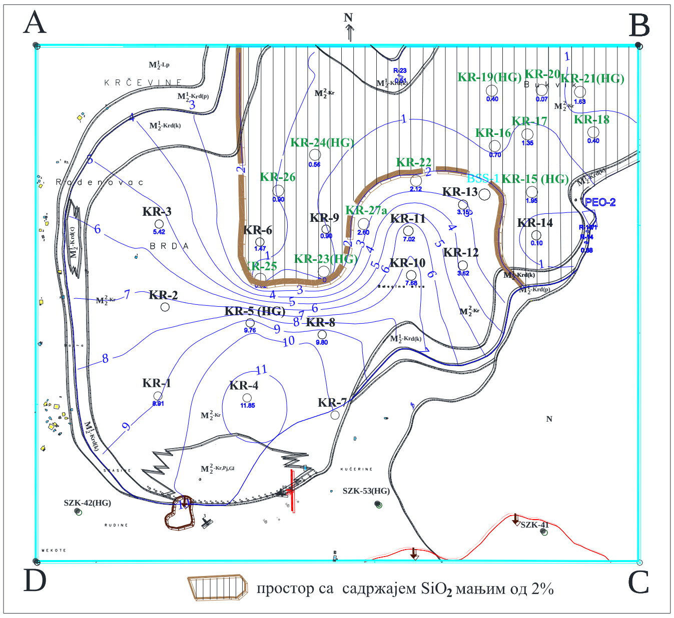

Figure 6 *Contour of the SiO_2 quality for the compact chalk (ore body 2)*

Distribution of calcium carbonate and silicon dioxide in the deposit is a product of various palaeogeographic conditions that dominated the Upper Badenian and Lower Sarmatian. Namely, regression in the Upper Badenian and transgression in the Lower Sarmatian with changing the coastline and sea depth, as well as changes the salinity of the same, caused the distribution of quality parameters as in figures.

The sponges *(Spongie)*, whose skeleton was formed from small spicules built of silicon *(silicispongia)*, and which massively inhabited in the Badenian sea (eucharistic environment), were by a lage part the carrier of SiO_2 in the shallow sea (lithoral-up to 200 m depth) of then Central Parateticis. During the Lower Sarmatian, there was the sweetening of the sea (brachyaline environment) and a smaller spread of the sponges, until their complete absence (Vrabac, 2014 and 2015). The presence of silicispongi certainly affected the percent-tage distribution of SiO_2 in the associated ore bodies. This is also visible on the quality map for SiO_2 of the Lower Sarmatian where the surface area with SiO_2content is below 1%, than it is in Badenian (ore body 2).

Changes in the quality of $CaCO_3$ are small (the order of a few percent), but they are not random and are the product of very subtle changes caused by either the yield of some terrestrial material or certain difference in the types of organisms that inhabited the lithoral, or the difference in the constitution of their carbonate skeletons.

The mutual dependence of $CaCO_3$ and SiO_2 for the ore bodies 2 and 3 is evident on the quality maps. Their isolines of maximum values of $CaCO_3$ are almost identical to the contours of minimum values for SiO_2 within the same ore body.

In the initial phase of exploration, the realization of two test-exploitation excavations is planned. Only one was made due to the justified reasons, with the intention that the exploitation of carbonate mineral raw material starts from already open benches of the coal open pit. The first results were not favorable in that part of the exploration field, so in the second phase, the trial-exploitation excavation 2 was carried out, in the segment of the deposit where very good quality indicators were already indicated.

The place of opening of the open pit (quarry) is immediately imposed, because the easiest way to access the limestone and chalk of the best quality and with the least overburden is from the east side of the deposit from the benches of the northern landfill, from the PEO-2 space. The opening of the same from the west and north sides is excluded because this terrain is falling steeply, and the inhabited areas are in the foot.

CONCLUSION

The two phases of detailed geological explorations were carried out on the deposit of carbonates (limestone and chalk) Spasine-Brdjani with the aim of establishing their quality and reserves, which would serve as an absorbent in the desulphurization process of flue gases of the Thermal Power Plant.

It has been determined that for the predetermined values of certain qualitative parameters there are spaces within the deposit that satisfy these qualities in their integrity.

Analyzing the quality maps for individual ore bodies, those areas with the best quality indicators are precisely defined, and their location in the space is a product of the paleogeographic circumstances that ruled in previous sea and its sweetness.

At the same time, the location from where the exploitation would start was also determined.

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ANALYSIS THE PROFITABILITY OF THE COPPER ORE EXPLOITATION ON THE CEROVO PRIMARNO-DRENOVA DEPOSIT FOR THE CAPACITIES OF FLOTATION ORE PROCESSING OF 6.0 AND 12.0 MILLION TONS ANNUALLY***

Abstract

The problem of exploitation planning refers to A criterion used to optimize the open pit. In spite of sophisticated algorithms, the problem of optimization is always an economic problem, within which the procedures for assessment the necessary economic parameters are defined. Every ore body is different, but the main steps in planning an open pit, when the main objective is to make a profit, are developed by the same principle. When planning the copper ore exploitation, the final economic result depends on the overall technological process of copper obtaining copper as a final product.This work present an economic analysis of the copper ore exploitation on the Cerovo Primarno-Drenova deposit for athe nnual capacity of flotation processing of 6.0 and 12.0 million tons, using the software for economic analysis and long-term planning of open pits Whittle surface (Dassault Systèmes - Geovia).

Keywords: *deposit Cerovo Primarno - Drenova, optimization of the open pit boundary, software Whittle, profitability of exploitation*

1 INTRODUCTION

Profit is the dominant driving factor of modern mining. The process of globalization of the world market is especially pronounced in the sphere of production the mineral resources. The largest world mining investors, as a rule, develop the projects outside of their home countries, and the exploited mineral resources are most often the subject of a global market economy. Under the conditions of globalization over the years, the necessity of formation a unique methodology for evaluation the mining investment projects has been imposed. This is above all significant from the perspective of potential investors, who need a recognizable and verifiable methodology for evaluation the value of mining investment project, in order to collect the sufficient valid and reliable evidences of the economic justification of investment in the same. The developed methodology, which provides a unique and recognizable way to evaluate the value of investment mining projects, is in practice known as a conventional approach to the planning and economic evaluation of the mining projects.

Despite the expressed characteristics of each mining project (specific geological, technological, infrastructural, socio-economic, political conditions), a conventional

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approach, through a set of generally accepted procedures and formal techno-economic documents, provides an opportunity for a recognizable and comparable evaluation the economic value of the investment mining projects.

In implementation the optimization of the final contour of the open pit, in addition to the optimal contours also a set of additional contours is constructed. These additional contours are constructed as identical as the optimal contour, but one parameter (rarely) for defining the economic model is changed, resulting in generation the optimal contours different from the initial (nominal) one. In essence, an analysis of sensitivity the contour of the open pit to the parameter being changed is actually carried out by this way.

When the final contour of the open pit is determined, it is necessary to define the order in which the blocks will be excavated inside the final contour of the open pit or to define the excavation dynamics. It can be viewed as the order of excavation by which the blocks should be removed during the lifetime of the open pit, in order to increase the total profit, in accordance with a series of operational-technological and physical constraints.

The aim of performed analysis is to define the optimal boundary of the open pit Cerovo Primarno-Drenova for the given techno-economic parameters and limitations of the flotation processing to 6.0 million tons (Variant I), or 12.0 million tons (Variant II), respectively.

The analysis was carried out using the software for economic analysis the long-term planning for development the open pits Whittle (Dassault Systèmes - Geovia).

The following was processed within the analysis:

1) Optimization of the open pit.
2) Selection the optimal contour of the open pit for defined technical-economic parameters, terrain topography and existing innovative block model of the deposit.
3) Optimization the dynamics of ore and overburden excavation at the open pit.
4) Calculation the quantity of ore and overburden and Net Present Value in the optimal contour of the open pit.

In order to implement the optimization process in Whittle software, the expected mining costs of ore exploitation and processing to the level of concentrate of the useful component, as well as the total metallurgical costs for the final product or cathode, were first estimated.

As the software manipulates only with the attributes/values of the mini blocks from the block model of deposit, it is necessary to attach this time dependence to the mini blocks. This dependence was achieved on the basis of production limitations, i.e. limited capacity of the flotation ore processing.

To optimize the open pits, the economic parameters were used which include: [1]

- excavation costs per ton of excavations,
- processing costs per ton of ore,
- costs of metallurgical processing per unit of produced basic product – cathode,
- metal prices,
- discount rate.

In addition to the economic ones, for the optimization process, the technological parameters as well as the capacity constraints are defined per technological phases for the optimization process:

- recovery and depletion of the ore in the stage of excavation,
- recovery in the phase of flotation processing,
- recovery in the phase of metallurgical processing,
- limitation the open pit capacity in the phase of ore excavation,
- capacity limitation in the phase of flotation processing.

Block model is the basis of the modern open pit mine planning. The block model is a regularized, three dimensional array of blocks used to represent the properties and characteristics of the ore body. The raster representation of the ore body is beneficial to the analysis using the computerized techniques and has resulted in development a variety of algorithms and software packages that use a discretization of the ore body into a block model as their basis [2].

Figure 1 shows the zone of future exploitation in the deposit Cerovo Primarno-Drenova, with the disposition of the existing mining facilities at the site Cerovo.

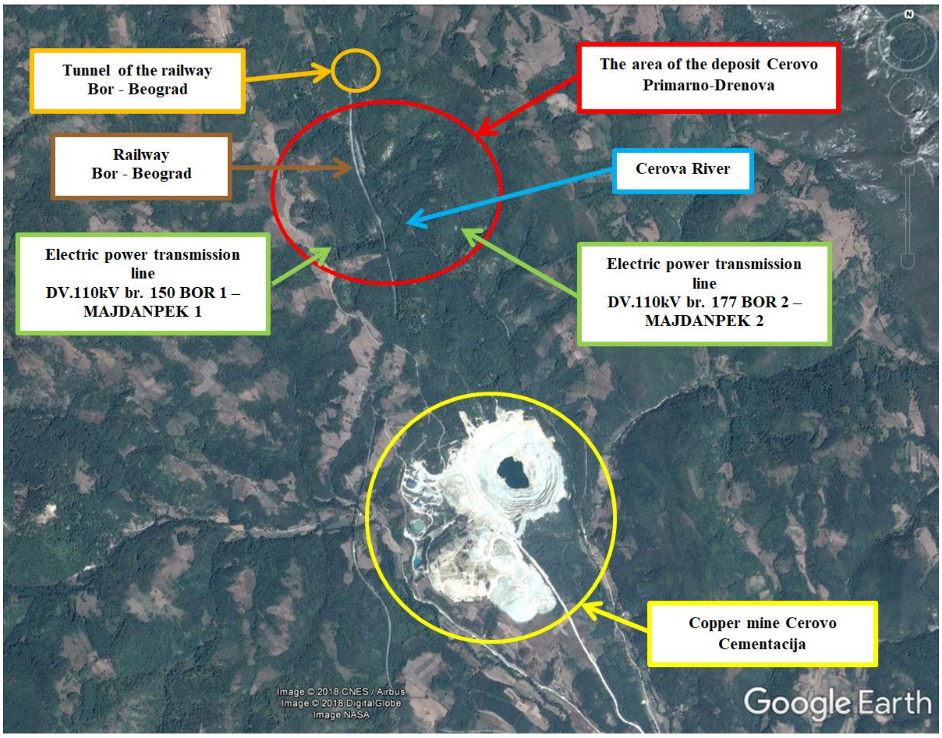

Figure 1 *Zone of the future exploitation on the deposit Cerovo Primarno-Drenova with a dispozition of the exisating mining facilities in the field Cerovo*

2 TECHNO-ECONOMIC PARAMETERS FOR OPTIMIZATION THE OPEN PIT

The techno-economic parameters used for optimization and determining the optimal open pit boundary are shown in Table 1.

The metal prices (Cu, Au, Ag) were adopted on the basis of long-term forecast of price movements on the world metal exchanges and forecast of the World Bank.

Table 1 *Techno-economic parameters for optimization the open pit*

Parameter	Unit	Value
Base metal prices		
• Copper	USD/t	6,000
• Gold	USD/kg	40,000
• Silver	USD/kg	500
Costs of ore and overburden (excavation) excavation	USD/t	1.30
Costs of flotation ore processing	USD/t	3.40
Costs of metallurgical concentrate processing		
• Costs of copper production from concentrate	USD/t Cu cathode	670
• Costs of gold refining	USD/kg	150
• Costs of silver refining	USD/kg	15
Flotation recoveries		
• Copper	%	85.0
• Gold	%	37.0
• Silver	%	21.0
Metallurgical recoveries		
• Copper	%	98.5
• Gold	%	91.0
• Silver	%	85.0
Annual capacity of ore processing	t/year	6 Mt/12 Mt
Discount rate	%	10

The final angles of general slopes have been adopted from the existing technical documentation [3].

3 OPTIMIZATION OF THE OPEN PIT AND SELECTION THE OPTIMUM PUSHBACKS

Generating the optimum open pit limit was performed applying the software Whittle, which uses the modified Lerchs-Grossmann algorithm. In this approach, a series of the open pits of different sizes is generated, wherein each open pit has the highest undiscounted value for the considered open pit size [4, 5].

It should be kept in mind that the only criterion used in the Whittle method is to maximize the net present value of revenues due to the sale of useful mineral resources or concentrate obtained from the open pit.

According to the Whittle methodology, the optimization algorithm can be roughly divided into three steps:

- Generating the shells of the open pits,
- The best and worst scenario of excavation,
- Selection the limit boundary of the open pit on a graph of changing the optimal contour depending on the revenue factor.

The results of optimization are shown in Tables 2 and 3 (the first 50 shells of the open pits, obtained by optimization from total 85, are shown) and on a diagram of the tonnage and Net Present Value (NPV) ratio for the best and worst case, Figures 2 and 3, for Variants I and II, respectively.

The presented diagrams represent the changes of optimal contours depending on the revenue factor of the net values. Diagrams represent the net present value for each optimal contour. The best and worst curves of the net values give the upper and lower limits of the value that can be achieved in practice [6, 7].

Table 2 *Results of optimization (Variant I)*

Pit	Cash flow	Cash flow	Ore	Waste	Mine Life
	Best case	Worst case	Best case	Best case	Best case
	$ disc	$ disc	t	t	year
1	9,227,466	9,227,466	452,404	35,816	0
2	13,066,903	13,066,903	694,819	133,863	0
3	20,086,204	20,086,204	1,197,439	199,234	0
4	31,946,480	31,946,480	2,172,439	495,228	0
5	46,351,099	46,351,099	3,425,007	1,124,705	1
6	61,123,468	61,123,468	4,888,398	2,102,701	1
7	117,985,032	116,825,082	10,490,013	10,348,358	2
8	178,515,651	173,391,252	18,446,085	18,432,804	3
9	238,678,559	225,550,581	29,026,560	26,233,636	5
10	268,398,761	249,161,379	35,561,756	31,326,060	6
11	325,631,616	290,802,758	50,841,475	49,926,553	8
12	348,812,488	303,447,349	58,800,079	59,841,902	10
13	376,513,606	313,154,101	70,894,017	75,267,682	12
14	390,178,785	314,207,717	77,964,086	86,573,628	13
15	405,423,512	311,780,208	87,974,041	100,624,047	15
16	419,543,434	302,054,308	100,836,404	118,195,992	17
17	433,432,525	281,548,744	119,118,263	142,831,919	20
18	451,660,973	230,968,841	164,437,256	210,332,798	27
19	**457,220,248**	**201,965,432**	**189,294,306**	**253,473,149**	**32**
20	461,564,667	162,721,027	228,334,024	317,448,710	38
21	462,588,525	150,810,330	241,151,133	338,871,350	40
22	463,288,457	137,687,721	252,525,626	362,755,601	42
23	463,850,082	124,859,193	264,732,853	386,944,862	44
24	464,231,341	112,449,210	275,372,025	411,458,177	46
25	464,357,852	108,105,937	280,185,787	420,058,695	47
26	464,607,019	92,951,797	291,044,150	452,197,081	49
27	464,740,703	83,109,788	299,297,517	474,927,517	50
28	464,846,582	72,776,395	307,879,670	498,529,020	51
29	464,914,079	64,392,420	314,168,753	519,816,798	52
30	464,963,595	55,927,317	321,469,484	541,567,569	54
31	464,977,254	54,085,099	323,998,606	550,173,943	54
32	464,945,621	17,847,297	366,926,233	679,880,261	61
33	464,949,969	16,149,495	368,957,960	687,615,412	61
34	464,953,733	6,222,044	378,990,143	726,843,152	63
35	464,955,030	2,960,718	383,045,168	741,726,584	64
36	464,954,450	52,310	386,155,988	756,633,914	64
37	464,951,337	-3,384,337	390,320,609	773,260,277	65
38	464,950,426	-5,185,777	391,812,791	779,260,101	65
39	464,944,907	-10,597,242	396,837,312	801,113,928	66
40	464,938,811	-14,278,516	400,496,108	820,924,673	67
41	464,936,880	-15,106,803	401,634,213	826,399,038	67
42	464,932,350	-17,154,222	403,590,067	837,025,698	67
43	464,922,655	-22,601,342	407,678,814	857,623,299	68
44	464,920,133	-23,418,127	408,665,172	862,470,790	68
45	464,917,126	-24,606,532	409,710,542	868,414,879	68
46	464,911,661	-26,509,630	411,244,876	879,152,030	69
47	464,901,016	-30,553,198	414,617,038	898,321,522	69
48	464,892,884	-33,858,669	417,011,273	912,440,851	70
49	464,892,854	-33,860,022	417,019,704	912,491,486	70
50	464,892,523	-33,881,642	417,120,869	912,980,981	70

Table 3 *Results of optimization (Variant II)*

Pit	Cash flow	Cash flow	Ore	Waste	Mine Life
	Best case	Worst case	Best case	Best case	Best case
	$ disc	$ disc	t	t	year
1	9,260,682	9,260,682	452,404	35,816	0
2	13,139,213	13,139,213	694,819	133,863	0
3	20,278,149	20,278,149	1,197,439	199,234	0
4	32,502,488	32,502,488	2,172,439	495,228	0
5	47,629,302	47,629,302	3,425,007	1,124,705	0
6	63,543,332	63,543,332	4,888,398	2,102,701	0
7	123,618,659	123,618,659	10,490,013	10,348,358	1
8	193,132,682	191,674,273	18,446,085	18,432,804	2
9	265,672,962	260,056,097	29,026,560	26,233,636	2
10	303,256,141	294,107,033	35,561,756	31,326,060	3
11	386,126,676	366,773,613	50,841,475	49,926,553	4
12	422,512,970	395,967,291	58,800,079	59,841,902	5
13	470,097,918	431,131,940	70,894,017	75,267,682	6
14	495,685,419	447,987,265	77,964,086	86,573,628	6
15	524,882,635	464,134,153	87,974,041	100,624,047	7
16	555,431,579	476,196,011	100,836,404	118,195,992	8
17	589,306,005	480,972,031	119,118,263	142,831,919	10
18	649,988,097	475,548,719	164,437,256	210,332,798	14
19	673,856,422	462,889,732	189,294,306	253,473,149	16
20	699,140,756	438,432,030	228,334,024	317,448,710	19
21	706,034,458	429,093,165	241,151,133	338,871,350	20
22	711,304,000	417,256,011	252,525,626	362,755,601	21
23	715,951,270	404,051,428	264,732,853	386,944,862	22
24	719,422,391	390,864,852	275,372,025	411,458,177	23
25	720,633,760	385,699,911	280,185,787	420,058,695	23
26	723,346,772	368,446,640	291,044,150	452,197,081	24
27	724,877,124	356,291,639	299,297,517	474,927,517	25
28	726,171,217	343,146,734	307,879,670	498,529,020	26
29	726,986,527	332,224,668	314,168,753	519,816,798	26
30	**727,686,074**	**320,656,572**	**321,469,484**	**541,567,569**	**27**
31	727,890,277	317,538,739	323,998,606	550,173,943	27
32	729,247,431	260,860,107	366,926,233	679,880,261	31
33	729,307,379	258,037,634	368,957,960	687,615,412	31
34	729,438,061	241,874,224	378,990,143	726,843,152	32
35	729,421,182	236,034,258	383,045,168	741,726,584	32
36	729,410,759	230,799,916	386,155,988	756,633,914	32
37	729,361,973	224,433,291	390,320,609	773,260,277	33
38	729,336,194	221,719,614	391,812,791	779,260,101	33
39	729,194,457	212,547,130	396,837,312	801,113,928	33
40	729,054,721	206,062,901	400,496,108	820,924,673	33
41	729,008,704	204,449,838	401,634,213	826,399,038	33
42	728,908,496	200,749,416	403,590,067	837,025,698	34
43	728,687,095	191,772,058	407,678,814	857,623,299	34
44	728,624,732	190,119,119	408,665,172	862,470,790	34
45	728,547,953	188,156,030	409,710,542	868,414,879	34
46	728,405,354	184,627,379	411,244,876	879,152,030	34
47	728,121,375	177,423,576	414,617,038	898,321,522	35
48	727,910,602	171,970,747	417,011,273	912,440,851	35
49	727,909,791	171,963,460	417,019,704	912,491,486	35
50	727,901,057	171,887,775	417,120,869	912,980,981	35

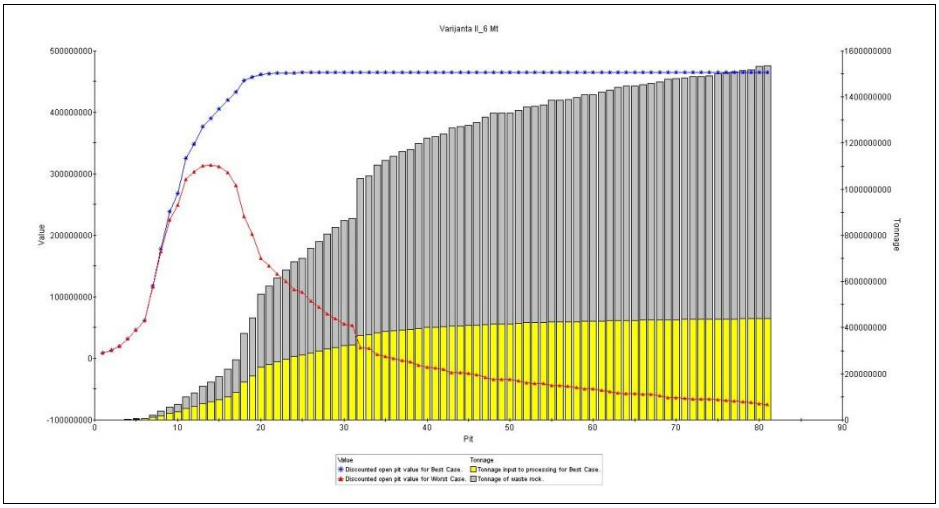

Figure 2 *NPV tonnage graph for the best and worst case – Variant I*

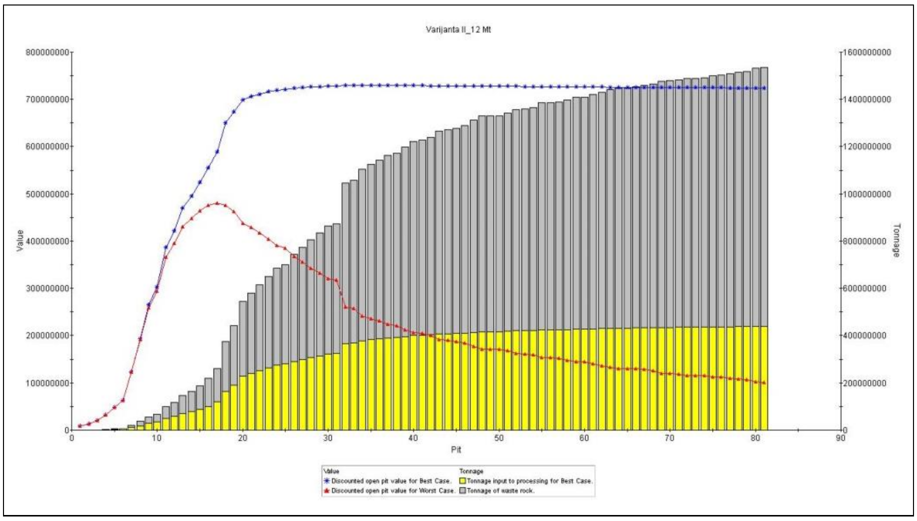

Figure 3 *NPV tonnage graph for the best and worst case – Variant II*

Based on the results of optimization process:

- For Variant I, a shell of the open pit No.19 was selected, which includes 189,294,305 t of ore and 253,473, 150 t of overburden.
- For Variant II, a shell of the open pit No.30 was selected, which includes 321,469,484 t of ore and 541,567, 569 t of overburden.

Figures 4 and 5 show the final contours of the open pit for Variant I and Variant II.

a) b)

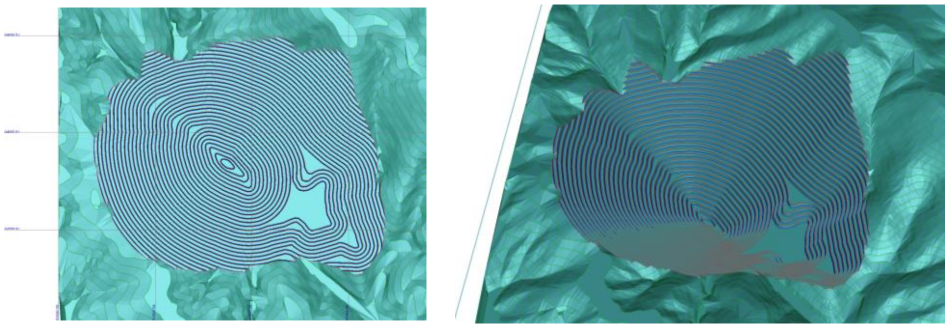

Figure 4 *Contour of the final open pit boundary – Variant I a) 2D view, b) 3D view*

a) b)

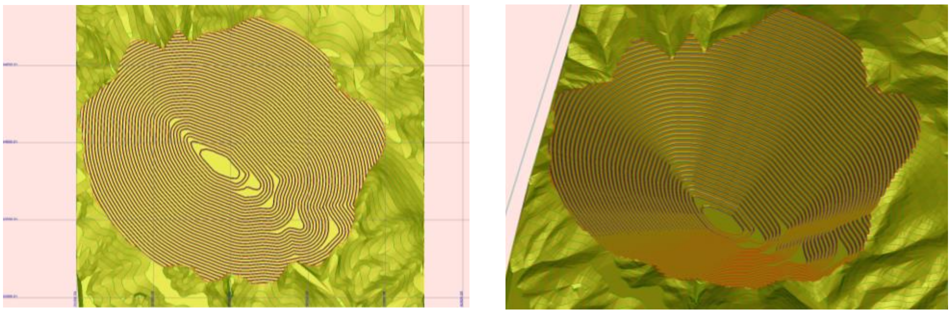

Figure 5 *Contour of the final open pit boundary – Variant II a) 2D view, b) 3D view*

4 OPTIMIZATION OF THE EXCAVATION DYNAMICS

When the final contour of the open pit is determined, it is necessary to define the order in which the blocks will be excavated inside the final contour of the open pit, or to define the excavation dynamics.

Whittle software can calculate the lifetime of the mine with the total quantities of ore and waste, content of metals, cash flows, and discounted cash flows, that is the NPV, in accordance with the given limits by the user [8].

The Milawa algorithm, incorporated in the Whittle software, was used to optimize the excavation dynamics.

The excavation dynamics was optimized in the case of balancing the excavations, with the established requirement for a constant annual capacity of flotation ore processing, according to the considerations of Variants I and Variants II.

On the basis of selected phases of the open pit development, the dynamics was generated that is used to realize the highest profit for the company for Variant I and Variant II.

The optimized excavation dynamics with the annual cash flow for Variant I and Variant II is shown in the graphs in Figures 6 and 7, respectively.

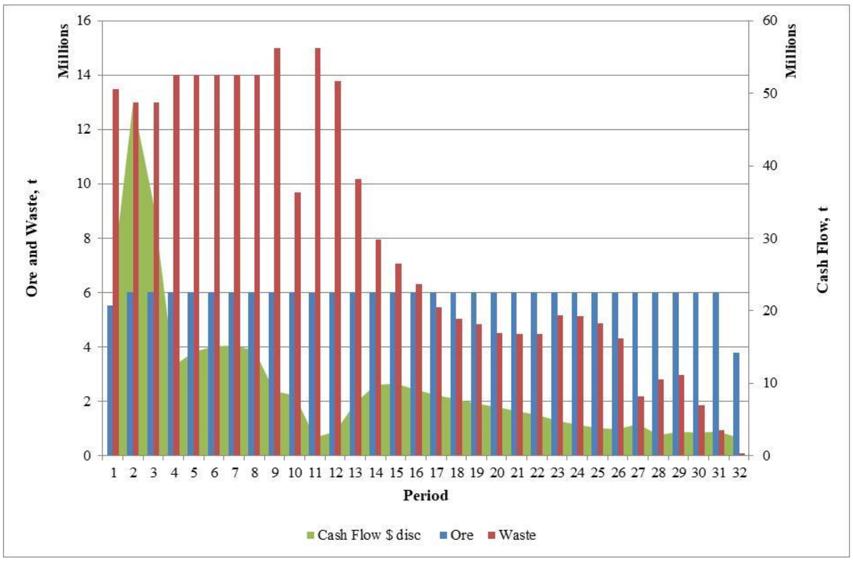

Figure 6 *Graphic view the optimized excavation dynamics with the cash flow (Variant I)*

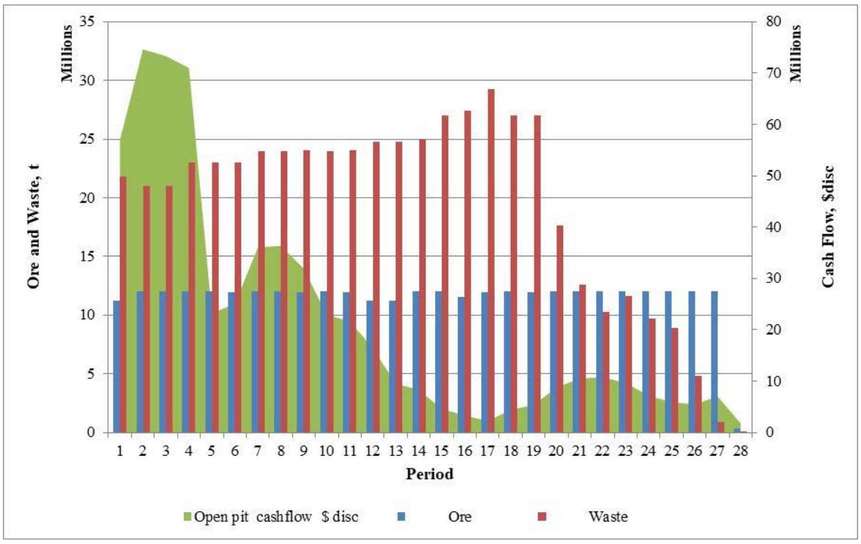

Figure 7 *Graphic view the optimized excavation dynamics with the cash flow (Variant II)*

CONCLUSION

The main goal of each mining operation is to make a profit. Basically, the mining processes are complex and complicated, with many different economic, technical, environmental and other parameters that must be planned before the project gets its practical value. Due to this, the costs, prices, reserves, excavation and processing of the ore, as well as many social aspects, are crucial for the project evaluation.

Profitability of exploitation the Cerovo Primarno - Drenova deposit was analyzed for the following annual processing capacities:

1) For capacity of 6.0 million tons annually – Variant I, and
2) For capacity of 12.0 million tons annually – Variant II.

The obtained techno-economic results are:

I Variant I:

i.	Ore quantity	189,294,305 t
ii.	Overburden quantity	253,473,150 t
iii.	NPV	316,895,258 $
iv.	Life time of the mine	32 years

II Variant II:

i.	Ore quantity	321,469,484 t
ii.	Overburden quantity	541,567,568 t
iii.	NPV	436,554,907 $
iv.	Life time of the mine	28 years

Based on the analysis, it can be concluded that significantly better economic results are achieved for the annual ore processing capacity of 12.0 million tons of ore - Variant II. Generated NPV is higher by 37.76%, or 119,659,649 $.

However, in deciding on the excavation capacity, apart from the economic aspect, the social aspect as well as the state interest must be taken into account.

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APPLICABILITY OF THE SHORTWALL MINING METHODS IN REMBAS MINE PITS**

Abstract

In the Rembas mine pits, the coal exploitation lasts for more than one century. During this period, most of coal reserves have been mined, so there is a need for introduction the new and modern technical solutions, which will enable rationalization of exploitation, higher productivity, safety on operations and better operation conditions with lower investments. In the Rembas mine pits for coal exploitation, the low-productive pillar mining methods are used. During the eighties of the last century in some pits, the mechanized longwall mining method was applied, but the expensive equipment and complex natural-geological conditions in the area Resava-Moravian coal basin restrict application of this metod. Bad financial situation, as well as the increasingly difficult operation conditions of exploitation, indicate a need to apply some of the methods which would be technically justified, and whose cost of exploitation would be proportional to the possibilities of mine. In this paper, the possibilities for application the shortwall mining methods are considered with their advantages compared to the previously applied mining methods in the Rembas mine.

Keywords: *underground mining, mining methods, shortwall mining, Rembas mine.*

1 INTRODUCTION

Rembas is the undergound coal mine with the head office in Resavica. It is a part of the Public Enterprise for Underground Coal Exploitation Resavica. The Rembas mine has a long tradition, over 150 years of coal exploitation and very rich history [1]. Currently, within the Rembas mine, there are four active pits: "Jelovac", "Strmosten", "Ravna Reka - IV block" and "Senjski Rudnik".

During a long-term coal mining from the area Resava-Morava coal basin, most of the coal reserves have been exploited. As the dominant systems of mining in deposits of this basin, the classical pillar mining methods were applied in different forms. The choice of these mining methods is caused by the deposit conditions which are not particularly favorable. Exploitation conditions in the Rembas mine pits are characterized by the expressed tectonics, relatively unfavorable physical-mechanical properties of the operation environment, variable thicknesses of coal seams, coal tendency for spontaneous self-ignition and presence of dangerous coal dust and hazardous gases in some pits [2].

According to the Book of coal reserves, the state of balance reserves on December 31, 2016 amounted to [3]:

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Table 1 *State of balance coal reserves in "Rembas" mine (in tonnes)*

Deposit	Category			
	A	B	C_1	$A+B+C_1$
Ravna Reka	419 790	849 380	880 770	2 149 940
Senjski Rudnik	117 070	131 130	192 480	440 680
Strmosten	371 230	984 990	1 690 930	3 047 150
Jelovac	610	1 085 440	514 600	1 600 650

Considering the coal exploitation is taking place at ever greater depths and in increasingly difficult conditions, there is a need for application of more efficient mining methods which, in addition to the lower investments and minimal costs, will enable more rational exploitation of the remaining coal reserves. Since the opening of underground coal mines, mostly low-production pillar mining methods have been used, so there is a need for implementation a new more mechanistic method that will enable the production increase, with far better indicators, better working conditions and significantly better level of safety in operations. Due to the complex geological conditions in the deposits, as well as due to the necessary high investments for application the longwall mining methods, the most realistic solution is the application of shortwall mining method by a direction of dip, with drilling and blasting technology and obtaining the roof coal.

In the "Senjski Rudnik" pit exploitation is carried out under the old works; the remaining coal reserves are low and mining will come to the end for couple of years. Due to this, it does not need to count on the new technological solutions of mining.

For the other pits in Rembas mine possibility for application the shortwall mining method will be represented on an example of the "Ravna Reka-IV block" pit.

1.1 Geological Structure of the Ravna Reka Deposit

In the deposit "Ravna Reka-IV block" in the coal-bearing horizon, there is a seam of good quality brown coal. Coal seam has a complex structure, and it is divided in two branches. The thickness of the coal seam ranges from 2.2 m to 18.1 m, the thickness of pure coal is from 0.5 m to 12 m, while the average thickness of pure coal is 4.54 m. The direction of the coal seam is, generally, east - west, with a fall of 12º-15º towards the north. The coal seam floor is made of gray-white to greenish clay sands, alumina and coal clays. Crossing between the floor series and coal seam was built mainly from coal clays. The coal seam roof is presented in the normal primary conditions with grayish-whitish marl, while in the intermediate and western parts of the deposits it is eroded by the pulled-over red Permian sandstone. Intermediate waste in the coal seam is represented by coal clay from 0.2 m to 4.7 m thickness and clayed sandstone from 0.3 m to 2.1 m thickness. These interlayers are completely absent in some parts of the deposit, and coal seam appears as a single compact seam without intermediate rock [4].

2 DESCRIPTION OF THE SHORTWALL MINING METHOD

The application of shortwall mining methods should represent a transition the classic pillar and longwall mining methods.

In shortwall mining methods, the face lengths are relatively small, not more than 20-30 m, which allows better adjustment to the specific conditions in deposit [5]. Depending on the conditions in deposit, there is a possibility to increase the face length, but also reduce it if there is a justification for this. The application of some of the possible shortwall mining method variants should enable the increase face length in order. Elimination of separate ventilation and elimination or reducing the use of timber support improves the operation conditions and safety on the excavation process [5].

2.1. Principle of Excavation

Currently, the exploitation on the Ravna Reka deposit is carried out in the ”Ravna Reka-IV block“ pit in the mining field OP-1 using the pillar “G“ method. In the mining fields OP-2 and OP-3, the conditions in the deposit are such that they enable the application of shortwall mining method by the full dip direction of coal seam. Within the development phase, the mining field OP-2 is divided into pillars per a coal seam strike by drivage a haulage and ventilation drift at a distance of 40 m. For the next pillar per strike, a new ventilation drift is driven instead of preserving the haulage drift of the previous pillar. On that way, between two strike pillars at a distance of 8 m, a protective pillar is created, through which the ventilation connections are made. At the end of the mining field,a preparatory incline between haulage and ventilation drift is driven. In this incline, the shortwall excavation equipment is installed: double chain excavation conveyor and friction or hydraulic props with steel or timber roof beam. Obtaining of coal in face is carried out by the drilling-blasting works, while the friction support is used for supporting the shortwall face. Double chain conveyor is used for removal the cast coal. This kind of a shortwall face structure enables a flow-through ventilation, while a separate ventilation is used during the shortwall preparation phase. Figure 1 shows the construction of a shortwall face.

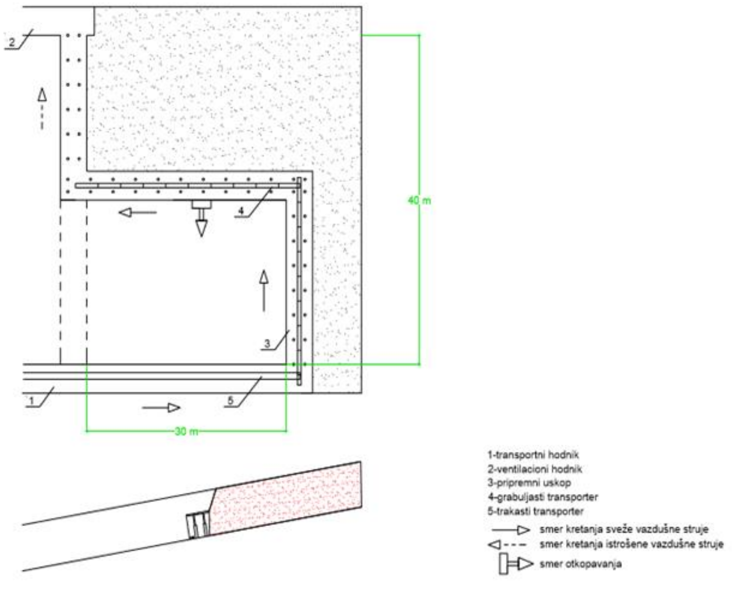

Figure 1 *Construction of a shortwall face by a distance of full dip*

The shortwall work technology consists of two basic phases, which are repeated cyclically. In the first phase, the coal undercutting is carried out in the subsection part of a shortwall face by the drilling-blasting works. Therefore setting support, loading and removal of coal are carried out. In the second phase, after the certain face progress in the subsection part and after removal the friction props from a demolition line, coal is obtained from the upper part of coal seam. Obtaining of a roof coal can be done alternately at the face; while in one part of the face there is excavation in a subsection, in the second part the caving of the roof coal will be done. The work cycle is shown in Figure 2.

The selected friction support, its carrying capacity, the layout and face advance (which causes a short open stope time) should ensure that the all projected phases are normalized without the difficulties caused by the face deformation of face due to the impact of the rock pressure in the excavation area.

For excavation in the first phase, the excavation height can be maintained as with the existing pillar "G" method applied in the "Ravna Reka-IV blok" pit, due to the existing drilling equipment. The height of the upper part of the coal, which is obtained in the second phase, is conditioned by the coal steam thickness.

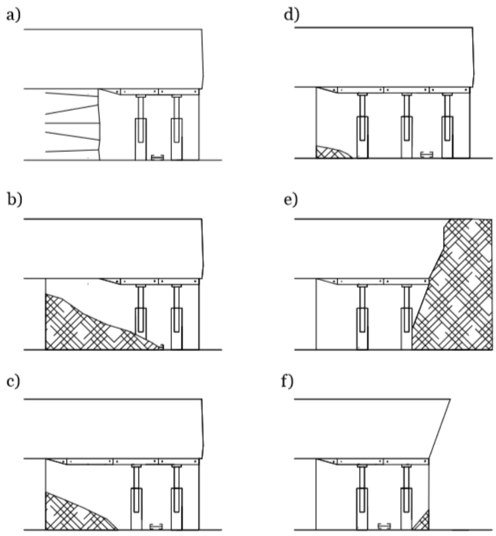

Figure 2 *The cycle of work at a shortwall face: a) drilling in the subsection, b) coal loading after blasting, c) setting of the roof beam, d) setting of the friction prop, e) obtaining the roof coal, f) moving conveyor to the starting position*

2.2. Parameters of Drilling and Blasting

The specific consumption of explosives depends mainly on the characteristics of the rock mass, selected type of explosive and surface of the room cross-section.

The specific consumption of explosives could be defined by the following relations [6]:

$$q = 0.4 \cdot \left(\sqrt{0.2 \cdot f} + \frac{1}{\sqrt{S}} \right)^2 \cdot e \cdot k = $$
$$= 0.34 \text{ [kg/m}^3\text{]} \qquad (1)$$

where:

$e = 480/A_x$ - coefficient of working ability of explosives,

Ax = 190 [cm^3] - working capacity of methane permitted explosive Metandetonit,

k=1 - coefficient which characterizes the necessary quality of the rock crushing,

f = 0.8 - strenght ratio,

S - surface of the cross section for blasting.

According to the Rulebook on Technical Norms for Handlings of Explosives and Blasting in Mining, only the methane millisecond detonators may be used, whereby in the adjacent drillholes it can be detonators of the same number or adjacent higher or lower number of deceleration interval. Also the sum of deceleration interval cannot exceed 136 ms. Because of that, the blasting will be performed in sections of 10 m, so the cross section area of one section will be S = 30 m^2.

The resulting value is increased by 5%, and the specific consumption of explosives will be:

$q = 1.05 \cdot 0.34 = 0.357$ [kg/m^3]

The required number of drillholes could be calculated according to the formula [6]:

$$N = \frac{1.27 \cdot q \cdot S}{d^2 \cdot g \cdot k_p} = 26.5 \qquad (2)$$

where:

q = 0.34 [kg/m^3] - specific consumption of explosives,

S = 30 [m^2] - surface of the cross section for blasting,

d_p = 32 [mm] - diameter of cartridge,

g = 1150 - density of explosive Metandetonit,

k_p= 0.435 - drillhole loading coefficient [7].

$$k_p = k_p' \cdot k_p'' = 0.75 \cdot 0.58 = 0.435 \qquad (3)$$

$$kp' = \frac{l_p}{l_b} = \frac{0.78}{1.03} = 0.75 \qquad (4)$$

where:

l_p- loading length of drillhole,

l_b- the length of drillhole.

$$kp'' = \frac{\frac{d_p{}^2 \pi}{4}}{\frac{d_b{}^2 \pi}{4}} = \frac{d_p{}^2}{d_b{}^2} = \frac{0.32^2}{0.42^2} = 0.58 \qquad (5)$$

where:

d_p- diameter of cartridge,

d_b- diameter of drillhole.

The length of borehole can be calculated according to the formula:

$k_{ib} = l_{sm}/l_b \Rightarrow l_b = l_{sm}/k_{ib} = 1.03$ [m] (6)

where:

l_{sm}= 1 [m] - predicted advance per shift,

k_{ib}= 0.97 - coefficient of drillhole utilization.

The required amount of explosives could be calculated according to the formula:

$Q = q \cdot S \cdot l_b \cdot k_{ib} = 10.7$ [kg] (7)

Quantity of explosives per one drillhole:

$Q_1 = Q/N = 0.4153$ [kg],

it being adopted 0.42 [kg] (8)

Quantity of explosives needed for the center cut:

$Q_z = Q_1 \cdot 1.2 = 0.504$ [kg] (9)

Quantity of explosives needed for the auxiliary drillholes:

$Q_p = Q_1 \cdot 1.1 = 0.462$ [kg] (10)

The following quantity of explosives is adopted:

$Q_z = 0.5$ [kg]

$Q_p = 0.5$ [kg]

The corrected number of drillholes will be:

$N_b = Q/Q_1 = 25.47$

The 26 drillholes, 4 in centre cut and 22 auxiliary drillholes are adopted.

The corrected quantity of explosives for one blast will be:

$Q = 22 \cdot 0.5 + 4 \cdot 0.5 = 13$ [kg]

Considering the number of drillholes, drilling according to the schedule given in Figure 3 is adopted. Initiation of loadings is done by the millisecond electric detonators, intended for use in the methane mode. In this case, four slowdown intervals are used.

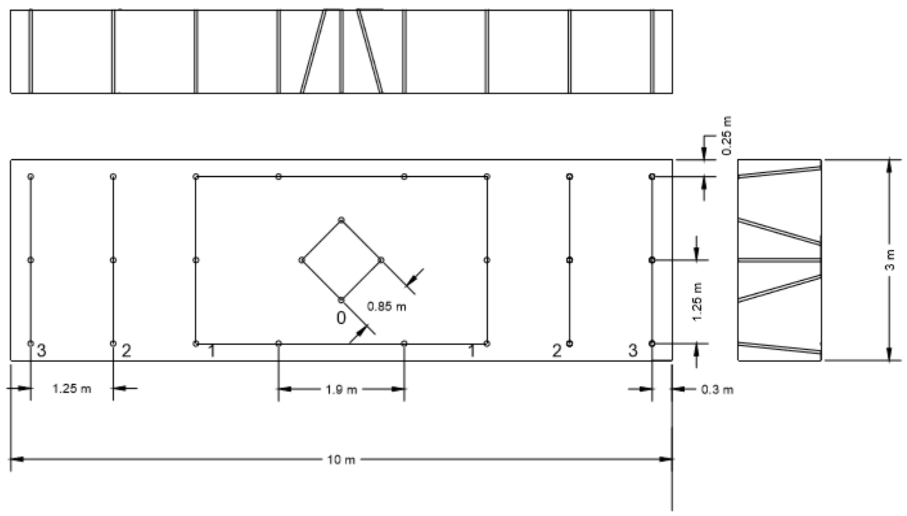

Figure 3 *Drilling diagram and order of loading initiation at the coal face with the center cut (interval of slowing is 34 ms)*

The roof coal is obtained in sections of 3 m long by the blasting of drillholes with a lenght equal to the roof coal thickness. For a specific consumption of explosive, a lower value is taken than for blasting in coal face, because a large slope and gravity have a positive influence on the coal collapse.

Using the shortwall mining method, i.e. increasing the face length, an increase in productivity could be achieved, the number of excavation units could be decreases, organizational conditions could be impro-ved, and utilization of the haulage system could be increased. It would also reduce the costs of timber consumption, reduce the hard physical labor, as well as the number of preparatory units. The flow-through ventilation ensures safety and better climate conditions, especially in methane pits.

RESULTS AND DISCUSSION

By comparison the face parameters and mining method indicators, it can be concluded that the application of the shortwall mining method has many advantages over the pillar mining methods, such as:

- a significantly lower preparation ratio than in the pillar methods,
- better excavation effects,
- higher excavation intensity,
- drilling of roof coal is carried out from the supported area, which also improves the operation conditions and safety on coal face,
- by increasing the shortwall face lenght, an increase of shortwall face output and excavation productivity is ensured,

- number of preparatory units and number of workers on preparation are reduced, as well as the cost of supporting,
- better organization with significantly better operation conditions, and
- higher recovery, less losses and less dilution.

Table 2 present the calculated indicators in case of application the shortwall mining method for miningthe field OP-2 in comparison with the same indicators for mining the field OP-2 in case of the pillar G method application.

Table 2 *Comparative overview of indicators of the applicable mining methods for the Ravna Reka deposit*

Mining method	Preparation ratio [m/t]	Shortwall face efficiency [t/sm]	Excavation effects [t/nad]	Excavation intensity [t/m^2]
Pillar G method	0.0139	34.58	8.89	5.87
Shortwall mining method	0.00503	48.53	12.1325	6.13

On the basis of all the considered parameters, it can be said that the proposed shortwall excavation is more than an adequate replacement for the pillar methods, both from the aspect of better productivity and organization, and from the aspect of financial profit.

CONCLUSION

The low productive pillar mining methods are applied for the coal excavation in the “Ravna Reka-IV block” pit. Observing the conditions of coal exploitation in the “Ravna Reka-IV block” pit, as well as observing the technical possibilities, the structure of the existing workers and Rem-bas mine financial situation, an analysis of possibility for application the shortwall mining method by direction the full dip of coal seam was performed.

Relative to the mechanized longwall mining method, along significantly lower investments, the advantage of the shortwall mining method is reflected in much better adjustment to the specific conditions in the deposit due to the occurrence of tectonics and irregularity. In comparison with the applied pillar mining methods, this method achieves higher face output, better excavation effects, lower preparation ratio, higher excavation intensity, and significantly higher productivity.

The technical solution of the excavation given in this paper enables more reliable operation, better working conditions caused by the flow-through ventilation, reduced participation of manual labor, because most materials fall on the chain conveyor, while the works on the face supporting are facilitated due to the application of friction props.

Due to the all above, the application of shortwall mining method by direction the full dip of coal seam is imposed as a quality and serious solution for ensuring the continuity, stabilization and improvement of production in the “Ravna Reka-IV block” pit.

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COMPARATIVE ANALYSIS OF AI MODELS IN THE MODELING OF FLOTATION PROCESS**

Abstract

This paper presents a comparative overview the modeling results of flotation process from the Veliki Krivelj plant. Within the research, a total of ten models were formed using the various methods of soft computing - fuzzy logic, artificial neural networks and hybrid system ANFIS. It was found that the flotation concentration process is best modeled using artificial neural networks, where the best correlation coefficients between the actual and predicted values of copper content in concentrate and tailings, as well as the copper recovery in concentrate are achieved. They also gave the minimal RMSE in all cases.

Keywords*: flotation, modeling, fuzzy logic, ANN, ANFIS*

INTRODUCTION

Modern industrial flotation systems and demands for the high quality technological products require the accomplishment of complex tasks with a high precision, under the insufficiently defined conditions [1, 2]. Classical process models and conventional control techniques do not provide enough effective results when it comes to such systems. On the contrary, there is an everyday need for inclusion the human factors (experts and/or operators) in the monitoring process, as well as the control and regulation of technological parameters. For these and similar reasons, a need arises to introduce the intelligent flotation control systems and soft computing based models, characterized by a certain degree of intuition in creating responses – analogous to human experts [3].

Intelligent control is a discipline where the control methods are developed so that they mimic important characteristics of human intelligence – adaptation and lear-ning, planning under high uncertainty, and computing immense quantities of data [4, 5].

Motivation for the use of soft computing methods in modeling the flotation process is also the possibility of incorporating the expert heuristic knowledge into models, as well as increased flexibility in interpretation the obtained results .

For development of mathematical models, the flotation plant in Veliki Krivelj was chosen. This plant is an integral part of the Mining and Smelting Combine Bor [3].

EXPERIMENTAL AND DEVELOPMENT OF MODELS

For the purposes of this research, THE fuzzy logic, ANFIS and artificial neural network based flotation models have been developed. Their brief systematization is shown in Table 1.

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Table 1 *Basic data about models*

SC Method	Label	Input variables					Output variables		
		Cu content in feed	Collector dosage (roughing)	Frother dosage	Pulp pH	Collector dosage (scavenging)	Final concentrate grade (CCU)	Copper recovery (RCU)	Final tailings grade (TCU)
Fuzzy logic (Mamdani system)	EMM*	+	+	+	+	+	+	+	+
Fuzzy logic (Takagi–Sugeno system)	ESM	+	+	+	+	+	+	+	+
Fuzzy logic (Mamdani system)	BMM	+	+	+			+	+	+
Fuzzy logic (Takagi–Sugeno system)	BSM	+	+	+			+	+	+
Adaptive neuro-fuzzy system	ANF1	+	+	+			+		
Adaptive neuro-fuzzy system	ANF2	+	+	+				+	
Adaptive neuro-fuzzy system	ANF3	+	+	+					+
Artificial neural networks	ANN1	+	+	+	+	+	+		
Artificial neural networks	ANN2	+	+	+	+	+		+	
Artificial neural networks	ANN3	+	+	+	+	+			+

**BMM – Basic Mamdani Model, BSM – Basic Sugeno Model, EMM – Extended Mamdani Model, ESM – Extended Sugeno Model*

Data for models were collected from the industrial flotation plant "Veliki Krivelj". The ore processing in the plant includes: two-stage grinding and classification, rough flotation of copper minerals, regrinding of the rougher and scavenger concentrate, three-stage cleaning of copper concentrate and scavenging after the first cleaning.

Experimental research was performed in the virtual conditions, using the MATLAB programming language. The validation of the proposed flotation models was carried out in Microsoft Excel. More details on development and results of these models are given in literature [3].

COMPARATIVE ANALYSIS OF MODELS' OUTCOMES

A comparative analysis of the modeling results was based on the correlation coefficient values and root mean square errors, obtained by the regression analysis. Figures 1 - 3 present the column chart diagrams showing the values of correlation coefficients, while Figures 4 - 6 present the column chart diagrams showing the root mean square errors for each of ten developed models.

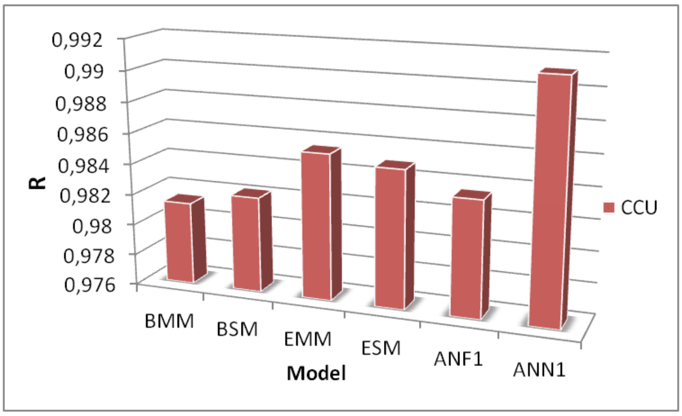

Figure 1 *Correlation coefficients of the real and predicted values of copper content in the final concentrate.*

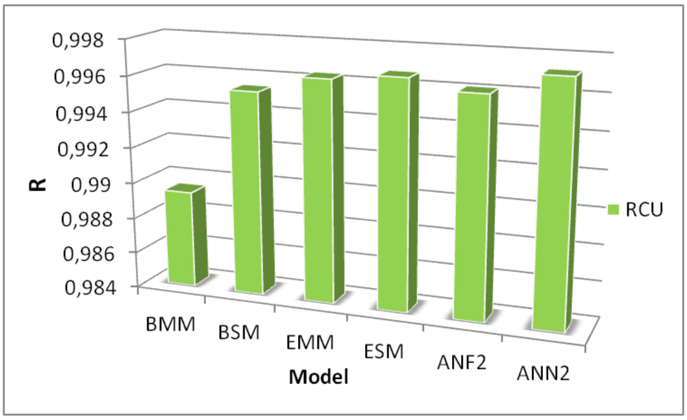

Figure 2 *Correlation coefficients of the real and predicted values of copper recovery in the final concentrate.*

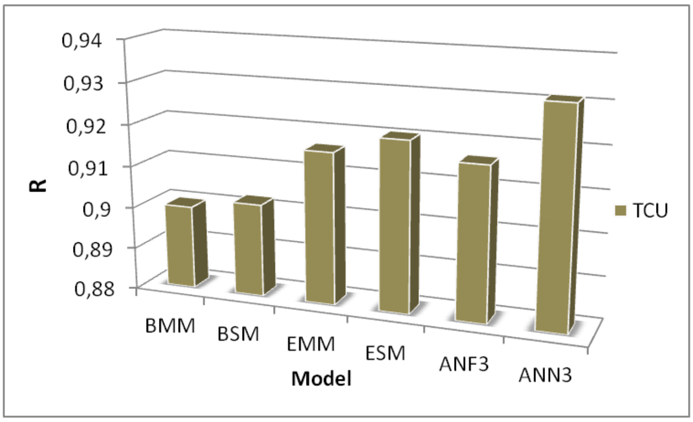

Figure 3 *Correlation coefficients of the real and predicted values of copper content in the final tailings*

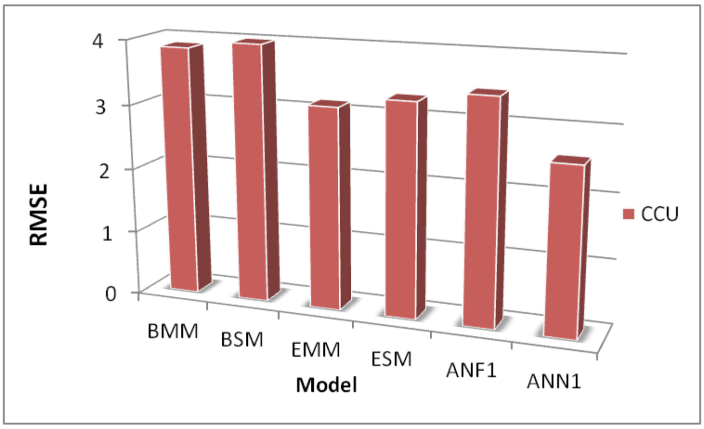

Figure 4 *Root mean square errors of the copper content prediction in the final concentrate*

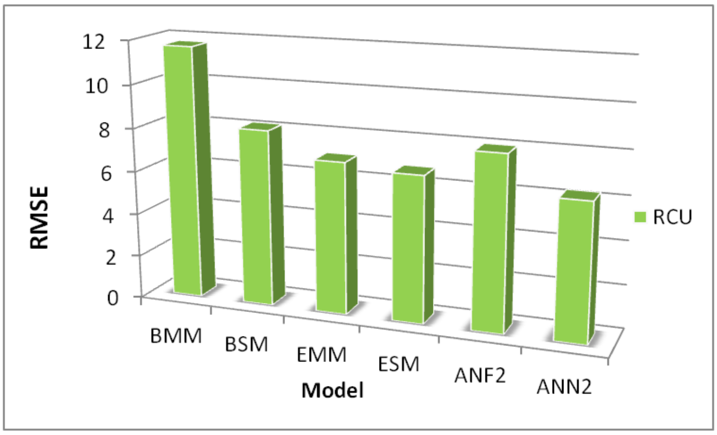

Figure 5 *Root mean square errors of the copper recovery prediction in the final concentrate*

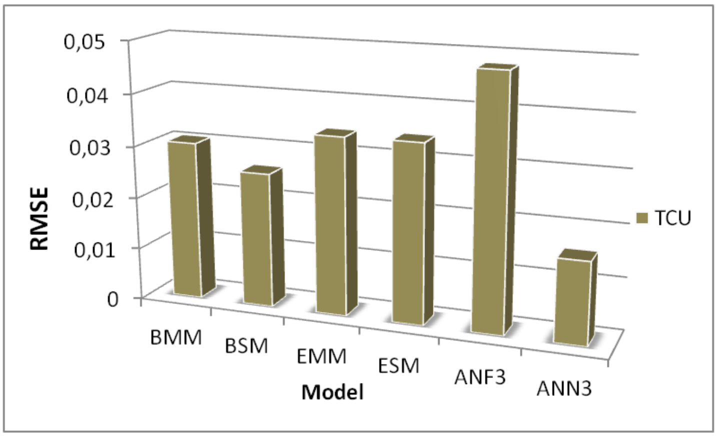

Figure 6 *Root mean square errors of the copper content prediction in the final tailings*

Considering the results shown in Figures 1 – 3, the obtained correlation coefficients are very high, which in general points to a good mutual relationship between the actual and predicted values of the output variables. However, the values of the root mean square error (Figures 4 – 6) indicate a significant deviations between the values predicted by the models and real process data. The assumption is that these deviations occurred due to the fluctuations in the real process data that can be caused by the different factors, such as: variable process dynamics due to the stoppage in the plant operation, higher oscillations in the process parameters that were considered constant in models (grinding fineness, pulp density), imperfections of the reagent dosing devices, differences in the lime activity, quality of reverse water, etc.

The lowest correlation coefficients between the actual and predicted values were obtained in predicting the tailings grade, and this is generally valid for all models. The reason can lie in a relatively narrow range of real values of the tailings grade in relation to the concentrate grade and recovery (see Table 2). Therefore, the influences of completely different values of the input parameters can be integratedly manifested through very similar or same tailing grades, without considering this during modeling. This situation could significantly affect the correlation coefficients.

Table 2 *Maximum and minimum measured values of the output parameters in the plant*

	CCU,%	RCU,%	TCU,%
Max	28.09	96.48	0.15
Min	7.91	40.78	0.01

Also, any possible imperfections in the sampling of tailings (which are especially coupled with instabilities in the plant operation), should not be ignored, because it is an extremely small content of Cu in the samples, and therefore a proper sampling is crucial for obtaining the precise chemical composition of tailings.

The highest correlation coefficients between the actual and predicted values were obtained in predicting the copper recovery in the concentrate, which is also generally valid for all models. On the other hand, the highest RMSEs are present on diagrams related to the variable RCU. Such results indicate that in the process of achieving the balance of performances of the flotation plant "Veliki Krivelj", more complete performances are achieved regarding the concentrate grade. This conclusion does not mean that the copper recovery is ignored, but that the process is a "fine-tuned" in a direction of obtaining the highest concentrate grade. This would be the underlying reason for the maximum RMSE in modeling of the RCU variable, under thecircumstances in which it is confirmed that the soft computing models illustrate well the state and variations of the system. Also, this data shows how the additional information about the current state of the system can be obtained by the modeling of that system.

Although it has already been noted that all models have the high values of correlation coefficients, some differences can be established by the mutual comparison of modeling results. For example, the BMM model has some poorer correlation coefficients than the other models, and the RMSE indicate the significant deviations from the real values, especially when it comes to the variable CCU and RCU. Also, it can be claimed that the ANF3 model is the least adequate because, regardless of the high correlation coefficient, it has a large RMSE of predicting the copper content in tailings.

On the other hand, the artificial neural network models have shown the best predictive properties regarding to all three output flotation variables. Therefore, there is a hypothesis that the artificial neural networks better "overcome" the datasets in which a large scattering of values is present, or in the other words, provide the responses that better follow the fluctuations in the output datasets, at least in terms of flotation modeling.

Generally speaking, performances of the fuzzy logic models with the five input variables (EMM, ESM) are somewhat better than the performances of fuzzy logic models with three input variables (BMM, BSM), especially regarding the copper concentrate grade and recovery. Based on this, it can be concluded that the introduction of a larger number of input variables leads to the improvement of predictive properties of this type of the flotation models. Therefore, there is a recommendation for development the fuzzy logic models with the six or more input variables. However, in this case, the maximum number of input parameters must be taken into account due to the size and complexity of the fuzzy logic rule base.

Finally, when it comes to comparing the fuzzy logic models with the models based on the hybrid ANFIS system, there are indications that the ANF1 model has better predictive properties than the BMM and BSM model in predicting the copper concentrate grade.

By mutual comparison the correlation properties of the BMM and BSM model, i.e. EMM and ESM model, and having in mind their root mean square errors of prediction, it was found that there is no significant difference of what fuzzy system is applied in the process of the flotation modeling (for the same conditions).

There are indications in literature that the Takagi-Sugeno method gives some better results regarding to modeling the same processes, under the identical conditions [3]. Accordingly, in this particular case, there are certain differences in favor of the Takagi-Sugeno method, but these differences are not distinctive.

CONCLUSION

Within this research, a total of ten flotation models were developed using the various soft computing methods – fuzzy logic, hybrid system ANFIS and artificial neural networks. Their predictive properties were compared by means of correlation coefficients (R) and root mean square prediction errors (RMSE). In general, it has been ob served that all methods give the high correlation coefficients between the actual and predicted values of output parameters, but some differences can be noticed among them. The highest values of Rare given by the artificial neural networks, while the lowest R values are given by the fuzzy logic models with the three input variables. Concerning the RMSE, this value is the lowest for the ANN models, and the highest for fuzzy logic models with the three input variables (copper content and recovery in the final concentrate) and ANFIS (copper content in the final tailings). Therefore, it can be concluded that the artificial neural networks present the most suitable tool for flotation modeling, when it comes to the soft computing methods.

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SELECTION OF PRODUCTION LINES IN THE METALLURGICAL INDUSTRY USING THE COMPROMISE PROGRAMMING METHOD

Abstract

Every organization today faces the problem of decision making. In this regard, the intent of this paper is to present an approach based on the multi-criteria decision-making methods. Primarily, the proposed approach is aimed to help solving problem of choosing the optimal production lines in the metallurgical industry. The proposed approach is based on the use of the AHP method for determining the weights of criteria, whereas the Compromise Programming is used for selection the alternatives. The usability, applicability and efficiency of the proposed approach is demonstrated in a conducted case study of selection the production lines in the metallurgical industry.

Keywords: *metallurgical industry; production lines; MCDM; Compromise Programming*

1 INTRODUCTION

Metallurgy represents a science that is aimed to the production of metal alloys. Most often it includes the refining, alloy production, shaping and refining, as well as studying the structure, composition and properties of metals. By a type of metal, it is most often divided into the ferrous (iron and steel) and metallurgy of non-ferrous metals (obtaining all other metals). Legrand et al. [1] states that the "metallurgical industry mainly transforms steel or its derivative products into products with either better surface properties (thanks to the surface transformations....), or into different shape products (lamination...), involves some processing tools which can generate the flaws (cracks, grooves...) within the process".

Until now, the multiple-criteria decision-making (MCDM) is often used as a tool for solving a wide range of complex problems. In the simplest sense, the MCDM can be defined as the selection of an alternative from the set of available alternatives [2]. Also, very rapid development of the MCDM field has caused a creation of many MCDM methods, such as: SAW, AHP, PROMETHEE, ELECTREE, COPRAS, MOORA, ARAS and MULTIMOORA, etc. Comparisons of some of them are given by Mardani et al. [3] and Turskis and Zavadskas [4]. So far, MCDM methods have been successfully applied in solving problems in the metallurgical industry such as: thermoplastic matrix selection for fiber metal laminate using the fuzzy VIKOR and entropy measure for objective weighting [5] and selecting the Complementary Metal Oxide Semiconductor (CMOS) Image Sensors using a fuzzy MCDM framework [6].

Based on the above stated, the main aim of the paper is to provide the effective approach based on the MCDM methods for

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selection the production lines in the metallurgical industry. The AHP method is applied for the weight determination whereas the programming is applied for ranking the alternative compromise.

Therefore, the paper is organized as follows. In Section 1, the Introductory considerations are presented. In section 2, the applied methodology is explained. In section 3, the conducted case study is presented. Finally, the conclusions are given at the end of manuscript.

2 METHODOLOGY

The Method of Analytical Hierarchical Processes (AHP), which is proposed by Saaty [7] is one of the most popular methods of multi-criteria decision making. The popularity of this method is influenced by the hierarchical problem structuring and comparison in pairs. Therefore, the AHP method was applied for determining the weight of criteria.

The concept of Compromise Programming (CP) was proposed by Yu [8] and Zeleny [9]. Until now, the CP was applied in order to solve different problems, such as: Fuzzy-based heat and power hub models for the cost-emission operation of an industrial consumer using compromise programming [10], a Nadir Compromise Programming for supplier selection problem under uncertainty [11], empowering cash managers through Compromise Programming [12], etc.

The basic idea of the CP is to determine the alternative that has the least distance from the ideal solution (ideal point).

For some problems of multi-criteria decision-making that involves *m* alternatives that are evaluated on the basis of *n* criteria, the procedure for selecting the most acceptable alternative can be represented as follows:

$$\min L_{p,i} = \left\{ \sum_{j=1}^{n} w_j^p \left(\frac{x_j^* - x_{ij}}{x_j^* - x_j^-} \right)^p \right\}^{\frac{1}{p}}, \quad (1)$$

where $L_{p,i}$ is the distance metric of alternative i for a given parameter p; w_j is the weight of criterion j; x_{ij} is the performance of alternative i to criterion j; x_j^* and x_j^- are the best and the worst performance of alternative i for criterion j, $i = 1, 2, \ldots, m$; m denotes number of alternatives, and $j = 1, 2, \ldots, n$; n denotes the number of criteria.

The parameter p, in equation (1), is used to represent the importance of maximal deviation from the ideal point. By varying the parameter p from 1 to infinity, it is possible to move from minimizing sums of individual deviations to minimizing the maximal deviations to the ideal point, in a decision-making process. More precisely, when the parameter p has a value of 1, all the distances in relation to the ideal point have the same significance and, in this case, the sum of distance in relation to each criterion is calculated, and alternative with the lowest sum value is the most acceptable. The choice of a particular value of this compensation parameter p depends on the type of problem and desired solution [13].

The best x_j^* and the worst x_j^- performance for criterion j should be determined as follows:

$$x_j^* = \begin{cases} \max\limits_i x_{ij}; & j \in \Omega_{\max} \\ \min\limits_i x_{ij}; & j \in \Omega_{\min} \end{cases}, \text{ and} \quad (2)$$

$$x_j^- = \begin{cases} \min\limits_i x_{ij}; & j \in \Omega_{\max} \\ \max\limits_i x_{ij}; & j \in \Omega_{\min} \end{cases}, \quad (3)$$

where $\Omega_{\max}$ and $\Omega_{\max}$ denote the set of benefit and cost criteria, respectively.

Determination of the most acceptable alternative with application of compromise programming method is considered to be relatively simple, but also efficient and understandable for decision makers. Accordingly, we suggest application of this method when solving problems of production lines in the metallurgical industry.

The evaluation of alternatives based on application of AHP and CP methods in the group environment will be presented below.

In a group environment, the decisions are made based on the views of several respondents, usually experts in the relevant field. In the literature, several approaches to a group decision-making have been considered, and as a commonly used procedure, it is possible to indicate the approach in which:

- determine the group weights of criteria based on the weights of criteria obtained from each respondent using the AHP method;
- determine the group performances of alternatives in relation to the criteria based on the performances of alternatives obtained from each respondent;
- determine the overall performances, i.e. the significance of each alternative of some MCDM method, and, in given case, using the CP method, based on the group weights and group performances.

Group weights and group performances can be determined using the following formula:

$$w_j = \frac{1}{K}\sum_{k=1}^{K} w_j^k \,, \tag{4}$$

$$x_{ij} = \frac{1}{K}\sum_{k=1}^{K} x_{ij}^k \,, \tag{5}$$

where w_j^k denotes significance of the j-th criteria obtained based on the standpoints of the k -th respondent, x_{ij}^k denotes performance of the i-th alternative in relation to the j-th criteria obtained from k-th decision maker; i=1,2, ..., m; j=1,2, ..., n; k =1,2, ..., K.

3 CASE STUDY - SELECTION OF PRODUCTION LINES IN THE METALLURGICAL INDUSTRY

In the considered case study, the evaluation of five production lines in the metallurgy industry was carried out based on the opinions of the five domain experts.

The production lines have been evaluated from three points of view:

- reliability, reflected in time and maintenance and repair costs, as well as the number of planned and unplanned downtime of the production line.
- quality of the products on these lines.
- productivity.

Therefore, the following criteria have been adopted for the purpose of evaluating production lines:

- C_1 – exploitation indicator,
- C_2 – maintenance and repair indicator,
- C_3 – performance indicator, and
- C_4 – quality indicator.

Table 1 shows the group weights obtained using the AHP method and applying formula (4), based on the standpoints of the five decision makers.

Table 1 *Group weights of the evaluation criteria*

	E_1	E_2	E_3	E_4	E_5	w_i
C_1	0.128	0.114	0.141	0.138	0.128	0.130
C_2	0.265	0.192	0.141	0.125	0.265	0.197
C_3	0.333	0.337	0.263	0.309	0.333	0.315
C_4	0.275	0.358	0.455	0.428	0.275	0.358

After determining the group weights, each of the five experts have evaluated the alternatives in relation to the selected set of criteria. For evaluation the alternatives, the five-step Likert scale was used as shown in Table 2.

Table 2 *Five-step Likert scale used for evaluation the performances of alternatives in relation to the set of criteria*

Rating	Meaning
5	Excellent performances
4	Good performances
3	Average performances
2	Below the average performances
1	Bad performances

The performance of the alternatives obtained from the five experts are shown in Tables 3-7.

Table 3 *Performances of alternatives in relation to the criteria obtained from the first decision maker*

	C_1	C_2	C_3	C_4
A_1	4	4	4	4
A_2	3	4	5	4
A_3	4	3	4	3
A_4	5	5	5	4
A_5	3	5	3	4

Table 4 *Performances of alternatives in relation to the criteria obtained from the second decision maker*

	C_1	C_2	C_3	C_4
A_1	4	3	4	4
A_2	4	5	5	5
A_3	5	3	4	4
A_4	5	5	5	3
A_5	3	5	3	4

Table 5 *Performances of alternatives in relation to the criteria obtained from the third decision maker*

	C_1	C_2	C_3	C_4
A_1	5	5	4	4
A_2	5	5	3	3
A_3	4	4	4	3
A_4	5	4	4	4
A_5	3	5	3	4

Table 6 *Performances of alternatives in relation to the criteria obtained from the fourth decision maker*

	C_1	C_2	C_3	C_4
A_1	4	4	4	4
A_2	4	3	5	5
A_3	3	4	5	3
A_4	3	3	5	3
A_5	3	5	3	4

Table 7 *Performances of alternatives in relation to the criteria obtained from the fifth decision maker*

	C_1	C_2	C_3	C_4
A_1	4	3	5	4
A_2	3	3	4	3
A_3	3	2	5	3
A_4	3	4	4	4
A_5	3	4	3	4

Finally, the group performances, obtained applying the formula (5), are shown in Table 8.

Table 8 *Group performances of alternatives obtained from five experts*

	C_1	C_2	C_3	C_4
A_1	4.200	3.800	4.200	4.000
A_2	3.800	4.000	4.400	4.000
A_3	3.800	3.200	4.400	3.200
A_4	4.200	4.200	4.600	3.600
A_5	3.000	4.800	3.000	4.000

The normalized and weighted normalized decision matrix was obtained using the following formula:

$$\bar{x}_{ij} = \frac{x_j^* - x_{ij}}{x_j^* - x_j^-}, \quad (6)$$

$$v_{ij} = w_j \frac{x_j^* - x_{ij}}{x_j^* - x_j^-}, \quad (7)$$

where $\bar{x}_{ij}$ denotes the normalized performance of the *i*-th alternative in relation to the *j*-th criteria, and v_{ij} denoted the weighted normalized performance of the *i*-th alternative in relation to the *j*-th criteria.

The normalized and weighted normalized decision matrix are shown in Tables 9 and 10.

Table 9 *Normalized decision making matrix*

	C_1	C_2	C_3	C_4
A_1	0.0000	0.6250	0.2500	0.0000
A_2	0.3333	0.5000	0.1250	0.0000
A_3	0.3333	1.0000	0.1250	1.0000
A_4	0.0000	0.3750	0.0000	0.5000
A_5	1.0000	0.0000	1.0000	0.0000

Table 10 *Weighted normalized decision making matrix*

	C_1	C_2	C_3	C_4
A_1	0.0000	0.1233	0.0787	0.0000
A_2	0.0433	0.0986	0.0393	0.0000
A_3	0.0433	0.1972	0.0393	0.3583
A_4	0.0000	0.0740	0.0000	0.1791
A_5	0.1298	0.0000	0.3147	0.0000

Overall performances of alternatives, as well as rank of alternatives, for parameter p=1, are shown in Table 11.

Table 11 *Overall performances of alternatives, for parameter p=1*

Alternatives	$L_{1,i}$	Rank
A_1	0.2019	2
A_2	0.1812	1
A_3	0.6381	5
A_4	0.2531	3
A_5	0.4445	4

As shown in Table 11, the most acceptable alternative is an alternative, i.e. production line designated as A_2.

The overall performances of alternatives, as well as the rank of alternatives, for parameter p=5, are shown in Table 12.

Table 12 *Overall performances of alternatives, for parameter p=5*

Alternatives	$L_{5,i}$	Rank
A_1	0.00003	2
A_2	0.00001	1
A_3	0.00620	5
A_4	0.00019	3
A_5	0.00312	4

Based on the data from Table 12, it can be concluded that the increase of parameter p does not affect the ranking of alternatives, which is why the production line designated as A_2 can be considered the most appropriate under the given conditions.

CONCLUSIONS

In modern business, often are used different methods and algorithms in order to solve the complex problems that accompany the production and optimization of production factors, which have an impact on profitability. The complexity of the problem often requires the application of decision making methods in order to solve the mentioned problems.

Every organization today faces the problem of decision-making. In this sense, one of the intentions of this paper was to present a model based on the multi-criteria decision making methods, which aims to solve problem of selecting the optimal production lines in the metallurgical industry.

The proposed model represents a hybrid AHP-CP model that was tested on a case study for the selection of production lines in the metallurgical industry. Applying this approach, the most acceptable production line was successfully selected. It was also found that an increase in the value of parameter p does not affect the ranking order of the alternatives, which makes the production line designated as A_2 as the most appropriate under the given conditions. Previously stated shows that the proposed model is applicable and effective, especially as it can help the management in a selection of strategies in order to optimize the allocation of available resources.

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EXAMINATION OF LEADERSHIP STYLES IN ORGANIZATIONS IN SERBIA WHICH IN ITS OPERATIONS APPLY THE CONCEPT OF PRESERVING THE NATURAL RESOURCES

Abstract

Leadership becomes an important topic of research in the organizational theory as it is an essential factor for success of organizations. Leadership can be understood as a process of influencing followers based on clear values and beliefs. Leaders, based on their own power, create trust in the organization and desire for followers to achieve the goals of both the group and organization. Bearing in mind that the natural resources are a factor necessary for functioning the societies in the modern world, the main goal of this paper is to determine the leadership styles in organizations that apply the concept of preservation the natural resources in their operations.

Keywords*: leadership; natural resources; leadership styles*

1 INTRODUCTION

The accelerated industrialization and increasing level of production in the world caused a faster depletion of natural resources and emergence of the environmental problems, which directly affects the environment. The whole world is affected by the serious environmental problems, but it is increasingly difficult to find a balance between the production and ecology.

Economic development is unthinkable without the natural resources. Natural resources belong to a group of basic and unavoidable factors on which development is based.

Leadership is the ability to focus the group on the organization's vision and goals. It can be said that it represents one of the key features of an organization that interacts with the employees, and has a great influence on the rate of turnover. Without leadership, the realization of a task is impossible [8].

Davis [2] states that the term leadership implies an attitude, guiding the organization or some of its part in a new direction, problem solving, creativity, launching new programs, building organizational structures and improving quality in an organization. According to Kotter [6], leadership is the art of mobilizing others who strive towards the goal realization and common aspirations.

Dulewicz and Higgs [3] consider that the relationship between the approach of a leader, i.e. the leadership style and context in which they function and act is extremely important. They also argue that behaviors of the leaders on the basis of investigated literature [4; 5; 11; 13] can be grouped into three categories: 1) Orienta

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tion towards the goals - goal orientation is a set of behaviors in which the leader sets the direction and behaves in the way that he / she plays an important role in directing others to accomplish the key goals necessary to achieve certain performance of an organization; 2) Involving - in this category, the focus of the leader remains to provide a strong sense of direction, however, there is a significant focus on the involvement of others (followers) with the aim of setting direction, and to a greater extent in determining the way in which the goals will be achieved; 3) participation - behavior of the leaders in this category is focused on facilitating others in achieving the nature of directions and the way to achieve the necessary goals.

Leadership styles are ways in which the relationships between the leaders and followers and others in the organization are based, i.e. the way through which the leader directs the behavior of subordinates and means by which it is used to acquire a consent to the desired behavior [12].

Leadership styles are patterns of behavior initiated by the leaders when working with the followers. Lewin et al. [7] identified three styles of leadership: autocratic leadership; democratic leadership; and liberal, i.e. "laissez-faire" leadership.

Autocratic leadership - in this style of leadership, people know exactly what to do and how to work and always expect the exact instructions to follow. Bhatti et al. [1] argue that, in terms of productivity, the autocratic style is most effective, however, Suša [12] states that the stated leadership style in time leads to a dissatisfaction with the group climate. Democratic leadership - it is often mentioned as the most effective style of leadership. In a democratic (often referred as participative) leadership, a "democratic leader" makes the final decision, he/she always invites other team members, followers to contribute and take part in a decision-making process. This way of leadership not only contributes to increasing satisfaction with the work of followers because they are involved in what is happening, but also contributes to development the skills and competencies of the followers. Liberal leadership "laissez-faire" leadership style - according to Lewin et al. [7], the liberal leadership represents the leadership style in which the leader is nominated and still physically occupies a leadership position, but where more or less avoids the responsibilities and assigned tasks.

Based on the above stated, the paper is organized as follows. In section 1, the Introductory considerations are presented. In section 2, the materials and methods are explained. The section 3 displays the results followed by a discussion. Finally, the conclusions are given at the end of manuscript.

2 MATERIALS AND METHODS

The survey of leadership styles was carried out in the period from 15/05/2017, until 30/06/2017 in 4 economic entities. The survey of leadership styles was made according to a questionnaire designed by Northouse [9-10].

Of the total number of surveyed leaders was 26 in all four economic entities, there were 65.38% of male leaders and 34.62% of female leaders. Regarding the age of the total number, there were 15.38% of the leaders in the age from 25 to 30, 26.93% of the leaders in the age from 31 to 45 years, and 57.69% of the leaders in the age from 46 to 60 years. Regarding the level of education, the total number of leaders were 19.23% of leaders with the college diplomas; 50% of leaders with the university degree. and 30.77% of leaders with the completed postgraduate studies.

Ranked importance of leadership styles are calculated by assigning the score value for each parameter that is characterized by a set of answers from the survey. Applying this methodology opens the way for implementation the parametric statistical test for evaluation the parameters set by the principle of interval values.

The obtained values correspond to the rules for applying the above tests. In this way, the commodity is obtained, and it is concluded that based on the average values that are in the interval from 6 to 30. By doing so, all parameters are compared, i.e. they are all present in this interval in generalizing the conclusions. By summarizing this way, the given ratings of the scattered ness of data was avoided, i.e. compression of the phenomenon itself resulted in precise, based on the survey data. By extracting the maximum from data, the new derived indicators were obtained which will provide the best possible way through an analysis (ANOVA) to generate the information on the reasons for determining the respondents when it comes to the leadership styles.

3 RESULTS AND DISCUSSION

Table 1 *Test of normality*

	Kolmogorov-Smirnov		
	Statistic	**df**	**Sig.**
Authoritarian	0.161	26	0.081
Democratic	0.147	26	0.155
Liberal	0.156	26	0.106

The Kolmogorov-Smirnov distribution normalization test is seen from Table 1 that all three leadership styles meet the normal distribution of probability, which implies the use of parametric statistical tests.

Table 2 *ANOVA test of the importance of leadership styles according to the gender of leaders*

		Sum of the square	df	Average of square	F	Probability of error
Authoritarian	Between the groups	2.615	1	2.615	0.641	0.431
	Inside the group	98.000	24	4.083		
	Total	100.615	25			
Democratic	Between the groups	5.213	1	5.213	1.018	0.323
	Inside the group	122.941	24	5.123		
	Total	128.154	25			
Liberal	Between the groups	0.111	1	0.111	0.007	0.936
	Inside the group	406.235	24	16.926		
	Total	406.346	25			

It can be seen from Table 2 that by detecting the differences based on the average scores, the statistical testing is con ducted for both genders of surveyed leaders. With statistical test, the gender differrences were tested and their influence on determination for all three leadership styles. These differences are put into a relationship through an F test giving an explanatory error probability that generalizes the conclusion about random variation or variation that has the natural and systemic foundation in this phenomenon explaining the very importance of a half of surveyed leaders towards the leadership styles. The observed differences expressed through the average scores for the gender of respondents are negligible between the group and within the group which can certainly be regarded that no one leadership style is important in relation to the others, and that variation is accidentally in this social phenomenon and work environment. With confidence, it can be argued that the phenomenon that defines the examined leader in terms of importance the leadership does not have the significant statistical differences in relation to the gender.

Table 3 *ANOVA test of the importance of leadership styles according to the age of the leaders*

		Sum of the square	df	Average of square	F	Probability of error
Authoritarian	Between the groups	37.025	2	18.512	6.696	0.005
	Inside the group	63.590	23	2.765		
	Total	100.615	25			
Democratic	Between the groups	24.106	2	12.053	2.664	0.091
	Inside the group	104.048	23	4.524		
	Total	128.154	25			
Liberal	Between the groups	31.489	2	15.745	0.966	0.396
	Inside the group	374.857	23	16.298		
	Total	406.346	25			

It can be seen from Table 3 that the detection of differences, based on the average scores, was accessed by the statistics testing for each category of age of the surveyed leaders. The statistical test was used to detect the arise of differences between the age groups and their effect on determination for all three styles of leadership. These differences are put into a relationship through the F test, which further explains the probability of error by which generalizes the conclusion on a random variation or variation that has a natural systemic foundation in this phenomenon which explains the very importance of the age of surveyed leaders towards the leadership styles. The observed differences are shown through the average scores for the age of employees, where the importance of authoritarian leadership can be considered with certainty and that variation has a systematic foundation in this social phenomenon in the working environment ($F = 6.7$, $p = 0.005$). It can be safely argued that the systematic phenomenon that defines the surveyed leader in terms of importance the leadership differs in relation to all three age groups. After confirming the statistical difference using the ANOVA test, it is approached to determine in which age groups the difference occurred and this is done by the following analysis.

Table 4 *Post Hoc test*

			Average difference	Std. error	Probability error	95% confidence interval	
						Lower	Upper
Authoritarian	from 25 to 30 years	from 31 to 45 years	-3.643*	1.042	0.002	-5.80	-1.49
		from 46 to 60 years	-3.033*	0.936	0.004	-4.97	-1.10
	from 31 to 45 years	from 25 to 30 years	3.643*	1.042	0.002	1.49	5.80
		from 46 to 60 years	0.610	0.761	0.431	-0.96	2.18
	from 46 to 60 years	from 25 to 30 years	3.033*	0.936	0.004	1.10	4.97
		from 31 to 45 years	-0.610	0.761	0.431	-2.18	0.96
Democratic	from 25 to 30 years	from 31 to 45 years	-3.071*	1.333	0.031	-5.83	-0.31
		from 46 to 60 years	-1.833	1.197	0.139	-4.31	0.64
	from 31 to 45 years	from 25 to 30 years	3.071*	1.333	0.031	0.31	5.83
		from 46 to 60 years	1.238	0.974	0.216	-0.78	3.25
	from 46 to 60 years	from 25 to 30 years	1.833	1.197	0.139	-0.64	4.31
		from 31 to 45 years	-1.238	0.974	0.216	-3.25	0.78
Liberal	from 25 to 30 years	from 31 to 45 years	-3.143	2.530	0.227	-8.38	2.09
		from 46 to 60 years	-3.000	2.272	0.200	-7.70	1.70
	from 31 to 45 years	from 25 to 30 years	3.143	2.530	0.227	-2.09	8.38
		from 46 to 60 years	0.143	1.848	0.939	-3.68	3.97
	from 46 to 60 years	from 25 to 30 years	3.000	2.272	0.200	-1.70	7.70
		from 31 to 45 years	-0.143	1.848	0.939	-3.97	3.68

*The average difference is significant at the 0.05 level

The afterwards (post-hoc) analysis can be seen from Table 4, which was conducted through the LSD method. Statistical differences occurred in younger age groups, which explain the importance of the age of employed leaders and their behavior through the empowerment of authorities. It can be safely concluded that the estimated reasons are increasing with age at most respondents expressed through the authority of personality who is the leader. The findings of the younger age group are statistically significantly different from the other two older age groups and, on the basis of this, it is concluded that less often the leaders who have a strong personality.

Table 5 *ANOVA test of the importance of leadership styles according to the education level of leaders*

		Sum of the square	df	Average of square	F	Probability of error
Authoritarian	Between the groups	3.017	2	1.509	0.356	0.705
	Inside the group	97.598	23	4.243		
	Total	100.615	25			
Democratic	Between the groups	6.787	2	3.393	0.643	0.535
	Inside the group	121.367	23	5.277		
	Total	128.154	25			
Liberal	Between the groups	47.702	2	23.851	1.530	0.238
	Inside the group	358.644	23	15.593		
	Total	406.346	25			

It can be seen from Table 5 that detection of differences, based on the average scores, was accessed by the statistics testing for each category of the education level of surveyed leaders. The statistical test was used to detect the arise of differences between the level of education and their effect on determination for all three styles of leadership. These differences are put into a relationship through the F test, which further explains the probability of error by which generalizes the conclusion on random variation or variation that has a natural systemic foundation in this phenomenon, which explains the very importance of the education level of surveyed leaders towards the leadership styles. The observed differences expressed through the average scores for the education level of leaders are negligible between the groups and within the group where it is safe to assume that no one leadership style is important in relation to the others and that variation is accidental in this social phenomenon in the work environment. It can be safely argued that the phenomenon that defines the surveyed leaders in terms of importance the leadership styles does not have significant statistical differences in relation to the levels of education.

CONCLUSIONS

Creating an organizational culture and initiating changes in the organization almost always starts from the leader. Therefore, the leaders are those who initiate changes in the organization and who have an influence on creating an organizational culture that will respect the concepts of sustainable development, especially in terms of presser-ving the natural resources. The culture of one group changes over time and is the result of the most frequent changes in various influencing factors such as the business environment, leadership, management practice and formal and informal socialization processes. Also, as research has shown the leadership styles have a great importance in applying the concept of sustainable development, and therefore preserving the natural resources. Organizations face the challenge of applying the concept of sustainable development and preserving the natural resources, however, this is possible with the active role of leaders. Therefore, a leader in the organi-zation provides the largest contribution in creating an organizational culture where it demonstrates how employees should behave in terms of preserving the natural resources and directs followers in a direction of use the resources, while respecting the principles of sustainable development. Also, the leader demonstrates to a large extent the conformity of his/her beliefs and actions regarding to creation an organizational culture aimed at preserving the natural resources, where employees led by the action of their leader align their behavior towards preservation the natural resources.

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ELECTROCHEMICAL SYNTHESIS OF FERRATE (VI) FOR THE WASTEWATER TREATMENT**

Abstract

Ferrate ion, FeO_4^{2-} or Fe(VI), has long been known as a very powerful and environmentally benign oxidizing agent suitable for a wide range of applications: organic synthesis, water and wastewater treatment, corrosion protection, and as a cathode material in the new super iron batteries. Several technique have been developed for the synthesis of ferrates including the thermal, wet chemical and electrochemical. The electrochemical approach has received the most attention of the three synthesis methods because it is easier to perform, does not require harmful and costly chemicals and provides the possibility for continuous production. The electrochemical synthesis of ferrate (VI) is reviewed in this work. Particular attention is paid to the influence of factors such as the anode material, electrolyte composition, temperature and current density. Mechanism of ferrate synthesis and recent advances in this field are discussed as well.

Keywords: *ferrate(VI), electrochemical synthesis, wastewater treatment*

1 INTRODUCTION

Iron usually exists in the 0, +2 and +3 oxidation state, however, it is possible to obtain the higher oxidation states of iron, theoretically up to +8. These high oxidation states of iron are in the form of oxyanions, called ferrates, and the most stable is +6 or FeO_4^{2-}. Ferrate (VI) has a dark purple color similar to permanganate, MnO_4^{2-}.

Ferrate (VI) has been considered for years as a possible alternative to the most commonly used oxidants in the water treatment plants (chlorine, hydrogen peroxide and ozone). The unique characteristics of this compound are: high redox potential (E = +2,2 V, under acidic conditions), as well as the non-toxic by-product - Fe (III) hydroxide which has the properties of an effective coagulation agent. Therefore, in literature, ferrate (VI) is often called a "green" oxidant. In most cases, ferrate (VI) provide a complete degradation of the pollutants without harmless by-products.

The superior performance of ferrate (VI) as an oxidant/disinfectant and coagulant in water and wastewater treatment has been extensively studied. Separate laboratory studies have confirmed the ferrate (VI) efficiency in removal the various pathogenic microorganisms, bacteria [1], and viruses [2], among which are those resistant to chlorine. By comparing the disinfection ability of ferates and other oxidants, it can be concluded that ferrate (VI) exhibits the same or better effect even in smaller doses and shorter operating times.

Ferrate has also been proven to be a good pre-oxidant in the removal of algae and for a biofilm growth control. It has

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been demonstrated that many organic compounds can be easily oxidized by potassium ferrate. Alcohols, phenols [3-5], carboxyl compounds, amines, thiourea [6], thioacetamide, hydrazine and monomethyl hydrazine [7] are just some of them. Ferrate (VI) decomposes rapidly many recalcitrant pollutant such as antbiotics and endocrine disruptors.

Potassium ferate, thanks to its dual role, as an oxidizing agent and coagulant, can break down and remove a range of inorganic impurities in the treatment of wastewater. Some of these pollutants are: cyanides, ammonia, hydrogen sulphide [8], heavy metals (Mn^{2+}, Cu^{2+}, Pb^{2+}, Cd^{2+}, Cr^{2+}, and Hg^{2+}) [9.10]. Removal of radioactive elements from wastewater with potassium ferate was also studied. In addition, potassium ferate is effective in oxidation of As (III) to As (V), and its subsequent removal by adsorption onto $Fe(OH)_3$.

In the field of the corrosion protection, ferrate(VI) can be utilized for passivation of aluminum, zinc and iron products, or to dissolve the resistant deposits from the different metal surfaces [11].

In the organic synthesis, ferrate (VI) can be a substitute and safer alternative to the other highly toxic oxidizing compounds, e.g. CrO_3, $K_2Cr_2O_7$, $KMnO_4$.

Ferrate has also been used in a new class of environment-friendly high capacity batteries, referred to as the super-iron batteries, as cathode material instead of hazardousMnO_2 [12].

Generally, three kinds of technique are used to synthesize ferrate (VI): (i)wet chemical synthesis, implies oxidation of ferric compounds by hypochlorite in highly alkaline environment(ii) thermal chemical synthesis, implies oxidation of ferric compounds at high temperature in molten state with alkaline peroxide and (iii) electrochemical synthesis, implies anodic dissolution of iron or its alloys in strongly alkaline solution in the low trans-passive region of potential. Chemical synthesis of ferrate (VI) must be conducted under the strictly controlled conditions in consideration a danger of poisoning and explosion. The additional problem is a separation and purification of the obtained ferrate (VI), because the toxic oxy-chlorine compounds are always present [13].

The electrochemical technique is the most promising because it uses electrons as the “clean” reactants and produces a pure dissolved Fe (VI) product with better yields [14]. However, the obtained maximal concentration of Fe(VI) is limited by the low stability of Fe(VI) species and deactivation of the anode surface.

2 ELECTROCHEMICAL SYNTHESIS

The process of electrochemical generation of ferrate (VI) usually consists of a sacrificial iron anode in strongly alkaline solution with electric current serving to oxidize iron to Fe (VI), Eq. (1), while the hydrogen gas is generated on a cathode, Eq. (2) [15,16]:

Anode reaction:

$$Fe + 8OH^- \rightarrow FeO_4^{2-} + 4H_2O + 6e \quad (1)$$

Cathode reaction:

$$3H_2O \rightarrow 3H_2 + 6OH^- - 6e \quad (2)$$

Overall reaction:

$$Fe + 2OH^- \rightarrow FeO_4^{2-} + 3H_2 + H_2O \quad (3)$$

$$FeO_4^{2-} + 2K^+ \rightarrow K_2FeO_4 \text{ (in KOH medium)} \quad (4)$$

The electrochemical generation of ferrate is significantly affected by many factors, mainly, the anode composition, type and concentration of electrolyte, temperature and current density. Thus, many researchers have focused their attention on optimization of these parameters. These parameters influence the structure of passive layer and possibility of its dissolution during the electrochemical synthesis of ferrate. Parameters should be selected in such way to avoid blocking the anode surface with poorly soluble species.

1.1 Anode Material Composition

Carbon content in the anode material has a crucial impact on the anode dissolution process. There is a general agreement that only carbon in the form of iron carbide (Fe_3C) positively influences the anode material dissolution. White cast iron (WCI), containing 3.17 wt.% of carbon in the form of Fe_3C is a typical representative. For a grey cast iron (GCI), where carbon is present in a form of graphite, the efficiency of ferrate (VI) synthesis is even lower than for a pure iron anode. Graphite on the surface of the GCI anode lowers the over potential to the competing oxygen evolution reaction and reduces the current efficiency of the electrochemical process. On the contrary, the Fe_3C readily dissolves in the concentrated NaOH exposing a fresh anode surface to the anolite. It was reported that the silicon content has the similar influence on the protective layer as iron carbide [17].

1.2 Temperature

The influence of temperature on the efficiency of electrochemical synthesis of ferrate (VI) has been studied from the earliest stage of research. There are two basic impacts of temperature on ferrate (VI) production. The first, rise in temperature increases the activity of OH^- ions and their interaction with the oxo-hydroxide layer, thus accelerates de-passivation of anode. This is especially important for materials that tend to build a compact protective layer, such as pure iron. In contrast, using an anode material with a high iron carbide content such as white cast iron (WCI), the high yields can be achieved at 20 °C. The second, increase in temperature causes an enhancement in the rate of ferrate (VI) decomposition [17].

Conclusion is that by the appropriate selection of anode material and electrolyte composition, the effect of temperature on the efficiency of electrochemical synthesis of ferrate can be minimized.

1.3 Electrolyte Composition

The electrolyte composition and its concentration is one of the most important factors that affect the synthesis of ferrate (VI). It was found that using more concentrated OH^- solution, both surface layer disintegration and ferrate (VI) stability are increased [17].

Stability of ferrate (VI) in a highly concentrated NaOH solution was investigated by L. Ding et al. Under these conditions, a ferrate ion undergo the spontaneous decomposition described by the following reaction, Eq. (5):

$$2FeO_4^{2-} + 5H_2O \rightarrow 2Fe(OH)_3 + 4OH^- + 3/2O_2\uparrow \qquad (5)$$

A set of experiments was carried out with initial ferrate (VI) concentration of 0.145mM in aqueous NaOH solution with concentration in a range of 1.5 – 14M. It was assumed that the reaction of ferrate (VI) decomposition follows the first order kinetics. A decomposition rate constant k_d and half-life of ferrate (VI) in different NaOH solutions were calculated. These results demonstrated a great effect of NaOH concentration on the aqueous decomposition of ferrate (VI). Free water activity in NaOH solution from 1.5 M to 14 M decreases and inhibits the redox reaction Eq. (6). For example, a half-life of ferrate (VI) in 1.5 M NaOH was found to be 0.48 h, in 8 M NaOH ten times longer 4.8 h, but in 14M NaOH was greatly extended to even 43h [18,19].

Numerous researches reported a maximum current efficiency of ferrate (VI) generation in 14M NaOH solution. Further increase in NaOH concentration causes a decrease in current efficiency and ferrate (VI) yield. When the concentration of sodium hydroxide approaches to its saturated value of around 20M, the electrolyte solution will become very viscous and solution conductivity will decline significantly resulting in a lower rate of electron transfer on the anode surface and ferrate (VI) generation [20].

Although NaOH is the leading electrolyte for electrochemical preparation of ferrate, the electrolyte solution may include a hydroxide selected from potassium hydroxide, lithium hydroxide, cesium hydroxide, barium hydroxide and combinations between them [15]. It was reported that when comparing LiOH, NaOH and KOH solutions, the NaOH solution provides the highest ferrate and current yields [21]. On the contrary, He et al. [8] reported that KOH is far better electrolyte for electro-sinthesizing ferrate (VI) than NaOH. The results showed that under the similar conditions, the obtained current efficiency in the concentrated NaOH solution was 55%, while it could reach 73.2% in a solution of KOH for temperature higher than 50ºC. Ferrate produced in KOH was more stable and with purity.

1.4 Other Important Synthesis Parameters

Anode activation before or during the electrolysis significantly improve ferrate (VI) synthesis efficiency. The following methods have been proposed for this purpose: mechanical polishing, chemical etching, ultrasound and cathodic pre-polarization.

Anode geometry is another important factor in the electrochemical synthesis of ferrate. Generally, increasing the specific surface area of the anode yields a significant enhancement of production rates. Several authors reported the utilization of three-dimensional iron anodes in a form of iron wire gauze [22,23], porous magnetite electrode [24], pressed iron powder [12,24], iron chunks [25], and sponge iron [20].

The efficiency of ferrate (VI) formation is also affected by the electrolysis time. Increasing the electrolysis time will decrease the amount of ferrate (VI) due to a decomposition, and anode deactivation. This represents a serious hurdle for the industrial continuous production [17].

1.5 Mechanism

The anodic behavior of an iron electrode in alkaline solutions has been studied in detail by numerous authors. The reason of an intensive research of this system were mainly the investigation of corrosion protection and improvement the construction of alkaline Ni-Fe cells. More recently, a trend in ferrate (VI) research has turned from optimization of electrochemical production toward a deeper understanding of the electrode reaction mechanism [26,17].

Anodic dissolution of iron takes place in several successive processes. Various fero- and ferric oxides, hydroxides and oxihydroxides are formed on the anode surface, among which the ferric compounds are particularly poorly soluble and lead to the anode passivation. With an increase in anodic potential the conditions for formation of soluble compounds of iron in higher valence state are obtained, i.e. trans passive dissolution [17,27].

Voltametric studies of iron behavior in the alkaline media exhibit several peaks and shoulders within the potential range of water stability, corresponding to the active dissolution of anode material and surface layer restructuring. The anodic current peak a_1 at a potential of about -0.1V (depends on the electrolysis conditions and electrode composition) corresponds to the active iron dissolution to Fe^{2+} according to Eq. (6). Oxidation reactions, Eqs. (7,8), may occur simultaneously [17,13,26]:

$$Fe + 2OH^- \rightarrow Fe(OH)_2 + 2e^- \quad (6)$$

$$3Fe + 8OH^- \rightarrow Fe_3O_4 + 4H_2O + 8e^- \quad (7)$$

$$Fe + 2OH^- \rightarrow FeO + H_2O + 2e^- \quad (8)$$

Current peak a_2, corresponds to a continuous oxidation of $Fe(OH)_2$ to Fe_3O_4, according to Eq.(9). Parallel oxidation of Fe_3O_4 is possible, according to Eq.(10) [13,26]:

$$3Fe(OH)_2 + 2OH^- \rightarrow Fe_3O_4 + 4H_2O + 2e^- \quad (9)$$

$$Fe_3O_4 + 2H_2O \rightarrow 3FeOOH + H^+ + e^- \quad (10)$$

It is assumed that the reactions of passive layer with OH^- ions, Eqs. (11-13), causes the iron surface to break down and enables continuous dissolution of the anode, corresponds to the current peak a_3 [1,14].

$$Fe(OH)_2+2OH^- \rightarrow FeO_2^{2-}+2H_2O \quad (11)$$

$$Fe_3O_4 + 4OH^- \rightarrow 3FeO_2^- + 2H_2O + e^- \quad (12)$$

$$Fe_2O_3 + 2OH^- \rightarrow 2FeO_2^-+H_2O \quad (13)$$

After the active dissolution region, a broad passivity plateau follows. At the potential of about 0.6V, the oxygen evolution commence, Eq. (16). At the same time, the oxidation reaction, Eq.(14), takes place, followed by the subsequent dispro-portionation reaction, Eq. (15). Peak a_4 the corresponds to the reactions (14-16) cannot always be observed because an intensive oxygen evolution overlaps the trans-passive iron dissolution, including ferrate (VI) formation [17,13].

$$FeOOH+3OH^- \rightarrow FeO_3^{2-} +2H_2O+e^- \quad (14)$$

$$3FeO_3^{2-}+H_2O \rightarrow 2FeO_2^-+FeO_4^{2-}+2OH^- \quad (15)$$

$$2OH^- \rightarrow H_2O + 1/2O_2 + 2e^- \quad (16)$$

During the negative scan of the potential, the three cathodic current peaks are often observed and attributed to the reduction of Fe(VI) to Fe(III), Fe(III) to Fe(II), and Fe(II) to Fe(0) [13].

3 THE NEW APPROACHES IN THE ELECTROCHEMICAL SYNTHESIS OF Fe(VI)

Ferrate can be synthesized by the oxidation of ferric ion with an inert electrode (Pt, BDD, SnO_2-Sb_2O_3/Ti) as well as in hydroxide melts by the oxidation of an iron anode.

In recent years, the electrochemical oxidation with conductive diamond anodes converted into very promising technology for electro synthesis of powerful oxidants such as peroxodisulfates, peroxsodifosfates and percarbonates. Electrochemical generation of ferrate (VI) using BDD (boron-doped diamond electrode) was successfully performed by Canizares et al. [28,29]. Within this research research, it was demonstrated that the application of ultrasound and iron powder as the raw material during the electrochemical synthesis of ferrate using conductive diamond electrode, enhances the efficiency of process. While high current density and hydroxide concentration increase the yield and stability of the generated ferrate product [29].

The formation of ferrate (VI) in molten NaOH – KOH system was studied by Hiveš et al. [30,11]. The most important advantages of these method are: (1) there is no decomposition of the resulting ferrate due to the absence of water in electrolyte, (2) after cooling down of the reaction mixture, ferrate (VI) is in a solid dry form and thus stable, (3) lack of passive layer formation on the iron electrode, (4) chemical step in the ferrate (VI) formation mechanism is accelerated by raise the operational tempe-rature of electrolysis.

The main issue in this synthetic approach that requires attention is the stability of ferrate (VI) product at the temperature of a suitable molten hydroxide mixture (170 - 200ºC). Therefore, this group of authors chose the eutectic mixture of the NaOH – KOH (51,5 mol% NaOH), characterized by a relatively low eutectic melting point of 170ºC and high electrical conductivity of 0.588 $\Omega^{-1}cm^{-1}$.

CONCLUSION

It has been demonstrated by numerous studies that ferrate (VI) is one of the most powerful oxidants for water and wastewater treatment. However, the challenges have still existed to the implantation of ferrate (VI) technology in practice due to poor stability of Fe (VI) solutions and high cost of the solid ferrate salts as they require costly chemicals and multiple purification steps.

Of the three synthesis methods – electrochemical, chemical and thermal, the electrochemical method is the most promi-sing due to its simple performance, high purity of product and absence of hazardous chemicals. Many factors affect the electrochemical ferrate (VI) production, such as anode composition, type and concentration of electrolyte, temperature, cell design, etc. Further work on optimization of these parameters is necessary. Although the electrochemical generation of ferrate (VI) has been known for almost two centuries and many advances have been made over this period, there are still many unresolved questions that should be overcome, such as: passivation of the anode surface during the electrolysis, self-decomposition and low yields of ferrate product. It can be concluded that ferrate (VI) represents vital and continuing field of research.

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KNOWLEDGE ECONOMY AS A FACTOR OF COMPETITIVENESS OF THE REPUBLIC OF SERBIA ON A WAY TO THE THE EUROPEAN UNION

Abstract

Knowledge, that is the obtained knowledge level of a certain community, its capacity to develop innovations, to adopt modern scientific and technological achievements, in other words, its capacity to create a new knowledge, which leads to further prosperity and development, is in the basis of competitiveness. Emphasizing knowledge and innovations as the main resources of developebment and relying on them in creating the competitiveness index surely leads to quality display of competitive capacities of a certain society which is the basis of this paper. Today, the Republic of Serbia is a candidate country for the EU membership and it is at an economic and social turning point, which brings the new challenges and chances. Just as it does for every European country, the European Union represents a basis for stable development and improvement of national competitiveness for Serbia.

Keywords: *competitiveness, knowledge economy, competitiveness index, innovation*

1 INTRODUCTION

Nowadays, in the knowledge era, the competitive advantage of an economy is based on technological development and innovativity, as well as using the potential chances and opportunities for realization which knowledge is necessary. Constant investment in the human capital increases the productivity, employment, and a direct source of innovaton and long-term competitiveness is obtained. Human resources and their knowledge represent a key to the success for economy and companies, while an incompetent workforce represents one of the most important obstacles in their business. Development of competitiveness on the domestic and foreign market has become an imperative for development a modern economy. Knowledge is a factor that generates the rapid changes. Changes are the condition for survival, thus it can be concluded that learning and training are, in fact, survival. For all these reasons, the modern management systems are based on changes, knowledge and constant learning. Human knowledge is a dynamic category that is constantly improved with development of science and technology directly resulting in a rapid obsolescence of the existing knowledge. “From the economic standpoint, with the function of gaining and improving an competitive advantage, as a prerequisite for development, the modern companies enable an efficient use of knowledge which can be seen in realization of innovations, at the same time decreasing the time required for its practical application” (Premovic, 2010).

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Knowledge enables to the individual and community to cope in reality. Know-ledge is the awareness of the cause, functioning and anticipaton of events. Nowadays, the main role in the economy belongs to a worker with knowledge. Know-ledge is the basic instrument for creating wealth.

According to the National strategy of sustainable development, knowledge society and knowledge economy do not refer to rigid, that is textbook knowledge, but rather a set of skills, abilities and competences used for creating innovations, solving problems, cooperating with others and working with the aim of general well-being (Government of the Republic of Serbia, 2008).

In order for countries to be able to respond to the challenges of an economy based on knowledge, the following factors in the National strategy for sustainable development of Serbia are listed:

- modern education and permanent training;
- means for research and development, especially for investment in the modern industries (computers, biotechnology, pharmacology...);
- adequate scientific-technological and cultural policy of a society;
- adequate management of economic changes in accordance with the changes in the world and its close surroundings;
- choice of a macroeconomic policy, systematic and structural economic solutions;
- telecommunications, massive use of computers and other modern technical devices;
- High technology sectors and defining incentive measures for attracting foreign investments into those sectors;
- degree of ownership rights protection and especially of intellectual property and
- social responsibility of a company's business.

The strategic course of Serbia is its integration in EU and launching domestic companies and economy on the European and world market among competitors from a great number of successful, exportoriented companies from the other countries, multinational companies with world famous products - brands, modernorganized companies with the use of the most modern information technology and modern - designed organizational structures with very educated, professional and experienced management (Vesic, 2010).

2 KNOWLEDGE ECONOMY – WHY AND HOW

Knowledge is the basis for progress and development of a society. Investing in knowledge includes the costs of education, research and software. It is very complex to be measured. Managing investments in knowledge and measuring these investments have developed into one of the most important issues which knowledge economy is dealing with. Knowledge economy has resulted out of the rise of knowledge intensity and increasing globalization of economic affairs. The rise of knowledge intensity is mutually moved by the information revolution and technological changes that are moving rapidly. Globalization is moved by deregulation and revolution in communication related to the Internet. However, it is important to note that the term "knowledge economy" refers to not only any individual phenomenon, or their combination, but the overall economic structure which occurs nowadays. Investing in knowledge that increases economic efficiency and economic growth will enable technological development and set the basis for increasing employment (Albijanic, 2010).

By analyzing the world economy today and its basic features, Draskovic emphasizes that there are "three basic driving and strategic forces of modern economy:

knowledge, changes and globalization" (Draskovic, 2010, pp. 83-90).

Improving the existing and introducing new products can be realized through the systematic and continuous implementation of processes for innovation and learning in companies. "Innovation in the knowledge economy is not only the process of creating the new products. In essence, it is an element of production and other business processes because a company either realizes innovations or it disappears" (Krstic, Petrovic, 2010, pp. 215-225). Knowledge and effective management of organizational knowledge encourages creativity of employees that is realized through various innovations. The ability to innovate is one of the important factors of change and success, which is why innovation is a necessity for the survival and vitality of companies and for the national economies and whole society (Premovic et al., 2011).

Knowledge economy is formed and spread through the basis of knowledge as a unique, unlimited and individual factor of production that cannot be substituted by the other resources. This same knowledge is converted into the economic goods and income in most economic activities, not only in those which are conditionally associated with the advanced technologies. In the knowledge economy, innovations are not only reserved for the new products and technologies, but are also of value for the new ways of organization and, therefore, for mutual relationships with customers. Innovations are a precondition for the company's competitiveness and whole economy, where knowledge enables the sustainable economic growth and development (Figure 1).

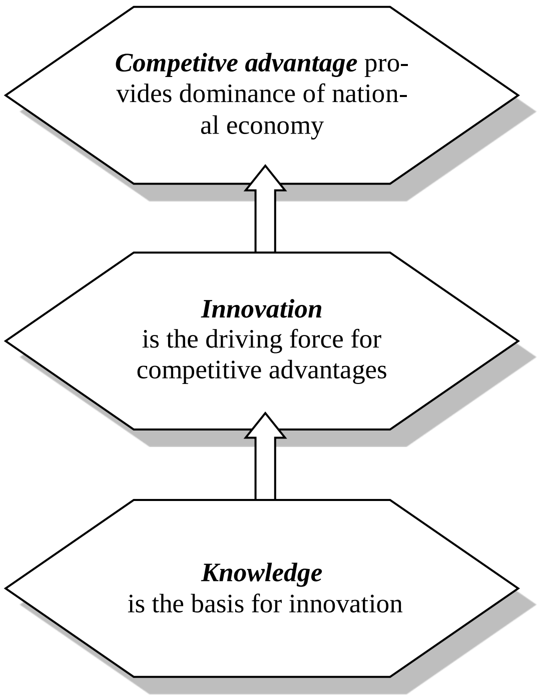

Figure 1 *Knowledge as the source of competitive advantage (Albijanic, 2010, p. 56)*

In order for knowledge economy to evolve towards a higher development level, it is necessary to create the conditions for compromise, equal and joint membership of countries into the global economy. Of course, knowledge here occurs as a necessary corrective of neoliberal globalization and precondition for the reconstruction of mankind. Only then, we will have an intelligent, sustainable and inclusive economy.

3 LEADING GOALS OF THE "EUROPE 2020" STRATEGY

The "Europe 2020" strategy, which entered into force in 2011, also focuses on the competitiveness which recognizes knowledge as one of the three crucial pillars of development (Kronja, 2011).

The Lisbon agenda, in many respects, represented a decisive step in the EU access to the social and economic development. There are open tensions, which must be dealt with by the EU protagonists in the near future. First of all, the tensions are related to the political and economic establishment of the EU and reform of the European society model in the global economy. The Lisbon agenda presented the first attempt at finding a new compromise through a clear Strategy (Natali, 2010).

Investing in knowledge is of crucial importance for research and development. The Lisbon strategy (Kronja, 2011, p.12) was started as a response to globalization. The idea was for the EU and member countries to cooperate in reforms, the aim of which is to enable growth and more jobs by investment in the intellectual capital and technological development and, in that way, overcome recession and transform the EU into a more innovative, sustainable and greener economy. The EU has revised the growth strategy for the period after 2010 by introducing more reforms at all levels. The new strategy tends to aid EU in overcoming the crisis and movement towards a society based on knowledge (Kronja, 2011).

Three crucial initiators of growth are the basis for a new strategy and they should be used through the specific activities at the national level and level of the EU: intelligent, sustainable and inclusive growth. The leading goals of the Europe 2020 Strategy can be seen in Table 1. The leading integrated guidelines for Europe until 2020 are:

1. Quality assurance and providing longterm sustainability of public finances,
2. Removal of macroeconomic disbalances,
3. Removing the disbalance in Eurozone,
4. Optimization of research and development and investment in innovation; strengthening the knowledge triangle and releasing the potential of a digital economy,
5. More efficient use of resources and reducing gas emissions which cause the greenhouse effect,
6. Improving the basic conditions for companies and consumers and modernization of the industrial base,
7. Increasing the employment rate and removing structural unemployment,
8. Educating workforce, the qualifications of which match the demands of the labour market, improving the quality of jobs and learning throughout life,
9. Increasing the efficiency of general education and training at all levels and facilitating access to the higher education institutions,
10. The fight against exclusion and poverty (Vukovic, 2011, p.507).

Table 1 *Leading goals of the Europe 2020 Strategy (Vukovic, 2011, p.500)*

<table>
<tr><th colspan="3">LEADING GOALS</th></tr>
<tr><td colspan="3">To increase the employment rate of 20-64 year olds from current 69% to at least 75%.
To invest 3% GDP into research and development; primarily, to improve conditions for investment of the private sector into research and development; also, to develop a new indicator for the assessment of innovativity.
To reduce gas emissions which cause the greenhouse effect for at least 20% in comparison to 1990, that is 30% if the conditions permit so.
To increase the share of renewable energy in consumption to 20%, as well as energetic efficiency for 20%. To reduce the rate of students leaving school from current 15% to 10%; to increase the share of 30-34 year olds with a college diploma from 31% to at least 40%.
To reduce the number of Europeans who live below the national poverty line for 25%, which would lift 20 million peple out of poverty.*</td></tr>
<tr><th>INTELLIGENCE GROWTH</th><th>SUSTAINABLE GROWTH</th><th>INTEGRATIVE GROWTH</th></tr>
<tr><td>Innovations
The EU initiative “Innovation Union” which improves the main conditions and availability of financial funds for research and development, with the aim of strengthening the innovation chain and increase investements by the Union.</td><td>Climate, energy and mobility
The EU initiative “Europe resource efficiency“ needs to contribute to separating economic growth from using resources by decarbonizing the economy, intensifying the use of renewable energy, modernizing traffic and improving energy efficiency.</td><td>Employment and qualifications
The EU initiative “Agenda for new employment qualifications and opportunities“ should modernize the labour market by facilitating mobility of the employed and acquiring qualifications throughout life, with the aim of increasing the employment rate and better compliance of supply and demand on the labour market.</td></tr>
<tr><td>Education
The EU initiative “Youth on the move“ which improves the education systems and makes the European universities more attractive for students from the whole world.</td><td rowspan="2">Competitiveness
The EU initiative “Industrial policy in the globalization era“ should imrove the business environment, especially fo small and medium size companies and build a strong and sustainable industrial structure which is competitive on the international market.</td><td rowspan="2">Fight against poverty
The EU initiative “European platform for the fight against poverty“ provides the social and territorial cohesion in order for everyone to benefit from growth and employment, and the people who live in poverty and social exclusion can actively participate in social life.</td></tr>
<tr><td>Digital society
The EU initiative “Digital agenda for Europe agenda za Evropu“ which accelerates the spreading of fast Internet and provides households and companies with the advantages of digital unique market.</td></tr>
</table>

* *The national poverty limit is defined as 60% median of available national income in every member country*

In a function of research, Table 2 offers an outline of ranking the countries in transition towards the realized progress in relation to the priorities determined by the “Strategy 2020“.

Table 2 *Ranking of countries in transition towards the priorities determined by the "Strategy 2020"*

Country	Intelligence growth				Integrative growth		Sustainable growth
	Company environment	Digital agenda	Innovative Europe	Education and training	Labour market and employment	Social inclusion	Environment protection
Sweden	5,05	6,13	6,12	5,75	4,65	6,40	6,31
Croatia	3,30	4,72	3,14	4,27	3,55	4,24	4,83
Estonia	4,13	5,94	4,07	5,03	4,66	4,66	4,67
FYR of Macedonia	3,70	4,7 2	2,72	3,84	3,98	3,36	3,47
Hungary	3,61	4,60	3,53	4,51	3,97	4,52	3,70
Lithuania	5,33	5,35	3,49	4,81	4,69	3,75	4,59
Montenegro	3,95	4,74	3,62	4,37	4,67	4,79	4,60
Poland	3,65	4,44	3,39	4,89	4,01	3,97	4,20
Romania	3,44	4,08	2,89	4,14	4,00	4,03	3,97
Serbia	3,12	4,10	2,79	3,81	3,53	3,85	3,49
Slovenia	3,73	4,88	4,08	4,95	4,26	5,19	5,04
Turkey	3,90	4,27	3,29	4,01	3,42	4,01	3,32

Source: *WEF; The Europe 2020 Competitiveness Report: Building a More Competitive Europe, Edition 2012.*

This battle for growth and jobs requires the accepting strategies at all levels and mobilization of all actors throughout Europe. On its way towards EU, Serbia must harmonize its development strategy with those demands if it wants to join the EU family. Europe is reducing the innovation gap in comparison to USA and Japan, but the differences in terms of success among the EU member countries are still great. The innovative and technological gap is increasing at a regional level: success in the innovation area has worsened in almost 20% of EU regions. This development is measured in knowledge indexes that describe the knowledge competitiveness. Namely, there are 23 composite indexes which define the competitiveness of an economy and they include the knowledge parametres. It has been noted that they can be classified into four categories (Katic et al., 2012, p.32):

1. Competitiveness indexes,
2. Knowledge competitiveness indexes,
3. Innovativity competitiveness indexes, and
4. Information-communication technologies competitiveness indexes

The mentioned knowledge indexes KEI, KI and IKT can be seen in Table 3 and in Figure 2 where data for the basic pillars of these indicators is presented.

Countries that realized the biggest shift are Estonia and Lithuania. The total progress was contributed by the openness and attraciveness of the EU research system, cooperation in the area of business innovations and knowledge commercialization, which is visible from income from permits and patents of abroad. However, the growth of public expenditures related to research and development is neutralized by the reduction in investment of venture capital and business investments in innovations, which are not in the area of research and development.

Table 3 *Ranking of the leading countries in transition towards indexes KEI and KI*

Ranking	Country	KEI	KI	EIR	Innovation	Education	IKT
-	Sweden	9.43	9.38	9.58	9.74	8.92	9.49
1	Estonia	8.40	8.26	8.81	7.75	8.60	8.44
2	Czech Republic	8.14	8.00	8.53	7.90	8.15	7.96
3	Hungary	8.02	7.93	8.28	8.15	8.42	7.23
4	Slovenia	8.01	7.91	8.31	8.50	7.42	7.80
5	Lithuania	7.80	7.68	8.15	6.82	8.64	7.59
6	Slovakia	7.64	7.46	8.17	7.30	7.42	7.68
7	Latvia	7.41	7.15	8.21	6.56	7.73	7.16
8	Poland	7.41	7.20	8.01	7.16	7.76	6.70
9	Croatia	7.29	7.27	7.35	7.66	6.15	8.00
10	Romania	6.82	6.63	7.39	6.14	7.55	6.19
11	Bulgaria	6.80	6.61	7.35	6.94	6.25	6.66
12	Serbia	6.02	6.61	4.23	6.47	5.98	7.39
13	Russia	5.78	6.96	2.23	6.93	6.79	7.16
14	Ukraine	5.73	6.33	3.95	5.76	8.26	4.96
15	FYR Macedonia	5.65	5.73	4.99	5.15	6.74	-

Source: *The World Bank; KEI and KI Indexes (KAM 2012);*

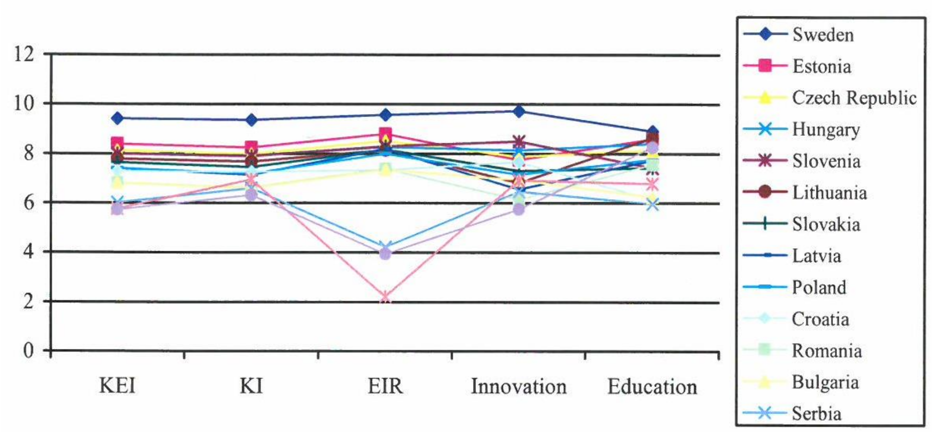

Figure 2 *Ranking of the leading countries towards the KEI and KI indexes*

Table 4 and Figure 3 show a comparison of the global competitiveness index and innovativity in the leading countries of the world for the period 2012-2013.

Tabela 4 *Comparison of competitiveness ranking (GCI) and innovativeness ranking for 2012-2013*

Country	GCI 2012-13		Innovativity	
	Ranking	Results	Ranking	Results
Switzerland	1	5.67	1	5.72
Singapore	2	5.61	13	5.14
Finland	3	5.54	2	5.65
Germany	4	5.51	4	5.59
USA	5	5.48	6	5.43
Sweden	6	5.48	5	5.46
Hong Kong	7	5.47	7	4.83
Netherlands	8	5.52	7	5.36
Japan	9	5.40	3	5.62
Great Britain	10	5.37	10	5.15

Source: Schwab, K., World Economic Forum, The Global Competitiveness Report 2013–2014

“Realization of innovations throughout Europe is still a priority if we want at least 20% of GDP of EU to come from production by 2020, which is the goal of our industrial policu. The key to growth is more business investments, greater demand for the European innovation solutions and a reduced number of obstacles to the innovation commercialization. We need the innovative companies and a framework adapted to a growth so that the innovations can be successfully launched onto the market” (Tijanic, 2014).

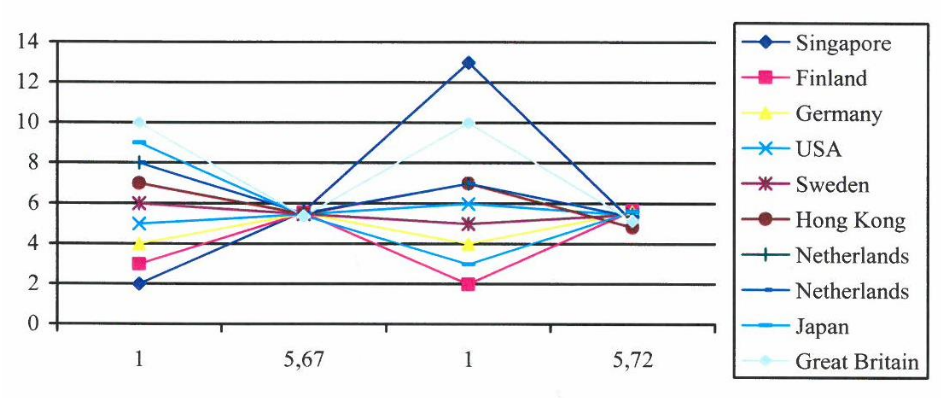

Figure 3 *Comparison of the ranking of competitiveness (GCI) and innovativity of the leading countries in the world for 2012-2013*

The main obstacle for development of Serbia is a bad macroeconomic environment –deepened budget deficit, reduction of national savings and increase of the public debt. For years, Serbia has been at the bottom of a\ competitiveness list, which is certainly a precondition for the pessimistic attitudes of businessmen.

4 SERBIA AND THE GLOBAL COMPETITIVENESS INDEX

WEF measures the quality and competitiveness of the business environment in 148 countries of the world by the Global Competitiveness Index. The GCI is obtained by analyzing more than 110 indicators, based on a research of the main managers'attitudes in the countries included in the research and reports of other international organizations, such as the World Bank and its Report on the facility of doing business. In the WEF report for 2013, Serbia takes only the 101st position in competitiveness, which is a fall for 6 spots when compared to the previous year and a worse result in comparison to all countries in the region, including Albania (95th place), Bosnia and Herzegovina (87th position), Croatia (75th position), FYR Macedonia (73rd position), Montenegro (67th position) and Hungary (63rd position) (*www.dw.de/zastoj-u-reformama*).

Serbia has improved its position on the global competitiveness list of WEF for 2014 for seven spots and taken the 94th positioon among 144 countries. The jump from 101st position on the list for 2013 Serbia noted, based on the increase in the value of the GCI from 3.8 to 3.9, as stated in the report published by the Foundation for Development of Economics (FREN) as a partner o WEF (*World Economic Forum, The Global Competitiveness Report 2013–2014*). The most competitive country in the world is Switzerland; Finland and Germany are leaders in the EU and on the Western Balkans, the leader is the FYR Macedonia. The value of the GCI ranges from 1 to 7, where 1 is the worst and 7 the best mark (*www.istmedia.rs/srbija-je-manje-konkurentna-od-clanica-evropske-unije*). According to the results for 2014, Serbia has repeated the historically largest value of the GCI, which is the result of the current perception of the business world about the capacity of a country to provide a longterm stable economic growth, as stated in the report. The biggest index value of 3.9 was realized by Serbia shortly before the first wave of the crisis in 2008. The value of GCI notably dropped to 3.77 the following year, in 2009 and after that, there was a period of gradual recovery of the index. Serbia is in the category of institutions on the 122nd position with the index 3.2; according to the infrastructure, it is on the 77th position (index 3.9); according to the macroeconomic environment, it is on 129th position (index 3.5) in the world and in the healthcare and elementary education on the 68th position with an index of 5.8. According to the criteria higher education and training, Serbia takes the 74th position on the list (4.3), and in the efficiency of the goods market – position 128 (3.8), efficiency of the labour market – position 119 (3.7), sophistication of the financial market – position 109 (3.5), technological readiness – position 49 (4.4), and according to the size of the market – position 71 (index 3.7). According to the sophisticaiton of the business processes, Serbia takes the 132nd position (indeks 3.2) among 144 countries on the list and according to the innovations – position 108 (index 2.9) (Table 5).

According to the ranking on the list of competitiveness for 2014, among countries of the West Balkans, the only country that has a worse ranking than Serbia is Albania, with the 97th position. Its index is 3.84. The FYR Macedonia is the best ranked, at the 63rd position, with an index of 4.26. It has jumped 10 spots on the list. Montenegro kept the 67th position. Based on the position of GCI basic value of 4.23, Slovenia takes the 70th position. The position (fall for 8 spots) with the index value of 4.22 was noted, while Croatia is on the 77th position according to competitiveness, two spots lower than in 2013.

Table 5 *The most important indicators of competitiveness of the Republic of Serbia*

Indicators	Position	Index
Institutions	122	3.2
Infrastructure	77	3.9
Macroeconomic environment	129	3.5
Health an elementary education	68	5.8
Higher education and training	74	4.3
Efficiency of the goods market	128	3.8
Efficiency of the labour market	119	3.7
Sophistication of the financial market	109	3.5
Technological readiness	49	4.4
Market size	71	3.2
Sophistication of business processes	132	3.2
Innovativity	108	2.9

Source: adapted according to the report of WEF for 2013-14.

With the GCI value of 4.13, Bosnia and Herzegovina was not ranked on the list for 2014 because of inability to collect data. In 2013 it was on the 87th place, with an index of 4.02 (Table 6 and Figure 4).

In the EU, there is still a gap between a very competitive north, on one hand, and south and east which are behind in competition, but there is a new classification among countries that perform the reforms and the ones which do not. Several countries greatly influenced by the economic crisis, such as Spain, Portugal and Greece, have made a significant progress in terms of improvement the funcioning of its markets and allocation of product resources. In the SEF report for 2014-2015, Spain is on the 35th position, where it used to be in 2013-2014 too, when the list included four more countries than today. Portugal is on the 36th position in compariso to the 51st from the previous year and Greece is on the 81st, which is ten spots higher than in the year before.

Table 6 *The absolute ranking of the former Yugoslav countries for the period 2007-2014*

Ranking	Slovenia	Montenegro	FYR Macedonia	Croatia	B&H	Serbia
2014	**70**	**67**	**63**	**77**	**-**	**94**
2013	62	67	73	75	87	101
2012	56	72	80	81	88	95
2011	57	60	79	76	100	94
2010	45	49	79	77	102	96
2009	37	62	84	72	109	93
2008	42	65	89	61	107	85
2007	39	82	94	57	106	91

Source: Adapted according to the Neighbour countries more competitive than Serbia, GCI Global Competitiveness Index - Rank

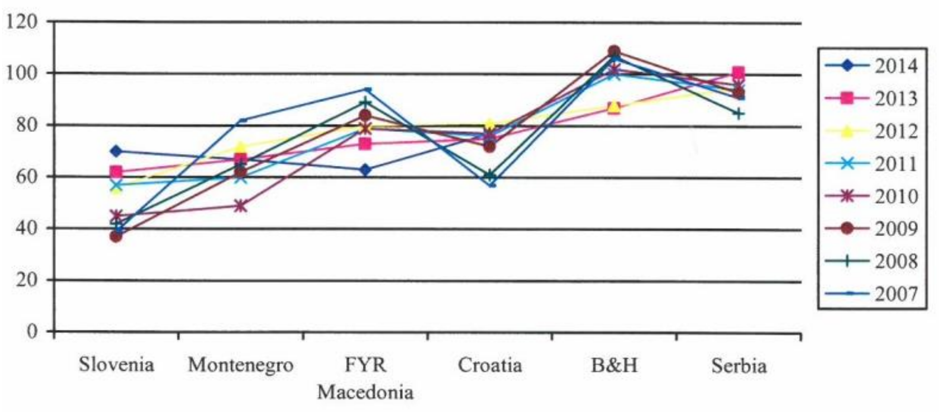

Figure 4 *Competitiveness of the formerYugoslav countries for the period of 2007-2014*

The most competitive countries in the EU are Finland and Germany. Both countries have fallen on the list for one spot, so Finland is now the fourth in the world and Germany is the fifth. Generally, Finland has a good performance in all areas and a small fall on the world list is mainly the consequence of weakening the macroeconomic opportunities. In addition, according to the SEF, a small fall of Germany is a consequence of fear about the institutions and infrastructure, which has only partially recovered the improvement of the macroeconomic environment and financial development. The German education system received the worse marks than earlier. Great Britain improved for one spot and it is now in the ninth position. The performances of that country have improved owing to the results which arouse from a lower fiscal deficit and public debt. Britain still benefits from an efficient labour market and high level of financial development (Lojpur, Peković, 2013, pp.61-75). The first position in the world for competitiveness and the highest index value of 5.7 in 2014 is held by Switzerland, while the worst value of 2.79 and the 144th position is held by Guinea and pushed Chad one spot up. The order of the leading three on the list is slightly changes in comparison to 2013. Switzerland and Singapore were joined by the USA on the top of the list and, by doing so, passed Finland and Germany. Russia is the 53rd, which is ten spots better than in 2013, China is the 28th, Turkey is the 45th, Brazil is the 57th and India is the 71st.

5 SERBIA ON THE WAY TOWARDS THE EU

The Republic of Serbia is going to encounter many challenges on the way to the EU. In order for Serbia to join a supranational community of countries such as the EU, based on a combination of international agreements, practices which must be respected and bodies which control the EU behaviour, it needs to carefully prepare. Serbia will not be able to become a part of the great European family until it meets all the criteria for joining the EU. Even if it could skip some phases that all countries of the EU passed, and be accepted in the Union for a shorter time period – it would return to as a boomerang. In fact, the effects of rapid acceptance would be in many ways negative. The economic consequences for the country would exceed the wish itself to join the European Union.

If we compare the goals set by the EU and Serbia for the period of 2010-2020, we can see that they differ in many respects taht can be seen in Table 7.

Based on the results, it can be seen that the Republic of Serbia is ten years behind the European Union (Milicevic, 2014, p.120).

Table 7 *Priorities of the European Union and Serbia for the period 2010-2020*

	EUROPEAN UNION		**REPUBLIC OF SERBIA**	
	2010	**2020**	**2010**	**2020**
Employment of population from 20-64 (%)	68	75	49	65
Investments in research and development (%GDP)	1.9	3	0.3	2.0
Participation of energy use from the renewable sources in the total energy use (%)	16	20	12	18
Energy efficiency (that is /1000$ BDP-a)	0.21	0.17	0.96	0.57
Population of 30-34 who have a university diploma (%)	31	40	21	30
Poverty rate (below 60% median of the available population income)	16	12	17	14

Source: Serbia 2020: The development concept of the Republic of Serbia until 2020, 2010, p.3

Joining the European Union represents a significant incentive for the rapid economic growth and creation the new jobs. The previous experience shows that all countries which joined the EU, after a longer or shorter time period, entered a phase of dominant economic growth. In that context, funds which Serbia would receive as a developing country are of great importance. Free performance on the market of EU would present a great incentive for the development of some economy branches, such as the textile industry, agriculture, food industry, construction and the like. Of course, at the same time this presents a potential danger, having in mind that a number of producers could not keep up with the competition of the other producers from the EU.

CONCLUSION

For Serbia, there is no simple or fast way to remove the numerous and big determinants of incompetitiveness because the creation of competitive advantages needs a lot of time, investment and knowledge. The Republic of Serbia is on a development intersection, which means that it is necessary to change the concept of development and system in which it is being realized. In the following development phase, Serbia needs to build an open, competitive economy, based on knowlede, which implies strengthening of institutions as crucial factors of competitiveness and development which enable the growth of resource quantity and the technology level and the growth og the range and quality of products and services. The disfunctional and undeveloped legal and institutional order in Serbia presents a great development limitation. The system is missing many laws, institutions of capital markets and, up to very recently, the international standards of accounting reports, a fast and efficient bankruptcy proceedings and so on. For the growth of competitiveness of the Serbian economy, system machanisms for stimulating and mobilizing the savings and credibility of the financial institutions are of special significance. They should contribute the company’s competitiveness growth and the economy’s as a whole. The central problem of Serbia on the way to the EU is incompetitiveness of the economy and financial sector and incomepetence of the public sector. Timely and high quality preparation of Serbia for the entrance in the European Union requires building a competitive market economy. Being very late when compared to the developed countries and successful countries in transition, which have become the members of the European Union, Serbia needs to adapt the strategy of its development to a new developmental and tehnological paradigm. In the other words, the Republic of Serbia should accept the new developmental and technological paradigm and change the previous development strategy and previous production-technologial, social and institutional system, with the aim of establishing an innovative environment and innovative behaviour and for all decisions, initiatives and activities to contribute to the creation of an innovative economy and knowledge society.

The main goals of knowledge economy in the Republic of Serbia are:

a) increasing the competitivenes of the economy,
b) joining the European integrations and
c) developing sectors and products which can be more intensive with knowledge and technology.

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GENERAL PURPOSE AC CURRENT TO DC VOLTAGE TRANSDUCER****

Abstract

The most of previously realized and implemented Distributed Control Systems (DCS) for the electricity consumption control are based on a control at the transformer substations level (transformer output cells level). In order to make such DCS systems, applicable to a wide variety of consumers, the new components are added into the existed DCS (transducers, controllers, communication modules, etc.). In that way, the realized DCS becomes easily applicable to almost all types of electricity consumers. Also, the DCS should be low-cost, to be available to the targeted customer groups. This paper presents the characteristics of recently realized transducer (AC current to DC voltage). The application of such device in the realized DCS enables measurement the electricity consumption of almost all electrical consumers in the industrial facilities, as well as in the households.

Keywords: *electricity consumption, current transducer, measurement*

INTRODUCTION

The Department of Industrial Informatics in the Mining and Metallurgy Institute Bor (MMI Bor), Serbia, has a long tradition in design and application the DCS for monitoring and control the industrial processes and electricity consumption [1-5]. The electricity costs include the peak power costs at a certain time interval (e.g. 15 minutes). Such costs can be significantly reduced by switching-off or delaying to switch-on the certain electricity consumer or a group of consumers for several minutes. In this way, the electricity consumption optimization system actually limits the amount of electrical energy consumed over a designated interval of time.

Most of the previously realized systems for the electricity consumption control are based on control the transformer substations level (cells level). In order to create the DCS applicable to a wide variety electricity consumers, the new components are introduced (transducers, controllers, communication modules, etc.). The new DCS should satisfy a requirement that the measurement accuracy remains unchanged in relation to

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the previously implemented systems. In this paper, the characteristics of recently realized transducer (AC current to DC voltage) are presented. The application of such devices enables measurement the electricity consumption of almost all electrical consumers in the industrial facilities, as well as in the households.

DESIGN AND APPLICATION

The electric power and current transducers are the basic elements of every electricity consumption control DCS. The AC current to DC voltage transducer (hereinafter - transducer), presented here, can be used to measure the alternating current of electricity consumers within a band determined by the power of consumer, a frequency of 50-60 Hz. Such input signal transducer converted to the output voltage signal in the range 0-5 V DC, which is galvanically separated from the input signal. That output signal is suitable for further processing by the DCS.

The transducer is housed in a standard plastic case, with the degree of protection IP20. The unit is designed for installation on a standard DIN rail (35 mm) in accordance with the standard EN 60715. On the front of housing (as shown in Figure 1), there are 12 terminal clamps, arranged in two rows of 6 terminals.

Figure 1 *Front panel of the transducer*

Terminals 1 and 6 are intended for the voltage supply of transducer, 230 V AC. Terminals 3 and 4 are intended for connection the main electric circuit of the electricity consumer. The wiring diagram of connecting the transducer into the electric circuit of electricity consumer is shown in Figure 2. Terminals 8 and 11 are transducer output terminals (0-5 V DC, max 100 mA).

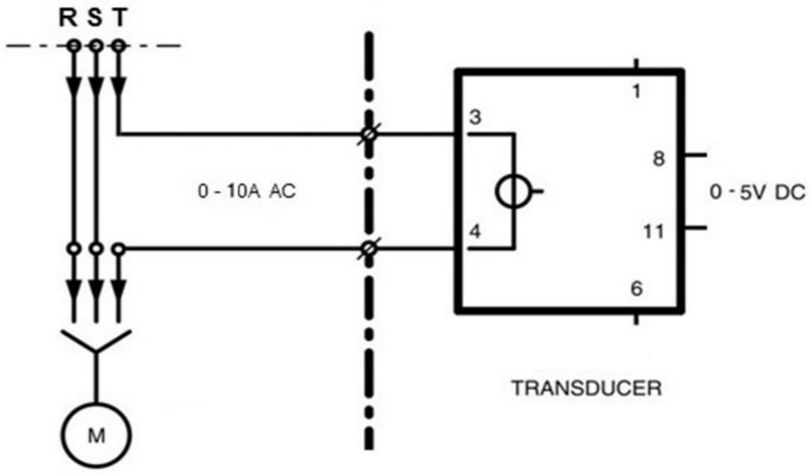

Figure 2 *Wiring diagram of connecting the transducer into the electric circuit of telectricity consumer*

PRINCIPLE OF OPERATION

The transducer components are located on a single-sided PCB, as shown in Figure 3. The transducer itself consists of the power supply, current transformer/ sensor, inverting amplifier, precise double-sided rectifier, and output stage. The circuit diagram of transducer is shown in Figure 4.

Figure 3 *Single-sided transducer's PCB with the attached components*

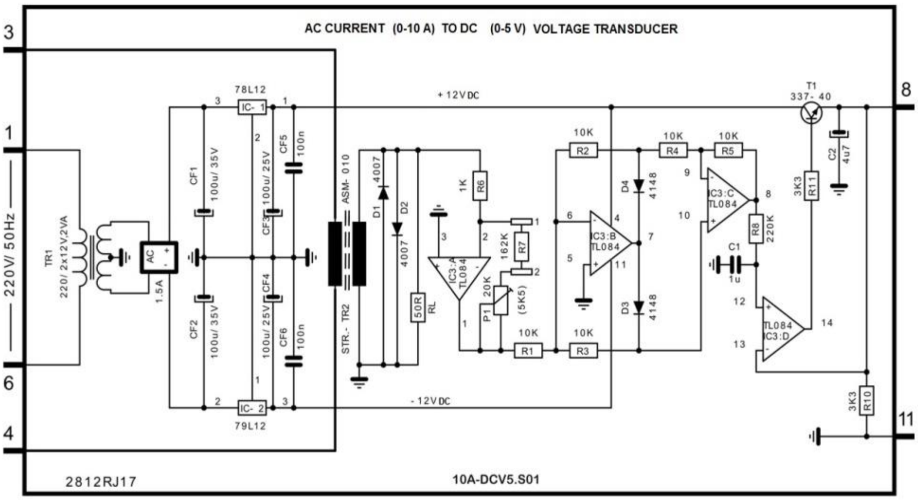

Figure 4 *Circuit diagram of a transducer*

Power Supply

Power supply of a transducer supplies the electronic components with ±12 V DC. It consists of the voltage transformer TR1 (220 V AC, 2x12 V AC, 2 VA), Graetz bridge 1.5A, voltage regulators IC1 (78L12) and IC2 (79L12), and electrolytic capacitors for filtering the supply voltage, referred as CF1-CF6 in Figure 4.

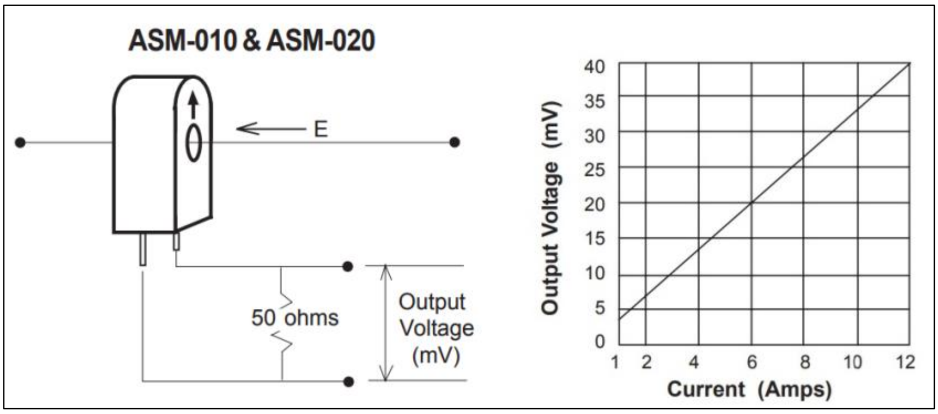

Figure 5 *ASM-010 current sensor characteristics[6]*

Current Transformer/Sensor

A current transformer is an instrument transformer in which the secondary current is substantially proportional to the primary current. Current transformers are switched on the primary circuit regularly because they need to reduce the current being measured. This is the reason they practically work in a short circuit regime. The transducer, shown in Figure 3, uses a miniature current sensor type: ASM-010/TALEMA. A typical characteristic of the ASM current sensor is shown in Figure 5 [6]. The accuracy of measurement can be improved by an adequate selection the accuracy class of the current sensor and other associated electronic components.

Inverting Amplifier

An operational amplifier (OP) IC3:A with resistors R6, R7 and potentiometer P1 forming inverting amplifier arrangement is shown in Figure 4. Non-inverting input of the IC3:A is bound to ground (zero potential). Since the input voltage of an ideal OP is zero, the inverting input of the OP IC3:A is virtually on the potential of ground. Since the input current of OP is zero, all input current is closed over R7 and P1. The amplification of this amplifier is negative and equal to -(R7+P1)/R6. The input resistance of this amplifier is equal to the resistance of R6.

Precise double-sided rectifier

OP amplifiers IC3:B and IC3:C, diodes D3-D4 and resistors R1-R5 forming a precise double-sided rectifier are presented in Figure 4. When the input voltage is positive, the diode D4 leads and on its anode, the voltage is equal to the input one, but with the opposite polarity. In the second OP (IC3:C), this voltage is only inverted and a positive voltage with single amplification is obtained at the output of the rectifier. Both OP amplifiers work as the inverting amplifiers with unity gain. When the input voltage is negative, the feedback circuit of the first OP (IC3:B) is realized via diode D3. The input current is negative and it is divided in the ratio of 1:2, with one third going upstream, and over R2 and R4 entering the second OP, and two-thirds closing via D3. The gain is, therefore, ±1 depending on the polarity. The output voltage is not affected by the voltage drops on diode; hence, the circuit acts as a precision rectifier (absolute value detector). The circuit is simple because the resistors of equal resistance are used. The disadvantages of the circuit are that there are only a unit gain and small input resistance [7].

Output Stage

The OP amplifier IC3:D, transistor T1 (BC337), resistors R8, R10, R11 and capacitors C1 and C2 forming the voltage controlled current source are presented in Figure 4. The OP amplifier IC3:D acts as a voltage comparator. Non-inverting input of the OP IC3: D is connected to the output of precise double-sided rectifier through an integrator, formed by the R8 resistor and capacitor C2. The output stage provides a greater current availability due to the use of transistor at the output instead of using the direct output from the OP. The OP IC3:D and transistor T1 ensure that the voltage over resistor R10 is kept equal to that coming to the non-inverting input of the OP IC3:D. The voltage on the resistor R10 is proportional to the AC current at the input of the transducer. Adjustment of the transmission characteristics of the transducer is done by a potentiometer P1.

TRANSDUCER APPLICATION

As an example of transducer application, the overload protection of the low voltage electric motor is presented (control box shown in Figure 6). Figure 7 shows a circuit diagram of the electric motor overcurrent load protection system. The protective element compares the preset maximum current load with the actual current load, measured by the transducer. When the actual current value exceeds the preset maximum, the protection system activates the sound and visual alarm. This scheme (on/off regulator) could also be applied for the electricity consumption control. If the electric motor is the electricity consumer that can be stopped for several minutes, it can be used to avoid the peak power or exceeding the allowed value for electricity consumption of the factory/facility. In such case, the additional electronics (Arduino board DCS node) has to be added into the existing overload protection system, as shown in Figure 7. Hence, the information about the actual electricity consumption of electric motor is forwarded from the Arduino board, that serves as a DCS node, via the wireless network to a DCS control level (PC workstation).

Based on the actual electricity consumption of the factory/facility, and other elements, contained in the control algorithm, the DCS decides whether to turn off the electric motor or not.

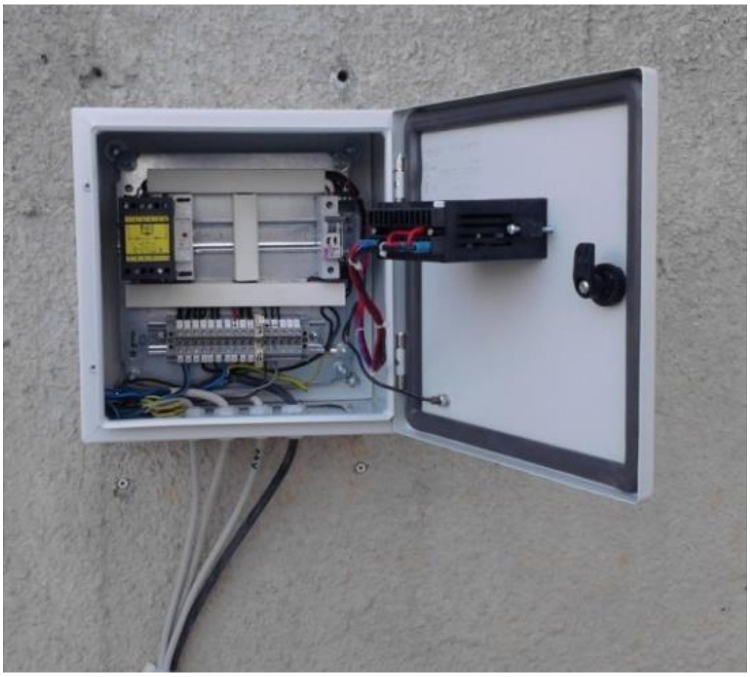

Figure 6 *Transducer applied for the electric motor overload protection [8]*

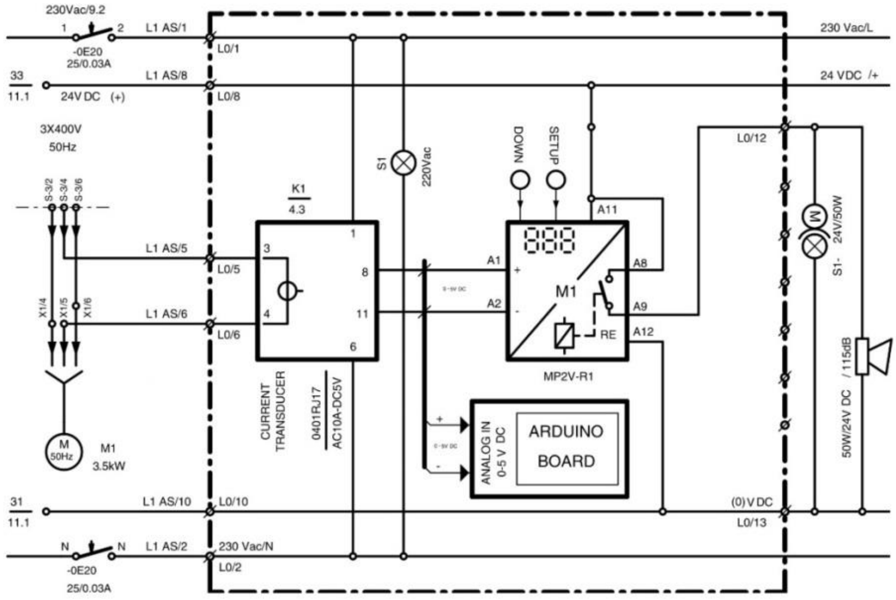

Figure 7 *Circuit diagram of the electric motor overload protection system[8]*

CONCLUSION

In this paper, the main characteristics of the recently realized transducer (AC current to DC voltage) are presented. The application of such devices enable measurement the electricity consumption of a wide variety of electrical consumers in the industrial facilities, as well as in the households. The device is easy to manufacture, install, calibrate and maintain. In the practical application, in the overcurrent protection systems, it has shown a good stability and reliability. It is expected that in the near future it will be extensively applied in the electricity consumption control systems.

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NATURAL LIGNITE RESOURCES IN KOSOVO AND METOHIJA AND THEIR INFLUENCE ON THE ENVIRONMENT

Abstract

The objective of this paper is to point out the significance of the natural lignite resources in the region of Kosovo and Metohija and to consider their influence on the environment of the said part of the territory of the Republic of Serbia. The region of Kosovo and Metohija is extremely rich in lignite. It makes up 76% of the total coal reserves in Serbia and it is the third biggest region in Europe regarding the coal reserves. Lignite is burned in the existing thermal power plants in Kosovo and Metohija, and the construction of the additional blocks is being planned at the moment. Lignite reserves are so immense that on one hand they enable the energy independence, but on the other hand the overall negative impact of reliance on lignite must be taken into account, especially since the existing thermal power plants operate according to the out-dated environmental standards, producing large emissions of air pollutants (harmful gases resulting from lignite combustion in thermal power plants) that have negative impact on health. In order to reduce the environmental pollution that such thermal power plants create, operating of the said power plants needs to be adjusted to the stricter standards in compliance with the legal requirements and the Industrial Emissions Directive of the European Union.

Keywords: *lignite, natural resources, energy independence, environment, environmental standards*

1 INTRODUCTION

The region of Kosovo and Metohija is rich in mineral resources. Its energy resources and non-ferrous metal resources represent a considerable potential for the overall development. Not all parts of Kosovo and Metohija are equally rich in mineral raw materials. Mineral deposits represent a true natural basis for development of industry, i.e. economy as a whole. Some of the most important resources are lignite, minerals of lead, zinc, silver and gold, silicate minerals of nickel and cobalt, iron – bauxite, manganese and magnesite. Moreover, there are also significant amounts of the non-metallic, industrial minerals and geological construction materials. Specified mineral resources and their rational exploitation, combined with a good management approach, represent a solid basis for quick and sustainable economic and social development.

All kinds of the existing resources that the country has at its disposal make up a foundation for planning and implementation of development and energy strategy. Each of the specified resources has bigger or smaller resource potential, but planning and strategic exploitation are insufficient. That is why it is necessary to define the accurate sector policies and strategies and to select the proper mechanisms for their implementation. Regarding Serbia, this goal is extremely difficult to realize at this moment because the region of the Auto-

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nomous Province of Kosovo and Metohija is the UN protectorate and subject to the Resolution 1244. In fact, at this moment, Serbia as a country does not have any mechanisms that could be used to protect those natural mineral resources from exploitation. On the other hand, the interim institutions in Kosovo and Metohija do everything in their power to use those resources for their own development. Pursu ant to any natural and international law, including resolution 1244, the mineral resources of Kosovo and Metohija should stay in Serbia. Since Serbia has been exposed to double standards by the developed Western countries that recognized the unilateral independence of the AP of Kosovo and Metohija, the so called independent state of Kosovo was given the opportunity to exploit all of the mineral resources.

Figure 1 *Mineral resources in Kosovo and Metohija [1]*

2 LIGNITE RESERVES IN KOSOVO AND METOHIJA

Lignite reserves are by far the most abundant among mineral resources in the region of Kosovo and Metohija. There are still no accurate estimates of the amount of lignite in the region of Kosovo and Metohija. According to the Serbian scientists, Nikolic and Dimitrijevic [2], lignite reserves in the Kosovo, Metohija and Drenica basin are 7.35 billion tons (Bt). Out of the specified amount, only 1.6 Bt in the Kosovo basin are economically exploitable, while 4.8 Bt are non-exploitable (as well as 0.7 Bt in the Metohija basin, and 0.25 Bt in the Drenica basin). As for the thickness of exploitable seam, it is the biggest in the Kosovo basin (24-60 meters) than in the Metohija basin (36-40 meters) and than in the Drenica basin (5-18 meters). Only in the Kosovo basin, the thickness of overburden is smaller than the thickness of lignite seam. In the Metohija basin, this overburden thickness is 2.5 times bigger than the thickness of lignite seam. Bigger overburden thickness implies more expensive lignite exploitation and, consequently, smaller profit, i.e. lignite-based wealth of the region. The average overburden to lignite ratio in the Kosovo basin is 1.3 m^3/t and 2.4 m^3/t in the Metohija basin

On one hand, it is positive that there are large amounts of lignite, but on the other hand the negative factor implies high contents of moisture and ash (because of gangues) and increased contents of toxic microelements of Ni and Cr in lignite, enriched in the thermal power plants smoke, so this lignite represents an important but law-budget raw material for exploitation and production of electric energy that pays off only with minimal transport or exploitation on the site. [3]

According to the data of interim institution, the Ministry of Economic Development, the estimated lignite resources on entire territory of Kosovo and Metohija are 12.4 Bt. [4]

In Rainer Hengstmann's report from 2004, the Independent Commission for Mines and Minerals of Kosovo, regulated by the UNMIK, published that the World Bank estimated the mineral reserves of Kosovo to be worth 13.5 billion euro. The most significant resource is lignite, with geological reserves of about 15 billion tons. [5]

This estimate is in line with the estimates by the experts from the Faculty of Mining and Geology in Belgrade who also estimated that the lignite potential in Kosovo would be sufficient to supply two thermal power plants, and to provide the electricity production in a hundred-year period which, according to the estimate of our Ministry of Mining and Energy from 2009, equals the value of 100 billion euro. Therefore, a major part of lignite reserves in the Republic of Serbia (over 76%) is located in the Kosovo-Metohija basin. [6]

Table 1 *Lignite reserves in Kosovo and Metohija [4]*

Basin	Reserves		
	Geological	**Balance reserves***	**Off-balance reserves****
Kosovo	10.09	8.77	1.31
Metohija	2.24	2.04	0.19
Drenica	0.10	0.07	0.03
Total	12.44	10.89	1.54

** Balance reserves are reserves in which thermal power of coal exceeds 5,450 kJ/kg*
*** Off-balance reserves are reserves in which the thermal power is smaller than 5,450 kJ/kg*

In one of its reports, the United States' CIA says that, according to the international standards, Kosovo is worth 500 billion dollars (estimated reserves of coal, natural gas and metal), and the remaining part of Serbia with Vojvodina only about 200 billion dollars. In line with one study mentioned in that report, the USA experts estimate that in Serbia there are coal reserves for maximum 35 to 40 years, while in Kosovo there is coal for as much as 16 centuries. Another study estimates that the coal reserves in Serbia are sufficient for 60 years, and in Kosovo for 200 years. They point out that the value of localities of seven strategic ore (lead, zinc, silver, nickel, manganese, molybdenum and boron) was estimated to as much as 1,000 billion dollars. [7]

It could be concluded that there is enough lignite to last more than one century, even with the increased exploitation. Importance of lignite for the region of Kosovo and Metohija is supported by the fact that the share of lignite in the total electric energy production is about 97%, while the hydroelectric power plants account for 3% of production. [8]

With the estimated lignite value of about 12[9] -15[7] Bt, Kosovo ranks as the third (after Germany and Poland) in Europe, and as the fifth in the world regarding the established lignite reserves.

3 EXPLOITATION OF LIGNITE IN KOSOVO AND METOHIJA

The main energy sources in Kosovo are located in two major lignite basins known as the "Kosovo" basin and "Metohija" basin, with the usable lignite deposits. [10] The Kosovo basin covers the area of 274 km², and Metohija basin the area of 49 km², while the other basins cover 5.1 km². [11]

The first systematized data on the lignite exploitation, i.e. small-scale lignite mining in the Kosovo basin, dates back to 1922. More extensive lignite production started with opening the open-pit mines Miras (1958) and Belacevac (1969), and by application of modern excavators (diggers). Lignite exploitation in those open-pit mines, that represented one collective exploitation area, ended in 2012. The annual production capacity in both mines was 28,000,000 m³ of gangue (solid mass) and about 17,000,000 tons of coal. Since 2010, coal has also been exploited from the so called "New Mine" (southwest of Sibovac), and this mine is in the final phase of development.

Among the lignite fields in Kosovo and Metohija, the Field Sibovac is the largest exploitation reserve. It comprises approximately 330 metric tons of exploitation reserves and has the smallest portion of overburden. The Field Sibovac covers the area of 16 km², with maximaldepth of 3.8 km and length of about 6 km. In addition to the new mine, the Sibovac Southwest, in which lignite has already being exploited, the plan is to start with exploitation of the southeast part of Sibovac field that has been explored, as well as with two alternative fields: Field D and Field South Sibovac. [12]

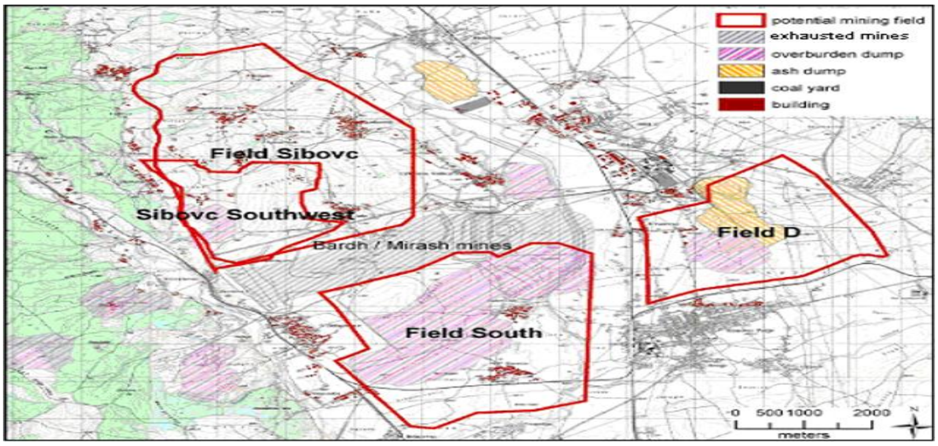

Figure 2 *Mining fields of lignite - Sibovac [12]*

Figure above presents the potential mining fields of lignite (Field Sibovac, Sibovac Southwest, Field D and Field South), as well as the mines in which the exploitable lignite has been depleted (Miras and Belacevac).

It is important to mention that the prospects of finding the new coal localities are very favourable and realistic due to the good geological prerequisites. There are indications that there is coal in many other locations, especially in the south part of the Pec lowland, in the part of Djakovica and Prizren. Also, one of potential locations is the Neogene basin of Kriva Reka that represents a tectonic basin, formed in the cross-border area of the Dardani massif in the east, and Vardar zone in the west, whereby the thickness of coal seam in this region reaches 5 m. It would be reasonable to expect an intensification of explorations aiming at discovery the new lignite localities.

Taking into account the specified lignite amounts, it would be reasonable to expect that lignite, as an energy generating product, will continue to be the main source of energy in Kosovo and Metohija. With that in mind, it is necessary to:

- follow up the developments, in our neighboring countries and worldwide, related to the technology of clean combustion of lignite, intended for increased utilization in the industry and heating plants and economically justifiable from the social and environmental aspect;
- intensify the geological explorations in order to develop the strategy of lignite exploitation planning;
- apply an economically and environmentally justifiable procedure of lignite refinement in order to comply with the modern technological solutions for utilization of lignite in the industry and mass consumption. [13]

4 THERMAL POWER PLANTS IN THE REGION OF KOSOVO AND METOHIJA

In the region of Kosovo and Metohija there are two thermal power plants: “Kosovo A” and “Kosovo B”. The Termal Power Plant **"Kosovo A"** consists of five working blocks, known as the A1, A2, A3, A4 and A5. The Block A1 of this Thermal Power Plant was put into operation in 1962 with the power of 65 MWe; A2 in 1965 with the power of 125 MWe; A3 in 1970 with the power of 200 MWe; A4 in 1971 with the power of 200 MWe and A5 in 1975 with the power of 210 MWe. At the moment, the blocks A3, A4 and A5 are in operation. According to the current production plan, two blocks are in use (A3 and A5), while one of them (A4) is a hot reserve because of their low readiness and age. The Blocks A1 and A2 are non-functional and are without defined status and, according to the current plans, they will remain like that until the end, when their decommissioning is expected. The whole Thermal Power Plant “Kosovo A” is in a bad condition, and considered to be the worst single pollution source in Europe. The interim institutions in Pristina plan to decommission it, but it cannot be done until the sufficient amount of electricity has been provided, which is not feasible at the moment. The annual electric energy production from the Thermal Power Plant Kosovo A is around 1500 GWh. [14]

The Thermal Power Plant “Kosovo B” Block 1, built in 1983, is active (339 MWe) and so the Block 2, constructed in 1984 (339 MWe), and they both need a rehabilitation after being operational for 35 years in order to be aligned with the environmental standards of the European Union.

The total capacity of these two thermal power plants (Kosovo A and Kosovo B) amounts to 988 MWe. The plan is to have the thermal power Plant Kosovo C, with Block 1 (300 Mwe) and Block 2 (300 Mwe), built and put into operation until the end of 2018 [15].

Table 2 *Thermal Power Plants in the region of Kosovo and Metohija [15]*

Thermal power plant name	**Thermal power plant Kosovo A**		**Thermal power plant Kosovo B**		**Thermal power plant Kosovo C**	
Block	Block 3	Block 5	Block 1	Block 2	Block 1	Block 2
Status	existing	existing	existing	existing	new*	new*
Operating since	1970	1975	1983	1984	2018	2018
Capacity MVe	200	210	339	339	300	300

** Beginning the operation of the new plants is based on estimate*

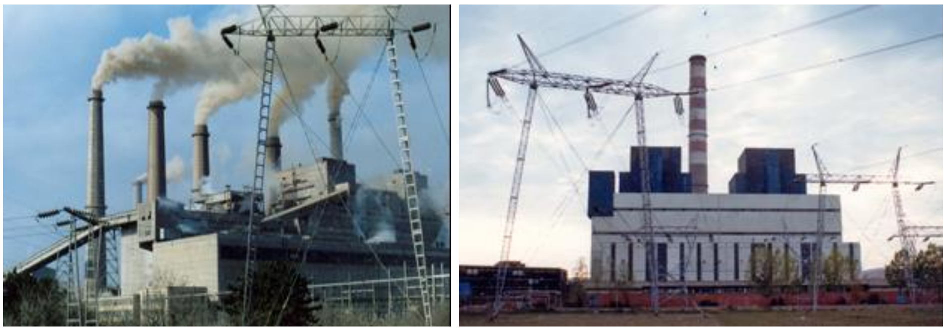

Figure 3 *Thermal Power Plants "Kosovo A" and "Kosovo B" [16]*

According to the plan, the Thermal Power Plant Kosovo A will be decommissioned by the beginning of 2023, when the Thermal Power Plant Novo Kosovo, currently under construction, is expected to be put into operation, and after that, the Thermal Power Plant Kosovo B will undergo a rehabilitation. [17]

5 ENVIRONMENTAL POLLUTION BY THE THERMAL POWER PLANTS IN KOSOVO AND METOHIJA

In this part, the environmental pollution related to air emissions of pollutants, created by lignite combustion in thermal power plants in Kosovo and Metohija will be discussed. As it was already mentioned, 97% of electric energy production is based on lignite exploitation in Kosovo and Metohija. The first step in this process is a procurement of raw material for further processing and transformation. [18] Large amount of lignite makes possible a certain level of energy independence on one side, while on the other side3, the negative effects of reliance on lignite must be taken into account. The Thermal Power Plants "Kosovo A" and "Kosovo B" operate according to the outdated environmental standards, thus producing the high emissions of harmful gases which, consequently, greatly affect the environment and human health. In order to reduce the harmful gases emission and, consequently, their negative influence, the Thermal Power Plant "Kosovo A" needs to be shut down (which is planned to be done until the end of 2023), while the Thermal Power Plant "Kosovo B" needs to be improved in order to comply with the new legal requirements based on the standards that are much stricter than those that are currently applied to the existing thermal power plants. Those new standards have been defined by the Industrial Emissions Directive (IED) of the EU. [19]

Regardless of the stricter standards, the negative consequences cannot be avoided

100%, but at least they can be reduced to a minimum that will not affect severely the environment and human health. If the quality of air in the region complies with the requirements, it does not mean that people who live in that region are fully protected from the influence of air pollutants from a certain source. Estimate of pollutant influence on the environment represents a subjective attitude and does not imply the absence of that influence. There are numerous studies of influence the air pollutants on health, both in our country and worldwide, according to which the risks are not limited to the areas in the imminent surrounding of the plants or other combustion objects, but extend to larger areas, sometimes several hundred kilometers away, because the said particles are transmitted by wind and end up deposited on the ground. These harmful substances bring about enormous environmental problems and are a threat to the human life and human health. [20] What can be done to reduce the harmful consequences of lignite combustion in the thermal power plants is to adjust them to the specified standards, and to increase the competitiveness of renewable technologies for the energy production in relation to the lignite exploitation and utilization in the thermal power plants.

By lignite combustion in the thermal power plants, the harmful particles (sulphur-dioxide SO_2, nitrogen-dioxide NO_2 and particulate matter (PM)) are emitted, which causes pollution of air. Influence of SO_2 and NO_2 is connected not only with exposure to the pollutants in the form in which they are emitted, but also to the products of their reactions, since they react with the other pollutants in the atmosphere forming the aerosol (ammonium-sulphate and ammonium-nitrate in particular) that contributes to the overall particulate loading of air. Nitrogen-dioxide also reacts with the volatile organic compounds in the presence of sunlight which results in production the increased levels of ozone, the other pollutant that is considered to be a threat to health. [15]. Other dangerous substances, emitted from flue-gas stacks of the coal thermal power plants, are heavy metals, e.g. mercury, and persistent organic pollutants such as dioxins and polycyclic aromatic chemicals. High emissions of mercury from the lignite-fired thermal power plants raise the special concerns about the health of children. [21]

The influence of air pollutants on health includes death due to the respiratory and heart problems, bronchitis, hospitalization and many other negative effects. Exposure to the open air contamination is associated with a large number of acute and chronic health conditions, ranging from irritation to death. [22]

Table below shows the annual number of cases of premature death in Europe that can be ascribed to the thermal power plants in Kosovo and Metohija.

Table 3 *Annual numbers of cases of premature death in Europe that can be ascribed to any plant operating with the capacity adjusted to the loading factor [15]*

	Sulphur-dioxide	Nitrogen-dioxide	PM2.5*	Total
Kosovo A, block 3	17	11	21	49
Kosovo A, block 5	36	22	45	103
Kosovo B, block 1	53	38	18	109
Kosovo B, block 2	53	38	18	109
Total	159	109	102	370

**PM2.5, fraction of "dust" with diameter smaller than 2.5 micrometers*

The latest data, published in the HEAL report, show that the influence of harmful particles, produced by lignite combustion in the thermal power plants at the annual level round the European Union resulted in over 18,200 cases of premature death, around 8,500 cases of chronic bronchitis, and over 4 million days of absence from work. Economic costs of coal combustion impact on human health in Europe are estimated as 42.8 billion euro per year. [23]

In addition to the negative health consequences, the harmful effects caused by the air pollution by the lignite-fired thermal power plants have the financial consequences as well, regarding both population and the state. Monetization of the influence of lignite combustion in thermal power plants is related to several factors: additional health care costs resulting from the hospitalization, increased consumption of medicines, etc.; lost productivity of workers who take the sick leaves because they themselves are ill or to take care of ill family members and; loss of what is labeled as the "usefulness" or "pleasure" in economic literature due to the pain, suffering and reduced life expectancy. [15]

Due to everything aforesaid, the air pollution brought by the lignite combustion in the thermal power plants is being increasingly acknowledged as a considerable threat to the public health.

CONCLUSION

If a country wishes to plan and realize the energy strategy, it should possess the energy resources. It is typical that the countries with larger reserves of energy resources have a higher level of energy independence.

The actual lignite reserves in Kosovo and Metohija are still not known as a fact. All lignite localities in Kosovo and Metohija are still not sufficiently known and have not been sufficiently explored. What is unknown known at the moment is that those reserves are so immense that owing to them Kosovo ranks as the third in Europe and fifth in the world, regarding the amount of lignite.

The big world players have joined the battle for exploitation the Kosovo resources. In addition to the American companies, German, British, French and Turkish companies are also interested in investing into the mininglocalities and exploitation the natural resources of Kosovo. It is an interesting fact that the American company "Envidity", run by a retired NATO general Wesley Clark, asked for a license to explore the coal reserves in order to be able to produce the synthetic oil from coal, with the production plan of 100,000 barrels of oil per day.

Lignite is the main energy source in Kosovo and Metohija. Its share in the total electric energy production is about 97%, while the hydroelectric power plants account for only 3% of production. Due to a large amount of lignite reserves, the situation is likely to remain the same in the period to come. According to the European Association for Coal and Lignite (EUROCOAL), coal will continue to be important as a factor among the energy generating products for a long time for the purpose of electric energy production, whose increasing needs are definite and will continue to grow. In order to meet the need for electric energy, it is necessary to modernize the existing and to apply the new, technologically innovative processes of obtaining lignite as an energy generating product.

Currently, there are two active thermal power plants in the region of Kosovo and Metohija: the thermal power plant "Kosovo A" (blocks A3, A4, A5) and thermal power plant "Kosovo "B" (block 1, block 2). These two lignite-fired thermal power plants emit thousands of tons of harmful pollutants every year, thus contributing to the air pollution considerably and not only in the region of Kosovo and Metohija, but in the Balkans region and farther, because the pollutants are transmitted by air to a greater distance. Operating of the said thermal power plants is characterized by the outdated environmental standards, which contribute to creation the high levels of emission of pollutants that have numerous negative effects on the environment and human health. Therefore, it is necessary to revise the energy production plans in order to reduce the reliance on lignite and exclude it in the end and in order to increase investments into renewable energy sources.

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EVALUATION OF THE SUSTAINABLE DEVELOPMENT BENEFITS IN THE SERBIAN MINING COMPANIES

Abstract

Sustainable development is the most current topic of today; it means a moderate development that meets the needs of the present generation, and does not interdict the needs of future generations. An analysis of the sustainable development benefits in the mining companies (Mining and Smelting Basin Bor, RTB) presents a problem that can be solved using the multi-criteria decision-making methods (MCDM). The interest in analyzing the benefits of sustainable development in the Mining and Smelter Basin Bor originated from the fact that the benefits influence the growth, development and survival of the company. One approach based on the AHP method is proposed to solve the complex problem in this paper. The usability and effectiveness of the AHP approach has been considered in the empirical application of the proposed method for assessment the sustainable development benefits in the mining companies of Serbia (RTB Bor).

Keywords: *sustainable development, AHP method, RTB Bor*

1 INTRODUCTION

A concept of sustainable development in the modern world implies improving the quality of life with respecting a healthy environment, using the social and economic qualities for both present and future generations [1].

Development of RTB Bor in Serbia depends on many investment factors. But, their development and survival depend to some extent on the benefits of sustainable development: sustainable production and consumption, implementation of the integrated management system (ISM), introduction of clean technology, development of social responsibility and environmental protection. Development of the mining companies in Serbia has a major contribution to the solution of social and demographic issues, positive impact on regional development and external trade balance of the country [2]. RTB Bor is one of the leading manufacturers of copper and precious metals (gold and silver) in Serbia.

Ranking of the sustainable development benefits of the mining companies (RTB Bor) was done implementing the multicriterion decision-making (MCDM) method.

The MCDM technique has the benefit to evaluate the different options according to the different criteria that have different units. Their benefit over the traditional methods is that the deciding criteria have to be converted into the same unit. Another benefit is that they can analyze the quantitative and qualitative evaluation criteria.

This paper deals with a multicriterial analysis of ranking the benefits of sustainable development in the mining compa-

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nies or selection the best alternatives from a set by conflicting attributes.

The main idea of implementation the MCDM methods is an efficient assessment the benefits of sustainable development of the mining companies in order to improve the performances, increase profits, survival, faster risk identification, achievement the strategic goals and stakeholders' demands.

In recent years, MCDM methods are rapidly developed towards an effective methodology for solving the conflicting real problems and have a significant interests of researches in the mining for: selection of the degraded areas [3]; evaluation and selection of the personnel [4,5,6]; selection of the optimal integrated management system [7,8]; selection of the mining tourism strategy [9]; choice of the suppliers [10]; optimal mining [11]; business strategy selection [12], etc. They have found an application for evaluation the sustainable business [13] and selection the most influential indicator of sustainable development in the mining companies [14].

One of the MCDM methods - the AHP (Analytical Hierarchical Process) method is used in this paper. The AHP method has assessed the benefits of sustainable development of RTB Bor with the given criteria.

2 EXPERIMENTAL PART

The concept of sustainable development in the world and in our country is accepted as a condition of survival and development the mining companies. Sustainable development of the mining companies should enable a continuous sustainable long-term economic growth that will be based on the moderate use of natural resources in accordance with the environmental principles and respect for the environment. The benefits of sustainable development for the mining companies are examples of implementation the sustainable development and business.

The objective of this paper is to evaluate the benefits of sustainable development the mining companies in Serbia for the purpose of creating a sustainable business model, providing opportunities for rapid recognition of opportunities, chances, strengths and weaknesses, better mission and vision, better positioning, gaining competition, winning the new products and markets.

The advantages of sustainable development are: sustainable production and consumption, implementation of an integrated management system (ISM), introduction of the clean technology, development of the social responsibility and environmental protection.

Alternative A1: Sustainable production and consumption: designed, real set and operationally managed production and consumption of the mining companies is one of the alternative benefits of sustainable development. Alternative (A1) creates the sustainable models of the mining companies with which the desired results are achieved with the start of exploration of mineral resources.

Alternative A2: Implementation of the ISM. As in the world, and with increasing importance, it has an integrated management system. It is defined as a comprehensive management tool that connects all elements of the business system into a single management system. The optimal model of the integrated management system is a processive [7, 8], supported by the new standard ISO 9001:2015, an international standard that includes the ISO-International Organization for Standardization. Alternative (A2) creates the sustainable business models for the mining companies that are willing to give answers to all stakeholders.

Alternative A3: Introduction of the clean technology as a priority for sustainable development is crucial for development and creation the sustainable business of the mining companies and healthier environment. Problems of pollution as a result of out-of-date technologies, worn out equipment, inadequate use of the secondary raw materials, inefficient use of the natural resources, decision-making without the ade quate models, lack of the waste management perceptions and incentives for introduction of the clean production.

Alternative A4: Development of the social responsibility improves a reputation and creates a confidence for the community, employees, users, and all stakeholders. The concept of socially responsible business contributes to a better society and healthy environment. The responsible business of the mining companies is an investment rather than a loss.

Alternative A5: The environmental protection, its requirements are defined with the ISO 14001 standard. Implementation of the ISO 14001 as a benefit of the sustainable development makes the model of mining companies that reduce the environmental pollution, ecological disaster risks, control emissions, execute certain controls related to the production, reduce the operating costs and increase the ability to generate the sustainable production and consumption, which is a condition for getting a successful sustainable business model.

Criteria: Criteria are measures that evaluate the alternatives for evaluating the benefits of sustainable development in RTB Bor, defined by the decision-making team.

Criterion (C1): Informing the employees and their participation in decision making as an important criterion for evaluation the benefit of sustainable development for the mining companies. A certain milestone in the way of information and their participation in a decision-making has been made by the companies in developed countries. Deming gave a major contribution to the employees: it is necessary to introduce a permanent training, improvement and transformation of the employees.

Criterion (C2): Competitiveness: The international competitiveness of a state is the ability to maintain and increase the share of national economy in the market by opening the international standards of the efficiency, sustainable use of the natural resources and product quality [15].

Criterion (C3): Reducing costs; many mining companies have met with demands of the foreign companies, so they are forced to provide the appropriate ISO standards to reduce the costs. The criterion of cost reduction is important for the mining companies in order to increase the production and thereby to increase the profits.

Criterion (C4): Introduction of the new technologies; a trend for drastic increase in the investment in the mining companies in Serbia (construction of the New Smelter in the Mining and Smelting Basin Bor) has been recently seen. This criterion increases the production and sales leading to a greater competitiveness and cooperation with the global companies.

Criterion (C5): Simpler procedures, as a criterion for evaluating the benefits of sustainable development of the mining companies is based on introduction the concept of business quality improvement on the PDCA cycle (Plan, Do, Chek, ACT) which includes: plan, perform, check and control.

Criterion (C6): The quality control of the process by Deming is: to design a product, to test the product on the production line or laboratories, to sell the product and test it, to find out what they think about it and those who bought it and who did not. The mining companies in modern business are forced to focus on the quality processes to be sustainable and competitive.

Criterion (C4): The introduction of new technologies has recently seen a trend for a drastic increase in investment in mining companies in Serbia (the production of the New Smeltery in the Mining Smelter Basin Bor). This criterion increases production and sales leading to greater competitiveness and cooperation with global companies.

3 EVALUATION OF THE SUSTAINABLE DEVELOPMENT BENEFITS BY THE AHP METHOD

The problems of evaluation the sustainable development benefits of the mining companies can be overcome using an analytical hierarchy (AHP) which Thomas L. Saaty (1970) introduced into the multi-criteria decision-making [16]. This compensatory decision methodology can be applied in various areas of planning, management and solving the real problems.

The AHP includes [17]:

a) Structuring the problem of a hierarchical decision;
b) Matrix obtained on the basis of comparative comparison the crite ria and alternatives;
c) The consistency test must be less than 0.1;
d) Comparison synthesis in order to obtain an optimal alternative,
e) The evaluation of criteria is done between each other and ranking of the individual alternatives using the Criterion Decision Plus software.

The weight coefficients of the criteria are determined using the scale of comparison the Sati's procedure (Table 1).

Table 1 *Scale of comparison the decision elements*

Dominances	
Description	**Rating**
Equal	1
Poor domination	3
Strong domination	5
Very strong domination	7
Absolute domination	9
2, 4, 6, 8 are the subtotals	

Table 2 *Matrix of comparison for criteria*

Criteria	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**
C_1	1	1/5	1/3	1/3	1/2	1/3
C_2		1	1	3	3	3
C_3			1	1	1/2	1
C_4				1	2	1/3
C_5					1	1/2
C_6						1

The obtained results are shown in Table 3. Figure 1 shows the decision hierarchy of the AHP method.

Table 3 *Results obtained by the AHP calculations*

Criterion	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**
Weight coefficients of criterion	0.053	0.327	0.160	0.136	0.127	0.197
Consistency coefficient	0.084					

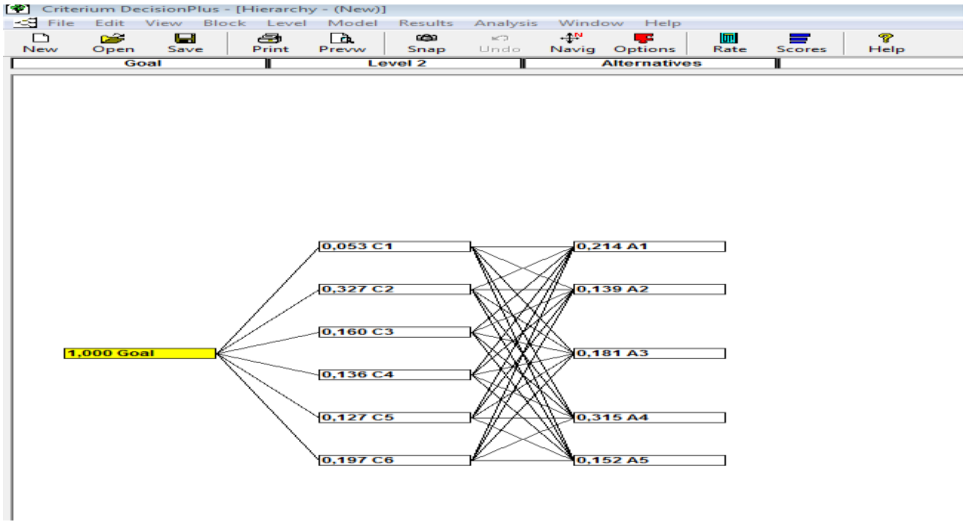

Figure 1 *Hierarchy of decision-making*

The next step is to evaluate the alternatives, individually with each C_1, C_2, C_3, C_4, C_5 and C_6. criteria. Alternatives are given as the benefits of sustainable development in RTB Bor. The choice of criteria is very important for solving the real problems.

Table 4 *Comparison of alternatives in relation to the criterion C_1*

Alternatives	A_1	A_2	A_3	A_4	A_5
A_1	1	2	3	1/2	1
A_2		1	1	1/2	3
A_3			1	1/5	1/2
A_4				1	3
A_5					1
Consistency coefficient 0.084					

Table 5 *Comparison of alternatives in relation to the criterion $_{C2}$*

Alternatives	A_1	A_2	A_3	A_4	A_5
A_1	1	1	1	2	1
A_2		1	1/3	1/2	1/2
A_3			1	1/2	2
A_4				1	2
A_5					1
Consistency coefficient 0.095					

Table 6 *Comparison of alternatives in relation to the criterion C_3*

Alternatives	A_1	A_2	A_3	A_4	A_5
A_1	1	1	3	1/2	2
A_2		1	2	1/3	1
A_3			1	1/5	1
A_4				1	5
A_5					1
Consistency coefficient 0.017					

Table 7 *Comparison of alternatives in relation to the criterion C_4*

Alternatives	A_1	A_2	A_3	A_4	A_5
A_1	1	2	3	1/2	1
A_2		1	3	1/3	2
A_3			1	1/5	1/2
A_4				1	1
A_5					1
Consistency coefficient 0.072					

Table 8 *Comparison of alternatives in relation to the criterion C_5*

Alternatives	A_1	A_2	A_3	A_4	A_5
A_1	1	2	1/3	1/2	1
A_2		1	1/3	1/2	1/3
A_3			1	5	1
A_4				1	1
A_5					1
Consistency coefficient 0.079					

Table 9 *Comparison of alternatives in relation to the criterion C6*

Alternatives	A_1	A_2	A_3	A_4	A_5
A_1	1	2	3	1/2	1
A_2		1	1	1/2	2
A_3			1	1/3	2
A_4				1	3
A_5					1
Consistency coefficient 0.067					

The AHP analysis of evaluation the sustainable business benefits in the mining companies shows that the highest benefit has the alternative (A_4) - development the social responsibility; the second place is the alternative (A1) - sustainable production and consumption; the third place is thealternative (A_3) - introduction of the clean tech nology; the fourth place is the alternative (A_5) - environmental protection and the fifth place is the alternative (A_2) - implementation of the integrated management system (Table 10). All alternatives are the benefits of importance for implementation the sustainable development in the mining companies.

Table 10 *The final ranking of benefits*

Order No.	Benefits	Result
1	A_4	0.315
2	A_1	0.214
3	A_3	0.181
4	A_5	0.152
5	A_2	0.139

4 ANALYSIS OF THE RESULTS

Using the AHP method, the most influential criterion was obtained as well as the certain alternative that has the highest benefit for the sustainable development of RTB Bor.

The results obtained by the AHP calculations (Table 3) show that the criterion C_2- competitiveness has the highest impact on the obtained result because its weight coefficient is 0.357; the second position occupies the criterion C_6 - quality control of the process with a weight coefficient of 0.197; in third place is the criterion C_3 - reduction of costs with a weight coefficient of 0.160; the fourth is the criterion C_4 - introduction of the new technologies with a weight coefficient of 0.136; the fifth place is the criterion C_5 - simpler procedures with a weight coefficient of 0.127 and the sixth place is the criterion C_1 - information of the employees and their participation in a decision-making with a weight coefficient of 0.053.

Evaluation the sustainable development benefits in the mining companies by the AHP calculation results in a fact that has the highest benefit has the alternative A_4 - development of the social responsibility, which has a maximum value of 0.315; the second place is the alternative A_1- sustainable production and consumption with a value of 0.214; the third place is the alternative A_{3c}- introduction of the clean technology with a value of 0.181; the fourth place is the alternative A_5 - environmental protection with a value of 0.152; the fifth place is the alternative A_2 - implementation the integrated management system with a value of 0.139 (Table 10).

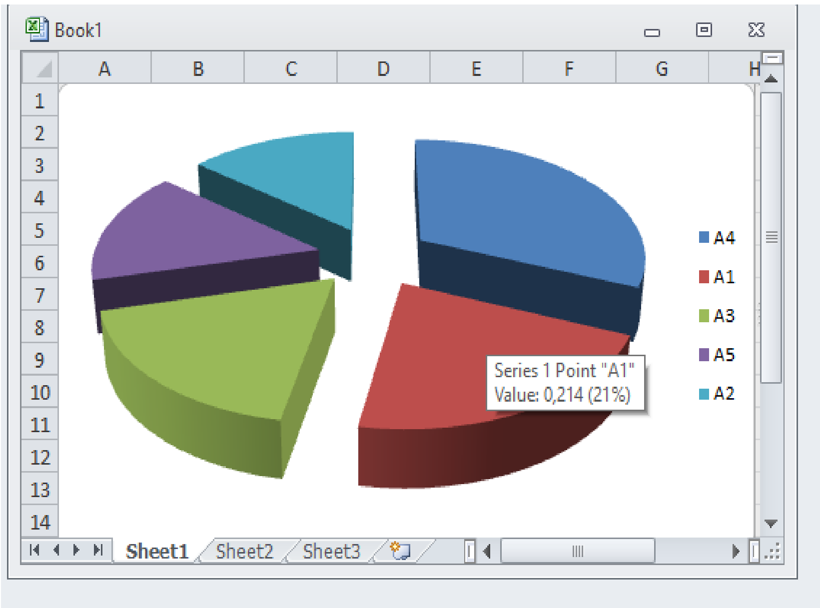

Figure 2 *Graph of evaluation the sustainable development benefits in the mining*

Figure 2 shows a graph of evaluating the benefits of the mining company (RTB Bor) in implementation the sustainable development. Calculation resulted in a fact that all benefits are almost equal. The responsible business as the best benefit of sustainable development means: investments for introducing the new and clean technologies for sustainable production and consumption, development the awareness of environmental protection and implementation the integrated management system (ISM). The responsible business improves the image of mining companies, creates confidence and thus increases the competition.

Alternative A_4 - development of the social responsibility does not create a loss but a prosperity (satisfaction) for all interested parties.

CONCLUSION

The applied MCDM methodology for evaluating the benefits of sustainable development creates a perception for implementation the sustainable develop-ment and creation a sustainable business model. An assessment of the sustainable development benefits gives stakeholders the opportunity to better understand the chances, opportunities, strengths and weaknesses of RTB Bor to the aim of sustainability, competitiveness and profitability.

The AHP method was used to evaluate the benefits of sustainable development. The assessment of the following alternatives was made: sustainable production and consumption (A_1), implementation of integrated management system (ISM) (A_2), introduction of the clean technology (A_3), development of the social responsibility (A_4) and environmental protection (A_5). CAlculation has provided that the alterna-tive A_4 - development of the social responsibility has the highest value showing that it is the best advantage.

The following criteria were used to evaluate the benefits of sustainable development: information about employees and their participation in a decision-making

(C_1), competitiveness (C_2), cost reduction (C_3), introduction of the new technologies (C_4), simpler procedures (C_5), quality process control (C_6). The criterion C_2 - competitiveness has the greatest impact on evaluating the benefits of sustainable development in the mining companies.

Based on all of these, the future research should be directed towards the implementtation of sustainable development in the mining companies.

A contribution of this paper is the perception for implementation the sustainable development in order to the company survival and meeting the requirements of stakeholders.

A contribution of science is focused on expanding the theoretical and practical knowledge on implementation the sustainable development in the mining companies.

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APPLICATION OF ECOFRENDLY OXIDANT FERRATE(VI) IN THE METALLURGICAL PROCESSES OF COPPER EXTRACTION****

Abstract

This works deals with investigation the efficiency of sodium ferrate, Na_2FeO_4, obtained by the electrochemical oxidation, as coagulation and flocculation agent for purification of wastewater from the electrolytic refining process from the Bor Copper Refinery and Copper Smelter Plant of the Mining and Smelting Combine Bor. Removal of heavy metals and selenium by barium ferrate in aqueous solutions could be possible up to: 100 % for Cu, 97.18 % for As, 98.37 % for Sb and 6.06 % for Se using ferrate(VI) in the ratio M : Fe(VI) = 1:12.

Also, the efficiency dependence of copper sulphide ore leaching from concentrate by the oxidation of copper sulfide and chalcopyrite with ferrate(VI) on the sulphuric acid concentration was investigated in this work. It is found that leaching of copper from vthe copper sulfide concentrate, carried out by ferrate(VI), proceeds easily due to the efficient oxidation of sulfide and sulfur, in respect of the classical acid process that usually needs the addition of strong oxidant, such as oxygen or hydrogen peroxide, to increase the process productivity.

Keywords: *ferrate(VI), chalcopyrite, hydrometallurgical, wastewater, oxidation*

INTRODUCTION

The first descriptions of ferrate(VI), Fe(VI), are given in 1702 [1]. In 1715, Stahl noted an unstable red-purple compound, obtained by dissolution the heated mixture of potassium nitrate and iron chips in water [2]. Poggendorf is the first, who documented occurrence of purple coloration in anodic oxidation of Fe electrode in strongly alkaline solutions [3]. In 1897, Moeser gave a detailed description of ferrate(VI), its chemical properties and methods of synthesis [4].

Interest in synthesis methods and application of ferrate(VI) was risen during the twentieth century, especially since 1950. Many possible applications of ferrate(VI) as a strong oxidizing agent, coagulant, flocculent and effective disinfectant were tested and confirmed. The biggest advantage of ferrate(VI) is an ability of application in the environment protection, in the wastewater treatment of different origin and composition, as an environmentally friendly oxidizing agent [5,6,7].

One of the possible methods for removal the heavy metal ions from the aqueous medium is application of ferrate(VI), an envi-

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ronmentally friendly oxidant, coagulant and disinfectant. Due to the suitable physical and chemical properties of ferrate(VI), such as high oxidation potential, which is 2.2 V in acidic conditions, and 0.7 V in alkaline conditions, forming of the oxygen by oxidation of water, and high capability of coagulation of iron (III) hydroxide, the reduction product of ferrate(VI). Ferrate(VI) ha\s been proved to be a very efficient and environmentally friendly oxidant, disinfectant and coagulation agent in a variety of application areas. Ferrate(VI) can be produced by the chemical or electrochemical synthesis. Ferrate(VI), produced by the electrochemical synthesis, has many advantages compared to the chemically synthesized ferrate(VI) [8,9] such as: simplicity, lower consumption of chemicals, non-toxic products and exceptional purity of the obtained ferrate(VI). Moreover, the electrochemically produced ferrate(VI) has no instability problem and needs no transportation, and due to the ecological advantages, it can be implemented in wastewater treatment practice, in situ. Also, as a strong oxidizing agent, ferrate(VI) decomposes the complexes of organic compounds with heavy metal ions, which could hinder the efficient coagulation and removal of heavy metal ions from solution and avoid the formation of toxic by-products, which is often a side effect of conventional methods [10].

Wastewater from the mining and metallurgical processes is characterized by the low pH value and high concentrations of sulfates, heavy metals and some nonmetals. The heavy metals load is of greater concern than the acidity in the terms of environmental damage. Heavy metals are generally considered those whose density exceeds 5 g/cm^3. Most of elements that falls into this category are highly water soluble, well-known toxics and carcinogenic agents. Consequence of discharge the untreated mine wastewater in the environment are reflected in aq long-term contamination of soils to which the mine water come in contact and accumulation of heavy metals therein, entering the mine wastewater into surface water, and mixing the mine wastewater with ground water. Therefore, the hydrometallurgical wastewater is among the most serious threats to the human population and fauna and flora of the receiving water bodies [11,12].

This work deals with investigation the efficiency of sodium ferrate, Na_2FeO_4, obtained by theelectrochemical oxidation, as the coagulation and flocculation agent for the wastewater purification from the electrolytic refining process from the Bor Copper Refinery and Copper Smelter Plant of Mining and Smelting Combine Bor.

Removal of heavy metals from wastewater can be accomplished through various treatment options. Some of the conventional treatment processes for their removal are the ion exchange, chemical precipitation, various adsorption methods and membrane separation process. However, all these methods have their drawbacks, which are primarily reflected in the insufficient level of heavy metals removal, high-energy consumption and formation of toxic products. [13].

Also, in this work, the efficiency dependence of copper sulphide ore leaching from concentrate by the oxidation of copper sulfide and chalcopyrite with ferrate(VI) on the sulphuric acid concentration was investigated. The aim is to explore a possibility of copper sulfide oxidation improvement by reduction the number of technological steps and increasing the efficiency of electrolyte preparation process of the copper electrolytic refinement.

The copper oxide ore is leached only by sulphuric acid to form copper sulphate, see Eq. (1).

$$Cu_2O + H_2SO_4 \rightarrow CuSO_4 + H_2O \quad (1)$$

Chalcocite and chalcopyrite ore, on the other hand, can only be leached under the oxidizing conditions with ferric ions or oxygen, see Eqs. (2) – (4).

$$Cu_2S + 4Fe^{3+} \rightarrow 2Cu^{2+} + 4Fe^{2+} + S^0 \quad (2)$$

$$CuFeS_2 + 4H^+ + O_2 \rightarrow Cu^{2+} + Fe^{2+} + 2S^0 + 2H_2O \quad (3)$$

$$CuFeS_2 + 4Fe^{3+} \rightarrow Cu^{2+} + 5Fe^{2+} + 2S^0 \quad (4)$$

The formed elemental sulphur, Eqs. (2) – (4), can be oxidized by means of oxygen and partially bacteria to form sulphuric acid which reduces the overall sulphuric acid, required for the leaching process.

The major issue with the leaching of chalcopyrite concentrate in an acidic solution of ferric sulphate at atmospheric pressure and temperatures below 110°C, is that copper dissolution typically slows down once approximately 30% of dissolved copper, depending on concentrate. Many authors [14] have concluded that this "passivation" effect is due to the formation a film on the surface that does not allow further reaction to occur, but there is no consensus to the actual composition of this layer. Munoz [15] proposed that a layer of sulphur is formed around a chalcopyrite particle. Formation of elemental sulphur or polysulphides: XS_n, and jarosites $XFe_3\ (SO_4)_2\ (OH)_6$, where X^+ = Na, K, Rb, NH_4, H_3O, Ag, Tl, causes a passivation of chalcopyrite concentrate. The metal deficient sulphides, and elemental sulphur are the prime candidates for any concentrate leaching passivation. [16,17]

Obviously, formation of an insoluble sulphur layer or its compounds may slow down or prevent copper copper from concentrate in the absence of strong oxidizing substance in the leaching process, particularly in the absence of oxidizing agents. Ferrate(VI), as a strong oxidizer, has shown the ability to oxidize sulphide and sulphur [18], so the aim of this research was to explore the feasibility of ferrate(VI) application as an oxidizer in the process of copper sulphide ore leaching from concentrate.

2 EXPERIMENTAL

Electrochemical Synthesis of Na_2FeO_4 Solution

Solution of Na_2FeO_4 was obtained in the process of electrochemical synthesis. The process of electrochemical synthesis of an alkaline solution of ferrate(VI) was based on a transpassive anodic dissolution of the iron alloys (3% Si, C) in 10 M NaOH solution at a constant current of 1A for a period of 1 hour, in accordance with the previous studies [19]. All measurements were performed at room temperature (25 ± 1^0C). This was carried out in a laboratory facility for electrochemical synthesis of ferrate(VI), (Fig. 1 and Fig. 2) consisting of a two-part flow-through electrochemical cell [20].

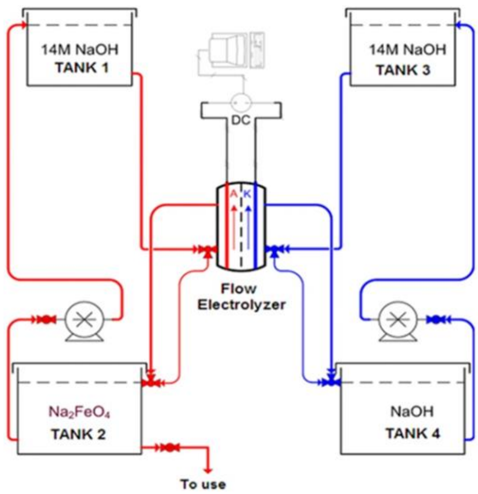

Figure 1 *Scheme of the pilot plant for the electrochemical synthesis of ferrate(VI)*

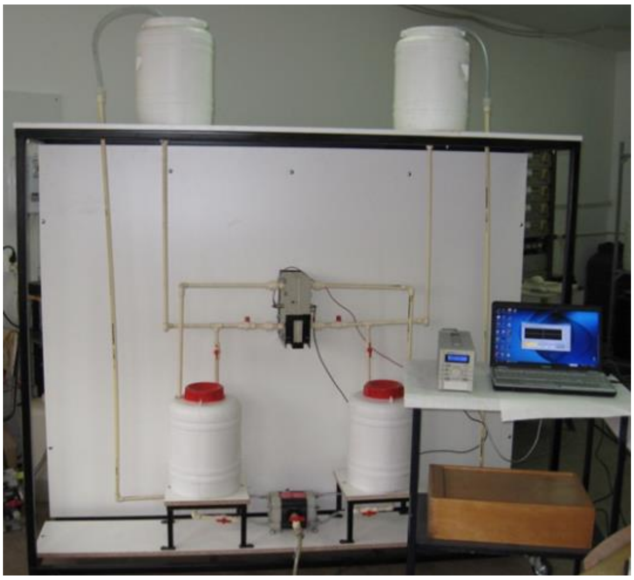

Figure 2 *Pilot plant for the electrochemical synthesis of ferrate(VI)*

Waste Water from the Electrolytic Refining Process in RTB Bor

Waste water sample from the electrolytic refining process in RTB Bor is characterized as a highly acidic water (pH = 0) with a light blue color (Fig. 1a) and content in Table 1. The wastewater samples (200 ml) were treated first with 6 ml of 10 M NaOH solution (p.a. NaOH, "Centrohem" Stara Pazova, Serbia) in order to show a difference between the treatment with Na_2FeO_4. After this step, 6 ml of 10 M NaOH solution with different quantities of Na_2FeO_4 were added (2 mg, 5 mg, 15 mg and 20 mg) as a target to investigate the influence of ferrate(VI) on removal of heavy metals (Cu and Fe) from the waste water solution. Value of pH was increased with the addition of ferrate(VI) from 11 to 14. The treatment of waste water samples was carried out using the Jar test equipment with a four-stirrer unit (Velp JLT4, Italy). The mixing rate was at first 300 rpm for 10 minutes, and then 160 rpm for 20 minutes. After 30 min, filtering was performed by the vacuum filtration on the Buchner funnel. Chemical analysis of the obtained solutions was carried by the Atomic absorption spectrophotometry analytical technique.

Wastewater from the Copper Smelter Plant of the Mining and Smelting Combine Bor

The stock solution of synthetic hydrometallurgical, used in the experiment, was synthesized according to the composition and characteristics of a real wastewater from the Copper Smelter Plant of Mining and Smelting Combine Bor, Table 2.

Table 1 *Content of elements in waste water solution from the electrolytic refining operation*

Element	Unit	Effluent from the electrolytic refining process
Al	mg/dm^3	7
Sb	mg/dm^3	<1
As	mg/dm^3	4
Cd	mg/dm^3	<1
Ca	mg/dm^3	64
Cr	mg/dm^3	<1
Co	mg/dm^3	<1
Cu	mg/dm^3	698
Fe	mg/dm^3	25.8
Pb	mg/dm^3	<1
Mg	mg/dm^3	18
Mn	mg/dm^3	<1
Ni	mg/dm^3	12.2
Se	mg/dm^3	<1
Na	mg/dm^3	11
V	mg/dm^3	<1
Zn	mg/dm^3	1.6
Ag	mg/dm^3	<1
Bi	mg/dm^3	<1
Hg	mg/dm^3	0.001
Cl^-	mg/dm^3	10.21
SO_4^{2-}	mg/dm^3	18563.3

Table 2 *Characteristics of the real wastewater sample from the Copper Smelter Plant of Mining and Smelting Combine Bor*

Parameter	Unit	August 2012.
		Average
Temperature	^oC	25
pH		0.1
Acid content	%	3.8
	g/dm^3	38.9
Dissolved metals		
Cu	g/dm^3	1.8
As	g/dm^3	0.1
Sb	g/dm^3	0.0008
Se	g/dm^3	0.361

Besides the heavy metals and Se, the sulphate and nitrate ions ($c(H_2SO_4)$ = 1.770 mol/dm^3i $c(HNO_3)$ = 0.001286 mol/dm^3) are present in waste water. For the stock solution synthesis of the synthetic wastewater with the same characteristics and composition as the sample of real water, the following chemicals of p.a. quality were used:

$CuSO_4$ x $5H_2O$, As_2O_3,Sb_2O_3, SeO_2, H_2SO_4 i HNO_3.

In the second stage of treatment, four samples from the previous stage were treated by Na_2FeO_4 in the molar ratios M:Fe(VI) = 1:2; 1:4; 1:8; 1:12, while the fifth sample remained untreated. The second stage of treatment was carried out at room temperature (25 ^oC), stirred for 30 minutes using the Jar test with a four-unit stirrer (Velp JLT4) at speed of 300 rpm and for 1h at speed of 100 rpm. After 24 h of precipitation, the treated samples were filtered through a filter with pore size of 0.20 μm. The changes in heavy metals and Se concentrations, treated by NaOH and Na2FeO4, were determined analyzing the treated samples using an ICP ThermoiCAP Q device.

Oxidation of Copper Sulfide and Chalcopyrite with Ferrate(VI)

For the purpose of oxidation the copper sulfide and chalcopyrite with ferrate(VI), the chalcocite and chalcopyrite copper ore concentrates (22.66 % Cu, 34.74 % S, 29.80 % Fe, 7.47 % SiO_2, 11.36 % H_2O and 1.93 % Al_2O_3) were used as the experimental sample. In sample of 2.1 g, the total sulphur content in a form of sulphide was 0.48 g, 0.0149 mol S, and copper 0.73 g, 0.0115 mol Cu, the quantity of ferrate(VI) addition is calculated according to the stoichiometry of sulphur oxidation using sodium ferrate(VI). Sodium ferrate(VI) has been electrochemically produced according to earlier reported procedure [19,20].

In a laboratory beaker sample of 2.1 g, the copper ore concentrate is mixed in to 0.5 dm^3 of demineralized water with a laboratory magnetic stirrer, with the final pH value 5.75. In such mixture 200 ml of 20 g/dm^3 Na_2FeO_4 in 10 M NaOH solution was added in small portions with intensive stirring, 300 min^{-1}, and later stirring is continued with low speed, 30 min^{-1}. After this operation, the pH of solution was 14, and visible flakes of pale blue colored cupric and brown-orange colored ferric hydroxides was clearly visible. The end of reaction was determined spectroscopically (UV-VIS spectrophotometer Shimadzu model UV-1800) following intensity of absorbance peak at 510 nm characteristic for Fe^{6+}.

In the course of copper and iron separation from insoluble residue, the acidification of solution is achieved adding the 2:1 mixture of water and concentrated sulphuric acid to convert copper and iron hydroxides into the soluble sulphates. The pH value was adjusted below 2. After sedimentation of insoluble particles, a greenish solution was filtered through double black labeled filter paper. The Cu and Fe content in filtrate was analyzed by a visible Cu and Fe spectrophotometry (UV-VIS spectrophotometer Shimadzu model UV-1800) and iodometric titration of copper. The iodometric titration was used for the quantitative determination of copper content in filtrate. As Fe^{3+} ions oxidize iodide, iron(III) present in filtrate is converted to $FeF_n^{(3-n)+}$ complex with NaF to avoid a positive error in copper determination.

3 RESULTS AND DISCUSSION

Waste Water from the Electrolytic Refining Process in RTB Bor

Due to a high concentration of Cu and Fe_{tot} in effluent (698 mg/dm^3 and 25.8 mg/dm^3 respectively), the chemical analysis of treated samples with ferrate (VI) was carried out only for this two elements, Cu and Fe_{tot}.

Figure 3 shows samples of waste water from the electrolytic refining process, before and after treatment with ferrate(VI). After neutralization with 6 ml of NaOH solution and adding 2 mg Na_2FeO_4, the pH value was increased to 13 and there was a hardly soluble precipitate formation of light blue color. With the increasing content of ferrate(VI) at 15 mg Na_2FeO_4, there were the hardly soluble dark green particles (Figure 3d). After filtration, the filtrate was completely discolored. Black precipitate with large particles (Fig. 3e) was formed after addition of 20 mg Na_2FeO_4.

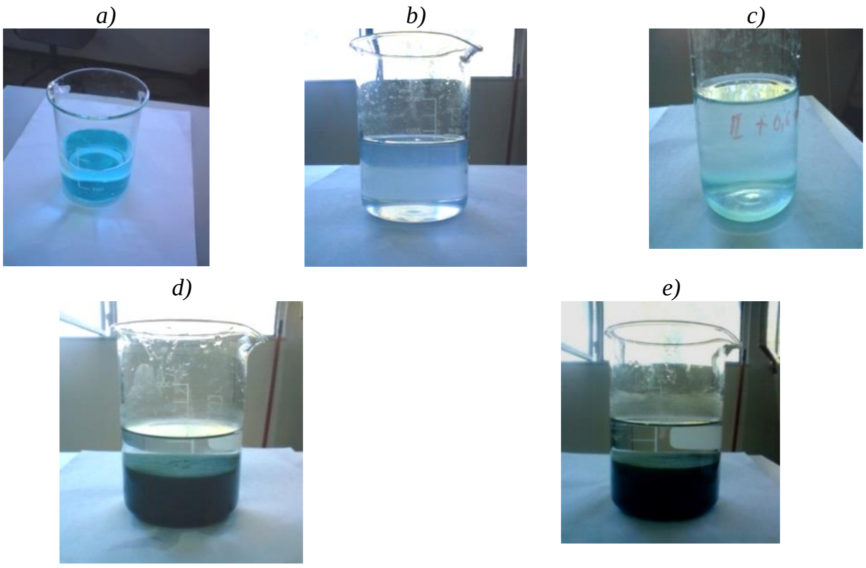

Figure 3 *Wastewater samples: a) initial wastewater sample: b) wastewater treated with 2 mg Na_2FeO_4 and filtrated; c) wastewater treated with 5 mg Na_2FeO_4ferrate(VI) and filtrated; d) wastewater treated with 15 mg Na_2FeO_4 ferrate(VI); e) wastewater treated with 20 mg Na_2FeO_4*

Table 3 and Figure 4 present the content of copper and iron in the waste solution refining operation after treatment with ferrate(VI).

Table 3 *Content of Cu and Fe in the wastewater refining operation after treatment with Na_2FeO_4*

Element	Cu, mg/dm^3	Fe_{tot}, mg/dm^3
6 ml NaOH	15	0.3
6 ml NaOH + 2 mg Na_2FeO_4	16	0.6
6 ml NaOH + 5 mg Na_2FeO_4	2.6	0.6
6 ml NaOH +15 mg Na_2FeO_4	0.4	0.3
6 ml NaOH + 20 mgNa_2FeO_4	0.2	0.3

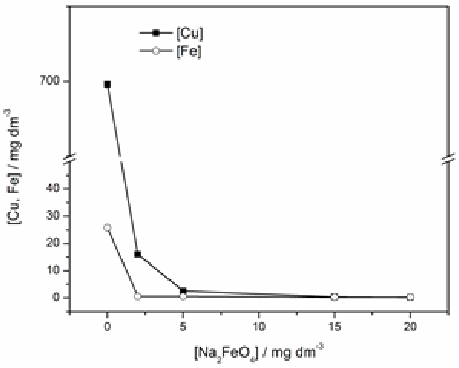

Figure 4 *Grafical illustration of Cu and Fe concentration change after treatment with 6 ml 10 M NaOH and 6 ml 10 M NaOH with Na_2FeO_4*

It is obvious from the results that the concentration of Cu in solution after treatment with ferrate (VI) is significantly reduced. The best results were achieved using 6 ml NaOH + 15 mg Na_2FeO_4. Cu and Fe_{tot} concentrations decreased from 698 to 0.4 mg/dm^3,and from 25.8 to 0.3 mg/dm^3, respectively.

According to the Ordinance on emission the limit values of pollutants in water and deadlines for their achievement ("Official Gazette of the Republic of Serbia", No. 67/2011), the limit values applicable to the wastewater from production and casting of the non-ferrous metals and byproducts of production and intermediate products before mixing with the other wastewater are: for copper 0.5 mg/l, and iron 3 mg/l.

Wastewater from the Copper Smelter Plant of the Mining and Smelting Combine Bor

The results of heavy metals and Se removal via precipitation with NaOH show a high efficiency in Cu and Sb removal, a but low efficiency in removal of As and Se, Table 4.

Table 4 *Reduction of heavy metals and Se concentrations in the samples of wastewater from the mining industry before and after treatment with NaOH*

	pH	c(Cu), mg/l	c(As), mg/l	c(Sb), mg/l	c(Se), mg/l
Before treatment	0	1800	100	0.8	361
NaOH	9	0.12	99.86	0.051	358.43
Removal, %		99.99	0.14	93.62	0.71

The synthetic wastewater, containing dissolved heavy metals (Cu, As, Sb) and Se treated with ferrate(VI), in various molar ratios (M : Fe(VI) = 1:2; 1:4; 1:8; 1:12), has shown a tendency of decreasing concentrations of metals and Se with increasing the amount of added ferrate(VI). The results of heavy metals and Se removal with Na_2FeO_4 from the samples of mining wastewater are shown in Table 5.

Table 5 *Reduction of heavy metals and Se concentrations in the samples of wastewater from the mining industry before and after treatment with $BaFeO_4$*

c(Na_2FeO_4), mol/l	pH	c(Cu), mg/l	c(As), mg/l	c(Sb), mg/l	c(Se), mg/l
0	0	1800	100	0,8	361
0.0224 (1:2)	9	<0.05	30.19	0.029	351.32
0.0448 (1:4)	9	<0.05	5.12	0.024	344.65
0.0896 (1:8)	9	<0.05	3.34	0.017	342.50
0.1344 (1:12)	9	<0.05	2.82	0.013	339.12
Removal, %		100	97.18	98.37	6.06

The treatment results show a very high efficiency in Cu removal with NaOH, 99.99% in the first step of the treatment. Therefore, further removal of Cu with Na_2FeO_4 is not necessary.

Due to a low mobility of As(III) in the aqueous solutions, it cannot be removed from the wastewater with NaOH. However, the As removal with Na_2FeO_4 could be up to 97,18 % when M : Fe(VI) ratio is 1:12 because of high oxidation potential of Fe(VI) which provides As(III) oxidation to As(V). Ferrous hydroxide, formed by the reduction of ferrate(VI), as a powerful coagulant removes it easily from solution.

Antimony could be successfully removed in a very high percentage (93.62 %) only using NaOH. Higher efficiency removal of Sb was achived with Na_2FeO_4 (98.37 %).

Removal of selenium was extremely low in the first stage of treatment, 0.71%. After treatment with Fe(VI), the removal was more successful (6.06 %), but not satisfying yet. Higher M : Fe(VI) ratio is needed because a large part of Na_2FeO_4 is spent on t oxidation. Further optimization of the treatment conditions should be done in order to improve the removal efficiency of selenium with Na_2FeO_4 from aqueous solutions.

Oxidation of Copper Sulfide and Chalcopyrite with Ferrate(VI)

Absorbance spectra of the intensely reddish colored complex $Cu(NH_3)_4^{2+}$, formed in the filtrate in reaction of the concentrated aqueous ammonia with Cu(II), presented in Fig. 5, confirms the presence of Cu^{2+} ions in filtrate. The absorbance peak at 470 nm characterizes the presence of Cu(II). The absorbance spectra of Fe(III) thiocyanate complex, obtained by the addition of ammonium thiocyanate in filtrate, with the characteristic absorbance peak of Fe(III) at 474 nm, is presented in Fig. 6.

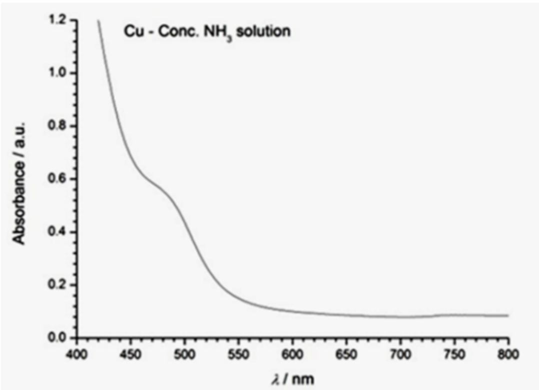

Figure 5 *Absorbance spectra of filtrate intensely reddish colored by $Cu(NH_3)_4^{2+}$ complex*

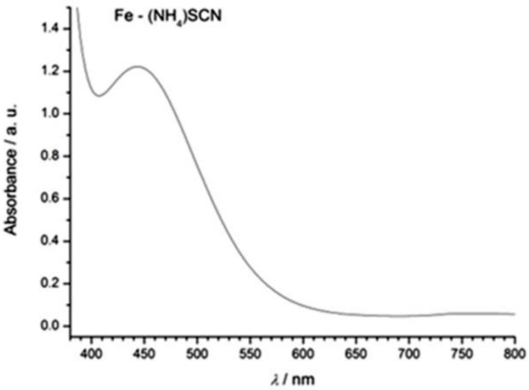

Figure 6 *Absorbance spectra of filtrate intensively red colored by Fe(III) thiocyanate complex*

Variation of sulphuric acid solution quantity was completed to investigate the influence of acidification on the leaching reaction efficiency.

Table 6 *Copper sulphide ore concentrate leaching with ferrate(VI) efficiency*

$V_{Sulphuric\ acid}$, ml	Time of ferrate(VI) reaction*, minutes	C_{Cu}, g dm^{-3}	Efficiency
50	90	0.52	0.71
100	50	0.62	0.85
150	30	0.69	0.945

The end of reaction was d spectroscopically determined following the intensity of absorbance peak at 510 nm characteristic for Fe^{6+}.

$$2FeO_4^{2-} + Cu_2S + 4H_2O \rightarrow Cu_2O + 2Fe(OH)_3 + SO_3^{2-} + 2OH^- \quad (5)$$

$$FeO_4^{2-} + S + 4H_2O \rightarrow SO_4^{2-} + Fe(OH)_3 + OH^- \quad (6)$$

The results presented in Table 6 obviously confirm a positive effect of the reaction solution acidification on the copper recovery efficiency from the chalcocite and chalcopyrite ore concentrate in presence of ferrate(VI). The acidification of reaction solution provokes the increase of redox potential of ferrate(VI) and its oxidative power, so speeding the copper sulphide oxidation reaction, reaction (5). Also, ferrate(VI) suppresses the formation of passive layer on the chalcocite and chalcopyrite ore particles by polysulphide-sulphide and sulphur oxidation which could be accumulated on its surface in the leaching process.

CONCLUSION

Iron(VI), known as ferrate, is a powerful oxidant, coagulant and flocculent and its reactions with pollutants are relatively fast with formation the non-toxic by-products. This work concluded that a high Cu and Fe removal efficiency with ferrate(VI) was attributed to a comprehensive effect of Fe(VI) together with its reduced forms and alkaline environment. The aim of this paper was to investigate the possibility of heavy metals and Se removal from the hydrometallurgical wastewater with Na_2FeO_4. It has been shown that the removal of heavy metals with Na_2FeO_4 in aqueous solutions can be possible up to: 100 % for Cu, 97.18 % for As, 98.37 % for Sb, 6.06 % for Se using ferrate(VI) in the ratio M : Fe(VI) = 1:12. By the use of larger amounts of ferrate(VI), more efficient removal of heavy metals could be reached requiring further optimization of the treatment process.

The investigation has shown a clear positive influence of ferrate(VI) on the rate and efficiency of copper sulphide ore leaching reaction, as the result of copper sulphide particles surface passivation pro-cess suppression. The increase of sulphuric acid concentration in a reaction pot speeds up the leaching process and increase its efficiency due to the ferrate(VI) redox potential growth in acid solutions

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COMPARATIVE ANALYSIS OF ENERGY CONSUMPTION AND CO_2 EMISSION IN THE EXAMPLE OF COMBINED RECONFIGURED SYSTEM AT THE OPEN PIT POTRLICA**

Abstract

This paper presents the calculation of CO_2 emission on the example of the CCS[1] system at thew open pit Potrlica in Pljevlja. Calculation was made before and after reconfiguration of the CCS system. It can be seen from calculation that the CO_2 emission, caused by the CCS system operation, have been reduced by about 3.5 times compared to the pre-reconfiguration state.

***Keywords**: CO_2 emission, CCS system reconfiguration, open pit Potrlica, energy efficiency, surface exploitation*

1 INTRODUCTION

Production of energy and other mineral resources is, as a rule, related to the management and manipulation of significant quantities of materials that are not found in the other industrial areas. In addition to the significant energy consumption necessary in the production of mineral resources, the environmental impacts and ecological factors of exploitation are also significant. Due to this reason, the issue of energy efficiency and application the procedures that enable the entire system to remain within the permitted limits of the impact on ecology is very important, that is, these two issues in the modern world become the crucial ones for assessment the success of exploitation.

As for the surface exploitation of coal, it is always related to the excavation, transport and disposal the large quantities of waste that exceed many times the quantities of coal. The focus of equipment engagement, total energy consumption and impact on the immediate environment is just related to the processes of overburden and waste that have to be excavated to provide the designed coal capacities, and which take place closer to the surface of the site where the consequences of these activities are more pronounced. Implementation of more efficient methods for excavation, transport and disposal of waste, both in terms of reducing the energy consumption and reduced time utilization of equipment, the use of easier and equipment requiring lower maintenance is the primary task in the process of optimization the exploitation.

The energy-efficient systems have a direct impact on a unit cost reduction, or

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an increase in the production efficiency. In addition to this primary factor, in the concrete examples of exploitation the lignite basins in Serbia and region, their ecological effect is also significant. Namely, in the last decades, there is a significant tendency for the diesel fuel production systems to be replaced with the modern systems and equipment that would be directly supplied by electricity from the thermal power plants, which, as a rule, with the coal mine, represent a unique organizational unit. Considering the structure of energy consumption within the exploitation system, they are realized in a part of transport of masses (waste and coal) in several ways:

1. Replacement of discontinuous systems with combined or continuous systems in which a significant part of transport the total masses takes place by the belt conveyors.
2. Reducing the length of transport by better use of the available excavated space within the open pits, managing the front of progress the excavation works of overburden and useful mineral raw materials, implementing the additional measures for protection the open pits from water, and indirectly changing the geometry of benches on excavation and disposal and better organization, efficiency and reliability of the basic equipment.
3. Using the modern, energy-efficient equipment.

Supply of electricity for the needs of lignite open pits is directly related to the thermal power plant in the immediate environment. The coal open pits, in addition to belonging to large energy systems for electricity production, are also big consumers. On the other hand, the production of electricity in the thermal power plants is related to the significant environmental impacts. These effects are very different in their character and, in the last decades, carbon dioxide emission is the most recognizable in the general public as a direct cause of the greenhouse effect, that is, the cause of global climate change.

In addition, there are legally formal obligations at the national and international levels relating to the maximum carbon dioxide emission and a need for its reduction. In the concrete case of reconstruction the CCS system at the OP Potrlica, the reduction of carbon dioxide emission was analyzed as a consequence of a more efficient system for transport of overburden and waste. This side effect is not a direct economic parameter of the exploitation system, but it contributes to a better understanding the overall benefit of introducing more energy-efficient procedures and equipment.

EXAMPLE FROM THE OP POTRLICA

Excavation of overburden at the open pit Potrlica is carried out with equipment with a discontinuous operation, and transport is combined, inside the open pit by trucks, and further on the external landfill by a conveyor belt system. Disposal is continuously carried out by a stacker, and a transitional element between the discontinuous and continuous part of the system by a crusher.

Technological system of overburden exploitation at the open pit Potrlica (Figure 1) consists of the following technological processes [1]:

- Preparation works
- Drilling and blasting
- Excavation and loading
- Internal transport
- Overburden crushing
- External transport
- Disposal

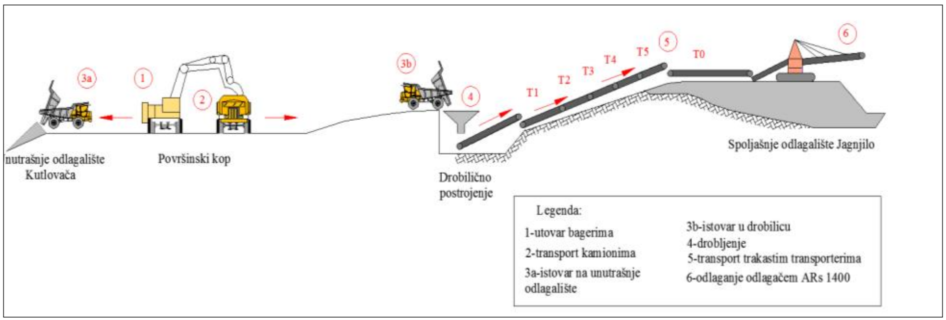

Figure 1 *Technological system of overburden exploitation [1]*

Configuration of the combined CCS system enables a continuous transport of overburden to the external landfill Jagnjilo in a length of 3680 m and overcoming of a height difference of 320 m. The transport system parameters before reconfiguration are shown in Table 1. [2]

Table 1 *Parameters of transporter before reconfiguration of the CCS system*

Belt conveyors	Length (m)	Slope (o)	Belt length (m)	Belt speed (m/s)	Lifting height (m)	Installed power (kW)
T1	212	9	1500	4.5	33.5	2*400
T2	543	6.26	1500	4.5	66.5	4*400
T3	529	7.53	1500	4.5	72.5	3*400
T4	620	9.5	1500	4.5	83.1	4*400
T5	500	10	1500	4.5	67	4*400
TO	1275	0	1400	4.5	0	3*400

Considering the applied exploitation system at the open pit, the costs of electricity for crushing and transport account for 40% of the total electricity consumption in the mine and these costs represent a significant part of the total exploitation costs.

By development of the open pit, the conditions have been created for further disposal of the total amount of overburden and waste on the internal landfill. For the purpose of forming an internal landfill by continuous equipment, reconstruction of the existing CCS system is needed, which has recently been carried out. The parameters of the reconfigured transport system are shown in Table 2.

Table 2 *Parameters of transporter after reconfiguration of the CCS system*

Belt conveyors	Length (m)	Slope (o)	Belt length (m)	Belt speed (m/s)	Lifting height (m)	Installed power (kW)
T1	303	1.37	1500	4.5	7.26	1*400
T2	623	0.43	1500	4.5	4.74	1*400
TO	1250	0	1400	4.5	0	1*400

Figure 2 presents the transport system after reconfiguration. Figure shows a disposal transporter TO set at a level of 750 m. There is a place for accommodation, installation and disassembly of equipment above the disposal transporter.

Figure 2 *Transport system after reconfiguration*

Justification of reconstruction was proven by the techno-economic analysis within which a configuration of the transport technology system and disposal of overburden for the next period are defined.

An integral part of the analysis is calculation the standardized electricity consumption for a continuous part of transport and disposal of excavated waste. This calculation was made on the basis of required power of the conveyor belt drive and measured average engaged force on the crusher and stacker. The electricity supply of the conveyor belt drive and stacker is carried out within the supply system of all consumers at the open pit. [2,3]

To produce the appropriate amount of energy, it is necessary to burn the appropriate amount of coal. In this case, based on the long-term monitoring of the production effects of the TPP Pljevlja, the average consumption of coal per kWh of produced electricity is 1.15 kg/kWh. This average consumption refers to coal from the OP Potrlica, whose mean values of the quality indicators are given in Table 3.

Table 3 *Statistical indicators of the quality parameters of the main coal seam*

Parameter	Mean value	Minimum value	Maximum value	Variation coefficient	Standard error	No. of drillholes
Wg (%)	20.18	15.00	28.00	21.46	4.33	11
Wh (%)	8.51	1.69	25.68	54.05	4.60	54
Wu (%)	31.11	21.46	37.69	10.35	3.22	56
P (%)	19.17	7.63	42.55	35.31	6.77	56
Ss (%)	0.61	0.12	1.79	54.10	0.33	54
Sp (%)	0.49	0.07	0.89	40.82	0.76	54
Su (%)	1.09	0.62	2.16	69.72	0.76	54
Zm (t/m^3)	1.35	1.22	1.57	5.18	0.07	49
CaO (%)	21.75	7.62	57.92	60.41	13.14	28
Isp (%)	27.30	14.93	43.29	15.24	4.16	52
Sag (%)	49.35	29.40	60.30	10.50	5.18	54
C-fix (%)	22.10	7.16	35.15	23.03	5.09	54
Coke (%)	41.43	21.08	53.38	13.15	5.45	54
GTE (kJ/kg)	12,947	5,347	15,673	24.15	3,127	56
DTE (kJ/kg)	11,648	4,409	14,281	12.33	1,436	56

METHODOLOGY OF CALCULATION THE CARBON DIOXIDE EMISSION

For calculation the carbon dioxide emission from coal combustion, the methodology given in the document "IPCC Guidelines for the National Greenhouse Gas Inventory, Volume 2 – Energy" [4] was used.

Generally, the emission of each of the greenhouse effect gases from stationary sources is calculated multiplying the fuel consumption and corresponding emission factor. Fuel consumption is first expressed in the mass or volume units, and then must be converted to the energy value of that fuel.

The energy values of individual fuels are determined by the statistical methods, collected systematically from the national agencies and processed and presented in a form of periodic inspections. The following tables presents the specific energy value of fuel (TJ/Gg) (Table 4) and carbon content (C) expressed in kg/GJ (Table 5).

Table 4 *Default net calorific value (NCV) and lower and upper limits of the 95% confidence intervals for different types of coal*

Coal type	Net calorific value (TJ/Gg)	Lower	Upper
Anthracite	26.7	21.6	32.2
Coking coal	28.2	24	31
Other Bituminous Coal	25.8	19.9	30.5
Sub Bituminous Coal	18.9	11.5	26.0
Lignite	11.9	5.5	21.6

Table 5 *Default values of carbon (C) content for different types of coal*

Coal type	Net calorific value (TJ/Gg)	Lower	Upper
Anthracite	26.8	25.8	27.5
Coking coal	25.8	23.8	27.6
Other Bituminous Coal	25.8	24.4	27.2
Sub Bituminous Coal	26.2	25.3	27.3
Lignite	27.6	24.8	31.3

The CO_2 emission factor is determined on the basis of the average carbon content in fossil fuel. In the case of CO_2, it is assumed that the oxidation factor of carbon is 1, or that the combustion is complete. Table 6 gives the content of carbon and emission factor of carbon dioxide. [5]

Table 6 *Carbon content and emission factor of CO_2 for various types of coal*

Coal type	Default carbon content (kg/GJ)	Emission Factor CO_2 (kg/GJ)
Anthracite	26.8	98.27
Coking coal	25.8	94.60
Other Bituminous Coal	25.8	94.60
Sub Bituminous Coal	26.2	96.07
Lignite	27.6	101.20

The gas emission with the greenhouse effect is calculated as:

*Emission = Fuel Consumption * Emission Factor * Oxidation Factor*

EXAMPLE FROM THE OP POTRLICA

Calculation the conveyor belt parameters in the CCS system configuration was made using the standard method according to JUS M.D2.05. Calculated conveyor belt parameters before and after reconstruction are given in Tables 7 and 8.

Table 7 *Parameters of a belt conveyor before reconfiguration of the CCS system*

	Engaged power (kW)	Installed power (kW)	Coefficient of engaged power
CRUSHER	566	1132	0.50
T1	460	800	0.58
T2	940	1600	0.59
T3	989	1200	0.82
T4	1142	1600	0.71
T5	926	1600	0.58
TO	594	1200	0.50
SPREADER	161.4	538	0.30
Σ	**5778.4**	**9670**	

Table 8 *Parameters of a belt conveyor after reconfiguration of the CCS system*

	Engaged power (kW)	Installed power (kW)	Coefficient of engaged power
CRUSHER	566	1132	0.50
T1	243	400	0.61
T2	359	400	0.90
TO	332	400	0.83
SPREADER	161.4	538	0.30
Σ	**1661.4**	**2870**	

Specific coal consumption per kWh was measured by a long-term monitoring and amounted to 1.15 kg/kWh. The specific coal consumption and CO_2 emission per kWh was determined and are shown in Tables 9 and 10. For the CO_2 emission calculation, the amount of carbon in coal was taken on the basis of testing results the quality of coal of the main coal seam of the deposit Potrlica which accounts for more than 90% of the total balance. The average carbon content is Cfix = 22.1%. It was assumed that during combustion the reaction with C was complete.

Table 9 *Calculation the emission of CO_2 (t) before reconfiguration of the CCS system*

	Engaged power (kwh)	Operation time (h)	Total energy (kwh)	Equivalent coal (t)	Total C (t)	Total CO_2 (t)
Crusher	566.00	3,000.00	1,698,000.00	1,952.70	431.55	1,582.34
T1	460.00	3,000.00	1,380,000.00	1,587.00	350.73	1,286.00
T2	940.00	3,000.00	2,820,000.00	3,243.00	716.70	2,627.91
T3	989.00	3,000.00	2,967,000.00	3,412.05	754.06	2,764.90
T4	1,142.00	3,000.00	3,426,000.00	3,939.90	870.72	3,192.63
T5	926.00	3,000.00	2,778,000.00	3,194.70	706.03	2,588.77
TO	594.00	3,000.00	1,782,000.00	2,049.30	452.90	1,660.62
Stacker	161.40	3,000.00	484,200.00	556.83	123.06	451.22
					Σ	**16,154.38**

Table 10 *Calculation the emission of CO_2 (t) after reconfiguration of the CCS system*

	Engaged power (kwh)	Operation time (h)	Total energy (kwh)	Equivalent coal (t)	Total C(t)	Total CO_2 (t)
Crusher	566.00	3,000.00	1,698,000.00	1,952.70	431.55	1,582.34
T1	243.00	3,000.00	729,000.00	838.35	185.28	679.34
T2	359.00	3,000.00	1,077,000.00	1,238.55	273.72	1,003.64
TO	332.00	3,000.00	996,000.00	1,145.40	253.13	928.16
Spreader	161.40	3,000.00	484,200.00	556.83	123.06	451.22
					Σ	**4,644.69**

On the basis of realized calculation, it can be concluded that the CO_2 emission, caused by the operation of the CCS system, has been reduced by about 3.5 times compared to the previous state. This indicator is the result of reduced specific energy consumption.

CONCLUSION

Reconfiguration of the CCS system is carried out on the basis of the results of techno-economic analysis for justification the relocation of the CCS system from the external to the internal landfill at the OP Potrlica of the Coal Mine Pljevlja. During economic evaluation, the costs of dismantling and assembly, equipment transport and other costs were analyzed, while the costs of transport and maintenance of the new CCS system were analyzed on the side of revenues [2]. Reduction of carbon dioxide emission and consequently reduction of deposit costs or CO_2 emission allowances have not been considered. The current legislation does not foresee any costs due to the CO2 emission. This situation will be changed in the future.

When analyzing the construction of a new or replacement block of the Thermal Power Plant Pljevlja, the costs of CO_2 emission have been discussed from 2025 onwards with a gradual increase in the prescribed fee from 0 to 100% over a period of 5 years [6]. These costs will fall into the electricity price and will also affect the exploitation economics. This will further aggravate the issue of energy efficiency of the surface exploitation system, and their participation in the CO_2 emission will be an important indicator of efficiency. In this case, the CO_2 emission is reduced by about 3 times with the reconfiguration of the CCS system and is a direct consequence of only reducing the length and height difference in the waste transport. Even better results can be achieved by:

- Optimal mass control at the open pit,
- The use of modern, energy efficient equipment supported by the automatic control,
- Better maintenance, primarily the elements of belt conveyor,
- Applying the new materials for conveyor belts, drums, rolls, etc.

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MULTI-CRITERION ANALYSIS OF THE MOST IMPORTANT ASPECTS OF THE ENVIRONMENTAL POLLUTION****

Abstract

Technological procedures for obtaining the useful mineral raw materials on the excavation site create the environmental pollution. This is manifested in several ways such as: blocking of land, degradation of soil and appearance the other forms of pollution (dust, gases, mineral water and noise, which affect the pollution of air, water, land, plants and human health). Consequently, in this paper, a multi-criterion analysis was carried out aiming to rank the all types of environmental pollution in order to identify the most difficult types of pollution. Also, the work presents the most important environmental protection measures, in accordance with the most severe types of pollution, and their ranking has been carried out with the aim of determining the most important measures. The AHP analysis was used for the multi-criterion analysi.

Keywords: *open pit, environment, protection, AHP method*

1 INTRODUCTION

Surface exploitation of useful mineral raw materials seriously disturbs the natural balance and environmental quality. The changes relate to the relief, regime of underground and surface water and microclimate. Also, the operationof mining equipment at the open pit creates dust and gases. Under the influence of natural air currents and thermal forces, these pollutants are released from the surface to the environment and atmosphere is contaminated. Emission of dust from the air pollutes the soil, water and plants in a wider area around the hoof [1].

The quality of environment at the open pit and its surroundings can also be determined by a prognosis the impact of surface exploitation on the near and further environment using the mathematical models and data obtained by measuring the concentration of dust and gases in the working environment of the open pit.

Previous research, especially in the field of mining, has led to development of several models for assessment the impact of various harmful effects from the open pit to the environment, such as calculation the range and intensity of blasting gases, blasting dust, transport, crushing and seismic waves caused by blasting [2]. Also, the models, based on a probability of ecological catastrophes around and in mines have been elaborated [3].

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The basic characteristic of this research is specifically related to each individual type of pollution, without taking into account their integration and without determining which type of pollution is dominant. In other words, no comparison of all or most important types of pollution has been performed in order to rank them and determine the most difficult types of pollution. This is important because, when ranking is done, the managers who manage the open pit have an overview of the priorities and, accordingly, can properly direct energy and take the appropriate measures to suppress or reduce the most serious forms of environmental pollution around the open pit.

Measures taken in order to reduce or eliminate the harmful impact of the open pit on the environment are very complex and they involve several types of procedures. These procedures are mutually different and have different efficiencies in preventing or reducing the pollution. Due to this reason, the managers need to determine the best practices and apply them to achieve the best results. They can do this only if they determine the priorities, and this is best if this procedure is done on the basis of ranking the most important measures to prevent or reduce pollution.

One of the method of multi-criterion decision making, the AHP method, is used to rank various types of pollution and measures that are undertaken in order to reduce or eliminate the harmful effect of the open pit on the environment. The multi-criterion decision-making methods (MCDMs) can be defined as the process of selecting the most appropriate solution from a set of available alternatives, based on their performance in relation to a set of criteria for evaluation [4]. The MCDM methods are implemented to solve the real problems in a series of areas such as: sustainable development [5, 6], economy [7], mining [8,9], quality system [10], management [11,12,13], construction [14,15], education [16], production [17,18], etc.

Also, these methods by extension or combining them are more effective tools for assisting in making the real decisions, for evaluating and selecting the personnel [19], selection of personnel in the mining companies [20], etc.

Today in the world and in Serbia, there are many software packages that enable fast setting up and solution of tasks from different fields (mining, mechanical and construction engineering, etc.). The best-known of these methods are the assessment models, the analytical hierarchy process - AHP, analytical networks of processes-AHP, TOPSIS, ELECTRE and PROMETHEE, as well as some of their combinations. The best known software program are QM for Windows, Electre, Expert Choice, Decision Lab, Criterium DecisionPlus.

2 EXPERIMENTAL PART

The damage of the environment by the open pit is reflected through

- Land blocking (alternative A_1),
- Land degradation (alternative A_2), and
- Pollution of air, water, soil and plants (alternative A_3).

Technological procedures for othe copper ore obtaining at the open pit create the pollution, which is concentrated in the zone around the open pit, and such a space is called the zone of increased impact, where the land is blocked. On blocked land, the field configuration retains its original appearance, only the people living and agricultural production are forbidden, and the plants from that zone are not propagated for the animal and human consumption. The land in this zone is acquisited by the mine.

Degraded soil occurs as a result of mining operations and the relief loses its original appearance. Instead of forests, orchards and arable land, the surfaces without the ability to self-eco-system are created. At the location where the deposits are exploited, the dents are formed in a form of funnel or crater. At the site of overburden (waste) disposal, the terrain is covered and the artificial hills-planes are created.

The mining activities at the open pit and landfills create pollution in a form of dust, gases, mineral water and noise, which affect the pollution of air, water, soil, plants and human health. The land is not acquisited in the zone of expressive impact (monitoring zone), zone of moderate impact and zone of possible impact, but the mine pays a compensation to the owners of the land for the resulting damage in the amount of income that would be realized on that land.

The most important environmental protection measures include:

- preventing the air pollution (alternative B_1),
- detection of the landslides at the open pit and landfill sites of overburden (alternative B_2),
- eliminate the possibility of contamination the underground and surface water, water from open pit and landfills (alternative B_3),
- soil protection (alternative B_4),
- plant protection (alternative B_5), and
- health protection of the population (alternative B_6).

Prevention of the air pollution is carried out applying the prescribed technical measures of protection, maintaining the proper dusting devices, respecting the designed operation technology, constant monitoring and measuring the air quality, etc. The most significant occurrence of air pollution comes from the following technological operations: drilling, blasting, loading of ore and waste, transportation of ore and waste, disposal of waste and ore (unloading) and ore crushing.

Detection of the landslide at the open pit and landfills of overburden are done by the instrumental observations. This implies setting up a network of benchmarks and tracking them. On the basis of the bench marks, the speed and mechanism of movement of the entire lkandslide is considered [21].

Eliminate the pollution potential of the underground and surface water, water from the open pit and landfills is carried out applying the appropriate measures, within the designed solutions for drainage of the open pit (construction of the circumferential channels, concreted riverbed, water pumping using the pumps from the water tank at the open pitm, proper storage of waste oils and their return to the manufacturer for recycling, etc.).

Soil protection is carried out applying the technical measures of protection at the open pit, which prevent the raising of dust, remediation the degraded surfaces (preventing the raising of dust), etc.

Protection of plants against pollution is achieved applying the technical measures for protection at the open pit, suppression the formation and emission of dust (wet procedure), suppression the emission of gases, drainage the aggressive water from the open pit to the predetermined water collectors (pre-collectors), where they are treated by remediation the degraded areas [22], etc.

Protection the health of population are measures that include prohibition to the people living in the sanitary protection zone, prohibition the agricultural production in the sanitary zone and using the plants from this zone for livestock and human research, cultivating certain plants in the monitoring zone, such as the root plants, grains (corn, wheat, rye, barley, oats), bean plants, then walnut, hazelnut and almond. Also, it is not recommended to cultivate the leafy vegetable crops in the zones of moderate and possible impact (spinach, cabbage and greens, then carrots, potatoes, garlic and onio).

In order to identify the most difficult types of pollution, the ranking of the most serious types of environmental pollution was performed. Ranking is done using the AHP method. In addition, the Criterion Decision Plus software was used for calculation.

The AHP is a quantitative technique that starts from decomposition a complex decision-making problem into a multidimensional hierarchical structure of goals, criteria, and alternatives. The AHP assesses the impact of tcriteria, compares the alternatives with respect to each criterion and performs the ranking of alternatives. The creator of the AHP method is Saaty, 1980 [23].

Assessment the relative impact of each criterion and comparing the alternatives with respect to the criteria is done through a comparison matrix. Then, the weight coefficients for each element of the hierarchy is calculated and assessment a degree of consistency in order to check the consistency of the entire process.

Comparison of criteria and alternatives is done on the basis of the scale from 1 to 9 - Table 1.

Table 1 *Scale of comparison the decision-making elements*

Description	Evaluation
Equally	1
Poor domination	**3**
Strong domination	**5**
Very strong domination	**7**
Absolute domination	**9**
2, 4, 6, 8 are the subtotals	

Determining the final rank of alternatives is done by the synthesis of results obtained at all levels.

The process is as follows: First, the definition of the multi-dimensional hierarchical structure of objectives and alternatives is defined - Figure 1. And, then the weight coefficients of the alternatives are determined using the scale of comparison given in Table 1.

The results of comparisons are shown in Tables 2 and 3.

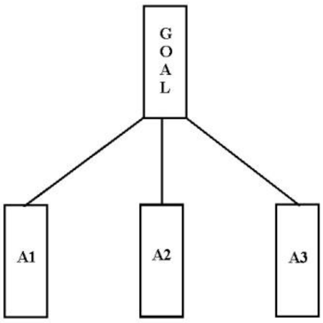

Figure 1 *Ranking hierarchy (Criterion Decision Plus software)*

Table 2 *Defining the weight coefficients of the alternatives*

Alternatives	**A_1**	**A_2**	**A_3**
A_1	1	1/3	1/5
A_2		1	1/2
A_3			1

Table 3 *Comparison results*

Alternatives	**A_1**	**A_2**	**A_3**
Weights of alternatives	0.109	0.309	0,582
Consistency degree		0.003<0.1	

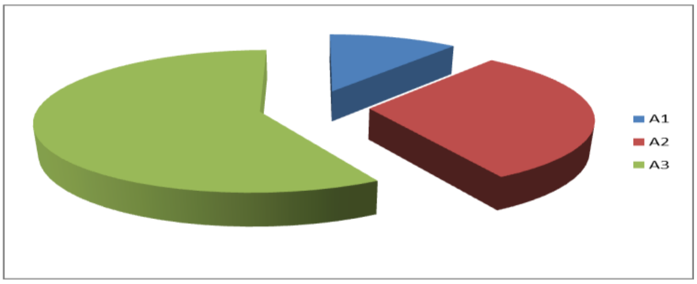

Figure 2 *Pollution type overview*

As it can be seen from Table 3, the degree of consistency is 0.003, which is less than 0.1. The obtained results show that the most pollution type is A_3-pollution of the air, water, soil and plants, alternatively A_2-soil degradation is the second most important alternative, A_1 is the blocking of soil (Figure 2).

The following procedure is the ranking of the most important environmental protection measures.

Prior to calculation, definition of the multi-dimensional hierarchical structure of objectives and alternatives, Figure 3, is then defined. After that, the weight coefficients of the alternatives are determined using the scale of comparison given in Table 1. The results of comparisons are shown in Tables 4 and 5.

Table 4 *Defining the weight coefficients of alternatives*

Alternatives	B_1	B_2	B_3	B_4	B_5	B_6
B_1	1	1	1/3	1/2	1/3	1/5
B_2		1	1/3	1/3	1/4	1/6
B_3			1	1	1	1/2
B_4				1	1	1/3
B_5					1	1/3
B_6						1

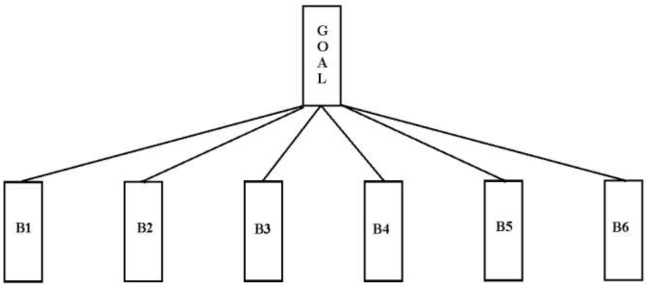

Figure 3 *Ranking hierarchy (Criterion Decision Plus software)*

Table 5 *Comparison results*

Alternatives	B_1	B_2	B_3	B_4	B_5	B_6
Weights of alternatives	0.064	0.055	0.172	0,151	0,171	0,387
Consistency degree			0.010<0.1			

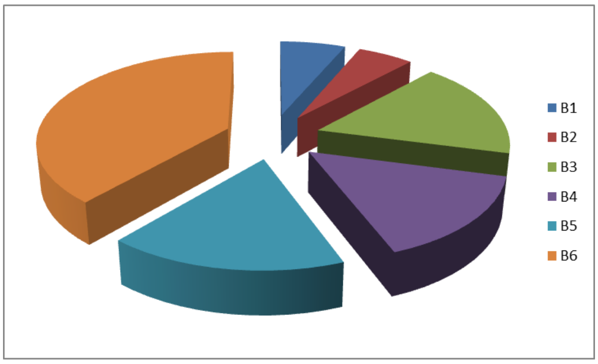

Figure 4 *Protection measures*

As it can be seen from Table 5, the consistency degree is 0.010, which is less than 0.1. The obtained results show that the most important measure of protection is the alternative B_6 - protection of the the population health; the second place is the alternative B_3-elimination the possibility of contamination of the underground and surface water, water from the the open pit and landfill; the third place is the alternative B_5 - protection of plants; the fourth place is the alternative B4 - soil protection; the fifth place is the alternative B_1-prevention the air pollution, and the sixth place is the alternative B_2 - landslide detection at the open pit and landfills of overburden (Figure 4).

3 ANALYSIS OF THE RESULTS

The analysis covers the most difficult forms of pollution, as well as the most important environmental protection measures for the open pit.

The results show that the most negative effect of the open pit on the environment is pollution of the air, water, soil and plants (alternative A_3). The reason is that these elements are the basis for the lives of people, animals and plant world. Any pollution that disturbs some or all of the above elements is very badly manifested in the health of the living world. Damage is the most often permanent and it is very difficult to correct the negative effects. In the second place is the land degradation (alternative A_2). This also represents a permanent damage to the environment, which can only be partially remedied by the remediation. Degradation includes the open pit, land where the landfills are located, as well as the other surfaces around the open pit. In the end, The alternative A_1 is blocking the land. This land is under the impact of pollution coming from the open pit. The existing vegetation can survive here, but living of people on this land are prohibited.

Regarding the environmental protection measures, the most important are those related to the protection of the population health (alternative B_6). Protecting the population is the most important because preserving health and ensuring the conditions for a normal life of people is the primary task of all companies. In the second place is the alternative B_3-eliminating the possibility of contamination the underground and surface water, open pit and landfill water. Water is one of the most important conditions for the life existence. Preservation the water resources and watercourses ensures the existence of this resource and its safe use, both by the humans, and animals and plants. In the third place is the alternative B_5 - plant protection. This measure is also important because it ensures the survival of plants, which is a precondition for survival of animals, as well as people in the end. The fourth place is the alternative B_4 - land protection. The land protection provides a condition for the plant growth, animal survival, development of agriculture, etc. In the fifth place is the alternative B_1-prevention the air pollution. Although the air pollution is the most pronounced at the open pit, and to a lesser extent in the environment of the excavation, the use of modern protective measures can significantly reduce this risk. In the sixth place is the alternative B – detection og the landslides at the open pit and landfills of overburden. Landslides that appear at the open pit represent a major danger for the open pit. They endanger the employees, as well as the equipment and installations that operate at the open pit. Measures to prevent the landslide appearance include the proper execution of the works, respect the designed excavation geometry, monitoring, etc.

CONCLUSION

This paper presents the ranking of all types of environmental pollution in order to identify the most serious pollution types, as well as the most important environmental protection measures in order to determine the most important measures. The three most difficult types of pollution are analyzed: land blocking (Alternative A_1), soil degradation (alternative A_2) and appearance the other forms of pollution (dust, gases, mineral waters and noise, which affect the pollution of the air, water, soil, plants and human health) (alternative A_3). Also, six types of environmental protection measures - prevention the air pollution (alternative B_1), detection the landslides at the open pit and landfills of overburden (alternative B_2) were considered, eliminating the possibility of contamination the underground and surface water, water from the open pit and landfills (alternative B_3), soil protection (alternative B_4), plant protection (alternative B_5) and health protection of the population (alternative B_6).

Ranking was done using the AHP method for the multi-criteria decision-making. On the basis of the obtained results, the most severe type of pollution is determined, which is the alternative A_3 (pollution of the air, water, soil and plants). As far as the environmental protection is concerned, the most important is protection of the population health (alternative B_5). The advantages of this analysis are in using the AHP method to find the best solution, that is, determining the most severe type of pollution and the most important environmental protection measures. Also, this method can be used to solve the other important problems and making decisions, not only in mining, but also in the other areas.

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