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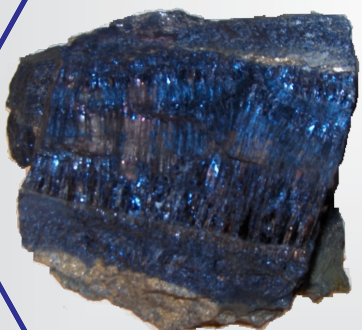

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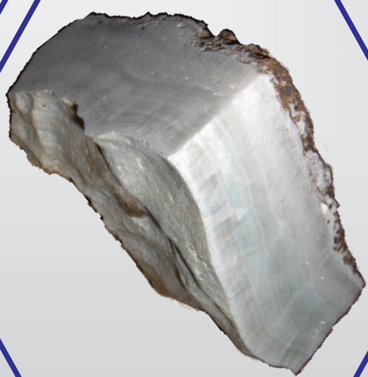

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Ivana Jovanović, Jasmina Nešković**, Sanja Petrović*, Dragan Milanović**

A HYBRID APPROACH TO MODELING THE FLOTATION PROCESS FROM THE "VELIKI KRIVELJ" PLANT***

Abstract

The purpose of the flotation process control is optimization the concentrate grade and recovery, while maximizing profits. Consequently, the research into modeling and control of this process has always been an important area in control engineering practice. This paper presents the results of development and validation the predictive models, based on the ANFIS hybrid system. Models predict the values of copper concentrate and tailings grade as well as copper recovery in the flotation plant "Veliki Krivelj". The copper content in the feed ore, collector consumption in the rough flotation stage and consumption of frother, were selected as the independent variables. Other technical and technological parameters, relevant for the process of flotation concentration were considered constant. The results of the models validation have showed that the models provide the good predictions of changes in the copper concentrate grade, while the predictions of changes in the copper recovery and tailings grade are somewhat poorer.

Keywords: *flotation, model, ANFIS, copper, concentrate, tailings, recovery*

INTRODUCTION

One of the approaches of flotation process modeling is by the classical mathematical methods including the empirical, probabilistic, kinetic, and population-balance based models [1–6]. However, taking into consideration the complexity of the flotation process, caused by the interaction of many micro processes on the boundary of three phases (solid, liquid and gaseous), the classical mathematical equations have not been enough effective so far.

Recently, the soft computing methods emerged as a perspective alternative to the classical modeling approach. These methods, unlike the conventional mathematical methods, exhibit a certain tolerance to the imprecision and uncertainty of the technological parameters in description of real systems. Therefore, they offer more flexible and more robust solutions to the problems of modeling the stochastic processes such as the froth flotation. From the standpoint of process technology, the most commonly used soft computing techniques are the artificial neural networks, fuzzy logic and support vector machines, while the genetic algorithms are mainly applied to optimize the flotation circuit configuration [1].

The adaptive Neuro-Fuzzy Inference System (ANFIS) is a combination of two soft computing methods – artificial neural networks and fuzzy logic. Fuzzy logic has

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the ability to change the qualitative aspects of human knowledge and insights into the process of precise quantitative analysis. However, it does not have a defined method that can be used as a guide in the process of transformation the human thought into the rule base fuzzy inference system (FIS), and it also takes quite a long time to adjust the membership functions (MFs). The artificial neural network (ANN) has a higher capability in the learning process to adapt to its environment. Therefore, the ANN can be used to automatically adjust the MFs and reduce the rate of errors in determining the rules in fuzzy logic [7,8].

The ANFIS architecture is an adaptive network that uses a supervised learning on learning algorithm having a function similar to the model of Takagi - Sugeno fuzzy inference system [7]. The ANFIS architecture is shown in Fig.1. Assuming that there are two inputs x and y, and one output z, two rules in the Takagi - Sugeno model can be expressed as:

If x is A_1 and y is B_1 then $z_1 = f_1(x,y)$

If x is A_2 and y is B_2 then $z_2 = f_2(x,y)$

where: A_1, A_2 and B_1, B_2 are the membership functions of each input x and y.

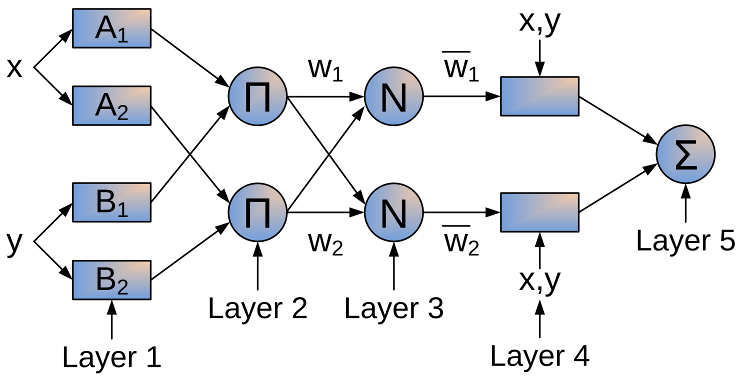

Figure 1 *ANFIS Architecture. Adapted from [7]*

The ANFIS architecture has five layers (see Fig. 1). In the layer 1, each node is adapted to a function parameter. The output from each node is a degree of membership value, given by the input of the membership functions. In the layer 2, each node is fixed or nonadaptive, and the circle node is labeled as Π. The output node is the result of multiplying of signal coming into the node and delivered to the next node. Every node in this layer represents the firing strength for each rule (wi). In the layer 3, each node is fixed or nonadaptive and the circle node is labeled as N. Each node is a calculation of the ratio between the i-th rules firing strength and sum of all rule firing strengths. This result is known as the normalized firing strength ($\overline{wi}$). In the layer 4, each node is an adaptive node to the output. In the layer 5, the single node is a fixed or non-adaptive node that computes the overall output as the summation of all incoming signals from the previous node [7].

EXPERIMENTAL

Experimental procedure was carried out in virtual conditions, using the MATLAB programming language. A total of three models (marked as ANF1, ANF2 and ANF3) have been developed using the ANFIS Editor Graphical User Interface.

The independent variables in each model were: the copper content in the feed ore (FCU), collector consumption in the rough flotation stage (PXR) and consumption of frother (FRT). The dependent variables were: the final copper concentrate grade (CCU) – for the ANF1 model; copper recovery of copper in the concentrate (RCU) – for the ANF2 model; and the final tailings grade (TCU) - for the ANF3 model. The basic structure of models is presented in Fig. 2.

Model development and testing was based on the real process data, collected from the flotation plant "Veliki Krivelj" during the multi-annual monitoring. The validation of the proposed models was performed in Microsoft Excel.

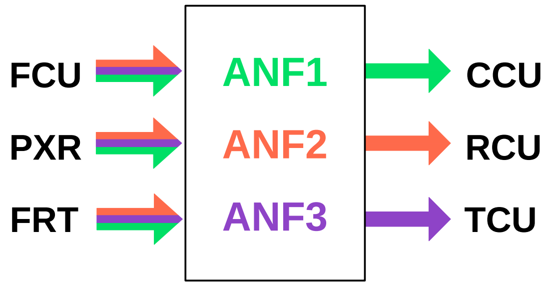

Figure 2 *Basic structure of models*

During the optimization of elementary conditions of the modeling process, the following two criteria were taken into consideration: (1) resulting surfaces should describe the real process in the best manner, and (2) the root mean square error of training should be minimal. In this regard, the expert analysis showed that the best results were achieved through the conditions presented in Table 1.

Table 1 *Optimal conditions for model development*

Model	Optimal membership function	Optimal output function	Learning algorithm	Number of epochs
ANF1	Gaussian	linear	Back propagation	100
ANF2	Bell	linear	Back propagation	400
ANF3	Gaussian	linear	Back propagation	400

For the neural network training, every second series of values of variables FCU, PXR, FRT and RCU (corresponds to the data of one shift) is chosen from the data base – "even cases". The structure of neural network, generated membership functions as well as generated surfaces are presented in Figures 3, 4 and 5, respectively.

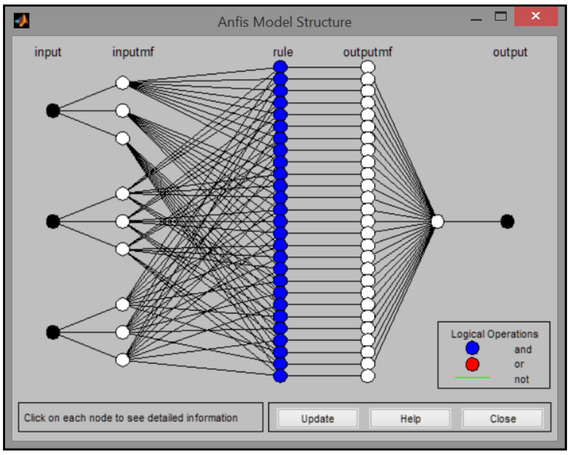

Figure 3 *Structure of the ANFIS neural network*

The structure of generated neural network is [3-9-27-1], and it is the same for each model. Number of nodes in the first hidden layer corresponds to the number of membership functions belonging to each input variable (9 in total), while the number of nodes in the second hidden layer corresponds to the number of fuzzy rules (27 in total), where the consequence of each rule is a linear function with different coefficients.

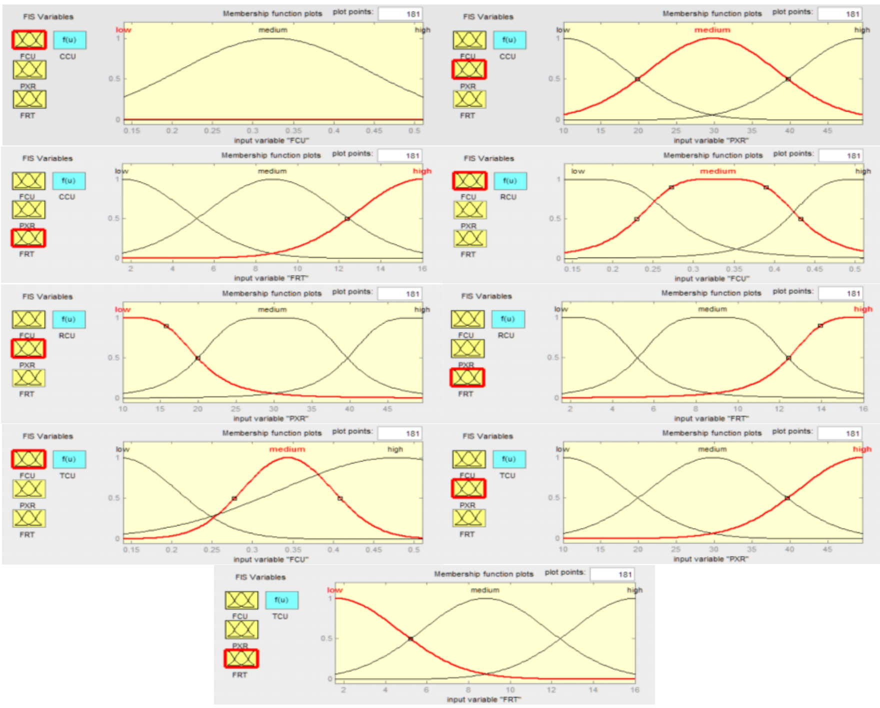

Figure 4 *Membership functions generated by the ANFIS models*

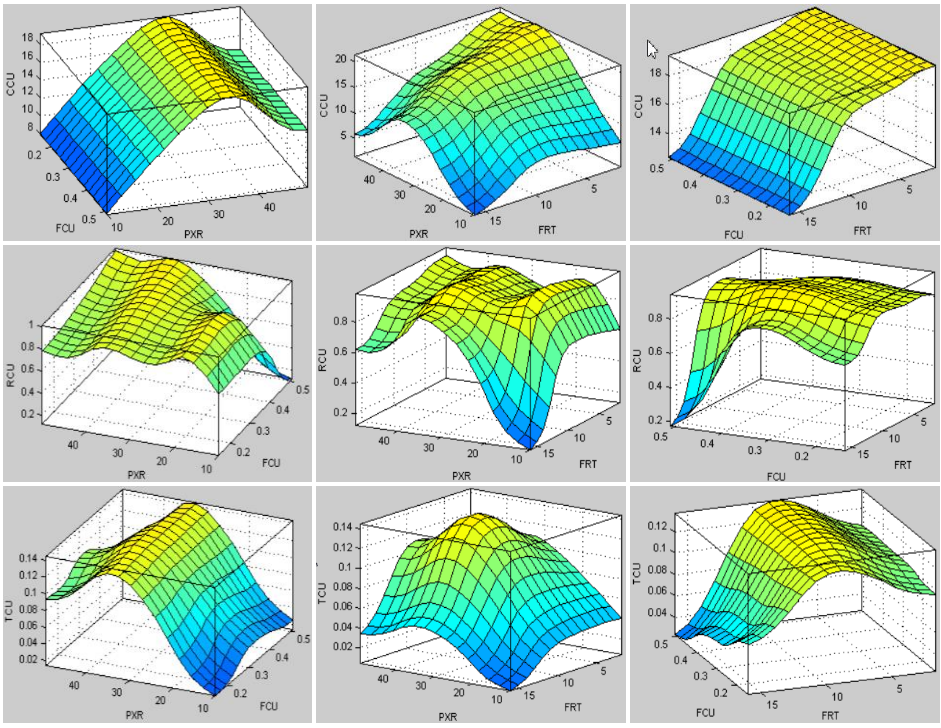

Figure 5 *Surfaces generated by the ANFIS models*

As it can be seen from Fig. 5, a dependence of concentrate grade (CCU) on copper content in feed (FCU) and collector consumption in the rough flotation (PXR) is described pretty well by the presented surface. As in the real flotation process, with the increase of collector dosage, the concentrate grade primarily increases, and then decreases. However, it should be noted that at low collector consumptions, the concentrate grade is quite low, which does not correspond to real conditions. The other two surfaces that show the dependence of CCU variable on FCU, PXR, and FRT variables also describe the real flotation process pretty well. Namely, with increase in the frother dosage, there is a certain decrease in the concentrate grade. This phenomenon is related to ability of the frother to "pull" the tailings particles into the concentrate, if it is in surplus in the flotation pulp.

When it comes to the copper recovery (RCU), the presented surfaces do not describe a real dependences in the flotation process in the best manner. In the observed range of values, with an increase of the amount of collector and frother, copper recovery in concentrate should be constantly increased. In this case, the resulting surfaces have a "wavy" shape.

Finally, when it comes to the tailings grade (TCU), it can be concluded that the surfaces do not correspond to the real process. In the observed range of values, with an increase of the frother and collector dosage, the copper content in tailings should be decreased. In both cases, the TCU variable firstly increases to the certain limit, and then decreases.

RESULTS AND DISCUSSION

The evaluation of models was performed in the software package MATLAB – entering the real values of the process input variables from the industrial flotation plant "Veliki Krivelj" and generating correspo-nding outputs, predicted by the models. The evaluation of each model was made forming a matrix of three independent variables and generating the column matrix for the output variable, using the module Fuzzy Logic Toolbox.

Possibility of models to reliably predict flotation parameters, on the basis of given input parameters, was determined by the regression analysis in Microsoft Excel. The egression analysis showed the correlation between actual process values and values predicted by models.

The results of the regression analysis are presented in Tables 2–4.

Table 2 *Statistical correlation of real and predicted values*

Statistical parameter	Technological indicator of flotation process		
	CCU	**RCU**	**TCU**
Correlation coefficient R	0.98347	0.99608	0.91642
Coefficient of determination R^2	0.96721	0.99217	0.83982
Adjusted R^2	0.96669	0.99164	0.83930
Root mean square error	3.44739	0.079921	0.04786
Observations	1910	1910	1910

Table 3 *Statistical analysis of regression linear equations*

	C	***SE***	***t***	***p***	***L95***	***U95***
CCU	0.95997	0.00405	237.30	0	0.95203	0.96790
RCU	1.06415	0.00216	491.78	0	1.05991	1.06840
TCU	2.46691	0.02466	100.04	0	2.41855	2.51527

Table 4 *Analysis of variance (ANOVA)*

		df	***SS***	***MS***	***F***	***SF***
CCU	Regression	1	669217.43	669217.43	56309.99	0
	Residual	1909	22687.56	11.88		
	Total	1910	691905.99			
RCU	Regression	1	1544.76	1544.76	241848.19	0
	Residual	1909	12.19	0.00639		
	Total	1910	1556.95			
TCU	Regression	1	22.9236	22.9236	10008.83	0
	Residual	1909	4.3722	0.00229		
	Total	1910	27.2958			

The regression analysis (Tables 2–4) indicates a strong link between the actual and predicted values of copper grade and recovery, given that the correlation coefficients are very high. In other words, the models ANF1 and ANF2 well follow the changes in real values of the observed parameters related to their rise or fall over time. Correlation coefficient of real and predicted tailings grade is somewhat lower.

Since it is necessary to make a comparison between the predictive abilities of models with different scales, a root mean square error is not a suitable parameter. Therefore, a normalized root-mean-square error (NRMSE) is taken into consideration. Values are shown in Figure 6.

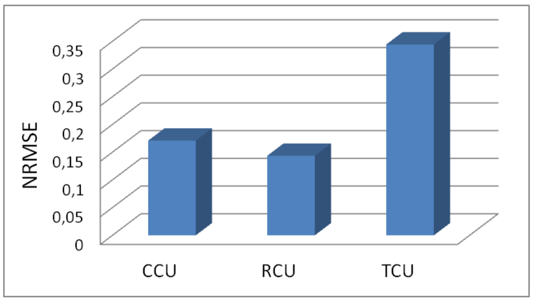

Figure 6 *Normalized root-mean-square error of prediction*

Normalized root-mean-square errors indicate that the ANF1 and ANF2 models can predict the concentrate grade and recovery values similarly good. On the other hand, the ANF3 model has significantly poorer predictive abilities.

Figure 7 shows the prediction errors of developed models. Error of prediction (ε), which also serves as one of the criteria for assessment the predictive properties of model, is calculated according to formula (1):

$$\varepsilon = y_{pr} - y_{re} \tag{1}$$

where:

y_{pr} – predicted value of technological indicator (CCU, RCU, TCU)

y_{re} – real value of technological indicator (CCU, RCU, TCU)

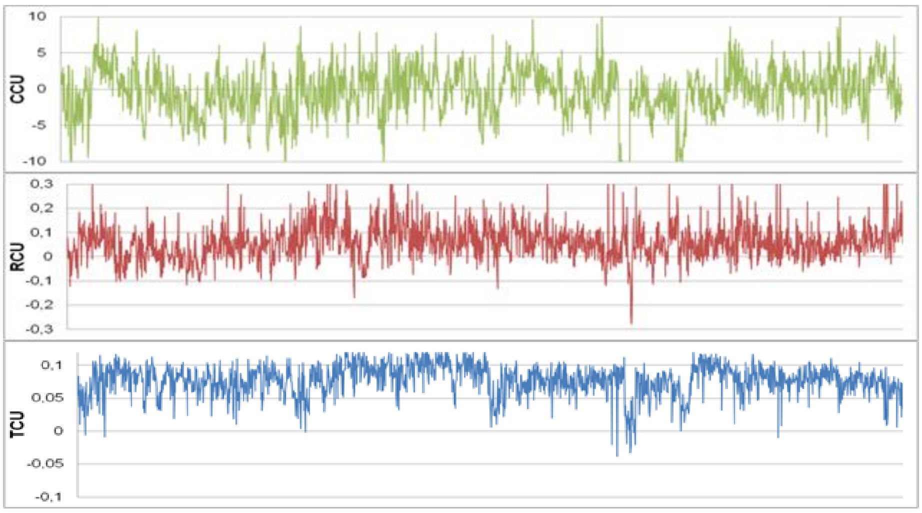

Figure 7 *Prediction error of concentrate grade, recovery and tailings grade*

Despite that correlation coefficients are pretty high (Table 2), better insight into the predictive abilities of models can be achieved considering the prediction errors (Figure 7), as well as by the visual analysis of results in relation to the training and test data (Figures 8 – 10). It should be noted that the test data, similarly to the training data, corresponds to the values of variables from every second shift – "odd cases".

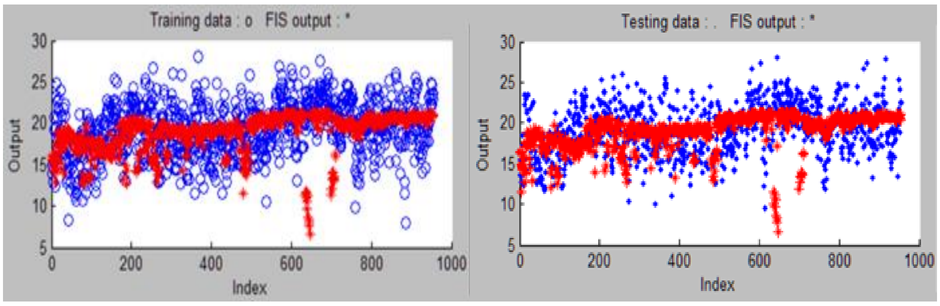

Figure 8 *Prediction of the concentrate grade in comparison to the training and test data*

Figure 8 shows that model ANF1 generally predicts the concentrate grade in the range between 17 and 22% Cu. This prediction can be considered as a quite correct, although, at first sight, it does not seem to be the case. The reason is a large dispersion of real data in the plant Veliki Krivelj. This is in line with the prediction error, which noticeably "oscillates" around the value zero, during the entire period of the plant operation (see Figure 7).

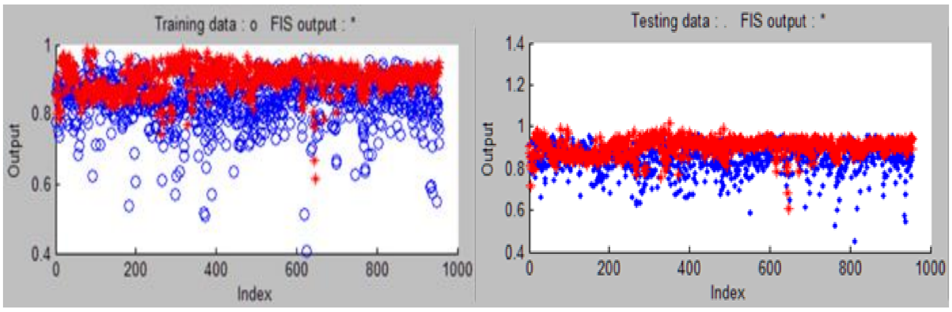

Figure 9 *Prediction of the copper recovery in comparison to the training and test data*

The recovery values obtained by the model ANF2 are generally higher than the real ones (Figure 9). This is also confirmed by the prediction error, which is mainly positive (Figure 7).

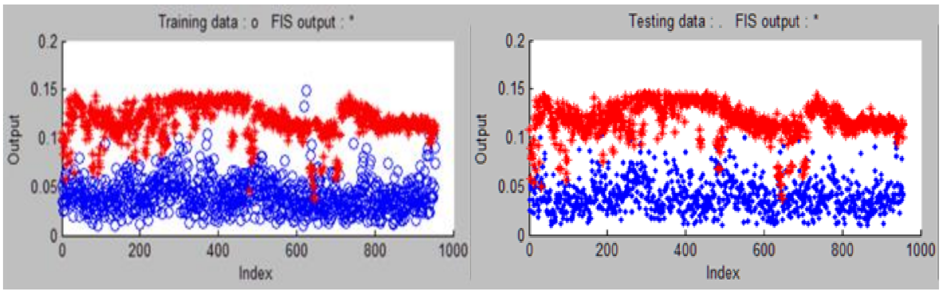

Figure 10 *Prediction of the tailings grade in comparison to the training and test data*

It can be seen from Figure 10 that the predicted values of copper content in the tailings are significantly higher than the real process data (when it comes to both training and test data), as indicated by a positive prediction error during the entire operating period of the plant (Figure 7). This error value often exceeds 0.1% Cu, so it is sugges-ted that such model cannot be considered adequate. This is a good example of how a high correlation coefficient means that the model well follows changes in the actual values of the observed parameters, but at the same time the predicted values do not meet the required criteria in terms of precision.

CONCLUSIONS

Modeling of flotation processes is not a simple task, mainly thanks to the complexity of the process, where the classical mathematical equations have not been effective so far. Recently, the soft computing methods have been emerged as a perspective alternative to the classical modeling approach. One of soft computing methods is the Adaptive Neuro-Fuzzy Inference System (ANFIS). The architecture of this system consists of five layers and integrate the principles of fuzzy logic and artificial neural networks.

For the purpose of this research, three ANFIS models have been developed. These models predict concentrate grade and recovery, as well as tailings grade in the flotation plant Veliki Krivelj. Predictive abilities are considered through several criteria.

According to the indicators of regression analysis (correlation coefficient and normalized root-mean-square error) model, which predicts the copper recovery, has the best predictive abilities. However, observing the prediction error, it seems that the model which predicts concentrate grade has the better predictive abilities. According to most criteria, the model which predicts the tailings grade cannot be said to be adequate.

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Vladan Čanović, Violeta Čolaković*, Svetomir Maksimović*, Stevan Ćorluka**

GEOLOGICAL EXPLORATIONS AND LABORATORY TESTING AT THE SITE DESIGNATED FOR INSTALLATION THE VERTICAL GRAVEL DRAINS

Abstract

Vertical gravel drainages are used to improve the geomechanical characteristics of sedimented dusty and sandy soils where the application of gravity drainage is not possible. They are formed in a membrane made of a cylindrical woven geotextile (GEC - geotextile encased columns). They are intended to improve the geomechanical properties of the soil by lowering the groundwater level. Their practical application was realized on a part of an unstable internal landfill at the open pit of lignite "Drmno" in Kostolac. At the sites planned for the production of vertical gravel drains, it is necessary to perform the complex hydrogeological, geotechnical and laboratory tests, and this is shown in this paper.

Keywords: *open pit, landfill, vertical drain, cylindrical geotextile*

INTRODUCTION

It is known that water has a significant effect on the soil stability. Changes in the pressure of pores cause a change in the effective stresses in the soil, and as a result, changes in strength and stability occur. In coarse materials, lowering of the groundwater level is achieved by a gravity drainage, while in a fine-grained and dusty material gthe ravitational drainage is too slow and inefficient, and lowering of the groundwater level is most often achieved by a previous consolidation, caused by the load [2]. Drainage of low watertight soil is now increasingly being carried out using the geotextiles and other geosynthetics. Soil drainage is carried out in order to: stabilize slopes, reduce soil compressibility, increase soil load, prevent liquefaction and erosion.

The applicability of some methods of hydraulic improvement depends on a type of soil, i.e. grain-size distribution as shown in Figure 1 [3].

Improvement of geomechanical soil properties applying the pre-load method can be applied in all types of soil, but the best results are obtained in a soft, damp sand and dust. Preloading improves the working environment increasing the load and decreasing the compressibility of soft, unbound soil. The consolidation process is accelerated by construction the vertical and horizontal drainage [1].

The production of vertical gravel drainages in a membrane, made of cylindrical woven geotextile (GEC-geotextile encased columns), is a method of improvement the geomechanical characteristics of natural soil or deposited tailings and improving the conditions of drainage. By installation of gravel or sandy material, the mechanical properties of natural soil or defective tailings are enhanced (the overall strength parameters and the average modulus of deposited material compressibility) [2].

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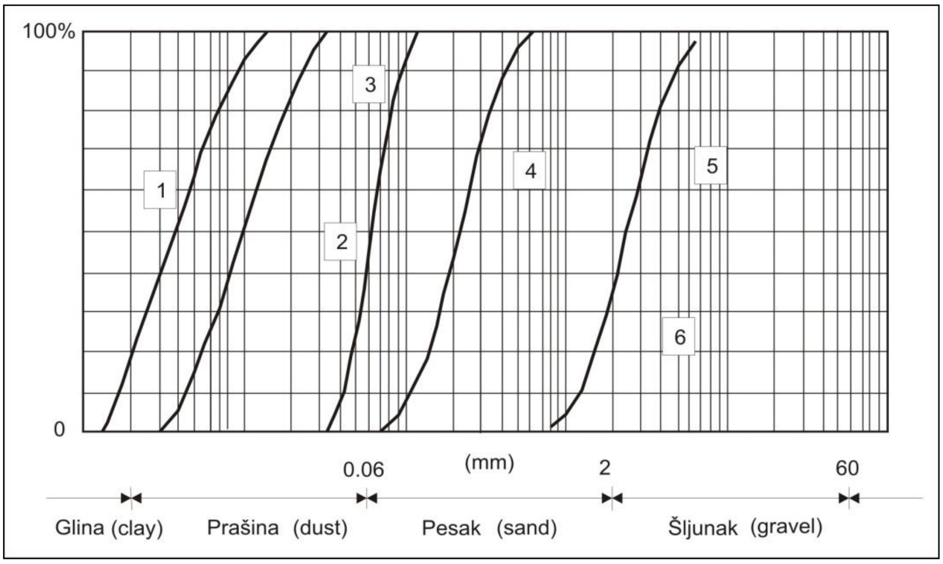

Figure 1 *Applicability of hydraulic improvement method*

Interpretation: 1 - electro osmosis, 2 - wells or vacuum wells,
3 - gravitational drainage too slow, 4 - gravitational drainage,
5 - necessary underwater works, 6 - use of large drainage pumps

Vertical gravel drains (Fig. 2) allow water, located in the pores, to flow horizontally (radially) to the nearest drain (the horizontal path of drainage is the shortest path of drainage and amounts up to a half of axial distance between the individual drains), and rapid evacuation of water from the ground. Drainage reduces the pore pressures in the underlying ground, and therefore the substrate enters the drainage state, which positively affects stability.

Vertical gravel drains improve the mechanical characteristics of the soil (increasing the load and reducing the sagging) because a certain volume of soil is replaced by the gravel or sandy material with better mechanical characteristics. Geotextile prevents the "spillage" of the gravel into a low-load material, i.e. allows the lateral fastening. It also provides a denser compaction of gravel, i.e. increase the average modulus of compacted material [5].

In addition, it prevents penetration of fine particles into the gravel, thereby reducing the watertightness and preventing the reduction of the average gravel strength that would result in the fine particles, deposited between the gravel. Vertical gravel drains can be mounted on a rectangular or triangular arrangement with a different axial distance. The installation diameter can be 600 or 800 mm. In our conditions, taking into account the costs and speed of installation, the vertical gravel drains can be made by drilling with a drill with a protective column as shown in Figure 3.

Figure 2 *Vertical gravel drains at the inner landfill of OP Drmno*

Figure 3 *Drilling using a drill with a protective column*

After the construction of vertical drainage (vertical gravel drains) and horizontal drainage (drainage carpet), new quantities of material are deposited. The newly-placed material with its weight plays a role of pre-loading and through the built-in drainage leads to the drainage of excess pore water the from natural soil or deposited tailings. In this way, the geomechanical properties of the base soil are improved and, in general, it allows more secure laying of tailings or construction of various objects. Figure 4 shows the basic concept of applying the preload method by production of drainage on the internal landfill of the OP Drmno [4].

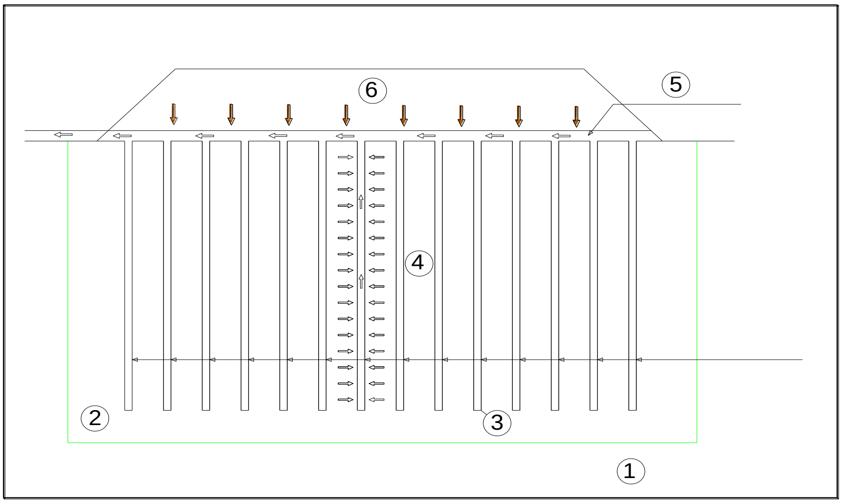

Figure 4 *Basic concept of the pre-loading method with production of drainage*

Interpretation: 1-soft ground, tailings, 2-improved soil, 3-vertical gravel drains, 4-excess pore water, 5-drainage carpet, 6-pre-load, deposited tailings

GEOLOGICAL EXPLORATIONS AND LABORATORY TESTING

On terrains for planned construction of vertical gravel drains, the preliminary hydrogeological and geomechanical explorations have to be carried out. For the purposes of defining the drainage and monitoring the fluctuations of groundwater level in the subject area, it is necessary to develop a network of observation piezometers for continuous monitoring a groundwater level regime over a period of one year. The main problem of preparation the piezometric network in the landfill space at the open pits is the inability to maintain the piezometer in a functional condition for a long time, because they are rapidlydestroyed by operation of the mining machinery. Therefore, it is necessary to clearly mark the field on the ground after the construction of piezometers, and due to the continuity of the repository, it is necessary to plan their overtop to the required peak elevation. The locations of piezometers should be determined on the basis of data from the previous exploration drillings, data obtained by the reconnaissance of terrain and dynamics of the mining machinery operation on disposal of tailings. Position of the placed vertical gravel drains on a part of the internal landfill OP Drmno is shown in Figure 5.

The exploration drilling is most often done by a direct method of diameter Ø146-101mm with constant circulation of working fluid. Drilling is performed from the beginning by a regular core pipe for continuous coring. A mild clay fume is used as the working fluid. During the drilling operation, the master driller runs a drilling journal in which the entire flow of work is recorded. The minimum percentage of core for the whole well should be 85%, with at least 75% in each drilling interval whose maximum length may be 6m. The core is stored in the wooden boxes with barriers 1m long.

Upon completion, the core should be photographed and the photos obtained are an integral part of the final documentary report. At the end of or during the construction of a drill hole, the extracted cores are mapped and this work is performed by the geologists, i.e. a geologist for hydrogeology, a geologist for geomechanics and a geologist for mine geology in the presence of the Supervisor [3].

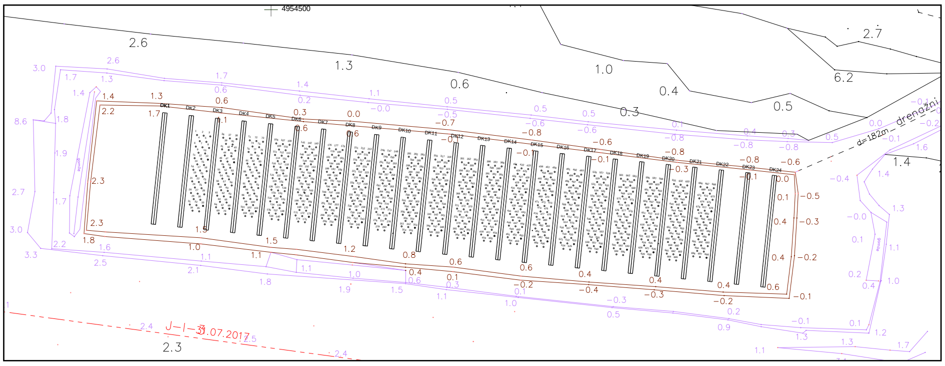

Figure 5 *Overview the position of placed vertical gravel drains*

During a detailed engineering-geological mapping of core of the exploratory drill holes, sampling of representative samples for testing in the laboratory is carried out, based on the preliminary macroscopic allocation of individual lithological environments within the terrain structure. Samples are taken from each material change or in an interval of 5m if the material was uniform. Length of an undisturbed sample is at least 30 cm. Samples are packaged in order to protect them from mechanical damage and shaking until their delivery to the laboratory. Untreated samples are packaged in the plastic foils. The samples should be delivered to the laboratory as soon as possible. With each sample, a label with the following data is placed: the designation and number of explored site – drill holes, locality, depth of taken sample, type of sample, type of test, date of sampling and name of responsible person as well as the observations entered in the field record in all, in accordance with SRPS U.B1.010 [3].

Laboratory tests of soil samples are carried out with a task of material classification, determining the parameters of strength, and defining the relationship of stress and deformation. Laboratory tests should be carried out in accordance with the natural conditions in the field.

The following laboratory tests should be carried out on taken samples:

1. Identification-classification tests
   - Determination the humidity of soil samples (SRPS U.B1.012)
   - Determination the volume of soil material by a cylinder of known volume (SRPS U.B1.013)
   - Determination the grain-size distribution (SRPS U.B1.018)
   - Determination the Aterberg limits of consistency (SRPS U.B1.012)

2. Testing the parameters of strength and deformability
   - Direct shear technique (SRPS U.B1.028). Testing the drainage shear strength after consolidation the test body up to σ = 100; 200 and 400 kN/m^2, in all in accordance with SRPS U.B1.028. Based on the results

of this programmed experiment, the Coulombs linear envelope which shows the soil stiffness from the normal stress ratio and strength will be shown.
- Oedometer technique (SRPS U.B1.032). After placement, the test body is immersed in water and loaded to consolidation under the natural conditions, and then by step-by-step stress increase σ = 25, 50; 100; 200 and 400 kN/m^2, in all in accordance with SRPS U.B1.032. The results are shown by a relative subsidence diagram and porosity coefficient change diagram.

Upon completion of exploration, the Final Report should be prepared including the following elements:
- name of a drill hole,
- description of used drilling technology and drilling equipment,
- angles and coordinates of a drill hole,
- photographs of a drill hole cores,
- lithological profile,
- report on theresults of laboratory tests,
- construction of piezometers,
- signature of the Expert (Investor) supervision, Design supervision and Responsible contractor that they agree that the Report contains the minimum elements about a drill hole.

CONCLUSION

Hydrotechnical soil stabilization using the vertical gravel drains in a cylindrical woven geotextile is applied most in the cases of stabilization the soft and sedimented soil. An important task in the accurate locating of the zone for carrying out the construction of vertical gravel drains is to analyze the geotechnical and hydrogeological situation. In this regard, the complex hydrogeological and geotechnical exploration works as well as the laboratory tests are carried out at the site. The obtained data from previous research are used for dimensioning the vertical gravel drains, and later for valori-zation of their drainage, and stabilization efficiency.

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STABILITY OF THE ASH AND SLAG LANDFILL "MALJEVAC" – PLJEVLJA FOR OVERTOP TO THE PEAK ELEVATION K+832 m**

Abstract

The existing landfill at the site "Maljevac" is still active and should provide the additional space for ash and slag disposal in the following period. For these purposes, the stability analysis of the existing landfill condition, as well as the stability calculation for overtop the landfill to the peak elevation K +832 m were carried out. The stability by analytical profiles was calculated by the licensed SLIDE v6.0 software.

Keywords: *ash and slag landfill "Maljevac" – Pljevlja, stability analysis and calculation, software SLIDE v6.0.*

1 INTRODUCTION

In order to provide the sufficient space for ash and slag disposal that occur as a by-product of opreation the Thermal Power Plant Pljevlja, a dam "Maljevac" was built in 1982 in the bed of Paleški stream, at a distance of about 7 km from Pljevlja. The ash and slag landfill for the Thermal Power Plant Pljevlja was formed by the construction of the "Maljevac" earth dam. In the first phase, a basic dam was constructed with the crest peak elevation of 790.5 m (height 27.5), and in the second phase the dikes - stairs were successively developed to the peak elevation of 813.2 m. Further elevation of dike, which downstream limits the cassette, was developed to the peak elevation K+826 m. The space of the active cassette II is bordered by a dike of an approximate height of about K+832 m, what also represents the final peak elevation of ash and slag disposal at the Maljevac landfill in all analyzed variants.

The transport system of slag and ash from the thermal power plant is solved by a hydraulic means, wherein the mixture of water and ash is led by the pipeline to the landfill where the ash is precipitated. Through the overflow structure, water is taken from the surface of the landfill, i.e. the horizontal precipitation channel, gravitationally to the excavator station, and in this a closed system of recirculation the technological water is formed at the landfill. Below the landfill there is a reinforced concrete collector, a wall thickness of 60 cm, and water of the Paleški stream are led through the channel. The collector consists of the main and secondary one. The length of the

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main collector is, after extension during the implementation of the project of stabilization the dam "Maljevac", 1460 m and the secondary is 600 m.

In 2014, stabilization of the dam "Maljevac" was carried out by construction a stabilizing ballast. The works have provided the set conditions of static and dynamic stability. The existing landfill at the site "Maljevac" is still active and it needs to cover the disposal of ash and slag from the TPP until the beginning of opening a landfill on a new location.

STARTING PARAMETERS FOR STABILITY CALCULATION

In 2015, geotechnical "in situ" and laboratory measurements were carried out for the needs of overtop and analyzing the stability of ash and slag dump "Maljevac" - Pljevlja to the peak elevation of 832 m, and all previous research, carried out at this site, were systematized [1].

Excavation of the exploratory pits was performed on the profiles between the exploratory drill holes in a part of the area where there is a small overhead of dike on the natural one for taking the large disturbed samples of disposed ash and slag. Mapping of all pits was carried out in parallel with the excavation, monitoring of the state in excavation and inspection of sampled material.

In addition to the exploratory pits, the exploration drillings were carried out. By performing the exploration drilling, the geological structure on the vertical profile of site was defined, the data on hydrogeological and physical-mechanical properties of soil were collected, the representative soil samples for laboratory tests were taken, the water level was measured in drill holes after their completion, the SPT test was carried out at certain depths and the water-penetration was tested using the filling method.

Calculation parameters, used in the stability calculation at the Maljevac site, are given in Table 1.

Table 1 *Calculation parameters for stability calculation of the landfill "Maljevac"*

Working environment	Cohesion, kN/m^2	Internal friction angle,°	Bulk density, kN/m^3
Site in the ground	7	18	20.0
Disposed ash and slag	0	29	17.5
Dam	5	20	25.0
Waterproof layer in the ground of overtop	5	20	25.0
Waterproof layer and reclamation layer over	5	20	25.0
Stone material in ballast	0	35	19.0

The water level - piezometric line is defined on the basis of NPV drill holes, made at the site. The liquid phase of ash and slag in the landfill is defined by the pore water coefficient of 0.9.

The stability calculation was done by the licensed SLIDE v6.0 program of the company Rocscience, Figures 1 and 2. By the SLIDE program, the stability calculation is done in the conditions of limit equilibrium. The calculation was made using the Janb method that gives the lowest values of stability coefficient in relation to the other methods that can be used (Morgenstern-Price, Bishop, ...) [4-11].

The stability calculation was made in the static and dynamic conditions for the seismic coefficient of the Maljevac region of the return period for 200 years from 0.1.

The stability criterion was adopted in accordance with the prescribed technical conditions for designing the earth dams and hydrotechnical dikes - SRPS U.C5.020 [7], which for the dams above 15 m high is minimum Fs = 1.50 and for dams with high less than 15 m is minimum Fs = 1.30 in case of constant static load, or Fs = 1.00 in case of occasional dynamic load for earthquake occurrence.

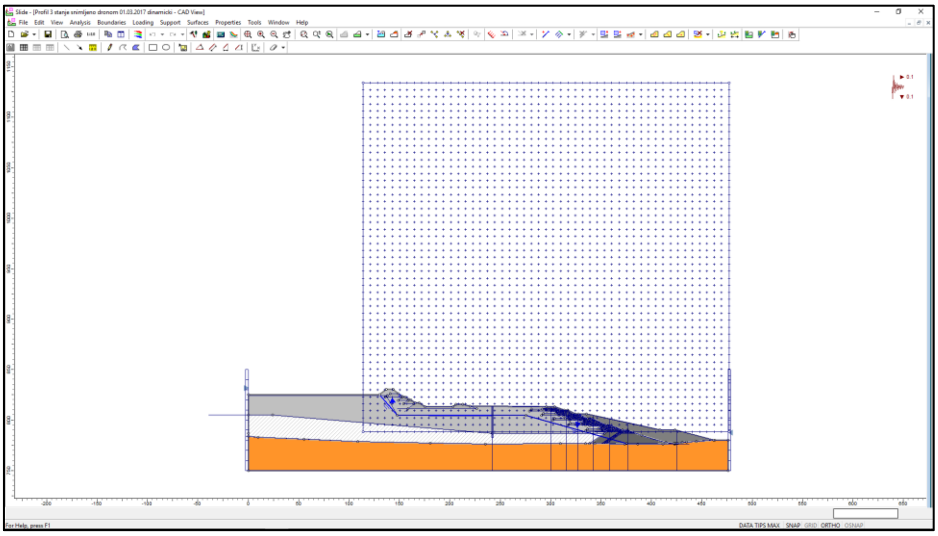

Figure 1 *Operating interface of the software Slide*

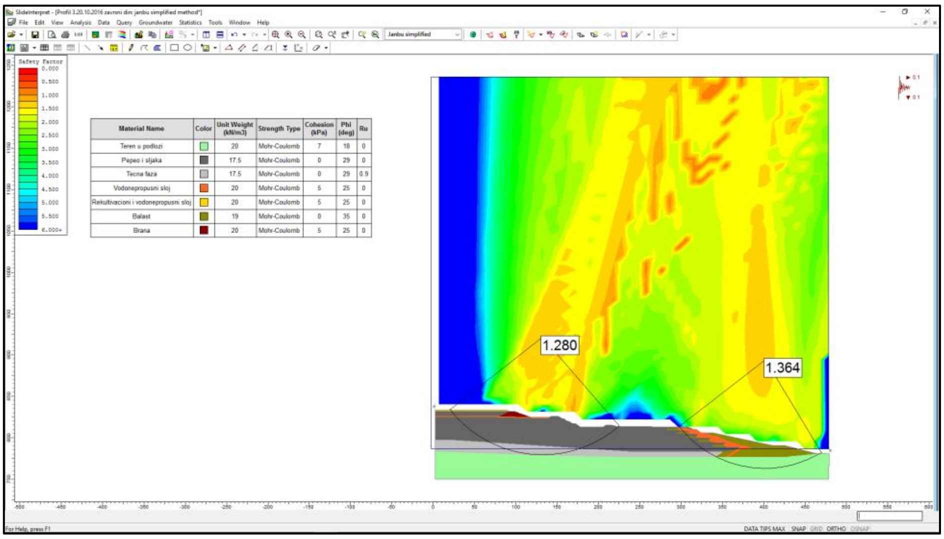

Figure 2 *Output interface of the software Slide*

STABILITY ANALYSIS OF THE CURRENT CONDITION OF THE LANDFILL

Stability analysis of the current condition of the landfill "Maljevac" was done on the profiles I-I' to IX-IX', shown in Figure 3. The profiles I-I' - III-III' are perpendicular to the main dam of the landfill. The profile IV-IV' is perpendicular to the slopes of the existing cassette I and towards the future cassette III. The profiles V-V' to VII-VII' are perpendicular to the slopes of the existing cassette II. The profiles VIII-VIII' and IX-IX' are perpendicular to the slopes of the cassette I [2, 3].

The obtained stability coefficients according to the analytical profiles of the current condition of the landfill "Maljevac" are shown in Table 2.

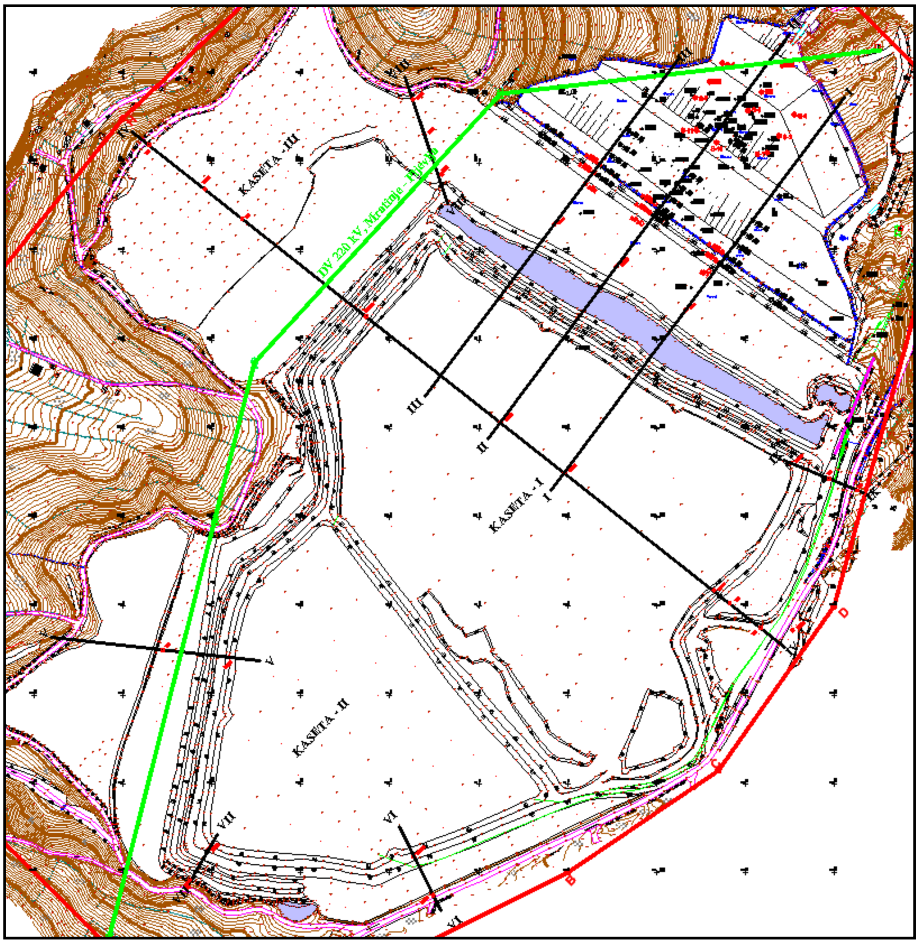

Figure 3 *Position of the analyzed stability profiles for the current condition of the landfill "Maljevac"*

Table 2 *Stability coefficient of the current conditions of the landfill "Maljevac" by the Janbu method*

Profile	F static	F dynamically
I – I'	1.591	1.287
II – II'	1.520	0.940
III – III'	1.537	1.229
IV – IV'	1.511	1.024
V – V'	1.238	1.021
VI – VI'	1.745	1.428
VII – VII'	1.672	1.367
VIII – VIII'	1.815	1.407
IX – IX'	1.549	1.177

By comparison the obtained stability coefficients with the coefficients prescribed by the technical conditions for designing the earth dams and hydrotechnical dikes - SRPS U.C5.020, it can be established that the critical part is the central part of the landfill "Maljevac" in the area of the main dam even in the case of dynamic loads due to the occurrence of earthquakes.

The main cause of insufficient stability in the central part of the main dam of the landfill "Maljevac" is a high level of liquid phase of ash and slag in this area, Figure 4.

As the overtop of the landfill is envisaged, it is necessary to take the remedial measures to ensure the required stability.

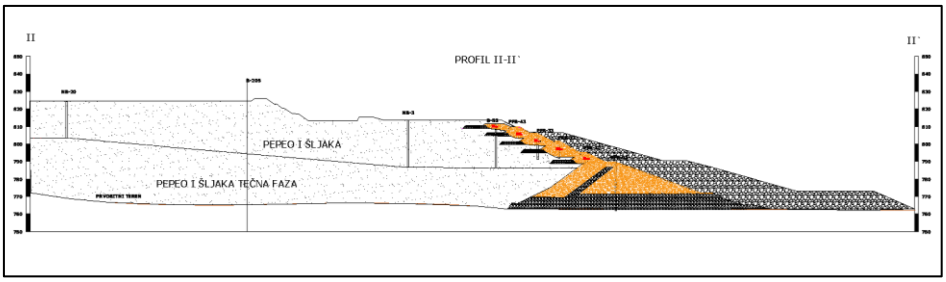

Figure 4 *Geological profile II – II' of the current condition of the landfill*

LANDFILL STABILITY TO K+832 m

As before ash and slag disposal in the cassettes in base, a waterproof layer is made, and after finishing the ash and slag disposal a waterproof layer is also placed on the cassette surface for the final condition of the landfill, the piezometric water level is below the waterproof layer in the base, Figure 5. The piezometric water level for the final condition of the landfill is lower than the initial condition, what is the result of application the following rehabilitation measures [3]:

1. Covering the cassette I with a layer of low-permeable clay, thickness 1 m;
2. Covering the 5^{th} step of the main dam with a clay layer of 1m;
3. Construction of a new horizontal precipitator with clay and HDPE foil;
4. Closure of the existing precipitator and covering a clay layer of 1m;
5. Construction of drainage wells on the 5^{th} step of the main dam for lowering the water level in the landfill;
6. Upon termination of exploitation of the cassette II, closure of cassette with a clay layer of 1m and 1m of soil for rehabilitation of the cassette.

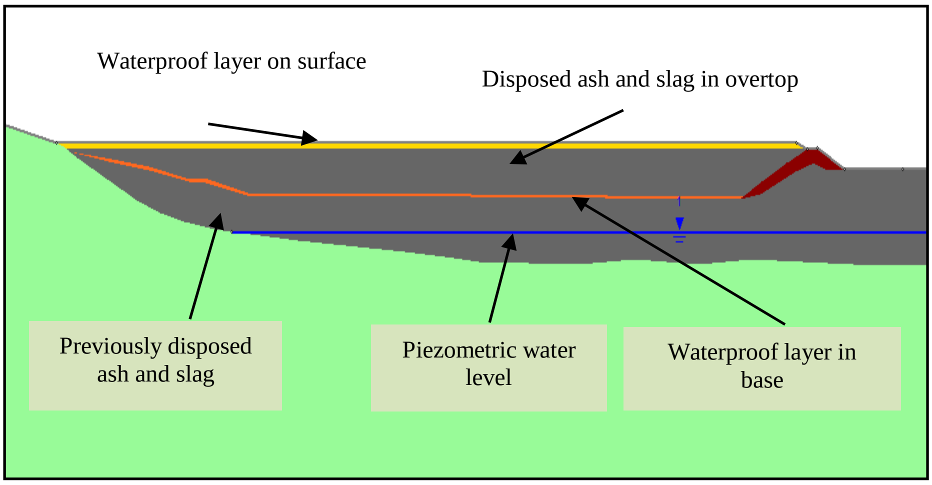

Figure 5 *Representative profile of the landfill after use of the rehabilitation measures*

Disposal of ash and slag in the future period, after filling the cassette II will be done in a unique cassette III and IV. The last phase is disposal in the cassette I. In order to prevent infiltration of water into the natural soil, a protection of base is predicted with a waterproof material - clay, a layer thickness of 1.0 m. This protection is made before the start of disposal in the unique cassette III and IV and cassette I. This prevents further contamination of soil and groundwater as well as the stability improvement of the existing and future dikes. This concept provides the completely hydraulically independent fields. The Field I is bordered from all sides by the waterproof material, both on the bottom and on the peripheral dikes that are also made of clay.

At the existing landfill in Maljevac, there is a functional system for accepting and recycling of overflow-technological water. This system consists of the concrete overflow chutes inside the active cassettes, which through the plastic pipelines drain water from the landfill to the entrance into the horizontal precipitation channel, in which the secondary precipitation of the finest ash particles is carried out. At the exit from the precipitation channel on the right side of the dam, there is an overflow structure with two overflow holes. This overflow structure will undergo small changes in the form of lowering the overflow edge so that the drainage water can be evacuated with this system. The horizontal precipitation channel will be moved down by the fifth step. A new precipitation channel will be coated with a layer of clay, thickness of 1.0 m, over which the foil is placed, thickness of 2.5. This is due to the prevention of ground water penetration into the dam body, thus achieving greater stability of the structure.

The existing precipitation channel is planned to be closed and sealed with poorly waterproof clay material, and a new precipitation channel is going to be built next to it in accordance with the modern technical and ecological solutions. This is done in order to create the waterproof conditions in a channel for overflow and drainage from the landfill. The existing channel is built in ash, and therefore in a waterproof material. The process water from the precipitation channel pass freely and drain into the lower layers of the dam, so that they significantly influence the level of groundwater in the dam body, which directly affects the stability coefficient of the entire slope of the landfill, which is in this part of the dam under the legal minimum. The new channel will be coated with the waterproof material. Waterproofing is provided with a layer of clay material, thickness of 1.0 m, and the HDPE foil, thickness of 2.5 mm.

In order to achieve the necessary stability coefficient of the landfill, it is necessary to continually drain the water from the body of the landfill. Technological water is partly discharged as the overflow water while one part is submerged, infiltrating into the body of the landfill. In order to achieve the necessary stability coefficient of the dike, the groundwater must be maintained at the appropriate level. The most efficient way to regulate the level of groundwater is the construction of an appropriate drainage system for drainage of water.

The drainage system increases the safety coefficient of the main dam of the landfill. By reduction the level of ground water in the body of the main dam, the efficient drainage system also achieves an increase in the useful volume for ash and slag disposal in the designated area, resulting in faster water drainage and, consequently, drying of deposited material.

In this case, the drainage system is laid on an already prepared base of waterproof material. The base is made towards the drainage pipes. By overtop of the landfill, the drainage pipes are installed on the floors of the dump overtop.

Upon completion of disposal, each cassette will be closed in accordance with the Rulebook on the closer characteristics of the site, conditions of construction, sanitary-technical conditions, operation method and closure of landfills. Construction of a waterproof layer of clay of 1m and 1m of soil for cassette rehabilitation was proposed.

Stability calculation of the cassette dike is made for profiles 8-11 and 14-20, for the final landfill, Figure 6, as well as for the profiles of the main dam I-I' to III-III' for the final condition of the landfill.

The obtained stability coefficients according to the analyzing profiles of the final condition of the landfill "Maljevac" are shown in Table 3.

By comparison of the obtained stability coefficients to the coefficients prescribed by the technical conditions for designing the earth dams and hydrotechnical dikes - SRPS U.C5.020, it can be established that by all analyzing profiles, the coefficients of stability are in the prescribed values.

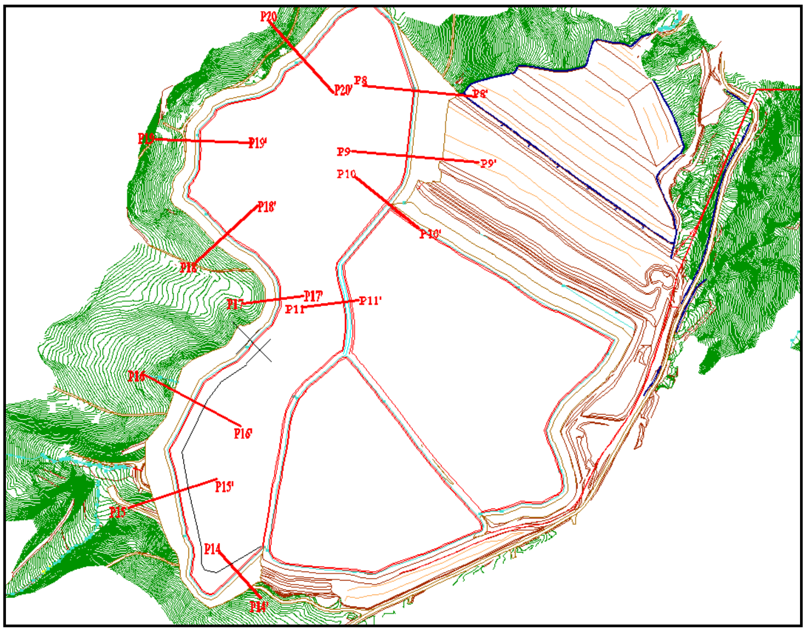

Figure 6 *Position of the analyzing stability profiles for the final conditions of the landfill "Maljevac"*

Table 3 *Stability coefficient of the final condition of the landfill "Maljevac" by the Janbu method*

Profile	F static	F dynamically
8 – 8'	1.923	1.315
9 – 9'	3.081	2.099
10 – 10'	1.504	1.195
11 – 11'	1.629	1.261
14 – 14'	1.860	1.328
15 – 15'	1.638	1.170
16 – 16'	1.865	1.297
*17 – 17'	1.314	1.044
*18 – 18'	1.449	1.136
*19 – 19'	1.501	1.181
*20 – 20'	1.413	1.115
I – I'	1.572	1.198
II – II'	1.561	1.057
III – III'	1.562	1.280

**lower height than 15 m*

The stability coefficients for the static and dynamic loads per profile II - II', which was the most critical before the introduction of rehabilitation measurements, after the application of these measures, are shown in Figures 7 and 8.

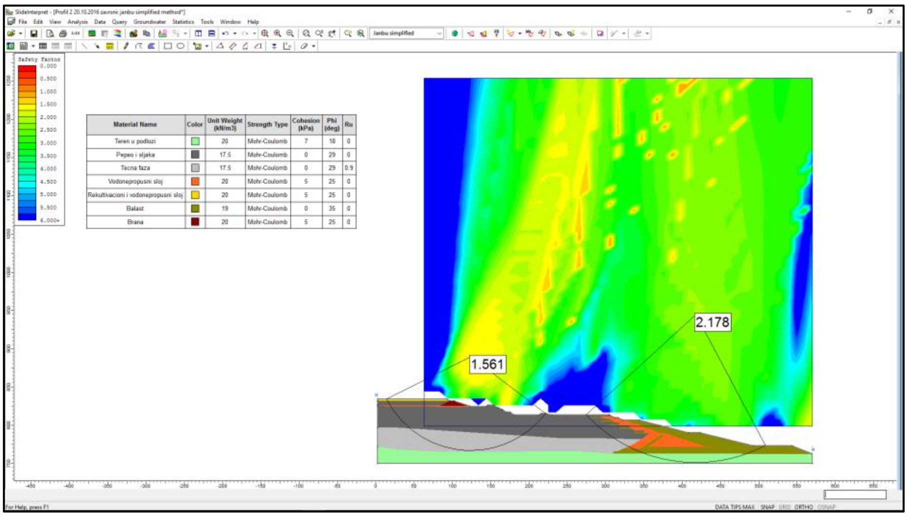

Figure 7 *Static stability coefficient on profile II – II' after application the rehabilitation measures*

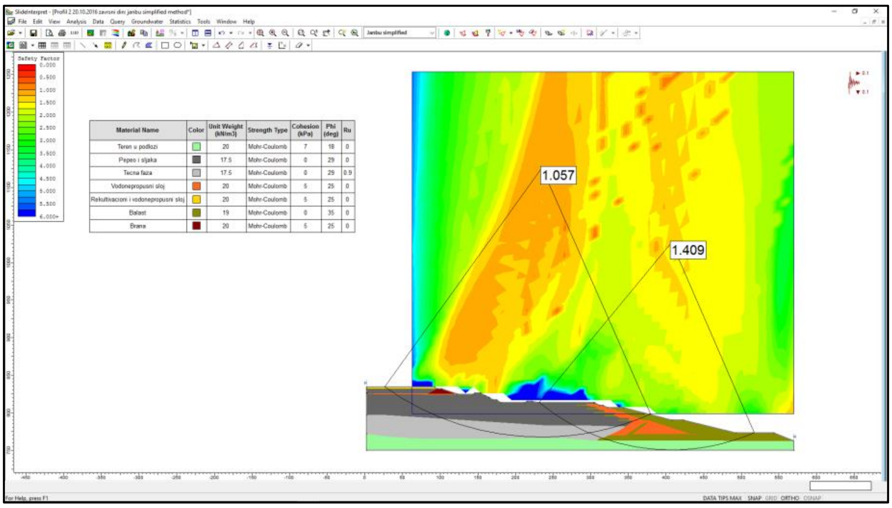

Figure 8 *Dynamic stability coefficient on profile II - II' after application the rehabilitation measures*

CONCLUSION

According to the technical conditions for designing the dams and hydrotechnical dikes - SRPS U.C5.020, for the dams (dikes) over 15 m in height with the constant load occurring in the regular exploitation of the structures for a longer or shorter period of time, the obtained static stability coefficients satisfy the prescribed standard, while in a dynamic sense, an instability occurs according to the prescribed standard.

In parts of the mentioned area where the regulation of the mentioned standard is not satisfied, the actions should be taken to bring this condition to the limits prescribed by the standard. Most of the problems with stability is in the cassette I, where the instability occurs due to a high level of the ash and slag liquid phase. Reduction the level of the liquid phase below the cassette I and by some of the rehabilitation measures, the conditions will be created for increasing the stability coefficient on the critical profile II - II' above the prescribed values.

The predicted rehabilitation measures are:

1. Covering the cassette I with a layer of low-permeable clay, thickness 1 m;
2. Covering the 5th step of the main dam with a clay layer of 1 m;
3. Construction of a new horizontal precipitator with clay and HDPE foil;
4. Closure of the existing precipitator and covering a clay layer of 1m;
5. Construction of drainage wells on the 5th step of the main dam for lowering the water level in the landfill;
6. Upon termination of exploitation of the cassette II, closure of cassette with a clay layer of 1m and 1m of soil for rehabilitation of the cassette.

After application of these measures, the stability coefficients after the overtop to the peak elevation K+832 m are in the values prescribed by the technical conditions for designing the earth dams and hydro-technical dikes - SRPS U.C5.020.

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POSSIBILITY OF APPLICATION THE STATISTICAL METHODS IN DEFINING THE ENGINEERING GEOLOGICAL COMPLEXES**

Abstract

This work presents the procedure of applying the statistical analysis methods for the needs of defining the engineering-geological complexes in the structurally complex geological conditions on the example of working environment of the open pit Gacko – Central Field. The open pits represent the exploitation objects explored over a longer period of time using the different exploration methods, in varying degrees and with different reliability, and the question of selecting the relevant values of investigated parameters is usually a complex task and crucial from the aspect of construction the exploitation objects. For the purposes of forming an open pit and determining its geometric parameters, inclination and height of the final, the system of working and general slopes and slopes of levels; a good knowledge of the basic physical-mechanical parameters of the working environment, and their values for characteristic separated units – the engineering-geological complexes is necessary. In order to present the working environment of the open pit as realistic as possible, and in the process of defining and limiting the engineering-geological complexes within a complex, only those lithological-structural units of similar engineering-geological parameters can be found, it is possible to apply the methods of statistical result analysis of geomechanical data research. The results of this analysis, in addition to the other relevant parameters of the working environment, can facilitate the separation process of characteristic geomechanical units, and enable the formation of a more precise engineering-geological model of the open pit area.

Keywords: *open pit exploitation, working environment, geotechnical parameters, slope stability*

1 INTRODUCTION

The open pit mining takes place at the open pits representing the objects of exploitation, characterized by their constructive parameters, such as the height and angle of the final, system of working and working slopes of the individual levels and width of horizontal parts between the pit slopes and berms. Slopes of the open pit (working and final) are formed in different materials, structural - geological environments, collectively referred to the working environment. The basic parameters of the working environment that influence the geometric parameters of the open pit are the volume mass and parameters of material strength (pressure and tensile strength, angle of internal friction, cohesion, modulus of elasticity, etc.).

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The structural parameters of the open pit must be such as to ensure the safe and economic exploitation of mineral resources. Even a slight decrease in the inclination angle of final slopes of the open pit regarding to the depth and size of the area in which the exploitation is carried out, can significantly increase the quantities of excavated waste masses, the order of millions of m^3, and significantly affect the economy of exploitation. On the other hand, any increase of the inclination angles of final slopes of the open pit decreases the safety factor of the open pit slope, minimizing the safety of objects, equipment and people at the open pit. Due to these reasons, in adopting the structural parameters of the open pit, the slope stability requirements, in the relevant regulations applicable in the field of open pit exploitation of mineral resources, must be met.

Physical-mechanical characteristics of the working environment, as a rule, are very variable in space, and one of the basic tasks of the experts dealing with this issue (geologists, geotechnicians, construction and mining engineers) is to identify the characteristic units, engineering - geological complexes, which are characterized by similar physical-mechanical parameters, and in that way to perform the required simplification of the problem of determining the stability degree of the open pit slopes [5, 6]..

The values of the physical - mechanical parameters of the engineering-geological complexes are adopted with the appropriate reliability, which is also prescribed by the regulations in the field of mining.

In the previous practice, the definition of engineering-geological units within the area of the open pit, or wider area of the mineral resource deposit, has often been reduced to the recognition of the present structural units (for example, clay, sand, silt, loess, marl, limestone, etc.) and the engineering - geological complexes, as a rule, coincided with the structural complexes. In the real situations, solving this issue is significantly more complex.

For the analyzed example of the working environment at the open pit Gacko, the phenomenon of marls in the overburden of coal seam is characterized by a wide range and great variability of the physical - mechanical parameters. For this reason, application of the method of statistical analysis, using the tests of determined the relevant physical - mechanical parameters, can be very useful in solving the problem of defining the engineering - geological complexes and determining the reliability degree of adopted values.

2 GEOTECHNICAL CHARACTERISTICS OF LITHOLOGICAL UNITS IN THE AREA OF THE FIELD C OF THE COAL BASIN GACKO

During the previous development of coal exploitation in the Gacko basin, the studies of physical and mechanical parameters of sediment overburden, tailings and coal were carried out repeatedly and over a longer period of time. The basic method of research is deep exploration drilling, and from the core of the wells samples for geomechanical laboratory tests were derived. In the course of the research, recognitions of certain structural units (clay, marl, sand, etc.) were carried out, and sampling was attempted to provide the sufficient number of tests from all geological - structural units [1, 4].

Using the laboratory-determined values of physical - mechanical parameters on individual samples, and in accordance with the other characteristics (chemical and mineral composition, color, appearance of fractures, etc.), the certain engineering - geological complexes have been defined.

Considering the number of geological structures, the scope of tests and extent of their representation, a concrete example of determining the relevant parameters was made for the working environments Ng8 and Ng7, which are mostly represented in the roof of coal seam. The seams market by Ng8 and Ng7, according to their mineral composition, are marls, and these units are derived from the spatial superposition. Both environments are complex seams in which clayey, sandy, coal and tufitic marls are separated [2].

For different types of marl, the statistical processing of laboratory-determined values of physical-mechanical parameters was performed in order to define the engineering-geological complexes

Within the geological explorations, carried out in the previous period, from designed drill holes for engineering-geological and geomechanical needs, the physical-mechanical properties of the wall masses of the neogene series as a whole, as well as the seams, were tested on taken samples that are the subject of this paper. The division was according to the parameters of uniaxial pressure strength, bulk density and other characteristic properties. According to Skoković R., the division was made into eight lithological complexes (Table 2) or by Ćimić S., into five categories (Table 1) [2,3].

The latest research of the physical-mechanical properties of the Gacko coal basin sediments dated from 2005 to 2012. By analysis and statistical analysis of the available parameters including the previous tests of physical - mechanical properties and geomechanical tests on samples from exploratory geotechnical drill holes, carried out in 2005, 2011 and 2012, as well as the results of laboratory geomechanical tests on samples, the review Table 3 was formed.It presents the parameters used to analyze the stability by lithological members within the most common lithogenic units for a part of the Central Field.

By analyzing and insight into the existing geological documentation, it is noticeable that the degree of exploration and geological data interpretation, both from the aspect of the raw material base of coal and its quality, and the aspect of hydrogeological and geotechnical parameters in the rest of the Central, East and South exploitation fields, is only partially sufficient (in the zones where the exploration drill holes are denser) for the needs of design at the level of technical projects.

The values of engineering-geological parameters, used for calculating the stability of the slopes of the open pit and landfills were adopted on the basis on the results of geotechnical explorations, given in:

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3. Final Report on Performed Detailed Engineering-Geogeological and Geomechanical Investigations and Tests of the Central Field at the Open Pit, Geoing Group, Belgrade, 2012.

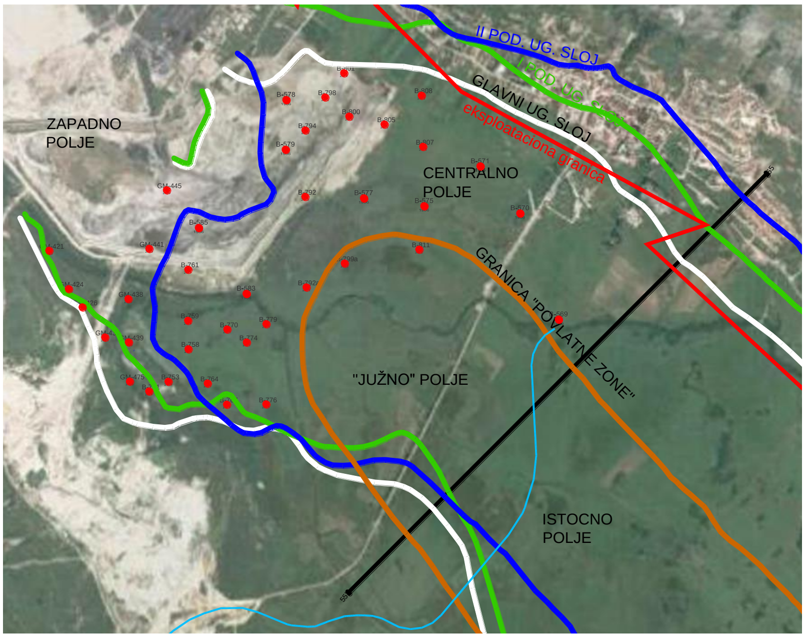

Figure 1 *Schedule of geomechanical drill holes, developed in 2005 and 2011-12 in the area of Field C*

The exploration results, i.e. the values of: bulk density, compressive strength, angle of internal friction and cohesion were statistically processed and analyzed for the needs of classification into the individual complexes and calculation the factor of slope stability. Taking into account the available data, exploration degree of the deposit in terms of knowing the engineering-geological characteristics of the deposit, and reserve categorization of the deposits of the Central Field of the Gacko coal basin, the minimum values of compressive strength, angle of internal friction and cohesion with reliability of 80 % were adopted for calculation the slope stability of the open pit Gacko, while the maximum value with the same reliability was adopted for the value of bulk density [1].

Statistical processing was performed for characteristic examples of structural-geological and, at the same time, engineering-geological complexes of marls, designated as ^{8}Ng and ^{7}Ng in the unique geological nomenclature for this deposit. These two complex engineering-geological units (complexes) are most represented in the geological structure of deposit.

The complex of overlying Neogene sediments is presented by marly limestones, sandy marls, sandy belt marls, marls and clayey marls within the complex ^{8}NG, and gray limestone marlsand marl, coal tufitic marls and belt marls within the complex ^{7}NG [2, 3].

2 STATISTICAL PROCESSING OF AVAILABLE DATA FOR THE NEEDS OF IDENTIFICATION THE ENGINEERING-GEOLOGICAL COMPLEXES

Over the set of available values for parameters: the bulk density γ_z (kN/m^3), compressive strength σ_p (MPa), internal friction angle φ (^{o}) and cohesion c (MPa) by individual lithological units, a statistical analysis was carried out, and the following parameters were determined:

1. Arithmetical mean,
2. Mediana,
3. Standard deviation,
4. No. of samples,
5. Minimum,
6. Maximum,
7. I quartile,
8. III quartile.

The results of statistical processing by individual lithostratigraphic units are given in Table 1.

Table 1 *Statistical parameters of the values of the basic physical - mechanical parameters*

Layer	Lithological member	Parameter	Arithmetic mean	Mediana	Standard deviation	No. of samples	Min	Max	I quartile	III quartile
N8	Marly limestone	Bulk density γ_z (kN/m$^{3)}$	21.74	21.825	0.940	100	19.39	23.53	21.21	22.37
		Pressure strength σ_p (MPa)	6.00	5.8	2.319	98	1.65	11.25	4.28	7.23
		Angle of internal friction φ (^{o})	36.68	38	4.938	100	26	48	32	40
		Cohesion c (MPa)	1.51	1.43	0.579	92	0.41	3.3	1.11	1.85
	Sandy marls	Bulk density γ_z (kN/m$^{3)}$	19.88	20.2	1.280	65	16.84	21.77	19.12	20.89
		Pressure strength σ_p (MPa)	2.79	2.7	1.138	67	0.61	5.89	1.92	3.5
		Angle of internal friction φ (^{o})	32.45	33	4.524	67	20	44	30	34
		Cohesion c (MPa)	0.75	0.74	0.288	67	0.2	1.36	0.5	0.95
	Sandy stripped marls	Bulk density γ_z (kN/m$^{3)}$	17.28	17.85	2.579	25	12.36	20.89	15.89	19.42
		Pressure strength σ_p (MPa)	3.09	2.8	1.232	23	1.43	5.77	2.14	3.85
		Angle of internal friction φ (^{o})	33.56	34	4.698	25	23	40	30	37
		Cohesion c (MPa)	0.82	0.7	0.326	23	0.42	1.4	0.55	1.15
	Marls	Bulk density γ_z (kN/m$^{3)}$	20.15	20.14	1.263	53	17.77	22.26	19.03	21.09
		Pressure strength σ_p (MPa)	3.60	3.5	1.562	52	1.5	8.65	2.69	4.34
		Angle of internal friction φ (^{o})	33.39	32	6.693	53	21	46	28	38
		Cohesion c (MPa)	0.95	0.92	0.369	53	0.42	2.1	0.75	1.1
	Clayey marls	Bulk density γ_z (kN/m$^{3)}$	20.94	21.47	1.242	29	18.34	22.63	19.91	21.67
		Pressure strength σ_p (MPa)	2.20	2.08	0.943	29	0.9	4.19	1.55	2.8
		Angle of internal friction φ (^{o})	28.16	25	7.040	25	18	44	23	34
		Cohesion c (MPa)	0.67	0.57	0.248	23	0.38	1.17	0.48	0.92

N7	Grey limestone marls	Bulk density γ_z (kN/m^{3})	18.54	18.54	0.711	28	17.36	20.22	18.04	19.03
		Pressure strength σ_p (MPa)	4.80	4.3	1.336	26	3.1	6.8	3.5	6.23
		Angle of internal friction φ (^{o})	33.69	33.5	5.744	32	19	42	32	37.5
		Cohesion c (MPa)	1.24	1.1	0.360	30	0.72	1.85	0.95	1.5
	Stripped marls	Bulk density γ_z (kN/m^{3})	17.37	17.55	0.843	13	16.48	18.73	16.57	17.55
		Pressure strength σ_p (MPa)	3.91	4.4	1.288	11	2.4	5.63	2.51	4.86
		Angle of internal friction φ (^{o})	32.77	32	5.480	13	26	40	28	38
		Cohesion c (MPa)	0.94	0.71	0.396	7	0.65	1.75	0.69	1.1
	Coal and tufitic marls	Bulk density γ_z (kN/m^{3})	16.90	16.73	0.803	13	15.46	17.85	16.57	17.75
		Pressure strength σ_p (MPa)	2.17	2.14	0.610	11	1.4	3.23	1.8	2.27
		Angle of internal friction φ (^{o})	33.85	39	7.701	13	22	44	27	40
		Cohesion c (MPa)	0.77	0.75	0.246	13	0.35	1.05	0.74	0.95

Distribution the values of physica l-mechanical parameters of the analyzed lithological members is shown in a form of histogram in Figures 2 to 5. In addition to the histogram columns, a normal distribution curve is also given. Although this distribution in principle does not correspond to the distribution of values of the analyzed parameters, it was used to make easier to see the boundaries of the value expansion, and the mean arithmetic value of the parameters on diagrams. Markings on the diagrams in Fi-gures 2 to 4 are: LK - marly limestone of the complex ^{8}Ng, PL - sandy marls of the complex ^{8}Ng, PTL- sandy belt marls of the complex ^{8}Ng, L- marls of the complex ^{8}Ng, GL – clayey marls of the complex ^{8}Ng, SKL-N7 - gray limestone marls of the complex ^{7}Ng, TL – belt marls of the complex ^{7}Ng complex, UTL - coal and tufitic marl of the complex ^{7}Ng.

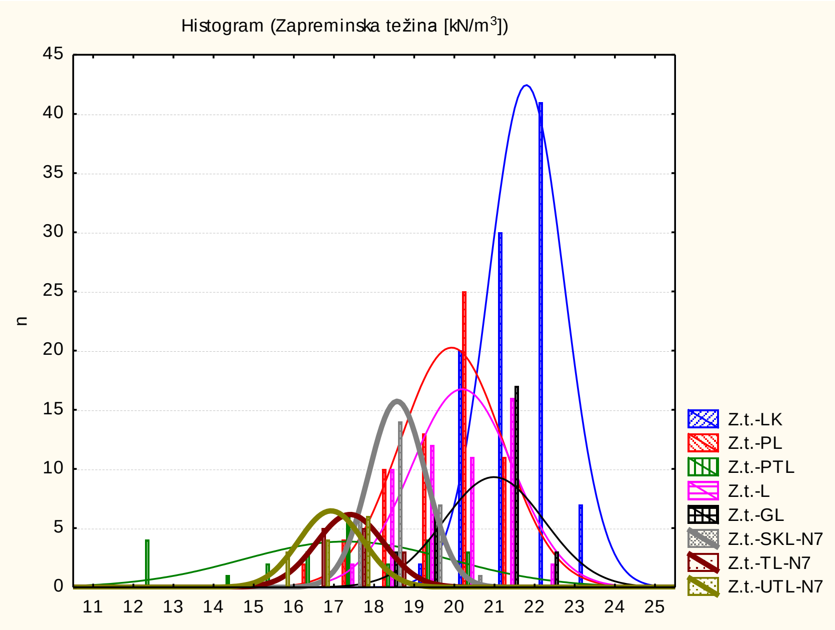

Figure 2 *Distribution the value of bulk density γ_z (kN/m^3)*

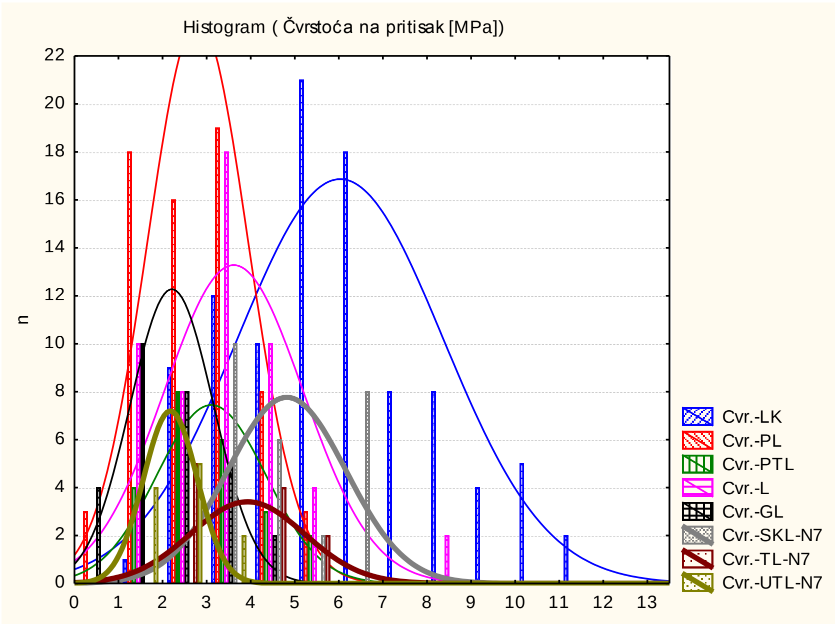

Figure 3 *Distribution the value of pressure strength σ_p (MPa)*

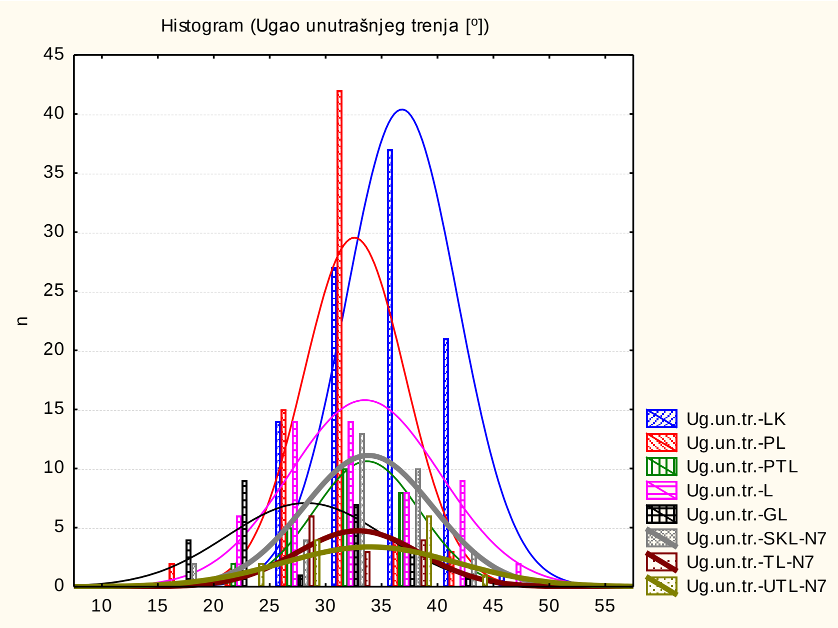

Figure 4 *Distribution the value of internal friction angle φ(°)*

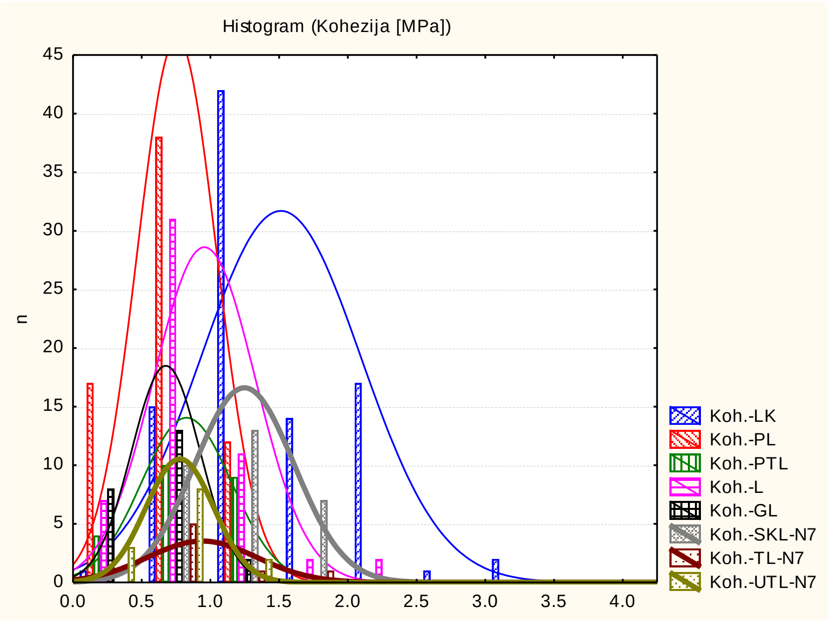

Figure 5 *Distribution the value of cohesion c (MPa)*

Comparing the obtained values of statistical indicators for some lithological members, it is possible to classify them into wider groups, that is the engineering - geological complexes. On the basis of carried out analysis, it can be concluded that the lithological structures of marly limestones and sandy marls, which, besides others, construct a complex of Neogenic sediments, ^{8}Ng, are determined according to their strength parameters, and that the separation of these structural units into the separate engineering-geological complexes can be considered. In addition to the above analysis, it is necessary to consider the structural - geological characteristics of the separated lithological units, continuity of expansion, quantity of participation in the total masses and other relevant characteristics in further consideration the physical - mechanical characteristics of the working environment of the open pit Gacko-Central Field.

The importance of proper classification into some complexes is in fact that a characteristic value of the physical – mechanical parameters, such as the angle of internal friction or cohesion is used in forming the geomechanical model of deposit and calculations the safety factor of slopes for the open pit. This simplification is due to a degree of exploration of the working environment and requirements to determine the characteristic quantities of parameters of certain, clearly limited, complexes for the needs of formation an engineering - geological model. This type of analysis allows better understanding o the variability of physical - mechanical parameters and reduces the possibility of finding the geological structures within the same complex with significantly different parameter values.

CONCLUSION

In the phase of exploration and testing of deposit and design of works at the open pit, one of the important issues is to determine the representative parameters of the working environment in which the future exploitation works will be carried out. The basic requirement is that the designed works can be performed safely and economically. These two requirements are most often opposed to one another. i.e. increasing the security of works as a rule increases the costs of exploitation and vice versa, increasing the economy is ensured by reduction the safety of works.

Defining the geometric parameters of the open pit is carried out using the appropriate geomechanical methods of calculating the stability factor for which the successful application and validity of the obtained results are necessary to dispose of the relevant input data, above all data on the parameters of material strength and bulk density.

In every consideration of the working environment of the open pit, it is necessary to carry out the appropriate separation of characteristic units by their mineralogical, hydrogeological, engineering-geological and other parameters, in order to show the real space of the deposit in which the exploitation object is formed in a manner suitable for formation the appropriate model and design. These units, complexes, are most often represented by the sets of several lithological units that have similar characteristics and behavior, or close values of parameters. In geomechanical term, these complexes, for the purposes of designing the geometric parameters of the open pit, are often the unique values of parameter (for example, compressive strength, cohesion, angle of internal friction, etc.).

The results of statistical analysis of geomechanical parameters, in the case of a satisfactory scope of data, can be a clear indicator for defining which lithological unit can be classified into a common enginee-ring-geological complex. In addition to this analysis, in order to create as realistic as possible the image of the space, it is necessary to examine the other parameters (mineral and chemical composition, hydrogeological characteristics, etc.) that can be of importance for the analysis of engineering-geological processes in the exploitation conditions and in the real space of the open pit.

Correct defining the engineering - geological complexes and selection of representative values the engineering-geological characteristics within them, based on the conducted statistical analysis, must ensure the rational values of parameters and measure of their reliability.

By implementation the shown statistical processing, these two goals are achieved. The results of analysis serve as an evidence of fulfillment the required conditions (the prescribed degree of data reliability), and the adopted values, or their selection from the set by measurement the established parameters are clear for the next processors (geotechnicians, geomechanics, mining engineers, etc.).

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SELECTION OF THE OPTIMUM PUSHBACKS IN A LONG-TERM PLANNING PROCESS OF THE OPEN PIT - A CONDITION FOR MAXIMIZATION THE NET PRESENT VALUE: CASE STUDY: THE OPEN PIT VELIKI KRIVELJ, SERBIA***

Abstract

Defining the pushbacks at the open pit is one of the most important planning activities. Designing the pushbacks is the first step in a long-term planning of production at the open pit where the production is planned. Despite the existence of a large number of software, used for different mathematical algorithms for optimization the open pits, a role of mining engineers is still a key one in development the mining plans.

The work presents the results of conducted impact analysis of selection the optimum pushbacks on the project economy. Based on the results, the importance of correct selection of pushbacks can be concluded for achieving the basic goal of the mining operation - the Net Present Value Maximization (NPV).

Keywords: *optimal pushbacks, open pit long-term planning, maximization of Net Present Value*

1 INTRODUCTION

Maximizing the net present value of a project is the usual objective of mine planning. Achieving this objective through the optimization of planning process has been the subject of significant research and development over the last fifty years, and new developments continue in the field.

Despite advances in the available algorithms, procedures, and software in the surface mine planning, the role of the human planner is still paramount. The mine plan is developed by the mine planners. Mine planning interacts with a variety of other planning areas, and is influenced by corporate objectives and constrained by regulatory requirements.

A consequence of not having an understanding of interdependencies in the planning system may be a plan that achieves a local goal at the expense of the broader plan objectives [1]. Hence, the application of experience and judgment in selecting the planning inputs is considered to be as important to producing the improved results as the software or optimization algorithms themselves [2, 3].

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Strategic mine planning requires, at a minimum, a definition of objective(s) of the study, a block model containing information on block characteristics grade(s), density, process recovery, etc.), an understanding of geotechnical constraints (allowable pit slopes), and estimates of commodity sale prices, mining and process operating costs, and capital costs.

The block model is the basis of modern open pit mine planning. A 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 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.

The focus of such analysis is on pits created at commodity prices below the long-term expected price, and even below the worst-case price. These pits help the planner to identify the highest value per ton portions of the ore body and thus guide the mining sequence [4].

A well-known early contribution to this field was made by Lerchs and Grossmann [5], who presented a graph-theoretic algorithm for determining the final contour of the open pit, known as the *ultimate pit* so that the total profit from the mine is maximized.

As a rule, the planning engineers are not specially trained for this type of work, but it is necessary to have a large amount of professional experience, as well as a significant knowledge of specialized software tools necessary for performing the precise and efficient analysis of design solutions. The importance of experience in planning in the mining projects is especially evident when taking into account the nature of the input parameters necessary for carrying out numerous analyses. Namely, the values of many parameters are not known or uncertain, or they move in a narrower or wider context. In such cases, the experience plays a key role in the planning process [6, 7, 8, 9, 10]. Due to the uncertain nature of input parameters, as well as a great reliance on the empirical making conclu-sions, the planning process is, as a rule, iterative and long-lasting.

There is no mathematical algorithm that will precisely determine the number of required development phases and correctly perform distribution of reserves according to these phases. Bearing this in mind, it is particularly focused that the engineering experience plays a major role in division of the open pit to the exploitation phases, and that this activity is often of an iterative character [11].

2 OPEN PIT OPTIMIZATION AND PUSHBACK SELECTION

Optimization of the open pit implies the obtaining of possible open pit contour on the basis of a deposit block model, which has an economic value, and which can be calculated. The concept of a possible open pit contour means the open pit contour with maximum inclination of the general slope, formed after drawing the transport routes and safety berms, which meets the stability criteria.

Figure 1 shows the *NPV - tonnage graph* on the basis of which the Whittle process finds an optimum excavation limit and pushbacks. The graph shows the achieved NPV, as well as the quantities of ore and waste for each nested pit.

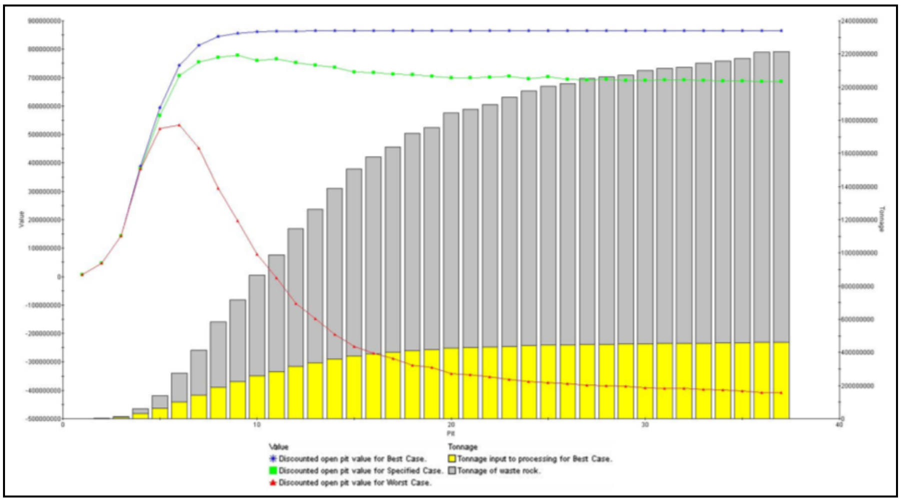

Figure 1 *A typical NPV tonnage graph by the Whittle method [12]*

The NPV curves for the best and worst case indicate the upper and lower limit values that can be achieved [13].

In this paper, the optimization of the open pit limit and excavation dynamics was carried out using the Whittle software. The Whittle process is based on a rapid implementation of the Lerchs-Grossmann (LG) series of algorithm. This algorithm gives the mathematically optimum final limit of the open pit, when the criterion for optimization is the maximum undiscounted cash flow.The process selects the optimal final limit for the best and worst case of mining excavation plans for which the NPV curves are obtained. In this way, a wide range of possible mines is generated, among which an engineer chooses an optimal mine, which once again confirms that the engineer still has an indispensable role in designing despite a strong development of software and computer equipment [14].

In addition to identifying the optimum pit limit, the pit limit analysis is also used to identify a series of nested pits within the final pit limit. The purpose of these nested pits is to establish a transition from the most profitable material (highest value per unit mined) in the pit to the least profitable or break-even material, which occurs at the pit limit. This understanding will aid the planner in selecting where to begin mining, and in what sequence to mine the pit out in order to produce the highest NPV from the material within the final pit limit.

Pushbacks are nothing more than a sequence of pit limits based on the alternative economic scenarios. Simply put, pushbacks describe how a pit will expand as the value of the recovered mineral increases. The progression of pushbacks or nested pit shells roughly corresponds to the optimal evolution of the mine over time. The underlying factor in design of the pushbacks is to generate a series of nested pits that conforms to not only the minimum required pushback width, but provide the highest dollar value for a particular pit size.

Pushbacks play a very important role in the open pit mine design and optimization. Production scheduling is based on the underling pushback mine sequencing which is widely used for a long-term production planning. The design of pushbacks for ease sequencing and scheduling should be governed by the optimized pushbacks which yield schedules with the highest NPV possible.

Most open pits are mined in a series of pushbacks. An initial mining pit is established within the bounds of the final pit. The initial pit is then expanded in pushbacks. The order in which the pit expands is the mining sequence. The specific time at which a given block is mined will be determined by the schedule, established during later planning. The initial pit contains high value material (higher than average grade and/or lower than average stripping requirements). Mining a smaller, high value pit first normally reduces the amount of waste that must be mined to access ore. If the grade of material is higher than the pit average, a higher value per ton of ore will result in the initial mill feed. These two factors combine to increase the NPV by realizing the larger profits earlier in the mine life.

An illustration of the impact of using pushbacks is presented by [15], and is commonly reproduced in the literature. For the section shown in Figure 2, a pit limit analysis is undertaken. Eight pit shells are generated. The mine can be developed to the pit 5 wall using two extreme approaches: the 'best case' or highest NPV sequence, and the 'worst case' or lowest NPV sequence.

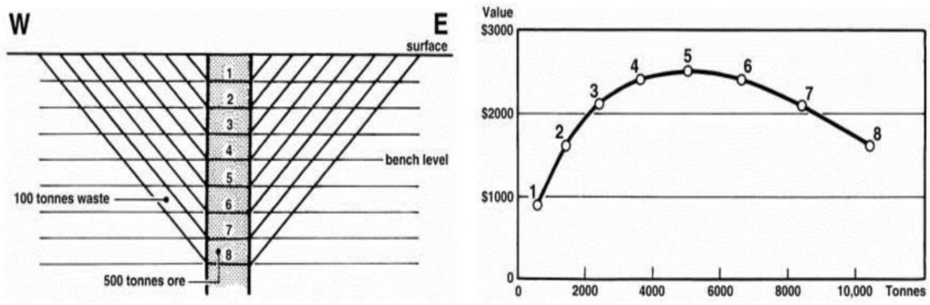

Figure 2 *Pushbacks and mine sequencing [15]*

The best case sequence requires mining of the nested pits sequentially. A schedule which seeks to balance ore and waste mining was developed for the pit shells in Figure 2, and discounting was applied to the block values. As indicated by the tones-value curve in Figure 2, pit five is the highest value pit given the assumed cost and price inputs.

In the optimization process of excavation dynamics, the simulation and Discounted Cash Flow Analysis (DCF) are performed in order to obtain the most favorable variant, i.e. determine the number of phases that affect maximization of the net present value in a long-term planning of the open pits. The analysis is based on the Milawa algorithm, which is specifically designed to optimize the excavation dynamics of the long-term exploitation planning strategy.

The Net Present Value is calculated by discounting the estimated annual cash flows at the present time using a discount rate, which represents the investment risk:

$$Net\ Present\ Value\ (NPV) = \sum_{t=0}^{N} \frac{Cash\ Flow\ (CF)}{(1+k)^t} \quad (1)$$

where:

k – discount rate

t – number of years

The significance of a correct selection of pushbacks in the planning of open pits is seen in the case of the open pit Veliki Krivelj where the copper ore is mined.

3 CASE STUDY

The copper deposit Veliki Krivelj, located about 3 km by the airline north of the town of Bor, has the primary role in the copper production of copper in the Mining Smelter Basin Bor Group (RTB Bor Group).

Considering that it is a deposit with a low mean metal content in the ore, which amounts to 0.318% in the total geological reserves, therefore the application of a modern software tool for strategic planning and optimization of the deposit Whittle dand software for construction of the open pit Gems is of exceptional importance for rational utilization of the deposit and achievement the maximum profit in exploitation.

The geological reserves of the copper deposit Veliki Krivelj are calculated using the method of mini blocks, dimensions 15 x 15 x 15 m. The basis for calculating the geological reserves is a digital block model of the deposit formed in the Gems software [16, 17]. The geostatistic method, used to estimate the metal content in the deposit modeling process is a method of real kriging.

Figure 3 shows a view of three-dimensional block model of Cu in the deposit Veliki Krivelj.

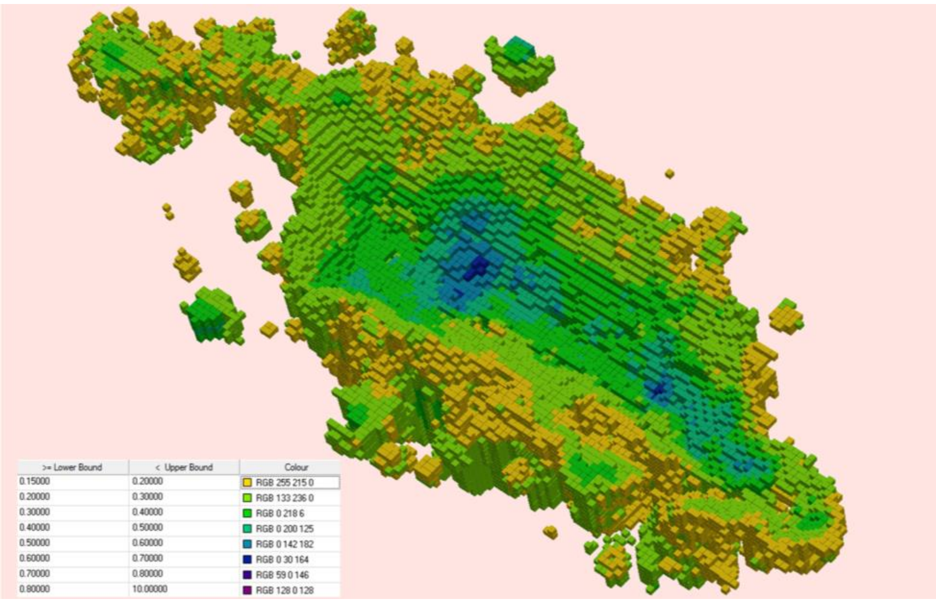

Figure 3 *View the 3D block model of the deposit Veliki Krivelj*

On the basis of defined block model of the deposit, the optimization of the final contour of the open pit in the Whittle software was performed. The obtained result was the Pit by pit graph (Figure 4), based on which the pushbacks were selected.

The 4 variants were considered in this work, which implied that the DCF analysis was done for each combination of selected pushbacks (Table 1).

Table 1 *Selected pushbacks for analyzed variants*

Variant	Selected pushbacks
1	9-14-17-19-22
2	9-12-15-20-22
3	10-12-15-19-22
4	10-13-16-19-22

The NPV for analyzed variants was obtained in the process of optimization the excavation dynamics.

4 RESULTS AND DISCUSSION

The results of conducted analysis are shown in the following graphs in Figures 4, 5 and 6.

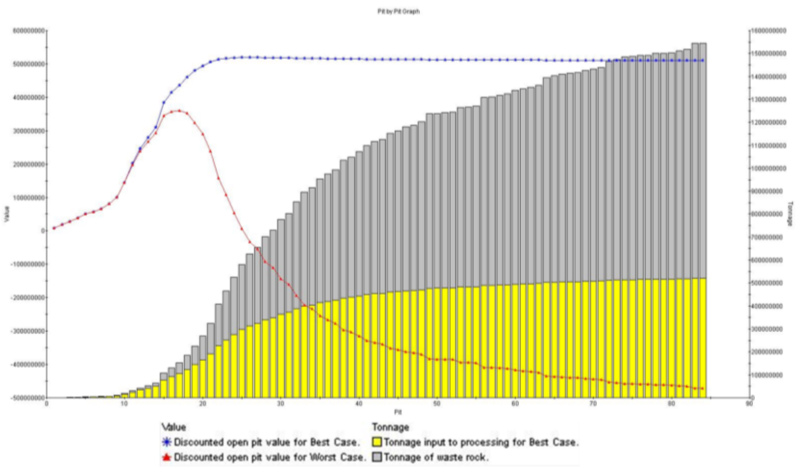

Figure 4 *Pit by pit graph*

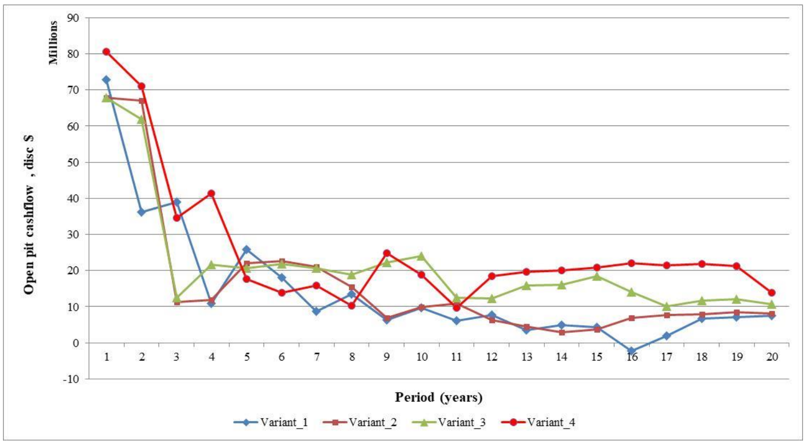

Figure 5 *Discounted cashflows for analyzed variants*

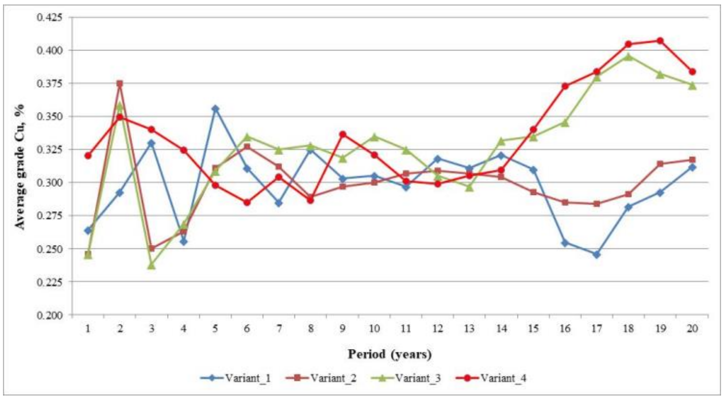

Figure 6 *Average grades for analyzed variants*

The following can be concluded from the shown graphs:

1) Cash flow for the analyzed Variant 4 in the initial years is considerably higher than the cash flows of the analyzed Variants 1, 2 and 3. The basic reason is that, in the analyzed variants 1, 2 and 3, the pushbacks are selected which are not optimal. Consequently, in the initial years of exploitation, larger quantities of waste are excavated than necessary, and thus the costs of exploitation are higher. Due to application the discount factor in calculating the maximum values of NPV according to analyzed variants, the results shown in Table 2 are obtained.
2) The higher average copper content in the ore in the initial years of exploitation is one of the most important factors leading to maximization the NPV value, which is the case for Variant 4.

Table 2 *Max. NPV values for analyzed variants*

	Variant_1	Variant_2	Variant_3	Variant_4
Open pit cashflow $ disc	356,653,607	369,341,333	429,523,617	498,575,975

CONCLUSION

Nowadays, several algorithms for optimization the open pits have been developed, which are incorporated into the modern software packages. Nevertheless, a successful long-term exploitation plan still depends on the knowledge and experience of a mining engineer. First of all, it means that an experienced mining engineer can form a rough image and idea of division into pushbacks if he first introduced well the basic geological characteristics of the exploitation reserves (structure, shape, quality assignment, amount of overburden in certain parts).

Also, a planner must be guided by a series of constraints, and above all that the overburden coefficient is within the acceptable limits for all pushbacks, and that the quality assignment according to pushbacks should be within acceptable frames, so that the qualitative conditions can be fulfilled at any time be fulfilled by the exploitation.

On the basis of conducted analysis on a real case - the open pit Veliki Krivelj - it is shown that the errors in selection of pushbacks can have the significant consequences on the business economy of the mining company.

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DETERMINING THE STRENGTH INDEX OF COAL FROM THE BROD – GNEOTINO DEPOSIT, BITOLA

Abstract

The Point Load Test (PLT) was performed in the geomechanical laboratory of of the MMI Bor, in order to determine the strength index of coal samples from the Brod - Gneotino, Bitola, Republic of Macedonia. On the basis of the obtained results, it is possible to predict the other parameters of the rock mass strength. This paper presents the values of the calculated uniaxial compression strength of coal.

Keywords: *Point Load Test, strength index, coal*

INTRODUCTION

The PLT test represents the fastest and cheapest way to determine the uniaxial compression strength of rocks, primarily in the field, but also in the laboratory conditions. It is possible to examine the samples of irregular shapes, as well as samples selected from the exploration drill holes. Test is carried out by an appropriate apparatus that performs a load on a rock sample, placed between the conical steel plates, until fracture appeared.

The tests were carried out on six coal samples from the core of exploratory drill holes from the site where the PLT tests were performed, according to ASTM D5731-08 standard.

TEST ANALYSIS AND RESULTS

For precise and efficient obtaining of the strength index, coal samples were previously processed and prepared for test on the PLT device (Figure 1). The axial and diametric tests were performed on samples, i.e. the tested strength was normal (⊥) and parallel (||) on a bedding.

After the test were performed, the uncorrected value of the strength index Is is calculated according to the formula:

$$I_s = P/D_e^2 \text{ (MPa)}$$

where:

P – breaking force [kPa]

D_e – equivalent diameter of core [mm]

$D_e^2 = D^2$ – for diametrical test [mm^2]

$D_e^2 = 4A/\pi$ – for axial test [mm^2]

After that, the corrected values of strength index for $I_{s(50)}$ were calculated, according to the formula:

$$I_{s(50)} = F \times I_s$$

where:

$F = (D_e/50)^{0.45}$ – correction factor

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Figure 1 *PLT device with prepared samples*

For the conversion factor of strength index in the uniaxial compressive strength, the value of

K= 21 ($\sigma_p = K \times I_{s(50)}$)

was taken, which represents a nominal value for this rock type.

Test results are presented in following tables and figures.

Table 1 *Values for index and UCS for sample 9/V_1 (85.20-86.55)*

N°	Test direction	I_s [MPa]	$I_{s(50)}$ [MPa]	σ_p [MPa]
1	⊥	0.235	0.239	5.023
2	⊥	0.152	0.156	3.277
3	⊥	0.493	0.497	10.445
4	⊥	0.414	0.406	8.535
5	||	0.112	0.141	2.970
6	||	0.122	0.154	3.23
7	||	0.108	0.136	2.864
average value ⊥			0.325	6.05
average value ||			0.143	3.02

Table 2 *Values for index and UCS for sample 9$_1$/V_1 (111.05-117.90)*

N°	Test direction	I_s [MPa]	$I_{s(50)}$ [MPa]	σ_p [MPa]
1	⊥	0.323	0.320	6.727
2	⊥	0.241	0.249	5.239
3	⊥	0.428	0.439	9.227
4	⊥	0.333	0.339	7.118
5	||	0.105	0.132	2.792
6	||	0.118	0.149	3.127
7	||	0.146	0.184	3.869
average value ⊥			0.370	7.070
average value ||			0.155	3.262

Table 3 *Values for index and UCS for sample 7_1/VI (64.60-67.00)*

N°	Test direction	I_s [MPa]	$I_{s(50)}$ [MPa]	σ_p [MPa]
1	⊥	0.459	0.483	9.725
2	⊥	0.327	0.313	6.592
3	⊥	0.517	0.512	10.789
4	⊥	0.740	0.753	15.816
5	⊥	0.537	0.527	11.072
6	||	0.255	0.321	6.758
7	||	0.208	0.262	5.512
average value ⊥			0.517	10.78
average value ||			0.262	6.135

Table 4 *Values for index and UCS for sample 7_1/VII (85.25-86.80)*

N°	Test direction	I_s [MPa]	$I_{s(50)}$ [MPa]	σ_p [MPa]
1	⊥	0.597	0.595	12.513
2	⊥	1.074	1.044	21.935
3	⊥	0.240	0.244	5.130
4	||	0.007	0.009	0.189
5	||	0.007	0.009	0.189
6	||	0.007	0.009	0.189
average value ⊥			0.627	13.19
average value ||			0.009	0.189

Table 5 *Values for index and UCS for sample 7_1/VII (94.60-96.20)*

N°	Test direction	I_s [MPa]	$I_{s(50)}$ [MPa]	σ_p [MPa]
1	⊥	0.297	0.304	6.40
2	⊥	0.624	0.618	12.985
3	⊥	0.448	0.446	9.576
4	||	0.014	0.017	0.353
5	||	0.010	0.012	0.265
6	||	0.012	0.015	0.318
average value ⊥			0.456	9.653
average value ||			0.014	0.312

Table 6 *Values for index and UCS for sample 8/VII_1 (55.50-58.25)*

N°	Test direction	I_s [MPa]	$I_{s(50)}$ [MPa]	σ_p [MPa]
1	⊥	0.693	0.625	13.13
2	⊥	1.042	0.021	21.44
3	⊥	0.829	0.895	18.80
4	||	0.007	0.009	0.189
5	||	0.007	0.009	0.189
6	||	0.007	0.009	0.189
average value ⊥			0.514	17.79
average value ||			0.009	0.189

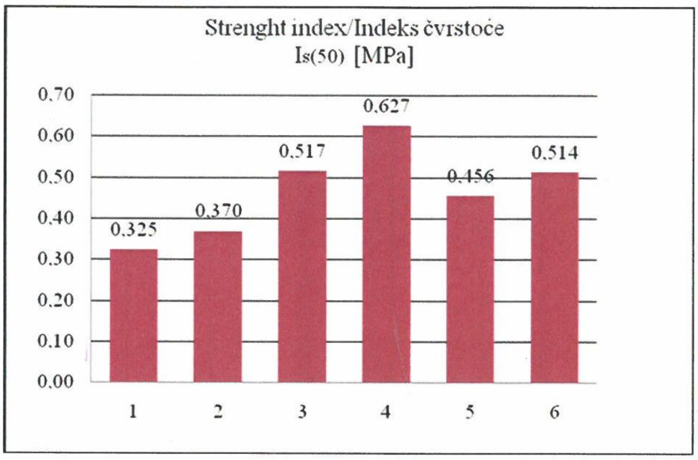

Figure 2 *Average values $I_{s(50)}$ of coal samples – tests were carried out normal on bedding*

The strength index of tested coal samples, ranges from $I_{s(50)}$ = 0.325-0.627 MPa, measured normally on a bedding, i.e. $I_{s(50)}$ = 0.009-0.155 MPa for measurements performed parallel to a bedding. The values of the obtained index strength of performed PLT and calculated value of the uniaxial compression strength for coal are mainly found in the range of previous laboratory results of testing the strength of coal in the area of this deposit showing that similar geomechanical parameters of the rock mass are obtained using a much cheaper method of determining. The results can be used in further assessment the parameters and classification the wall mass.

CONCLUSION

In the framework of geomechanical testing the coal samples from the Brod - Gneotino Bitola, determining the strength parameters using the PLT apparatus was carried out. The results of the obtained index strength are the values that can be used to estimate the intact strength of coal, as well as the other parameters for numerical geotechnical classification of the wall mass.

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METHODOLOGICAL PROCEDURE FOR SELECTION THE TYPE AND CONSTRUCTION OF SELF-PROPELLED HYDRAULIC SUPPORT FOR COAL EXCAVATION ON THE EXAMPLE OF THE COAL DEPOSIT "POLJANA"

Abstract

For the application of a wide forehead method, decisive is an assessment, respectively, selection of the type and construction of self-propelled hydraulic support, both for horizontal and vertical excavation concentrations. This is especially important in the excavation of coal seams whose immediate floor and roof are composed of clay sediment.

In the last decades, this theme has not been more fully explored in the coal mines in Serbia, and its processing has the character of original research, whose aim is, with the obtained research results, to contribute to the development of mining science.

The coal deposit "Poljana", with a comprehensive expert analysis, was assessed as promising for activation in the production sense, especially taking into account the certified reserves of quality coal and natural-geological conditions favorable for the use of mechanized wide forehead excavation systems.

It is particularly important that the research is related to concrete the working conditions, with a particular emphasis on the geo-mechanical aspect and its connection with selection the type and construction of the self-propelled hydraulic support.

***Keywords**: mine, coal, support, coal excavation, wide forehead, coal deposit*

1 INTRODUCTION

For the underground coal excavation in developed mining countries, in general, the methods of mechanized wide forehead excavation on the principle of horizontal or vertical concentration are applied, with a tendency of gradual to complete automation of the basic work operations.

In the entire production system of the pit, the basic and starting problem is the excavation, as the basic production unit, because other technological phases directly depend on it.

In essence, the methods of excavation of the coal seams are grouped according to their characteristic of the process of coal production into:

1. wide forehead excavation method;
2. chamber method of excavation;
3. pillar method of excavation.

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By the wide-forehead methods, the horizontal and slightly inclined seams of coal, small, medium and large thickness can be successfully excavated as well as the steep seams with special solutions. The defining condition for applying the wide-forehead method in a particular deposit is the rational length of the excavation field (belt).

By definition, a wide-forehead excavation, supported with the self-propelled hydraulic support and supplied with the receiing machine as well as equipment for loading and transportation of coal, is considered to be as the mechanized excavation.

The self-propelled hydraulic support is more expensive than a single support. It is a complex, mobile machine with mechanical, hydraulic, electrical and electronic elements, which in continuous operation must withstand the load of rock mass, not to break and deform, to provide the working space and ensure the accelerated coal excavation [1]. The efficiency of use the self-propelled hydraulic support and entire mechanized complex of wide-forehead excavation is dependent on the adaptability of structure to the natural-geological conditions of exploitation, that is, the excavation [2,3].

In the mines, the problem of securing and supporting the working area of excavation is extremely complex, so the area of underground coal excavation is determined for this research subject by the mechanized wide-foreheads, and f narrower area of the coal deposit "Poljana", in order to demonstrate the methodological procedure for selecting the type and construction of the self-propelled hydraulic supports as an integral part of the mechanized complex.

2 DESCRIPTION THE METHODOLOGY OF SELECTION THE TYPE AND CONSTRUCTION OF SELF - PROPELLED HYDRAULIC SUPPORT

The natural and geological conditions in the coal deposit decisively influence the selection of the excavation system (methods and technology) and its technical - technological, economic and safety parameters [4,5].

For the rational and efficient excavation of coal by the underground system, the conditions of the working environment, that is, the natural and geological conditions of the deposit must be studied in detail, and on the basis of the determined results, the excavation system and the associated mechanization shall be selected [6,7].

Since the natural-geological conditions cannot be directly influenced, the technical and technological conditions of the excavation process must be adaptive with them. Adequately to conditions, chosen excavation method and excavation technology, the best construction of the machines for obtaining and transport, the choice of type and ways of supporting and managing the roof, as well as the organization of work, represent a number of possibilities for improving the effects of the excavation [1,8,9].

The systematized natural-geological conditions that have a definite influence on the selection of the excavation system in specific coal deposits are shown in Table 1. [10].

Further consideration of the subject matter is continued by determining the ranking of influence the natural-geological conditions on the selection of the excavation system (Table 2) for specific conditions. [10].

Continuation of research in this topic is the definition of technological phases for the selected excavation system, through technical conditions (Table 3).

The self-propelled hydraulic support is a special type of equipment used to secure and support the working front of a wide-forehead, and it is functionally linked to the machine for coal obtaining and coal transport devices. In mining practice, there are several types of self-propelled hydraulic supports, as supporting (syllable), support-shield (syllable-shield) and shield. Supporting platforms are used in the supporting of a wide-forehead work area for larger roof ranges (over 4 m), while support-shield supports are designed to maintain a working space with a span of 3-4 m. Shield supports are designed to support the work space of a wide-forehead with a small span of immediate roof of 2-3,5 m. In relation to the possibility of supporting the workspace, depending on the type of roof, the support is selected according to the security parameters that characterize that sort and type of self-propelled hydraulic support. The selected self-propelled hydraulic support must satisfy, on the first place, the requirements related to the required load capacity, assessed by the interaction between the self-propelled hydraulic supports and massive [11].

In mining practice, there are several approaches for solving the problem of selection the required load capacity of self - propelled hydraulic support. According to the first approach, the type of support is selected, whose reaction will prevent excessive convergence, and, on the other hand, the other approach starts from the point of view of selection the type of self-propelled hydraulic support with the largest reaction, thus preventing separation of the seams in the forehead area. In this second approach, the specific pressure occurs as a limiting factor on both roof and floor, which must not exceed the hardness of immediate roof or floor [12].

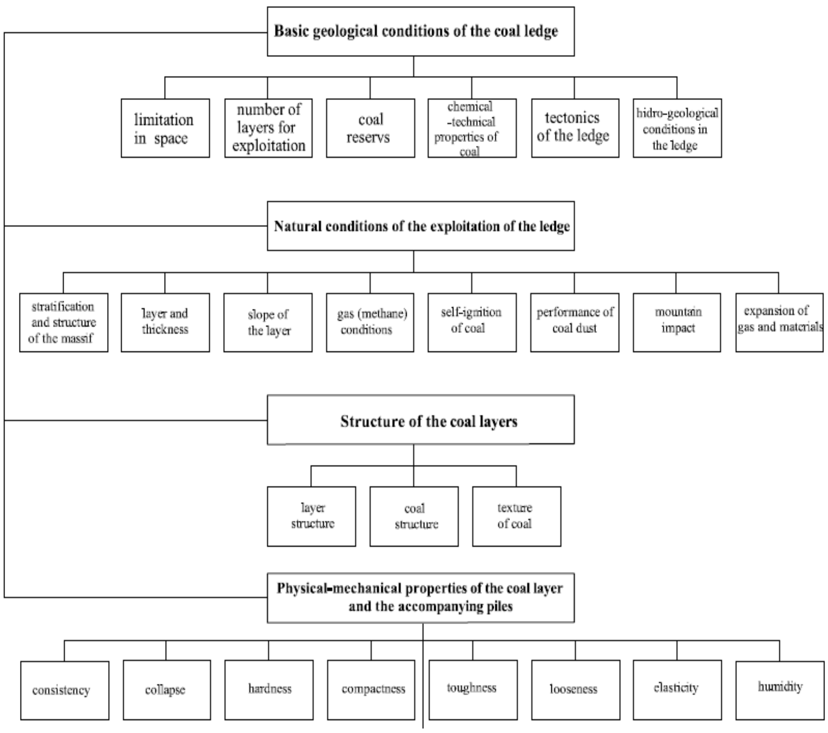

Table 1 *Systematization of THE natural-geological conditions influencing the selection of excavation system [10]*

Table 2 *Categorization - range impact of natural and geological conditions on selection the excavation systems [10]*

SYSTEM OF EXCAVATION		CATEGORY-RANK -affected by the natural and geological conditions			
		I CHOOSING	II ADDITIONAL	III LIMITED	IV EXCLUSIVE
The principle of concentration of face excavated	Horizontal conc.	1. thickness of seam up to 5 m	1. subsidence slope of seam	1. rock burst 2. gas explosion	
	The vertical conc.	1. thickness of seam over 5 m	1. subsidence slope of seam	1. propensity of coal to selfignition	1. thickness of seam less than 5 m
MINING METHOD	Longwall face (HK)	1. thickness of seam up to 5 m 2. rational length of mining field in direction of full dip	1. subsidence slope of seam 2 .physical-mechanical properties of seam and adjoining rock 3. changes in thickness of seam	1. high coal -seam methane content 2. size of coal reserves 3. physical and mechanical properties of immediate floor	1. irrational length of mining field in direction of full dip
	Longwall face (VK)	1. thickness of seam up to 5 m 2. rational length of mining field in direction of full dip	1 .subsidence slope of seam 2. physical-mechanical properties of seam and adjoining rock	1. abundant in water 2. propensity of coal to selfignition 3. high coal-seam methane content 4. size of coal reserves	1. irrational length of mining field in direction of full dip
	Chamber Method	1. thickness of seam over 5 m 2. strength and compactness of immediate roof	1. changes of slope and thickness of seam	1. subsidence slope of seam 2. high coal -seam methane content 3. density of coal to self-ignition	1. unfavorable strength and compactness of immediate roof
	Pillar Method	1. thickness of seam up to 5 m 2. rational length of mining field in direction of full dip	1. subsidence slope of seam 2. physical-mechanical properties of seam and adjoining rock	1. subsidence slope of seam 2. high coal -seam methane content 3. propensity of coal to selfignition 4. rock burst	
T EXCAVATION TECHNOLOGY	Blasting	1. physical and mechanical properties of coal seam	1. thickness of coal seam	1. properties of coal dust 2. coal-seam methane content 3. structure of coal seam	according to selected principle and mining method and decisive factors appropriate mining technologies are chosen (alternative combinations of two or more technologies)
	Undercutting	1. physical and mechanical properties of coal seam	1. thickness of coal seam	1. structure of coal seam	
	Ploughing	1. physical and mechanical properties of coal seam 2. thickness of coal seam	1. physical-mechanical properties of immediate floor	1. structure of coal seam	
	Cutting	1. physical and mechanical properties of coal seam	1. subsidence slope of seam 2. physical- mechanical properties of immediate floor	1. subsidence slope of seam over 25° 2. structure of coal seam	
	Hydro fracture	1. physical and mechanical properties of coal seam		1. pronounced tendency towards spontaneous combustion of coal	

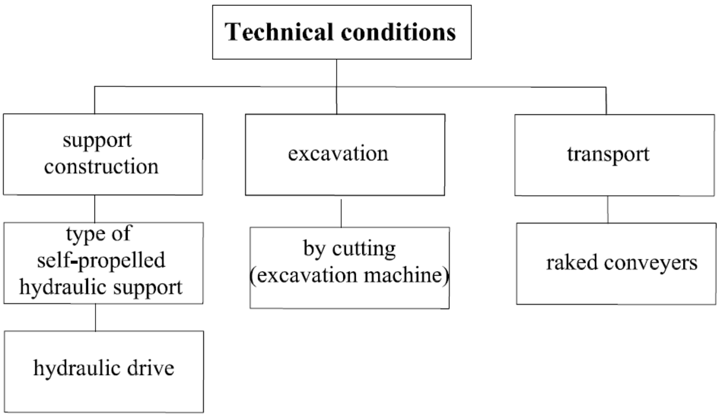

Table 3 *Technical conditions for selection the mechanized wide-forehead excavation system based on the principle of horizontal concentration*

3 DESCRIPTION THE NATURAL - GEOLOGICAL CONDITIONS IN THE COAL DEPOSIT “POLJANA”

The “Poljana” coal deposit belongs to the southern part of the Kostolac coal basin and it is located in a distance of 4 km from the city of Pozarevac giving it a well-appointed communication links with the consumers. The deposit extends on the relatively narrow belt of the Pozarevac Greda from Pozarevac to the village of Sljivovac in a length of 9 km, and spreads in a direction of the seam fall towards the northwest and sinks under the alluvial of the river Velika Morava. Till now, the maximum researched width of the deposit is 3 km, and the northern border is still open for research [13].

Productive series is represented by the clay-sandy sediments with two coal seams, the lower A which is exploitable and the upper B which has no economic value (unstable thickness, stratified with mullock and poorer quality) [13].

The thickness of the coal seam A is greatest in the central parts of the deposit and ranges between 4.5 m - 5.5 m, and the most is 7 m. It is lightly is grown from the south to the north, so the average (weighted) value of the coal seam thickness in various parts ranges from 4.5 m to 5.06 m. The coal seam has mostly a homogenous structure, rarely stratified with coal clay thickness of 0.2 m, less frequently up to 0.5 m [13].

Immediate underlying stratum of the main coal seam (A), for the most part, is composed of yellow and gray sands, which may be, to a lesser extent, clayey. Immediate roof via the inter-seam horizon of the seams A and B, is made of green and blue sandy clay and clay with coal seams and coal clay, or green and blue sand.

Investigations have found that the productive series with coal seams are slightly falling in the direction of the NNW at an angle of about 5º in general, locally and up to 10º, and yhe bigger inter-seams are not determined in the deposit range, so that the deposit is characterized by a lower tectonic or structural set without tectonic activities. The certified total coal reserves in the deposit are amounted to 62.1 million tons, out of which 58.9 tons are balanced. Based on the analyses of coal quality and ash analysis and related characteristics for coal combustion for coal of this deposit, it is confirmed that it represents a suitable fuel in the domain of energy raw materials and in a wide consumption. The average values of combustion heat are, for lower heat value 10.451 kJ/kg and upper heat value 11.960 kJ/kg [13].

According to the hydrogeological parameters, the inflow of water into cave rooms, taking into account the static and dynamic reserves, will amount to maximum of 1000 l/min. and that with open works up to 15 km long. All registered waters in the coal deposit "Poljana" are without pressure, i.e. t water is at a free level.

The coal deposit "Poljana" is non-methane at present; there will be no phenomenon of mountain impacts and eruptions, and the coal dust can exhibit hazardous properties under certain conditions, and coal is self-inflammable.

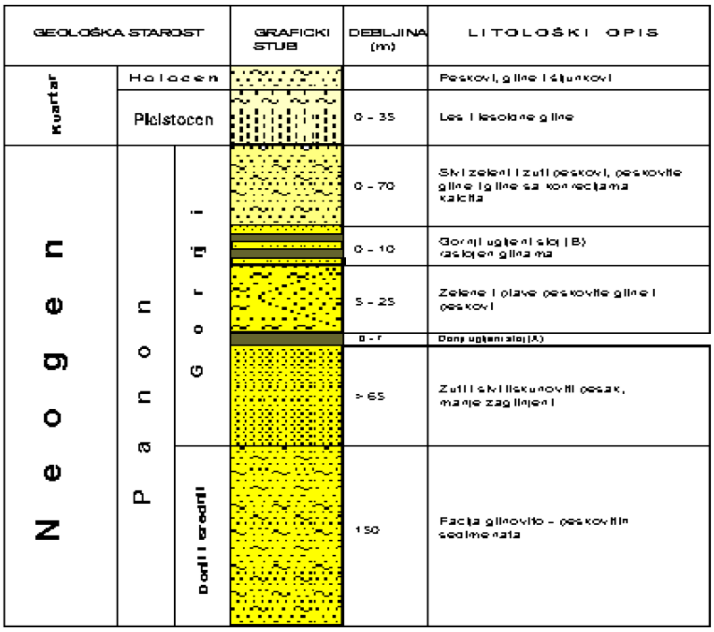

Figure 1 *Lithological-stratigraphic pillar of the coal deposit "Poljana" [13]*

4 ANALYSIS OF THE GEOMECHANICAL PARAMETERS

The subject of the study of geo-mechanical characteristics were the rocks of roof and floor of the coal seams as well as the coal seams themselves. Since the deposit is not mined open or active, the geo-mechanical characteristics are studied through the laboratory-acquired parameters on the physical and mechanical characteristics of these rocks. The laboratory tests were carried out on disturbed and undisturbed samples, depending on a degree of material coherence.

Tests of undisturbed samples of rock masses from the floor were used to determine the grain-size distribution, volumetric mass, water content, angle of internal friction, cohesion, Ateberg limit of consistency (flow limits, boundaries of plasticity, plasticity index and consistency index). The obtained values are shown in Tables 4 and 5 [13].

Table 4 *Results of testing the disturbed samples of the working environment from the coal deposit "Poljana"*

Type of rock	Parameter name and value							
	W (%)	γ (kg/m³)	φ (°)	C (daN/cm²)	Flow limit, (%)	Boundaries of plasticity, (%)	Plasticity index	Consistency index
Sand III	9.52	1,450	31°	0.0				
Sand III	20.52	-	30°57'	0.0				
Sand III	23.81	-	27°25'	0.0				
Clay I	15.04-23.72	1,810-2,070	11°30'-21°30'	2.2-5.0	42.58-93.00	17.13 -38.48	15.43-55.03	1.08 -1.63
Clay I/II	16.84-28.47	1,700-1,810	17°40'	0.6				
Clay II	25.53-31.06	1,840-1,900	13°	3.0-4.4	61.50	31.08	30.42	1.08
Sandy clay II	25.46	1,910	13°30'	2.5				
Loess	26.83-28.16	1,870-1,950	19°58'	1.1-2.5	56.50 -63.50	22.78 -23.65	33.72-39.85	0.84 -0.92

W-humidity; γ-volumetric mass; φ-angle of internal friction; C-Cohesion

Table 5 *Results of testing the undisturbed samples of the working environment from the coal deposit "Poljana"*

Drill hole/interval	Name and value of parameter							
	W (%)	γ_s (kg/m³)	γ_1 (kg/m³)	σ_c (daN/cm²)	σ_i (daN/cm²)	C (daN/cm²)	φ (°)	E (daN/cm²)
L-8 49.9-50.1	-	-	1,200	49.05	5.24	9.05	52°18'	-
La-939 90.0-98.0	79.19	1,880	1,390	28.40	3.50	5.57	49°58'	-
B-759								
76.25-76.65	76.08		1,230	79.61	9.08	15.10	51°15'	
77.80-78.20	64.12	-	1,340	41.15	3.13	7.40	53°15'	-
78.20-78.60	74.56	-	1,220	92.08	3.10	10.39	68°18'	-
Lg-899								
64.00-64.30	78.56	1,480	1,210	35.80	4.20	6.87	50°47'	1,250
58.10-58.35	76.00	1,570	1,230	35.10	3.10	5.97	55°18'	1,230
60.07-60.30	89.00	1,530	1,210	23.05	3.40	4.87	46°57'	1,175
La-939								
90.00-90.25	87.00	1,510	1,180	119.58	50.40	33.62	17°52'	2,240
92.60-92.90	91.57	1,740	1,260	82.57	30.60	23.44	23°45'	1,960
90.50-93.00	79.17	1,880	1,390	28.40	3.50	5.57	49°58'	1,140
Ka-889								
51.50-51.80	101.02	1,610	1,260	23.50	10.30	6.35	16°01'	1,100
54.70-54.90	81.48	1,650	1,270	30.46	4.16	6.24	48°15'	1,360
55.80-56.00	69.04	1,500	1,190	79.96	7.40	13.88	54°34'	1,790

W-humidity; γ_s-specific density; γ_1-volumetric mass; σ_c-compressive strength; σ_1-stretch strength; C-Cohesion; φ-angle of internal friction; E-modulus of elasticity

The lithological environments (Figure 1) that can be the subject of mining activity are by strength, mostly incoherent and loose environments in the roof of the main coal seam and partially coherent clayey working environment in the roof sediments. There are several classifications of the working environment [14,15,16,17]. According to M.M. Protodacon, based on the hardness, the rocks of the deposit "Poljana" belong to the category from VII-IX (Table 6).

Table 6 *Classification of the working environment according to the hardness in the coal deposit "Poljana"*

Rock type	Group of rock	Name of the	Hardness of the rock	Category	Coefficient (f)
Hard rocks	Sedimentary rocks	Coal	Very soft	VII-a	0,8
Connected (clay) rocks	Un-petrified compact walls	Sandy clay, clayey sand	Very soft	VII-a	0,8
Unconnected rocks	Loose, loess rocks	Loess, loess clay	Loose	IX	0,6
Unconnected rocks	Large-scale, non-cemented rocks	Gravel, sandy gravel	Loose	IX	0,5

Clays and partly sandy clays are located in a wide interval below the loess and loess clays, all the way to the A-horizon, and partly occur in the floor of A-horizon (the thickness is up to 0.6 m). Otherwise, in the roof as well as in the floor, they are replaced by sand and clay sand. They make many heterogeneous physical - mechanical characteristics that are conditioned by their composition, both mineralogical and granulometrical. The clays between A and B horizon have the weakest physical-mechanical characteristics, since their cohesion is the smallest (around 0.60 daN/cm^2), and the angle of internal friction is about 17°. The sandy clays and clays immediately in the floor and roof of A-horizon have the smallest resistance to shear because their internal friction angle is 13°, while cohesion is larger and ranges from 2.5 to 4.4 daN/cm^2. These clays are the most important because they are located next to the coal itself so that the underground rooms will often pass through such an environment that is prone to swelling.

Sand and partly clay sand extends over the entire interval of loess and loess clay in seams with clay and sandy clay to the floor of the A-horizon, and everywhere appearing in the floor of coal or along with thin seams of dark grey clay. No other tests were carried out since it was not possible to take the undisturbed samples by the exploration drilling, except determination the grain-size distribution in the laboratory. Based on the experience data, the following values, volumetric mass and angles of internal friction can be adopted: γ = 1800 to 1900 kg/m^3; φ = 30-40°, while cohesion for pure sand is c = 0, and it increases to 0.5 daN/cm^2 for clay sand. These sands are dry and anhydrous in the conditions of the coal deposit "Poljana", which was ascertained by the exploration drilling. They are suitable as an environment for mining works, provided that support is done immediately after excavation. Stability of walls of underground rooms is higher in clay sand than in sand [18,19]. Based on the penetration experiments, carried out in drills, the permitted loading of the floor sands is about 5 daN/cm^2. Problems will arise in load transferring from the roof seams to the floor of underground rooms, because the carrying capacity of these sands is not sufficient, so the protective coal boards will have to be left in the floor of the mining rooms and facilities.

Coal, i.e. coal seam, is mostly homogeneous in its lithological composition; it is less abrupt with coal clay, but it is cut by cracks and fissures that extend approximately parallel to a direction of providing the coal seam with a sub-verticular decline. The crack size varies from 0 to 2 mm. Coatings of a fine crystalline pyrite were observed on the walls of cracks. Coal is a wooden structured and brittle. Being in the air, coal quickly dries up and becomes friable and breaks into smaller pieces. Based on described natural conditions, which, in this stage of research, are proved in the coal deposit "Poljana", it is possible to predict the method of development and potential coal exploitation in this deposit.

5. METHODOLOGICAL PROCEDURE OF SELECTION THE TYPE AND CONSTRUCTION THE SELF-PROPELLED HYDRAULIC SUPPORT

Based on the analysis of geo-mechanical parameters, it is concluded that one of the modern methods of excavation of the wide-forehead type can be used in the deposit.

Selection of the method was, to a considerable extent, influenced by the following reasons:

- Adverse thickness of 0-6 m (4.7 m) of coal seam eliminates the effective application of mechanized wide-forehead with vertical excavation concentration;
- Application of the vertical excavation concentration would not give the designed effects due to the small thickness of coal in the upper coal seam because it would much faster aloud penetration of the mullock as a specific heavier material than coal. According to the known deposit and experience, this would significantly, if not completely, impair the efficiency of the system [20,21,22];
- Blending of coal with the mullock in the process of vertical excavation concentration would require the separation (cleaning) of the raw coal, or otherwise the quality of commercial product would be permanently and significantly reduced. In the case of using the coal cleaning, there would be significant increases in the total production costs.

With a high degree of accuracy, it can be established that, in the conditions of the coal deposit "Poljana", the horizontal concentration system of the excavation will bring a higher percentage of utilization of the affected coal reserves than the vertical concentration. The following relation also shows this:

- Horizontal concentration:
  4.2: 4.7 = 89.4% (due to leaving the plate of coal);
- Vertical concentration:
  89.4% × (2.5 + (0.6 × 1.7)) = 66.9%, or without leaving a plate of coal
  (2.5 + (0.6 × 2.2)) = 81.2%.

The vertical excavation system significantly increases the potential risk of endogenous cave fires. Especially when considering the relative proximity of the terrain surface (the average depth of the coal seam is 86 m), with which the excavation could, via cracks and fissures, establish the communication of air.

In excavation by the horizontal concentration system, the terrain surface is evenly shrugging and causes minor damage to the surface of the terrain.

By detailed analysis, the impacts of natural geological conditions in a particular deposit can be concluded that the use of a mechanized wide-forehead method of excavation by the principle of horizontal concentration, by the technology of obtaining by cutting, is rational.

In the concrete case of the coal deposit "Poljana", based on the analysis, it was concluded that the self-propelled hydraulic support must satisfy the following construc-tive conditions:

1. It is necessary to achieve a complete protection of the working space while ensuring the necessary working confrontation;
2. To transmit as little pressure on the floor as possible, which depends of the surface area of the support and system and direction of transmission the pressure force from the roof;
3. To have a complete functionality and compliance with the excavation machine and coal transportation transporter;
4. The total resistance of dynamic support elements without mechanical gearbox should not be less than 3,200 kN per section of the self-propelled hydraulic support;
5. The hydraulic cylinder on the shielded timber (board) shall be capable of withstanding a mechanical part of at least 150 kN;
6. To have an automatic elastic indulgence of the support in the event of increased load on support;
7. It should provide the hydraulic range of adjustment of digging height from 2.0 m to 4.5 m;
8. Tensile force of the self-propelled hydraulic support should be at least 2,400 kN per section;
9. To have cylinders for withdrawal of section and suppressing the frontal transporter with a power of 450 kN or 250 kN per cylinder;
10. The step of moving the sections should be max. 800 mm per one move.

Taking into account these requirements and geo-mechanical, i.e. physical - mechanical properties of the working environment, and which should be taken with the reserve until the new targeted tests are carried out, the type of shield support has been chosen. This type of self-propelled hydraulic support, even at the most disadvantageous position of the support, transmits the most direct and minimum pressure on the excavation floor and adapts well to the vertical, horizontal and eccentric loads on the support; it well protects the working area of the forehead and provides the mechanization for all working operations and functional accommodation, and connection with the other equipment on a wide-forehead, also providing the conditions of work comfort.

Based on the presented, methodological procedure of selection the type and selection the self-propelled hydraulic support, applied to the mechanized wide-forehead excavation, based on the principle of horizontal concentration, consists of the following phases (Table 7).

Table 7 *Methodological procedure of the self-propelled hydraulic support type*

1. Systematization of the available data of natural-geological conditions for concrete deposit, with an assessment the need for additional research.
↓
2. Selection of parameters (methods and technologies) of excavation system with mechanized wide-forehead with definition the necessary equipment.
↓
3. Systematization of technical conditions for equipment of a particular excavation system.
↓
4. A detailed analysis of the physical and mechanical properties of coal and asso-ciated rocks, selection the self-propelled hydraulic support type, consideration the joint action of rock massif and self-propelled hydraulic support with calculations of the strain in the floor and roof, and defining the requirements for structural characteristics.

CONCLUSION

This work processes the methodological procedure of selection the type and construction of self-propelled hydraulic support on a mechanized wide-forehead excavation, based on the principle of horizontal concentration for specific conditions. Based on the defined procedure, the same methodology can be applied to the other coal deposits in which the mentioned method of excavation is applied.

A further step, that is the continuation of research, is a new dedicated investigation of the physical and mechanical properties of coal seams and accompanying sediments in the geo-mechanics laboratory in order to build, based on the obtained results, the construction requirements for self-propelled hydraulic support and make an adequate selection from a wide range of various manufacturers.

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SELECTION OF THE MOST FAVORABLE VARIANT FOR OVERTOP THE ASH AND SLAG LANDFILL "MALJEVAC" - PLJEVLJA TO THE PEAK ELEVATION K + 832 m[**]

Abstract

The existing landfill at the site "Maljevac" is still active and it should provide the additional space for ash and slag disposal and continue the exploitation period as long as possible. For these purposes, in the licensed GEMS and Minex software, the variant solutions of the dump overtop to the peak elevation K + 832 m were developed in the licensed GEMS and Minex software to see the all possibilities of the "Maljevac" site. Out of the four offered variant solutions, an optimal variant was selected giving the largest disposal space and the least unit costs of exploitation.

Keywords: *ash and slag landfill "Maljevac" - Pljevlja, construction, GEMS and Minex software, variant solutions*

INTRODUCTION

In order to provide the sufficient space ash and slag disposal from the Pljevlja Thermal Power Plant Pljevlja as a by product, in 1982 a dam "Maljevac" was built in the Paleški stream, at a distance of about 7 km from Pljevlja. The ash and slag landfill for the Thermal Power Plant Pljevlja was formed by the construction of the "Maljevac" earth dam. In the first phase, a basic dam was constructed, with a dam crest of 790.5 m (27.5 m high), and in the second phase, the dykes - stairs were successively constructed to the peak elevation of 813.2 m. Further overtop of the embankment which limits downstream the cassette I to the peak elevation K+826 m. The space of the active cassette II is an oblique dyke of an approximate height of about K+832 m, which represents the final angle of ash and slag disposal at the Maljevac landfill in all analyzed variants.

The transport system of slag and ash from the thermal power plant is solved hydraulically, wherein the mixture of water and ash through the pipeline leading to the landfill where ash is deposited. Through the overflow structure, water is taken from the surface of landfill, i.e. the horizontal precipitation channel, gravitationally drains to the excavator digger, and in this way forms a closed recirculation system of technological water at the landfill. Below the landfill, there is a reinforced concrete collector, wall thickness of 60 cm, and through it the water of the Paleški stream are led. The collector consists of the main and secondary one. The

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length of the main collector, after extension, during implementation of the project of stabilization the dam "Maljevac", is 1460 m, and the secondary one is 600 m.

During 2014, stabilization of the dam "Maljevac" was carried out by construction a stabilizing ballast. The works have provided the given conditions of static and dynamic stability. The existing landfill at the site "Maljevac" is still active and it needs to cover the disposal of ash and slag from the TPP until the beginning of opening the landfill on a new location.

CONSTRUCTION OF THE OVERTOP

The overtop of the ash and slag landfill "Maljevac" is projected to the peak elevation K+832 m. In the construction of new cassettes, in order to prevent the pollution of the Paleski stream, a watertight clay layer of 1.0 m thickness is placed on the bottom. The filling is done in all cassettes up to the peak elevation K+832 m, after which, there are closure and recycling of the landfill in accordance with the applicable regulations. A waterproof layer is placed up to the peak elevation K+833 m, and a reclamation layer is placed up to the peak elevation of K+834 m.

In the Maljevac landfill, the ash and slag from the thermal power plant are deposited in the currently active cassette II at the Maljevac landfill. The dyke of cassette II has already has been built up to the peak elevation K+832 m in some places, while in some places the height of dyke is around K+830 m. The overtop of the cassette II practically represents a correction of dyke up to the peak elevation K+832 m in the places where it has not been reached, so that the newly formed dyke has a 6 m wide crest at the peak elevation K+832 m, with an inclination of inside and outside slopes of 1:2. Upon completion of the works on correction the peripheral embankment, the ash and slag disposal will continue to the peak elevation K+832 m.

The cassette III overtop was done for three possible cases [1].

The first case: overtop of the cassette III covers the space up to the existing path around the cassette III. Along the access road around the cassette III, a circum ferential embankment of 5 m waterproof material will be made, the width of the dike crest will be 6 m and the slope of the inner and outer slopes of 1:2. Correction of the existing dyke towards the cassette I will also be done in the places where it is needed. Geometric elements for the overtop according to this variant are: general angle of the overtop slope 1:3; floor height 5 m; angle of floor slope 1:2; width of the final floor level is 5 m.

The second case: overtop the cassette III covers the space up to the peak elevation K+832 m. Before the cassette III overtop, a circumferential embankment will be made in the northern and southern part of the cassette III, and corrections of the existing dyke to the cassette I, so that the newly formed dyke has a 6 m wide crest at the peak elevation K+832 m, with an inclination of inside and outside slope of 1:2 for the southern dyke, while the northern dyke will have the same inner slope, but due to the stability, the inclination of the outer slope will be 1:2.5. The new cassette IV on the west side of the landfill is added, with the formation of one dyke with the same geometry.

The third case: overtop the cassette III covers the space up to the peak elevation K+832 m, together with the space of the new IV cassette, without the construction of a central dyke. Before the cassette III overtop, the circumferential embankment in the northern part of the cassette III will be made, corrections of the existing dyke towards the cassette I will be made, and the peripheral dyke will be constructed in the southeastern part of the space, so that the newly formed embankment has a 6 m wide crest at the peak elevation K+832 m, with an inclination of the internal and external slopes of 1:2. Upon completion of the works on the construction and correction of the peripheral embankment, the ash and slag disposal is made to the peak elevation K+832 m. The northern dyke that connects the cassette I dyke and the paleorelief will have an internal slope of 1:2, while the external will be 1:2.5.

The new cassette IV on the west side of the landfill is added, with the formation of one dyke. Also, this cassette is filled up to the peak elevation K+832 m. Geometric elements are the same as for other dyke. Upon completion of the works on the construction and correction of the peripheral embankment, the ash and slag disposal is made to the peak elevation K+832 m.

The cassette I overtop will be realized when the favorable conditions for its construction are achieved, i.e. when sufficient dynamic stability of the main dam is achieved. In the first phase, its surface is covered with a waterproof material of 1 m thickness, in order to prevent further infiltration of atmospheric and technological water from the surface of landfill to the lower parts of the landfill, which is aimed to reduce the influence of groundwater on the cassette stability as well as the pollution of the Paleški stream. Then, all necessary measures are implemented in order to achieve a satisfactory stability coefficient in the case of a peak elevation up to K+832 m. If the required stability is achieved, the cassette I is extended to the peak elevation K+832 m with formation the circumferential embankment of the same characteristics as for the other cassettes and space filling with ash. In the event that the required stability is not achieved, the closure is reached, i.e., rehabilitation of the cassette I [1].

Construction of the ash and slag dumps of the Maljevac Thermal Power Plant Pljevlja to the K + 832 m was done in the licensed software Gemcom, and calculation the quantities in the licensed Minex software [4 - 9].

VARIANT SOLUTIONS OF THE OVERTOP

By development the variant solutions of the overtop of the existing landfill Maljevac, it was possible to consider the possible variants of ash and slag disposal of the Thermal Power Plant Pljevlja in order to find an optimal variant for the continued use of the landfill in the next period.

The considered variant solutions take into account all restrictions that directly affect the realization of the expansion and elevation the existing landfill, such as: Urbanistic technical conditions, Detailed spatial plan, relocation of the existing transmission line, land expropriation, stability of the existing dam and assessment the stability of designed overtop to the peak elevation K+832 m, as well as the condition of the existing collector for deviation of the Paleški stream under the landfill body. In addition to these factual constraints, the legal constraints must also be taken into account which strictly define the way of forming the new cassettes, drainage of leachate and atmospheric water and way of closure - rehabilitation of the landfill, i.e. all restrictions that reduce the negative impacts of landfill on the environment [2, 3, 10].

Based on the construction of cassettes of the Maljevac landfill, it is possible to provide several variant solutions for the overtop. The following variants of the landfill overtop were analyzed according to the construction phases:

1. Variant 1: cassette II – cassette III to a road
2. +– cassette I;
3. Variant 2: cassette II – cassette III to isohypse K+832 m – cassette I

4. Variant 3: cassette II – cassette III to isohypse K+832 m – cassette IV – cassette I
5. Variant 4: cassette II – unique cassette III and IV to isohypse K+832 m – cassette I

Figures 1 - 4 show the 3D model [4 - 9] of the final contours of the landfill for all 4 variants. Comparative calculation of the amount of deposited material and service life of exploitation according to the variant solutions is shown in Table 1.

Table 1 *Comparative overview of disposal capacities at the landfill for the variant solutions*

CASSETTE	Variant 1	Variant 2	Variant 3	Variant 4
II (m^3)	453,483.00	453,483.00	453,483.00	453,483.00
III (m^3)	136,782.00	2,532,031.00	2,532,031.00	4,995,721.00
IV (m^3)			2,463,358.00	
I (m^3)	906,797.00	908,475.00	906,797.00	906,797.00
Total ash, (m^3)	2,728,103.00	3,893,989.00	6,355,669.00	6,356,001.00
Service life, (years)	4.5	6.4	10.5	10.5

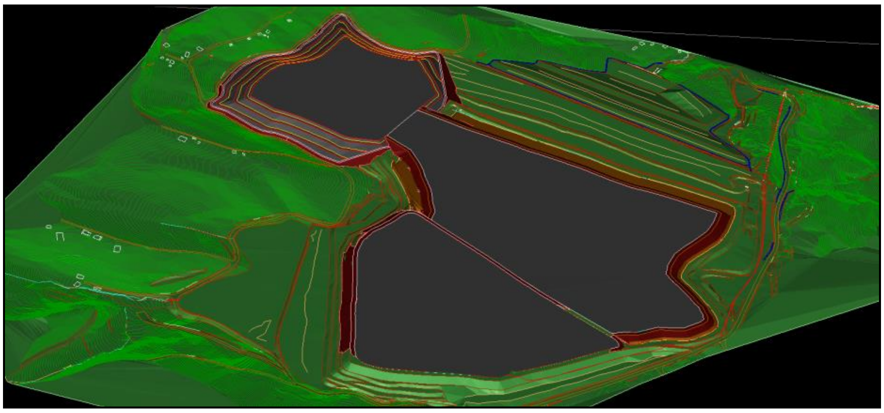

Figure 1 *3D model of the final landfill view by the Variant 1*

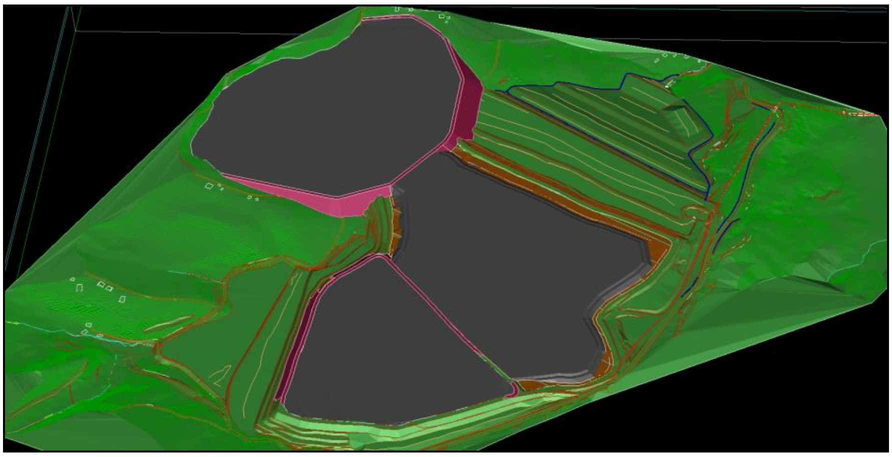

Figure 2 *3D model of the final landfill view by the Variant 2*

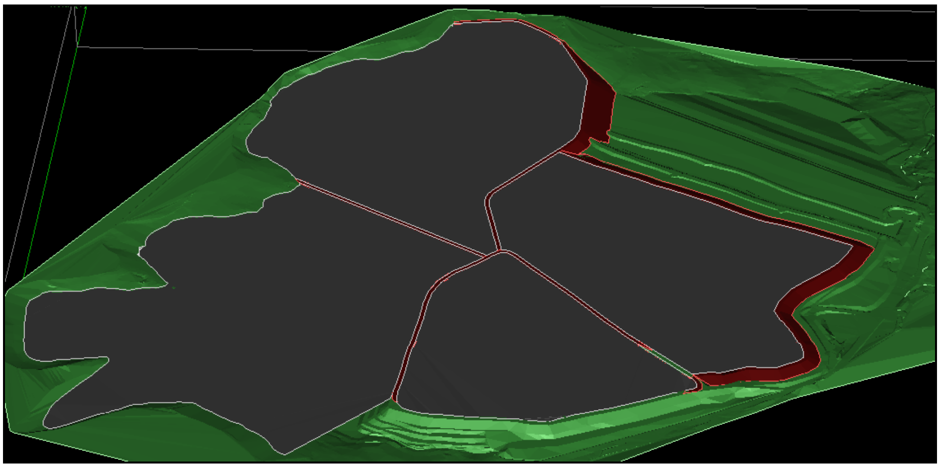

Figure 3 *3D model of the final landfill view by the Variant 3*

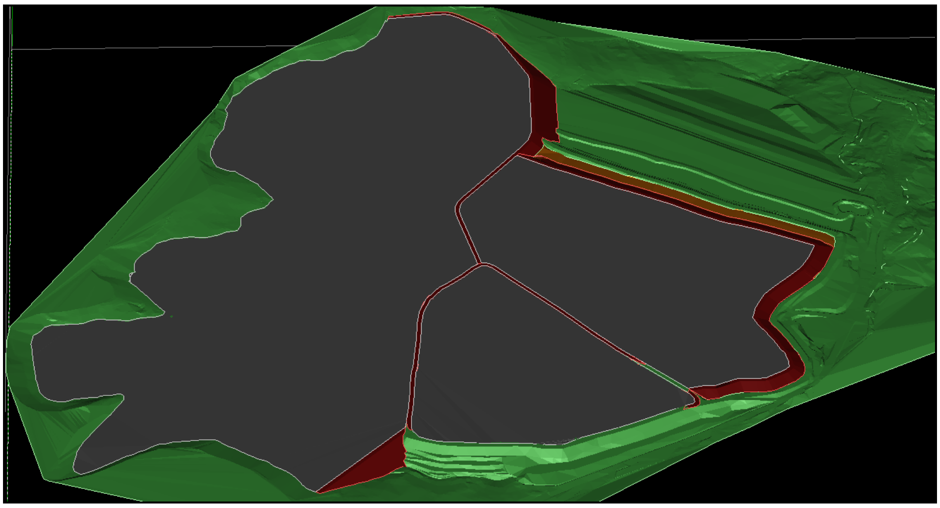

Figure 4 *3D model of the final landfill view by the Variant 4*

SELECTION OF THE MOST FAVORABLE VARIANT FOR OVERTOP

In selection the most favorable variant solution for overtop of the landfill, the all limitations, specified in the previous chapter, have been taken into account, and the main selection criteria are the unit costs of disposal and service life of exploitation at the landfill. Table 2 gives a comparative overview of these criteria.

Table 2 *Comparative overview of the unit costs of disposal at the landfill for the variant solutions*

Cassette	Variant 1	Variant 2	Variant 3	Variant 4
Service life, (years)	4.5	6.4	10.5	10.5
Investments per cubic of deposited ash, (€/m^3)	1.86	1.98	1.66	1.59
Investments per cubic of deposited ash for expropriation, (€/m^3)	0.92	1.05	0.98	0.98
Investments per cubic of deposited ash for reclamation, (€/m^3)	1.24	1.21	1.05	1.05
Total investments per cubic of deposited ash, (€/m^3)	4.02	4.24	3.69	3.62

On the basis of the all applied technical, economic, social and environmental considerations of selected variant, and adhering to the basic criteria of evaluation, ie. providing as much as possible volume of the ash disposal area, with achievement of as long as possible the period of exploitation of the landfill, and as little as possible the unit costs of exploitation, and in accordance with the given Urbanistic technical conditions, the Variant 4 was selected as the final technical solution for the landfill overtop.

The selected variant has the unit operating costs of 3.62 €/m^3 of deposited ash and slag, and a space of 6,356,000 m^3 is provided which ensures the service life of the landfill for a total of 10.5 years, taking into account the all necessary ecological standards.

CONCLUSION

By development the variant solutions of the overtop of the existing landfill Maljevac, it was possible to consider the possible variants of ash and slag disposal of the Thermal Power Plant Pljevlja in order to find an optimal variant for the continued use of the landfill in the next period. The considered variant solutions take into account all restrictions that directly affect the realization of the expansion and elevation the existing landfill. In addition to these constraints, the legal constraints were also taken into consideration which strictly define the way of forming the new cassettes, drainage of leachate and atmospheric water and way of closure - rehabilitation of the landfill.

The use of cassette I for ash disposal would be as the next logical phase of ash disposal in the present disposal conditions, after the completion of exploitation the cassette II, as its height is about K+825 m. However, the stability calculation for the cassette I to the peak elevation K+832 m does not provide a sufficient stability coefficient, due to the saturation of landfill body with water in the zone upstream from the primary dam, and collector zone of the Paleški potok, therefore it was decided that this cassette would be the last stage of overtop - in all variants. This data has affected that some of the planned variants are immediately eliminated.

Four variants of the landfill overtop were considered using the modern software for mining design, which is now the standard in this field. For each variant, its configuration in space, the method of cassette formation, volume of ash and slag storage space, method of closure and rehabilitation, drainage of leachate and atmospheric water were given. As a result, the evaluation of unit costs of the landfill exploitation per m^3 of deposited material was obtained, and the most favorable variant for the continuation of disposal at the site "Maljevac" was selected.

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Srđana Magdalinović, Ivana Jovanović*, Dragan Milanović*, Slađana Krstić**

THE EFFECT OF SMELTING AND GRANULATION ON SOME PROPERTIES OF SMELTER SLAG**

Abstract

The technogenic copper deposit of slag Depo 1 is located in the industrial district of the Smelter and Refineries of RTB Bor. Exploitation reserves are 9 190 940 t of slag with the average copper content of 0.715%. Sample of this deposit was melted in a furnace and then cooled with a jet of water when it was poured into a thin jet, whereby the small - granulated pieces were formed. Comparison of some properties of this sample was done with the sample in the form in which it was deposited in the deposit. This paper presents the chemical analysis, SEM - EDS analysis, Bond working index in a rod and ball mill, grinding kinetics and experiments of flotation concentration of copper depending on the grinding fineness in the range of 60 - 95% -0.075 mm.

Keywords: *slag, granulation, properties*

INTRODUCTION

A large amount of slag, formed in the processing of copper concentrate, is an ecological problem because it takes up the space for disposal. In the literature [1], it is stated that 2.2 t of slag are formed for each ton of the obtained copper, and it is estimated that around 24.6 million tons are produced annually in the world. In the past, this slag was seen as a waste, but today there are the great possibilities for its use.

Depending on the properties, the slag can be recycled, i.e. copper can be flotated again from the slag, because the copper content in the slag is higher than in the ore that are now exploited. Also, the slag can be used for making cement as an aggregate for making asphalt road covers and concrete because it has the excellent physical characterristics. It is also used as an abrasive material for the machine processing of objects. Further use of slag depends on its characteristics. Some of them can be influenced by the cooling method.

The deposit of slag Depo 1 is a technogenic deposit located within the Mining Smelting Basin Bor, Serbia. It was formed from a flame furnace slag resulting from the copper concentrate melting. On the site, this material in a melting state was poured out of the containers for transport. It was cooled, so it was poured and formed a relatively solid mass of semi-crystalline structure. The upper limit of the slag size class is 150 mm.

On the basis of qualitative mineralogical analysis, the following mineral composition of slag was determined: solid sulfide solution (Cu-Fe), chalcosine, pyrite, copper, cuprite, magnetite and waste minerals. Non-

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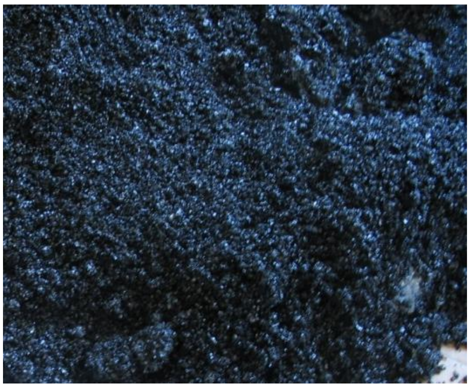
metallic minerals (waste) are represented by glass with the appearance of various eutectic dendrites (fayalite et al.). The most prevalent ore mineral is the sulphide phase "solid sulfide solution Cu-Fe" [2].

EXPERIMENTAL PART

For the purposes of testing, a slag sample was taken from the slag deposit Depo 1 from the technological process of slag processing in the Flotation Plant Bor after crushing to the upper size class limit of 20 mm. One part of the sample was melted in furnace and then cooled with a jet of water when it was poured into a thin jet, whereby small – granulated pieces of amorphous glass structure of the upper size class limit of 6 mm were formed. Comparison of some properties of this sample was done with the sample in a form in which it was deposited in the deposit.

Figure 1 present a view of sample before and after melting and cooling.

a)



b)

Figure 1 *Sample of slag before melting (a) Sample of slag after cooling (b)*

Figure 2 presents a photo of granulated slag taken with binocular with a magnification of 20 times.

Figure 2 *Photo of sample of granulated slag taken with a binocular with a magnification of 20 times*

Figure 2 shows the amorphous glass structure of the pieces. It is also noticed that many pieces have a proper spherical appearance.

Table 1 presents the chemical analysis of two slag samples that are differently cooled.

Table 1 *Chemical analysis of sample*

Element, compound	Slag	Granulated slag
Cu, %	0.68	1.05
Fe_3O_4, %	1.754	0.092
CaO, %	17.26	15.50
S, %	1.07	0.56
Fe, %	25.69	26.25
FeO, %	26.75	28.65
SiO_2, %	43.76	36.28
Al_2O_3, %	3.89	12.67

Differences in chemical analysis are not the result of the cooling method of slag, but are primarily the result of furnace operation mode. Melting was carried out in a Birlec electric arc furnace. When pouring the material from the furnace, a certain amount of material of higher density that cannot be discharged is retained at the bottom, thus there are differences in the chemical composition between two tested samples.

The mineral composition [3] is determined on the slag sample: fayalite, ferrite with sprayed pyrite, chalcopyrite, chalcocite, bornite, cuprite, magnetite, copper matee and native copper. copper are pierced.

The following mineral composition was determined on the granulated slag sample [5]: Mainly fayalite and ferrite, on which basis the fine grains of magnetite, pyrite, chalcopyrite, chalcocite, bornite, copper matte and native copper are sprayed.

A photo of the taken starting sample by a scanning electron microscope is shown in Figure 3.

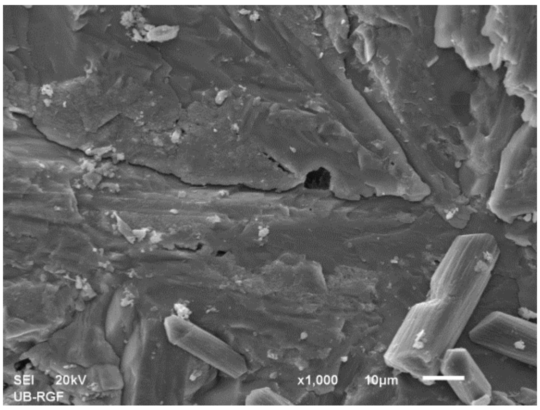


Figure 3 *Structure of slag sample*

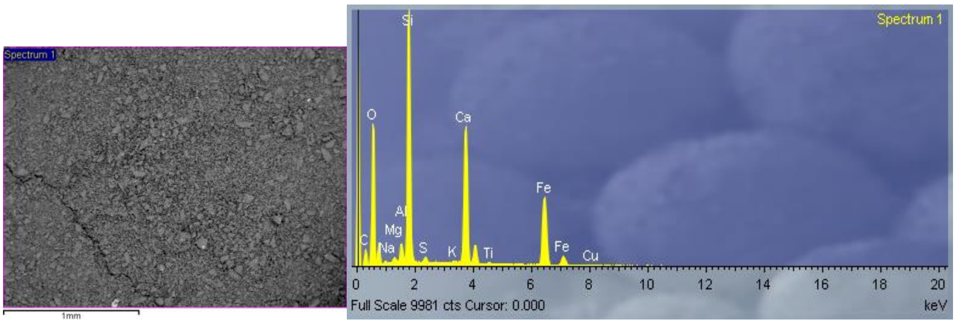


Figure 4 *Slag*

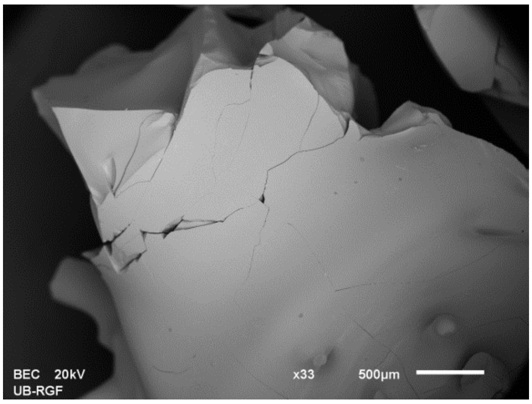


Figure 5 *Structure of granulated slag sample*

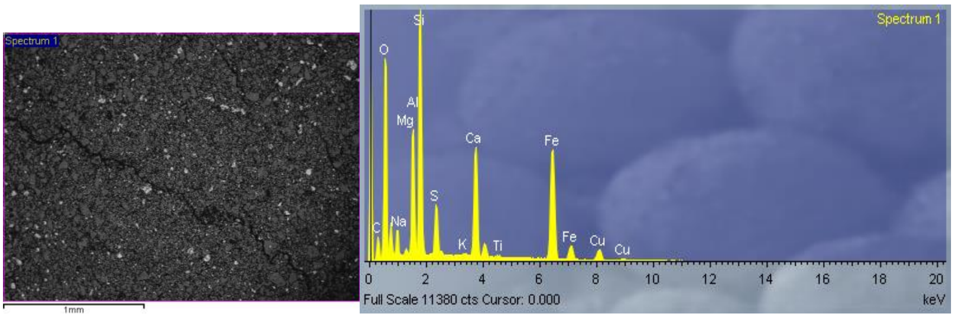


Figure 6 *Granulated slag*

Table 2 presents the slag density, natural pH value, bulk density for two size classes and the Bond working index in the rod and ball mill.

Table 2 *Some characteristic sizes of slag samples*

Size	Slag	Granulated slag
Density	3410 kg/m^3	3230 kg/m^3
Natural pH	6.58	7.83
Bulk density at size class -12.7 mm	2.090 t/m^3	1.578 t/m^3
Bulk density at size class -3.35 mm	1.969 t/m^3	1.544 t/m^3
Bond's working index in a rod mill	22.2 kWh/t	29.41 kWh/t
Bond's working index in a ball mill	15.22 kWh/t	19.84 kWh/t
Upper size class limit of pieces after cooling	150 mm	6 mm

SPECIFIC CONSUMPTION OF COMMINUTION ENERGY

In the processes of mineral processing, about 70% of energy is spent on crushing and grinding and depending on the raw material it can be up to 20 – 60 kWh/t [5].

In the mineral processing, the methodology of estimation the energy consumption on comminution, developed by F.C. Bond [6], is based on the studying the real processes of comminution. Bond also developed a laboratory methodology for calculation the Wi coefficient (the Bond working index) used in calculation the required energy for comminution of the mineral raw material by the equation:

$$W = Wi \cdot \left(\frac{10}{\sqrt{P}} - \frac{10}{\sqrt{F}}\right), \text{ kWh/t}$$

where:

W – specific energy consumption, kWh/t
Wi – Bond's working index, kWh/t.

According to the definition [6], Bond's working index is the energy that is required for one short ton of an infinitely large class size of raw material to be comminuted to a size class where 80% of the raw material passes through a sieve with the square holes in the size of 100 µm. (Through the methodology of laboratory determination the Bond index, a short ton was transformed into a metric).

F, P – dimensions of the square openings of the sieve through which 80% of the raw material passes before (F) and after (P) comminution, µm

If the required energy is calculated for comminution the samples from the size class after cooling to the size class in which 80% of the material passes through a sieve of 212 µm, according to the Bond form where the size F for slag of 42300 µm, and the same size for granulated slag of 2967 µm, and the value of P for both samples of 212 µm, the following values are obtained:

$W_{š}$ = 9.713 kWh/t

$W_{gš}$ = 9.984 kWh/t

GRINDING OF SAMPLES

After grinding to the size class of -3.35 mm, the samples were ground in a laboratory mill. Table 3 and 4 show the content of the class -75 µm depending on the grinding time of the slag and the granulated slag and Figures 7 and 8 show the kinetics of slag grinding and granulated slag.

Table 3 *Class content -75 µm in slag for different grinding times*

Grinding time, min	5	10	15	30
Class content -75 µm %	31.20	64.80	80.00	96.00

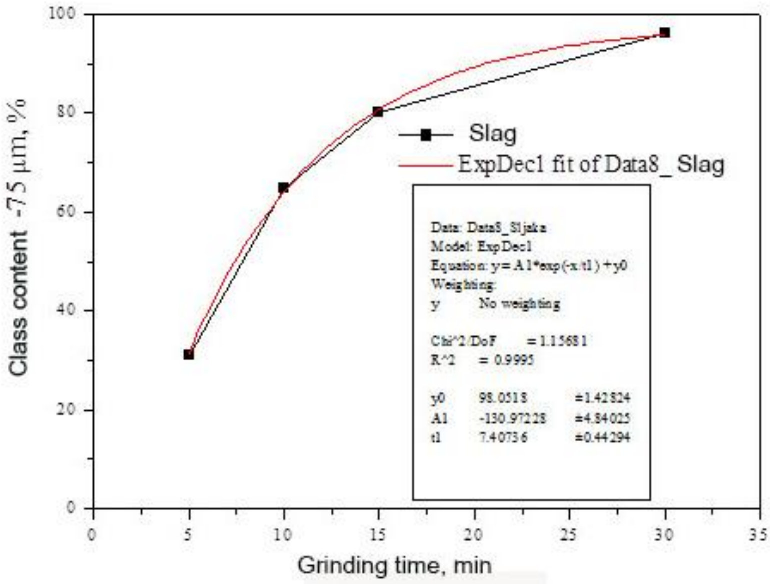


Figure 7 *Dependence of the class content -75 µm on the grinding time of slag*

Table 4 *Class content -0,075 mm in granulated slag for different grinding times*

Grinding time, min	5	10	15	30	40
Class content -75 µm %	24.80	49.00	63.60	91.20	96.80

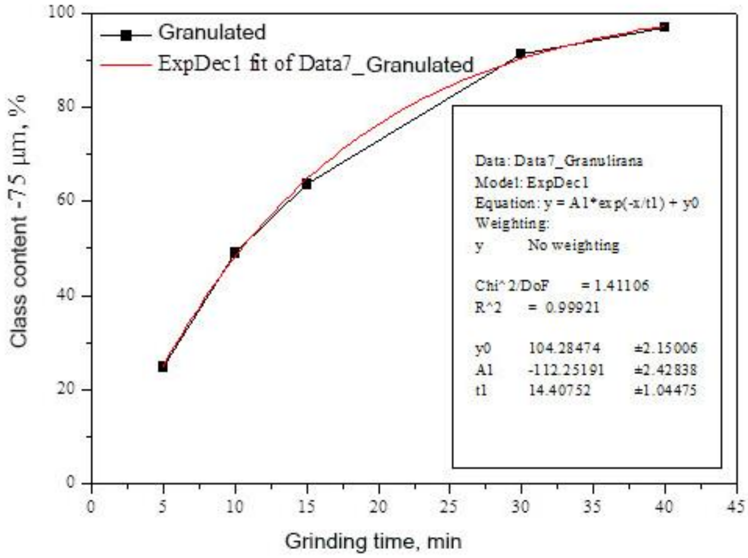


Figure 8 *Dependence of the class content -75 µm on the grinding time of granulated slag*

FLOTATION CONCENTRATION

Experiments on flotation concentrations were carried out on slag and granulated clay in order to examine the influence of grinding fineness on technological results. All flotation concentration experiments were carried out under the same conditions with 920 g of slag, a dose of KAX collector of 200 g/t, different grin-ding fineness. Tables 5 and 6 and Figures 9 and 10 present the test results.

Table 5 *Slag starting sample*

Grinding fineness	m,%	Cu,%	Cu recovery, %
60 % -75 µm	9.55	3.02	58.08
65 % -75 µm	11.73	2.7	61.35
70 % -75 µm	10.32	3.0	61.16
75 % -75 µm	11.12	3.08	63.15
80 % -75 µm	12.25	2.8	64.08
85 % -75 µm	12.99	2.64	64.40
90 % -75 µm	14.93	2.44	66.99
95 % -75 µm	14.80	2.38	66.96

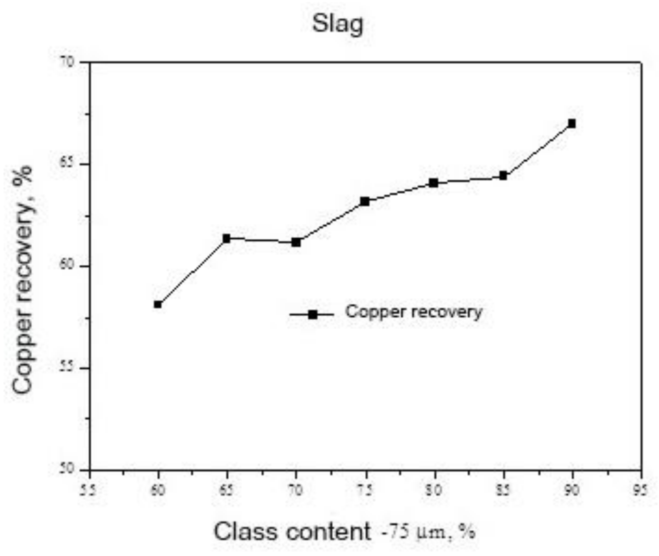


Figure 9 *Dependence of the copper recovery in the concentrate on the class content -75 µm in slag*

There is a clear trend of increasing the copper recovery in the basic slag concentrate, depending on the grinding fineness. The copper recovery in the basic concentrate ranged from 58.08 to 66.96% with an increase in grinding fineness of 60-95% -75 µm.

Table 6 *Granulated slag*

Grinding fineness	m,%	Cu,%	Cu recovery, %
60 % -75 µm	14.48	5.5	82.91
65 % -75 µm	17.72	4.95	84.73
70 % -75 µm	17.80	4.95	84.67
75 % -75 µm	20.40	4.78	86.39
80 % -75 µm	22.05	4.1	85.80
85 % -75 µm	24.30	3.6	85.88
90 % -75 µm	28.00	3.34	87.00
95 % -75 µm	30.39	2.9	86.42

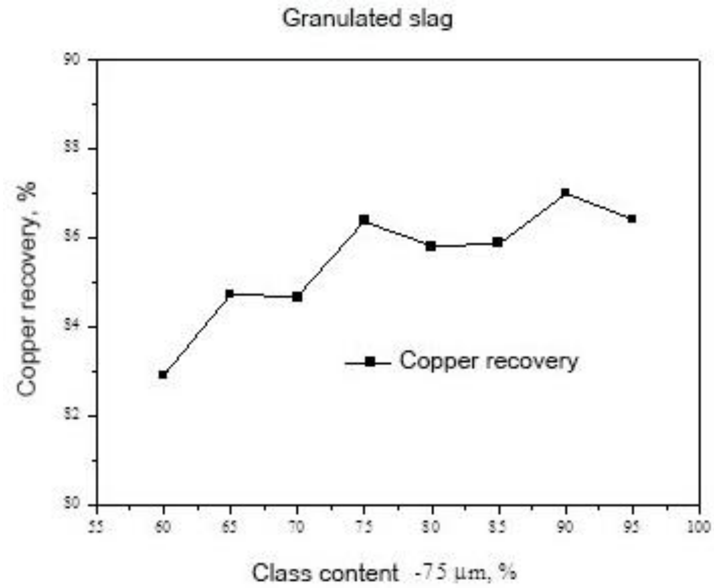


Figure 10 *Dependence of the copper recovery in the concentrate on the class content -75 µm in granulated slag*

In the granulated slag, the copper recovery in the basic concentrate is also increased with an increase in grinding fineness from 82.91 to 87.0% for grinding fineness of 60-95% -75 µm. In comparison with the results on the slag samples, the higher copper recoveries were obtained by 19.46 - 24.83%.

CONCLUSION

Comparison of sample characteristics of different cooled slag was performed in this paper. One is the slag sample from the "Slag Depot 1". It is a slag that is left from the metallurgical melting process of the copper concentrate. This slug was poured on the depot and it was cooled down. The slag sample was excluded from the technological process of flotation processing after crushing to -20 mm. The second sample is a sample of granulated slag obtained by melting one part of the slag sample of the deposit "Slag Depo 1" and then by rapidly cooling with the water jet during pouring.

Tests were carried out on the slag and granulated slag samples to determine the properties.The differences in the physical properties of sample are very noticeable. The size class of the "Slag Depot 1" in the deposit is -150 mm, while the class size of granulated slag is -6 mm. The granulated slag has a glass amorphous black structure with a lot of regular spherical grains, and slag has an irregular shape with a shell-like fracture and is gray in color.

The difference in the Bond working index is significant on tested samples both in the rod mill and ball mill. A sample of granulated slag has about 30% higher Bond index.

The required energy is calculated for comminution the samples from the size class after cooling to the size class in which 80% of the material passes through a sieve of 212 μm.

The obtained value for slag sample is 9.713 kWh/t and for granulated slag sample is 9.984 kWh/t, which is very similar to the granulated slag sample, although the calculated energy is for comminution of -150 mm, and granulated slag of -6 mm.

The density of these two slags is slightly different, but this is not the result of the cooling method, but the way of experiment performance. When pouring material from the Birlech furnace, it is not possible to empty the furnace to the end, but at the bottom there is a certain amount of material that is "washed" with the inert substance after the experiment. The retained material has a slightly higher density. For the same reason, the slag and granulated slag have a different chemical composition, and this is not the result of cooling.

A very significant difference in the two tested samples was observed in the flotation concentration experiments depending on the grinding fineness. Copper recoveries in the base concentrate from 58.08 to 66.99% were obtained on the slag sample, and on the granulated slag sample from 82.91-87.00%. The differences are from 19.46 to 24.83% in favor of the granulated slag. The highest recoveries in both samples were obtained with a grinding fineness of 90%.

The slag properties are largely dependent on the cooling mode of slag. Particularly large, variable, flotation results. When considering further use of the slag, this knowledge should be taken into account and the cooling mode should be selected accordingly.

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CHARACTERIZATION OF COPPER-BASED SHAPE MEMORY ALLOY WITH ZINC AND ALUMINUM***

Abstract

Copper-based shape memory alloy with zinc and aluminum was manufactured, plastically deformed, heat treated and characterized in terms of the physico-mechanical, structural and micro-structural investigation. Typical martensitic microstructure with twins is revealed by the optical and electron microscopy. The presence of martensite in the structure was further confirmed through an X-ray diffraction. Toughness and hardness of the alloy are investigated, too. Optimal properties are obtained for the condition of the alloy that was subjected to the heat treatment according to the following scheme: annealing at 850^{0}C and 900^{0}C (10 min) + quenched in water + aging at 400^{0}C (1 hour) + air cooling.
Keywords: *shape memory, SEM-EDS, hardness, copper-zinc-aluminum alloy, martensitic structure*

1 INTRODUCTION

The effect of shape memory is ability of some metals and alloys deformed in the martensite state or at temperature interval of martensitic transformation to regain their original shape during the heating process due to a complete or almost complete absence of deformation [1,2].

The heating process causes restoration of crystals in the high-temperature phase called beta or parent phase, and removal of plastic deformation. In the same time, the all physical and mechanical properties are restored.

During the shape recovering process, the alloys can produce a displacement or force, or combination of the two, as a function of temperature. The starting force of recovering shape process is difference between the free energies of parent and martensitic phases during the reverse transformation. The complete shape recovering is only notice if the martensitic transformation is crystallography reverses, and if the deformation process is done without the plane shearing [2,3].

The shape memory effect has been studied for many binary and ternary alloys, as well as for some pure metals. However, a wide application can be found only for the nitinol (Ni-Ti alloys) and copper-based alloys that show shape memory effect. Copper-based alloys, compared to nitinol alloys, possess somewhat lower mechanical properties due to their larger grain size and elastic anisotropy [4]. But, they can be improved, considerably without deterioration of the shape memory effect, by the small grain, method of rapid solidification, sinter metallurgy, or by adding the elements such as Zr, V, B, Ti, Cr, etc. [5].

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2 COPPER-BASED SHAPE MEMORY ALLOYS

Copper-based alloy with shape memory effect are very commercial and they are mainly alloys with zinc, aluminum and nickel. Figure 1 shows the liquidus projec tion in the copper-based alloys with zinc and aluminum, while Table 1 gives a review of the possible invariant reaction in the same system of alloy [6].

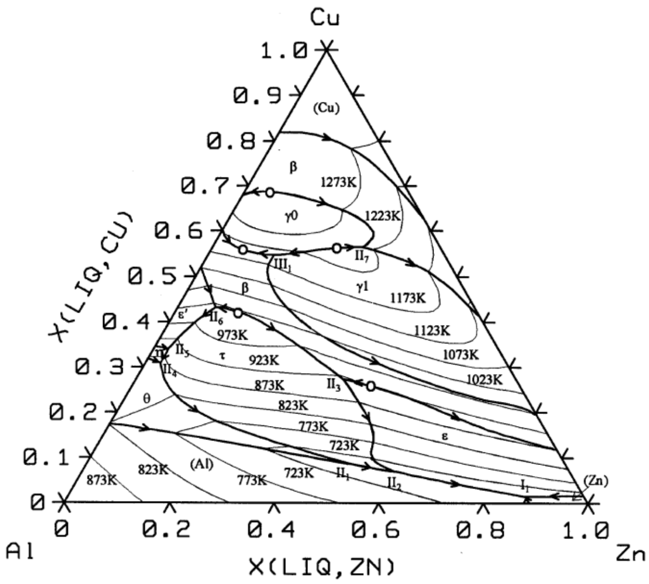

Figure 1 *Calculated liquidus projection in the Cu-Zn-Al system of alloy*

Table 1 *Calculated invariant reactions in the Cu-Zn-Al system of alloy*

Reaction	Temperature, K	Composition of liquid phase
L+θ→(Al)+τ	698	Cu8,6Zn50,5Al40,9
L+τ→(Al)+ε	694	Cu6,8Zn60,1Al33,1
L→(Al)+(Zn)+ε	654	Cu1,6Zn87,2Al11,2
L+β→ε+τ	917	Cu27,4Zn39,5Al33,1
L+η→τ+θ	853	Cu31,2Zn2Al66,8
L+ε`→τ+η	893	Cu34,3Zn2Al62,8
L+β→τ+ε`	1010	Cu43,5Zn6,9Al49,6
L+γ°→β+γ	1226	Cu56,4Zn28,6Al15
L+γ+γ°→β	1197	Cu54,6Zn12,6Al32,8

The possibility of shape memory effect depends upon the alloy ability to undergo the thermo-elastic martensite deformation. The alloy is first cooled and transferred to the martensitic phase, when there is q possibility of mechanical deformation. As long as the lower temperature, the alloy is deformed, or if heated, martensite again deformed into the austenite and the alloy returns to its ori-ginal shape.

Martensitic transformation does not oc-cur at a certain temperature, yet there is a whole temperature range which is different for each monitored system.

Various deformation temperatures and the corresponding voltage curves for the copper-based alloy with zinc and aluminum are shown in Fi-gure 2.

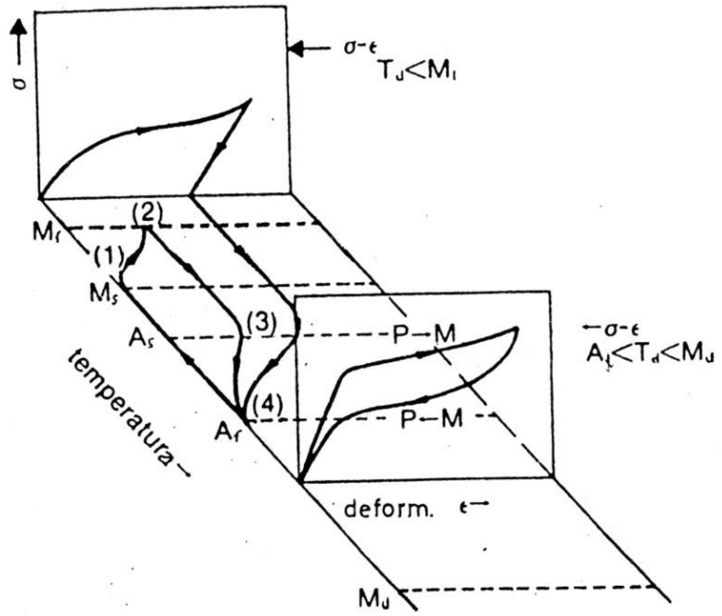

Figure 2 *Schematic overview of the voltage curves depending on deformation temperature (Ms-temperature of beginning martensite formation at cooling; Mf-temperature of the martensitic transformation ending; As-starting temperature of high temperature phase formation; Af-ending temperature of high temperature phase formation at heating; Md-below this temperature martensite can be reversed into the original phase)*

In the upper left corner in Figure 2, the alloy deformation below the Mf temperature is shown, while alloy is fully in martensitic condition. For a relatively low stress, there is a possibility when the deformation can be deposited in the martensite structure at cer-tain stress. When unloading once, the elastic distance can be observed in any metal. Heat-ing to Af temperature, martensite with added deformation disappears and the original structure returns.

In contrast, in the lower right corner in Figure 2, the curve corresponding to the alloy deformed between the temperatures the Af and Md is shown, while the alloy is in the initial phase at high temperature. Here is a tensile martensite before the applied de-formation (P→M). After release, the mar-tensitic structure is unstable, and is conver-ted to the original phase (P←M). During this reversible process, each deformation, incor-porated into the tensile - martensite, disappears and the material returns to its original shape. This behavior of materials was called the pseudo-elasticity.

The copper-based shape memory alloys with zinc and aluminum are widely used in the industry as the thermostats, control equipment, connectors, etc. The most obvious examples are the various types of springs with different systems for remote regulation and control. The shape memory alloys based on copper also have wide applications in home use as the constitutive elements of various assemblies. Their great advantage over the other types of smart materials alloys is a low price, as well as the role of environmental friendly materials.

3 EXPERIMENTAL

The copper-based shape memory alloy with zinc and aluminum are usually obtained by the classical method of melting, casting and manufacturing. Generally, all alloys with martensite structure have the heavy plastically deformation consisting of few cycles of rolling at hot and drawing at cold with the series of intermediate annealing treatments, from ingots to rods and wires of small cross-section. However, it is necessary to keep the chosen composition of alloy during the production process, which is difficult by the zinc evaporation during the casting process. Also, the plastically deformation of these alloys is heavy, with many operations of rolling, drawing and intermediate annealing treatments.

Because of that, the copper-based shape memory alloy with zinc and aluminum is obtained using the technology of continuous casting of wire and profiles of small diameters, developed in the Mining and Metallurgy Institute Bor for some pure metals [7].

The principle of this method of continuous casting has used the procedure of crystallization above the melt for directly obtaining the copper-based shape memory 8 mm wire. The principle of technology is as follows [7]: The cooler for copper-based shape memory wire casting is dipped into the melt to a depth of h. The protection shell made of heat-resistant material, which does not react with molten alloy and layer of heat-insulation material, protects the cooler from the influence of melt and high temperatures. Hydrostatic pressure of surrounding melt drives the molten alloy into a graphite crucible. The molten alloy hardens in the crucible by the heating exchange through the primary part of crystallizer, which is water-cooled. Hardened wire leaves the graphite crucible at a high temperature. Vacuum is used for prevention the cast wire oxidation, caused by the high temperature on its surface. Apart from the above mentioned role, the vacuum serves also for provision the required differential pressure inside cooler enabling a penetration of molten alloy into the graphite crucible. For prevention the cast wire oxidation after leaving the cooler, the temperature on its surface should be below 60^{o}C. Cooling provides this cast wire in the secondary part of crystallizer. Cast wire drawing is done according to the drag-pause schematic. The process stability is ensured by adjustment the wire drawing speed and heat removal from its side surface.

4 RESULTS AND DISCUSSION

The chemical composition of obtaining 8 mm wire is: Cu-69.7%, Zn-26.3% and Al-4%. The samples of wires are treated in the aim to obtain the wire of 1.8 mm with the shape memory effect as follows: 2 h of homogenization at 800^{0}C in low oxidation atmosphere, then drawing to the dimension 4x4, with the thermal treatment: 15 min of annealing at 400^{0}C, quenching in water, 120 min annealing at 550^{0}C, cooling in furnace to 450^{0}C and air cooling and drawing to the dimension 1.8 mm. In the aim to reach the martensite structure, samples are heating 5 min in nitrogen atmosphere at 800^{0}C and-quenched in cold water and in martensite state the alloy was memorized.

In the aim to determine the characteristics of obtained shape memory alloy, the investigations of mechanical properties, structural and micro-structural analysis, as well as SEM-EDS and X-ray are done. The obtained results are shown in Table 1 and Figures 3-8, respectively.

Table 2 *Results of physic-mechanical properties toughness and hardness by Vicker's method*

N^0	Condition of materials	Toughness	Hardness
		J/cm^2	HV
0	As-cast condition	20	314
1	Hot-rolled at 850^0C	40	354
2	Annealing at 850^0C (10 min), quenched in water	34	379
3	Annealing at 900^0C (10 min), quenched in water	33	368
4	(2.) + ageing at 400^0C (1 h) + air cooling	22	492
5	(2.) + ageing at 450^0C (1 h) + air cooling	16	475
6	(2.) + ageing at 500^0C (1 h) + air cooling	26	448
7	(2.) + ageing at 450^0C (1 h) + cooling in furnace	21	454
8	(3.) + ageing at 400^0C (1 h) + air cooling	20	504
9	(3.) + ageing at 450^0C (1 h) + air cooling	19	478
10	(3.) + ageing at 500^0C (1 h) + air cooling	18	464
11	(3.) + ageing at 450^0C (1 h) + cooling in furnace	23	479

According to the results of mechanical investigation, shown in Table 2, it is noticed that the optimal characteristics of alloy are obtained for the following state of materials: annealing, quenched in water, ageing at 400^0C 1 hour, and then air cooling. This conclusion is verified by the metallography, Figures 3-8.

Figure 3 *Microstructure of the as-cast alloy, (x960)*

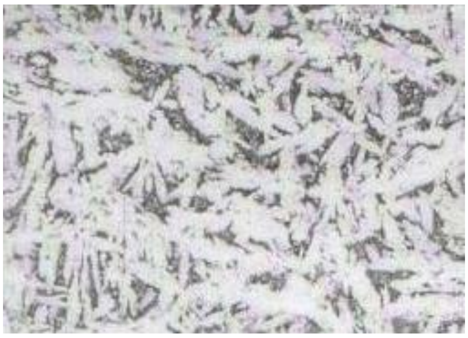

Figure 4 *Microstructure of the alloy, hot deformed (x960)*

Figure 5 *Microstructure of the alloy, annealed at 850^{0}C for 10 min and water quenched (x960)*

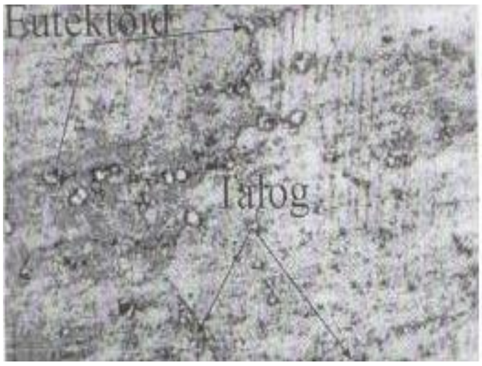

Figure 6 *Microstructure of the alloy, annealed at 900^{0}C for 10 min and water quenched (x960)*

Figure 7 *Microstructure of the alloy quenched from 850^{0}C and aged at 400 ^{0}C for 1h (x960)*

Figure 8. *Microstructure of alloy quenched from 900^{0}C and aged at 400^{0}C for 1h (x960)*

Microstructure of the cast alloy consists of a lot of big bright crystal α-solid solution in the dark basically β-crystals (Fig. 3). In appearance, this structure corresponds to the martensite structure with notable locality Widmanstatten structure. This structure is not favourable for the cold plastic deformation, because the present structure is very brittle, and therefore the only possible deformation is at elevated temperatures.

Hot-processed alloy sample consists of bright crystals of α-solid solution surrounding the crystals of dark β-phase. Between the crystals of α-solid solution in the dark based β-phase particles extracted notice precipitate, but in a very small volume shares (Figure 4). Compared to the as-cast structure, the microstructure is somewhat finer, because the α-solid solution is better deployed in the β-base as a result of deformations in hot condition.

The microstructure of annealed state of the alloy is given in Figures 5 and 6. It is noted that the large polygonal grains are formed with the present of eutectoid and precipitate deposited on the grain boundaries. Due to higher temperatures (Figure 6), there is a complete transformation of martensite structure.

Microstructure of the aging state of alloy consists of the large polygonal grains with separate participate and eutectoid on the grain boundaries. In the alloy sample, quenched in water from 850^0C, the appearance of residual martensite structure is observed with a fine needle (Figure 7), while the sample quenched from 900^0C and subsequently ageing at 400^0C, the presence of residual martensite and eutec toid is noted, but there has been a phenomenon of thermal deposition in the grain boundaries and with in each grain (Figure 8). In this sample, the martensite structure with the Widmanstatten schedule is observed, since the α-solid solution is separated in the form of martensitic needles.

The typical martensite twins are also observed on a scanning electron microscope image (Figures 9 and 10), while the elemental analysis (EDS), detailed in Figure 11 locates the manufactured alloy in the compositional range for the shape memory alloys in the Cu-Zn-Al system.

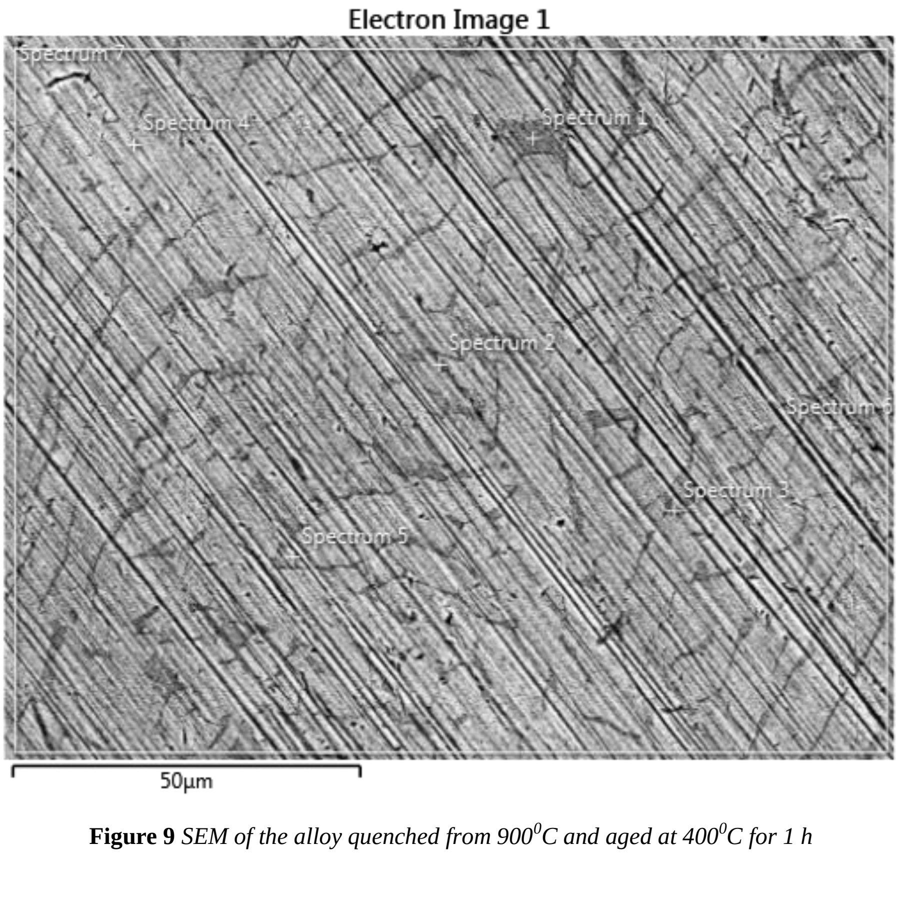

Figure 9 *SEM of the alloy quenched from 900^0C and aged at 400^0C for 1 h*

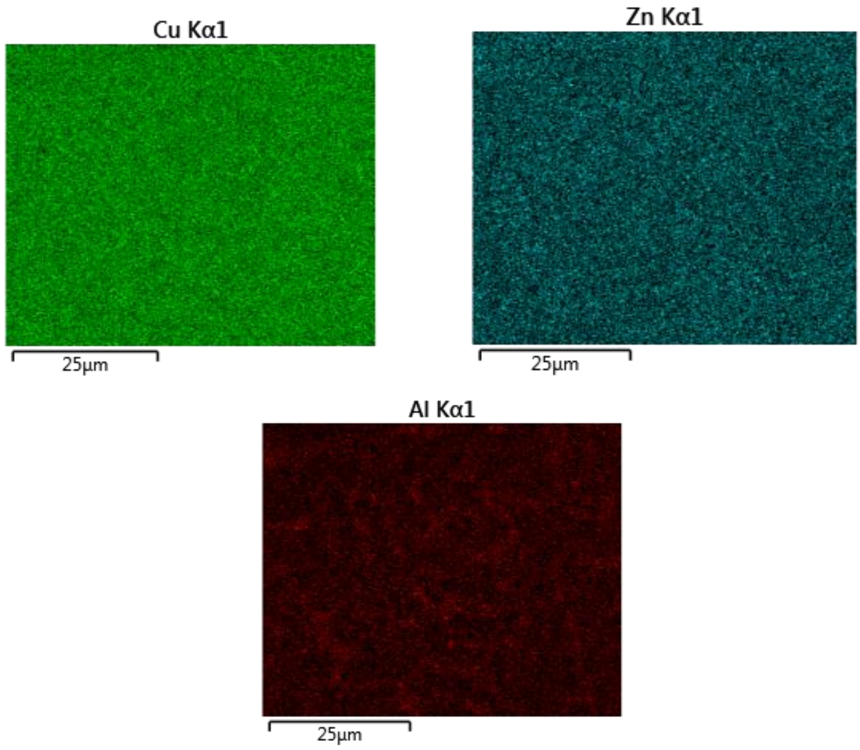

Figure 10 *SEM map of based elements of the alloy quenched from 900^{0}C and aged at 400^{0}C for 1 h*

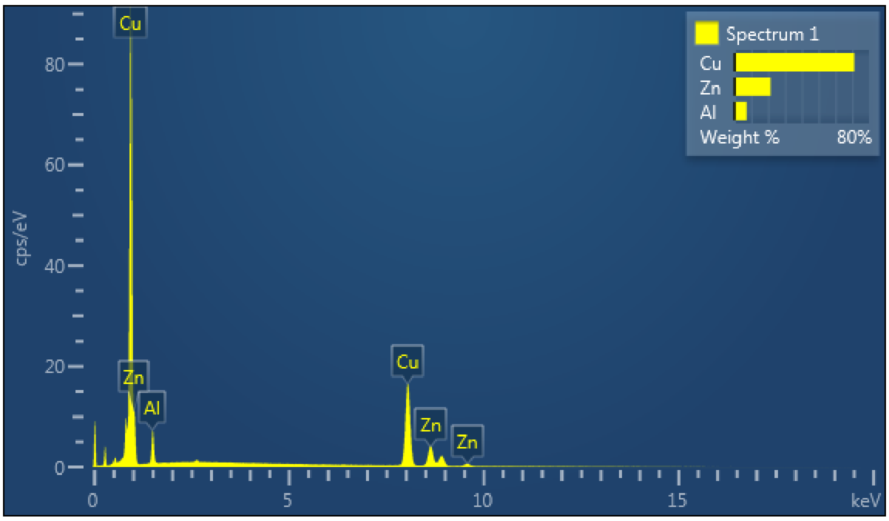

Figure 11 *EDS analysis of the investigated alloy quenched from 900^{0}C and aged at 400^{0}C for 1 h*

The X-ray diffraction data collected for the quenched sample of alloy, showed in Figure 12, indicates a predominantly mar tensitic structure, with the relevant peaks in the 40^0 to 45^0 2θ range.

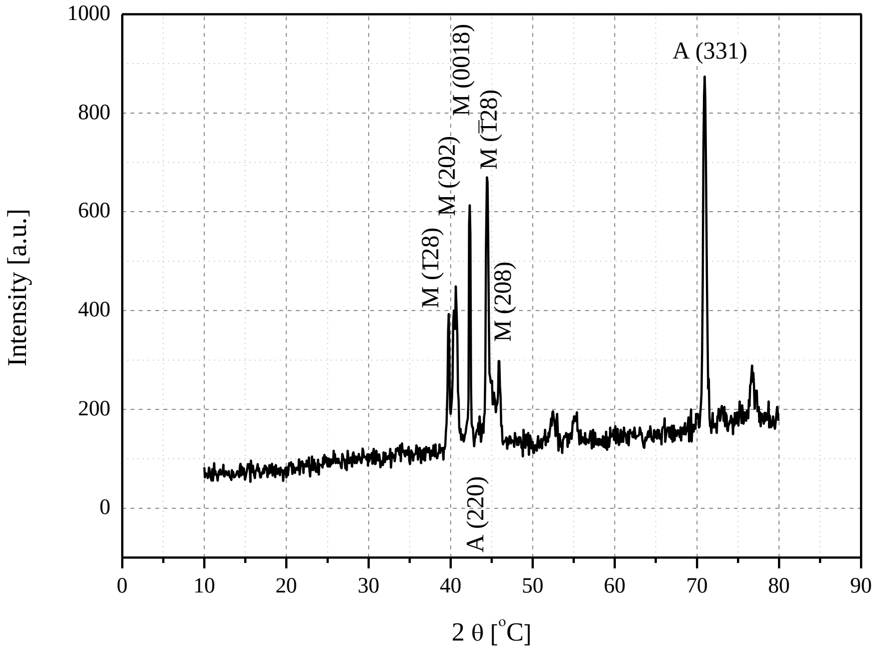

Figure 12 *X-ray diffractogram of the quenched alloy*

CONCLUSIONS

The copper-based shape memory alloys with zinc and aluminum was manufactured, plastically deformed, heat treated and characterized in terms of the physic - mechanical, structural and micro - structural analysis.

Quenching in water, following heating at 850^0C and 900^0C, lead to the observation of a typical martensitic microstructure, with the twins revealed by the optical and electron microscopy.

The presence of martensite in the structure was further confirmed through an X-ray diffraction.

Severe plastic deformation lead to an increase of hardness compared to the undeformed samples, a more pronounced increase was observed for the quenched samples.

Establishing a correlation between the material state, microstructure and mechanical properties, it can be concluded that the combination of thermo-mechanical processing regime, can achieve such a state of the material that provides the good mechanical properties.

Reducing the particle size α-solid solution of hot processing increases the hardness and impact toughness compared to the as-cast state.

Heat treatment of hot-processed alloy increases the hardness, while the impact toughness gradually decreases as the microstructure can be explained by the appearance of brittle phases, as a result of thermal deposition.

The optimal properties are obtained for material condition, subjected to the heat treatment, according to the following scheme: annealing at 850^0C and 900^0C (10 min) + quenched in water + aging at 400^0C (1 hour) + air cooling.

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SPATIAL AND TIME ASPECTS OF THE ANALYSIS OF POLLUTANTS IN THE RIVER WATER AND ITS SEDIMENTS

Abstract

The main objective of this study was to determine whether there are the spatial and temporal changes in physico-chemical properties of water and concentrations of heavy metals in water and sediment of the River Ibar upstream and downstream of Kosovska Mitrovica and Kraljevo. The following physico-chemical parameters were determined: pH, electrical conductivity, suspended matter content, biological oxygen demand, chemical oxygen demand, total organic carbon, contents of nitrates, ammonium ion, total phosphorous, sulphates. Concentrations of heavy metals in water and sediment samples were determined using an inductively coupled plasma optical emission spectrometry (ICP-OES) using a SPECTRO AR COS instrument. The water of the Ibar River after flowing through Kraljevo shows a higher degree of pollution than in Kosovska Mitrovica. However, the water upstream and downstream of Kraljevo is of similar quality indicating that the pollution source is not located in Kraljevo, but along the river section between the two towns. This study has also proved that the water quality in Kraljevo did not significantly change during the period 2010-2016. The highest concentrations of nitrates, nitrites, ortophosphates and ammonium ion are found in colder months. During spring-summer change electrical conductivity, pH and concentration of sulphates has most prominent change in the analyzed Ibar River water in Kraljevo.

***Keywords**: inorganic pollutants, river water, urban pollution, environment*

1 INTRODUCTION

Urban development, which is largely an irreversible process, is one of the major driving forces of change of Earth's surface. It has an adverse effect of river flowing through the towns which are inevitably changed regarding the channel morphology and water quality. Municipalities and industry are a constant pollution source, while the surface runoff is a seasonal occurrence and depends on the climate characteristics of the basin [1].

Determining the degree of surface water contamination by numerous physical agents and chemical substances has become a growing health and general social problem [2,3]. Organic chemicals and heavy metals do not necessarily remain at one place but can be transported by the air or water throughout the environment [4].

In order to ensure a proper evaluation of the environmental status of a watercourse and application the environmental protection policies, a constant monitoring of the environmental parameters has to be applied. Heavy metals can enter a river through the natural sources mainly during the weathering of rock and soil or anthropogenic sources such as the industry, agriculture or

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municipal waste, and surface sediments represent a sink for heavy metals [5].

The aim of this research is to determine a degree of pollution of the River Ibar and to compare the water quality of this river upstream and downstream of two towns, Kosovska Mitrovica and Kraljevo during the period 2010-2016. In the last few decades, the quality of water of the River Ibar has been the subject of numerous researches [6,7,8,9] but none of them used a methodology including determining the spatial and temporal changes.

This research relies on the study done by Milicević et al. [9] and the main objective is to determine whether there are spatial and temporal differences in the physicochemical properties of water and concentrations of heavy metals in water and sediment of the River Ibar upstream and downstream of Kosovska Mitrovica and Kraljevo. The aim of the paper is to propose a model of research that could be applied on the water and sediment analyses in the urban areas. Furthermore, in order to determine the intensity of anthropogenic impact, the obtained results are compared with the values defined by the official regulations of the Republic of Serbia on the limit values of pollutants in the surface and groundwater and sediment.

2 EXPERIMENTAL PART

2.1 Study area

The River Ibar flows through the southern and central part of Serbia and the eastern part of Montenegro and it belongs to the Black Sea Basin (Fig.1). The total length of the River Ibar is 276 km, and the watershed covers an area of 8,059 km². The River Ibar springs under the Hajla Mountain in the eastern Montenegro, flows east to Kosovska Mitrovica, and north to Kraljevo where it meets the River West Morava. The water of the Ibar River is used for water supply for about 500.000 inhabitants in towns through which the river flows, therefore monitoring the quality of water of the Ibar River is of the primary importance for determining the contamination of aquatic ecosystem and protection the human health.

The lower River Ibar flows through the territory of the two municipalities of Raška and Kraljevo. In its middle and lower parts, the River Ibar accepts a large quantity of wastewater from the industry, agriculture, municipal landfills, and part of urban waste water which are discharged without any treatment. This is also the main reason why many parameters of the water quality of the River Ibar do not meet the limit values of the II class of water, which should be the case on the basis of the Decree on Categorization of the Watercourses and the Water Classification Regulation ("SRS Official Gazette" No. 5/68).

The confluence of Rivers Sitnica and Ibar is in Kosovska Mitrovica. In this area, the River Ibar flows along several mining-metallurgical-chemical plants and tailings of the Trepča Combine. To the north of Kosovska Mitrovica and Zvečan, about 45 km, the River Ibar flows along the flotation plant of lead-zinc ore and its mines in Leposavić, and after 20 km in Rudnica also flows near the flotation plant of zinc ore ("Suva Ruda"). About 10 km kilometers north of Rudnica, and immediately upstream of Raška, the very polluted River Raška flows into the River Ibar. In Raška, the River Ibar is polluted by dairy and meat industry waste water, municipal waste water disposal sites in Raška, Baljevac and surrounding towns. Additionally, the River Ibar is polluted with the waste water of the coal separation processes in Baljevac.

2.2 Samples

In this study, the analyses of water and sediment samples of the River Ibar downstream and upstream from Kosovska Mitrovica and Kraljevo were carried out. The water and sediment sampling from the

Ibar River was conducted during the period 2010-2016, and included four locations: 1) Upstream of Kosovska Mitrovica and ~ 6 km downstream from the dam of Gazivode Lake, at the town Zubin Potok (ZP); 2) Downstream of Kosovska Mitrovica in Veliko Rudare (VR); 3) Upstream of Kraljevo in Konarevo (K); 4) Downstream of Kraljevo in Ratina (R) (Fig. 1).

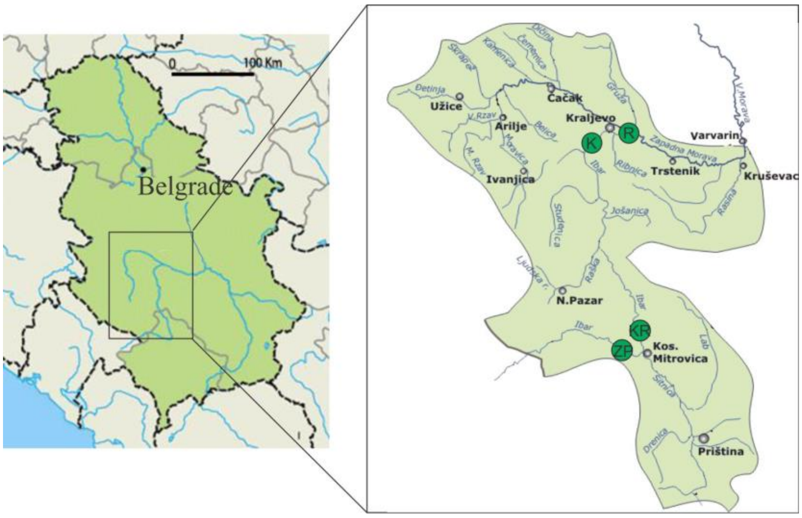

Figure 1 *Watershed of the River Ibar with sampling locations: ZP – ZubinPotok, VR – Veliko Rudare, K - Konarevo, R – Ratina*

2.3 Methodology

The following methods were used for analyses the water samples: pH, suspended matter, biological oxygen demand, chemical oxygen demand, total organic carbon, nitrates, nitrites, ammonium ion, total phosphorous, sulphates, electrical conductivity at 20^{o}C. Concentrations of heavy metals in the water and sediment samples were determined using an inductively coupled plasma optical emission spectrometry (ICP-OES) using a SPECTRO AR COS instrument.

2.4 Legislation for surface water and sediments

The limits of pollutants and methodology of parameters determination in surface water according to the Regulation – Decree on limit values of pollutants in surface and ground water and sediment and deadlines for their reaching (Official Gazette RS, No. 50/12), was used as a criteria for pollution determination in the samples from the River Ibar (Class I- water in the natural state or after disinfection can be used as drinking water, Class II - water suitable for recreation, Clas III- water that can be used for industry, Clas IV- unusable water).

3 RESULTS AND DISCUSSION

3.1 Physico-chemical parameters in the River Ibar water

Screening of water and sediment quality was conducted on selected samples from two locations at the River Ibar. Upstream and downstream of the towns Kosovska Mitrovica and Kraljevo, the physical and chemical characteristics (pH, suspended matter, dissolved oxygen, biological oxygen demand and chemical oxygen demand) of water and concentrations of heavy metals in water and sediment, were determined.

Statistical analyses proved that the water quality decreases from Kosovska Mitrovica to Kraljevo. Concentrations of soluble oxygen, chlorides, sulphates, nitrates, ortophosphates, ammonium ion and electrical conductivity increase in the River Ibar water downstream from Kosovska Mitrovica to Kraljevo. The results of the pH-value measurement showed that water of the River Ibar is alkaline, indicating the presence of organic waste materials (Table 1).

Table 1 *Results of t-test of the River Ibar water samples upstream and downstream of the towns Kosovska Mitrovica and Kraljevo*

Parameter	Kosovska Mitrovica (n=21)		Kraljevo (n=19)		t value	Significance (2-tailed)
	Mean	Standard deviation	Mean	Standard deviation		
pH	7.96	0.36	8.20	0.14	-2.80	0.01
Soluble oxygen / mg O_2 l^{-1}	8.16	3.81	11.21	1.52	-3.26	0.00
Chlorides / mg l^{-1}	11.95	3.72	14.11	5.31	-1.50	0.14
Nitrates / mg N l^{-1}	1.83	0.98	2.45	0.58	-2.38	0.02
Electrical conductivity at 20^0C/mS cm^{-3}	278.32	87.14	425.79	69.80	-5.87	0.00
Orthophosphates/mg Pl^{-1}	0.03	0.04	0.10	0.04	-5.27	0.00
Sulphates / mg l^{-1}	10.69	15.64	25.38	7.57	-3.48	0.00
Ammonium ion / mg N l^{-1}	0.02	0.05	0.72	0.32	-10.05	0.00

3.2 Heavy metals in sediment and water from the River Ibar - comparing Kosovska Mitrovica and Kraljevo

According to the obtained preliminary results, the concentrations of Cd and Zn in sediment (Table 2) downstream from Kosovska Mitrovica are five times higher, and As is more than 50 times higher than upstream. Concentrations of copper and mercury decrease downstream, while chromium and iron vary from 2 to 10%. In this part of the watercourse, there are the mine tailings dumps rich in zinc, cadmium and arsenic.

As the concentration of these parameters in the sediment is high, it refers to a long-term source of pollution (probably decennial). This also means that in the future it cannot be expected that the concentration of these ions will decrease in water. Data presented in Table 3 show that the concentrations of heavy metals in water have been significantly increased downstream of Kosovska Mitrovica, which is additionally proves this pollution.

Table 2 *Concentrations of heavy metals in sediment from the River Ibar*

Metal	Sample mark				Legislation values			
	ZP	**VR**	**K**	**R**	**1***	**2***	**3***	**4***
As /*ppm*	4.52	220.4	56.23	39.26	29	55	55	55
Cd/*ppm*	0.41	5.65	2.39	1.63	0.8	2.0	7.5	12
Cr/*ppm*	61.55	63	158.33	177.47	100	380	380	380
Cu/*ppm*	125.8	66.11	47.82	42.23	36	36	90	190
Hg/*ppm*	0.14	0.02	0.53	1.06	0.3	0.5	1.6	10
Ni/*ppm*	73	94.22	297.18	355.87	35	35	45	210
Pb/*ppm*	31.22	404.9	87.19	74.52	85	530	530	530
Zn/*ppm*	149.72	646.53	344.66	280.82	140	480	720	720

[*]1. Target value: Concentrations of pollutants in sediment are at the level of natural background. Sediments can be dislocated without special protection measures; 2. Limit value: Sediment is slightly polluted. Disposal is allowed without the special protection measures; 3*. Sediment is contaminated. Its disposal is not allowed without the special protection measures. It is necessary to store in the controlled conditions with special protection measures on preventing the spread of pollutants into the environment; 4*. Extremely polluted sediments. Remediation is mandatory or keeping the stuffed material in the controlled conditions with the special protection measures to prevent it Spreading of polluted substances into the environment*

At the Kraljevo site, the concentrations of arsenic, barium, cadmium and zinc decrease 2 to 3 times downstream, while only the mercury concentration increases doubly. Concentrations of other metals vary in the range of 2 to 10%. The obtained results indicate that during removal of sediments downstream of Kosovska Mitrovica and Kraljevo, it has to be treated as a hazardous waste under rather demanding conditions (a sealed landfill with hazardous waste treatment) due to the increased concentrations of nickel, arsenic and mercury. The concentrations of lead, cadmium and zinc are close to the legal limits, and in the future, given the accumulation in sediment, it can be expected that the concentration exceed limits defined in Table 2. Removal of sediments with increased concentrations of heavy metals is necessary for reduction the concentration of certain heavy metals in water.

Based on the obtained values for heavy metals in water of the River Ibar, given in Table 3, it can be concluded that the concentrations of arsenic, iron, manganese and zinc increase downstream from Kosovska Mitrovica from three to ten times (three times Zn, from five to six times As and Fe, while Mn increases ten times), only the concentration of mercury decreases. Upstream from Kosovska Mitrovica concentrations of Cd, Cr, Cu, Ni, Pb are below the detection limit. This is in accordance with above statement about influence of landfills in Kosovska Mitrovica rich in heavy metals. The obtained concentrations for the area of Kraljevo show that there are no major deviations downstream and upstream from the town.

Table 3 *Concentrations of heavy metals in water samples (ppb)*

Sampling location	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
ZP	1.12	LOD	LOD	LOD	66.02	4.15	11.35	LOD	LOD	45.59
VR	5.21	0.65	1.91	LOD	422.7	2.79	123.9	7.06	1.04	180.8
K	5.87	0.28	5.01	LOD	586.4	2.03	73.28	14.9	6.59	76.96
R	6.03	0.29	4.7	LOD	597.7	2.02	71.45	18.13	9.96	72.6

[*]According to the Decree on limit values of pollutants in surface and ground water and sediment and deadlines for their reach, (Official Gazette RS, No. 50/12); LOD – bellow limit of detection

One of the major mechanisms of accumulation the heavy metals in sediments is an interaction with the organic matter. Mobilization of Zn and Pb is affected by a higher concentration of Mn in sediment (Table 2). Significantly increased heavy metal concentrations of Pb and Zn originate from the mining-metallurgical-chemical combine of lead and zinc Trepča. Pollution associated with the mining contamination of sulphate ore deposit, such as Trepča, could result in a high concentrations of sulphate ions in water, however, the obtained results do not show it (Table 1).

3.3 Physico-chemical properties of the River Ibar water in Kraljevo

As indicated above, the obtained results indicate that the River Ibar water has a poorer quality in Kraljevo than in Kosovska Mitrovica. Therefore, a data set containing 14 parameters, determined in 47 water samples, collected during the period 2010-2016, was analyzed to determine the spatial and temporal differences. Spatial analyses included a comparison of the physico-chemical parameters upstream and downstream of Kraljevo, and temporal included both annual and seasonal comparison.

The upstream and downstream samples from Kraljevo do not show a statistically significant difference in the water quality in any of tested parameters (Table 4). This indicates that there are no major pollution sources in the town of Kraljevo. This also indicates that the reason for water quality decrease in Kraljevo is a consequence of pollution along the river section between two towns.

Table 4 *Results of physical and chemical analysis of water from the River Ibar sampled upstream and downstream and results of t-test and during period 2010-2016 in Kraljevo and ANOVA results*

	Upstream (n=27)	Downstream (n=20)	t value	Significance (2-tailed)	2010	2011	2012	2013	2014	2015	2016	F value	Significance
Temperature / ^0C	10.39	10.73	-0.15	0.88	13.04	11.22		14.45	14.8	11.16	11.9	6.53	0
Soluble oxygen / mg O_2 /l	11.04	10.24	1.05	0.3	11.01	7.58	11.15	11.68	10.44	12.03	11.33	2.59	0.03
pH	8.12	8.05	1.11	0.27	8.01	7.85	8.16	7.98	8.21	8.23	8.14	3.01	0.02
Electrical conductivity at 20 ^0C / $mScm^{-3}$	422.91	439.07	-0.79	0.44	423.75	440.83		437.25	404.38	450.14	426	0.48	0.79
Nitrates / mg N/l	2.29	2.34	-0.21	0.84	2.04	2.06	1.95	3.31	2.61	2.31	2.37	2.07	0.08
Nitrites/ mg N/ l	0.03	0.04	-0.71	0.48	0.02	0.06		0.06	0.03	0.03	0.03	0.79	0.56
Ammonium ion / mg N/ l	1.25	0.88	0.48	0.64	0.47	0.66	1.09	4.83	0.78	0.77	0.54	1.92	0.1
Chlorides / mg/ l	18.74	15.23	0.7	0.49	15.38	16.33	17.5	15.94	14.73	12.47	39.8	1.91	0.11
Chemical oxygen demand / mg O_2/l	6.49	6.29	0.1	0.92	7.15	4.93		14.08	4.05	4.83	7	2.14	0.09
Biological oxygen demand / mg O_2/l	3.95	8.61	-1.45	0.15	3.33	2.35	18.33	6.45	2.99	1.94	2.8	2.91	0.02
Sulphates / mg/ l	28.75	27.54	0.41	0.68	29.73	29.83		36.93	22.27	29.59	24.24	2.25	0.07
Orthophosphates / mg P /l	0.16	0.1	0.74	0.46	0.05	0.15	0.1	0.54	0.12	0.07	0.1	1.98	0.09
Suspended matter / mg/l	16.97	14.3	0.73	0.47	10.5	9.57		22	14.25	20.86	25.25	2.46	0.05
Total organic carbon mg/l	1.91	5.96	-1.37	0.18	2.2	1.06	11.1	2.43	1.9	1.81	2.13	0.97	0.46

Temporal comparison showed differences in the River Ibar water samples from Kraljevo. During the time period 2010 - 2016, the water quality changed significantly regarding the following parameters: temperature, soluble oxygen, pH and biological oxygen demand (Table 4, Fig. 2) which are probably connected to the climate variations during this time period.

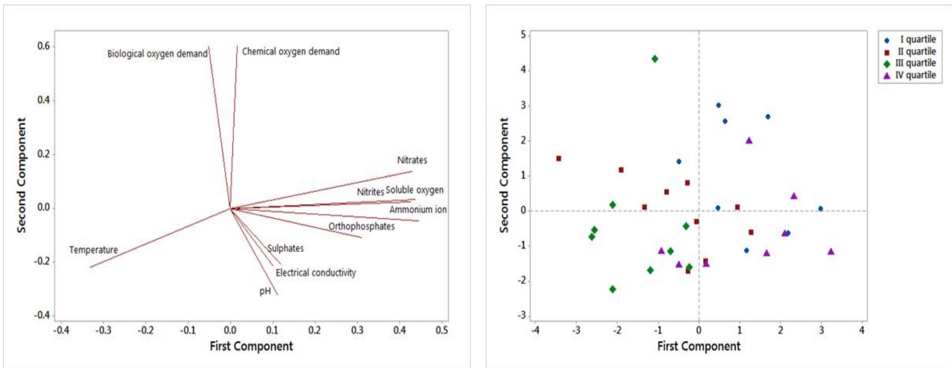

Figure 2 *Principal component analyses of seasonal change physico-chemical parameters in the River Ibar water samples*

Large flow changes, as well as statistically significant change in water temperature, necessarily lead to a change in the solubility of oxygen. The present oxidable substance will therefore also affect the chemical oxygen demand and biological oxygen demand (Table 4). Decreased oxygen concentration, and increased concentrations for chemical oxygen demand and biological oxygen demand indicate the anthropogenic and industrial contamination.

An important change was observed comparing the water quality over seasons during the observed period (2010-2016). Large flow changes are characteristic for this river [10]. During colder months, represented by I and IV quartiles, the water samples had higher concentrations of ortophosphates, nitrates, nitrites (anthropogenic contamination source) as well as soluble oxygen since it increases with the water temperature decrease (Fig. 2, Table 4). During warmer months, II and III quartiles, water expectedly had higher temperature, and higher biological oxygen demand due to a growth of water biomass. During spring-summer change the water electrical conductivity, pH and concentration of sulphates has most prominent change (Fig. 2).

CONCLUSIONS

The River Ibar from the spring to the confluence of the West Morava accepts wastewater in a direct or indirect way from is influenced by the population, economy with entire infrastructure, waste materials, etc.

Significantly increased of heavy metal concentrations above target values Pb and Zn in Kosovska Mitrovica come from the mining-metallurgical-chemical combination of lead and zinc Trepča. Sediment in almost all samples has concentrations of Ni, Cu and As above the target values, and concentration of Hg is above target value in samples from Kraljevo.

The water of the River Ibar after flowing through Kraljevo generally shows a higher degree of pollution than in Kosovska Mitrovica. However, this study proved that the water upstream and downstream of

Kraljevo is of lower quality indicating that the pollution source is not in located in Kraljevo, but along the river stretch between the two towns.

This study has also proved that the water quality did not significantly change during the period 2010-2016, except regarding the following parameters: temperature, pH, soluble oxygen and biological oxygen demand which is probably a consequence of climate variations during this time period. Most important conclusion is connected to seasonal changes in the water quality in Kraljevo. The highest concentrations of nitrates, nitrites, ortophosphates and ammonium ion were found in colder months (I and IV quartile). During spring-summer change electrical conductivity, pH and concentration of sulphates has most prominent change in analyzed Ibar River waters in Kraljevo.

In this paper the geochemical and physico-chemical parameters were used to determine the temporal and spatial changes of water and sediment quality in the River Ibar from Kosovska Mitrovica and Kraljevo. The proposed approach should be used in Kosovska Mitrovica and other urban locations along the Ibar River, as well as the other watercourses, for both temporal and spatial proper identification of pollution points.

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ECONOMIC APPLICABILITY AND VALUE OF JEWELRY MINERALS, METALLIC AND PRECIOUS RESOURCES IN KOSOVO AND METOHIJA

Abstract

This research referes to the estimates of economic usability and value of jewelry minerals, metallic and precious resources in Kosovo and Metohija. In this regard, there is a great economic interest in already proven exploitable and profitable investments in the target mines and deposits of Trepca, Goles, but also in the deposits of Crepulja, Malisevo near Prizren, Slivovo etc. To the contrary, we have insufficiently known and explored jewelry minerals-raw materials. Therefore, the common opinion and estimation of geologists and gemologists is supported that there is a significant interest of foreign investors in the mineral raw materials and that those investors in jewelry minerals - raw materials which are evidently found among the deposits in Kosovo and Metohija that have already been explored or are insufficiently explored, are to be encouraged. It is certain that there is an evident mineral and jewelry wealth that is still unused a great extant.

Keywords: *jewelry minerals, metallic resources, precious resources, investors*

1 INTRODUCTION

Evidently, the natural wealth of earth's rocks are metallic ore and jewelry minerals-raw materials from Stari Trg and other mines such as Ajvalija, Kisnica, Novo Brdo and Belo Brdo belonging to a business system of Trepca in Kosovo and Metohija. Jewelry minerals-raw materials such as pyrite, sphalerite and galena in combination with quartz are an important source of known metals such as lead and zinc. Other not so well known and insufficiently explored deposits of famous gemsotnes of quartz chalcedony, opal group and chrysoprase, were found in Goles near Pristina, Klobukar near Belo Brdo, Banjice near Pec, then Leposavic, Donje Jarinje and other places. Jewelry minerals are not only irrationally used, but are somehow destroyed in some places by the unplanned explosions. The ignorance of jewelry mi-neral resources through the law and regulations that have not been adopted in Kosovo and Metohija only increase this negative and irrational trend towards them.

The research points on the mineral resources; zinc, silver and gold in Kosovo and Metohija, as well as points brought by the certain corporations, primarily from Canada, in this paper will only confirm the record of the Byzantine historian Hristovulov from the first half of the 15th century, whom we quote: "... gold and silver literally outburst from sources, everywhere where it is being dug there is gold and silver powder in large quantities and the best quality, even better than the one in India.

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That is why the Serbian state has been privileged from the beginning". This paper will only confirm the extraordinary properties of the earth's rocks, especially through the fact that there are andesite, dacite and other rocks in Kosovo and Metohija where exist exploitable gold deposits.

2 JEWELRY MINERAL AND THEIR ECONOMIC VALUE AND APPLICABILITY IN KOSOVO AND METOHIJA

The archaeological excavations prove that the mineral resources in Kosovo and Metohija had been exploited even before the arrival of the Romans, and during the Roman rule, the province of Southern Mesia (today's territory of Central Serbia and Kosovo and Metohija) was considered as a mining province. In the Serbian professional literature on gemstones, the first paper was a manual of the famous mineralogist and geologist Sava Urosevic "The precious minerals and gemstones" from 1925. The precious minerals in ex-Yugoslavia began to be more intensively explored in the 1970s by a mining engineer Slobodan Zegarac. For the to-pic that is being dealt with in the paper is most interesting that back in 1981, more detailed research was carried out on the territory of Kosovo and Metohija, where the significant quantities of gemstones exist. The most interesting are deposits of opal and chrysopras of various colors in the deposite of Goles, otherwise known as the magnesite mine.

The region of Kosovo and Metohija and thus Serbia was among the first countries in Europe involved in the mining and metallurgy of precious metals, and also of precious and semi-precious stones in the Middle Ages. The name semi-precious stone in Serbian gemological terminology is now abandoned. In the past, the main center of jewelery production and forging coins was Novo Brdo, and the gemstones were taken from the nearby deposits of opal, chalcedony, chrysoprase, and other minerals. The most important European mine in the era of Nemanjic was Novo Brdo, in which lead and silver mixed with goldwere obtained. At the beginning of the 15th century, one of the oldest mining laws in Europe dates back to the Mining Code of Despot Stefan Lazarevic from 1412 (Figure 1). During the time of Djuradj Brankovic, a fifth of Europe's needs for silver was satisfied from here.

Figure 1 *Law on the mines of Stefan Lazarevic [1]*

This region is gemsotne Opal-rich with a deposit on the mountain Goles in the mine that has the same name. The reserves of magnesite are considered to be the largest reserves in the Balkans estimated at 2.4 million cubic meters of medium to high quality magnesite of pure white colour, whose the European market value in 2005 was 800 euros and more per m^3. Significant quantities of decorative Opal stone green in colourare contained in magnesite. In Kamenica municipality in Strezovci, there is a deposit of magnesite whose reserves are estimated at 4.5-5.5 million tons, while the European market value in 2005 was 400-800 euro per m^3. There is also a research and estimates taken from the research of the London magazine for the Goles mine which is one of the largest magnesite mines in Kosovo and Metohija. The mine has reserves of 1.74 million tons with the classification of 46.23% magnesiteore and 2.66% silicon dioxide resulting in 804,400 tons of magnesite and 46,300 tons of silicon dioxide (Table 1). Both mines originally worked before 1990, where production in the Goles mines was 110.000 tons of magnesite, 22,000 tons of synthesized magnesite and 10,000 tons of calcium mixture in the form of magnesite per year.

Table 1 *Mixed reserves of magnesite of the Goles and Strezovac basin mine [2]*

Mine	Tones	MgO%	SiO2%	CaO%
Goles	1.740.000	46,23	2,66	0,95
Strezovac basin-Belo brdo	3.660.000	40,49	6,29	5,45

The name of the jewelry mineral opalis derived from the Sanskrit word "upala" which means gem, and it refers to the gemstones in general. Its color has several nuances of brown, white (especially attractive milky white), green - Prase in several shades, yellow and bluish (Figure 2). Brown opal and colorful calcedon are present in the Klobukar region near Novo Brdo-Kosovo and Metohija. Nowdays, the price per kilogram at the world market is 10-250 euros. There is also a deposit of calcedons on the mountain Goles, whose color is orange and whose price per kilogram is 10-250 euros. Calcedon has been in use in the Mediterranean area already in the Bronze Age. It was as been used in the ancient Greece and central Asia for jewelry and seals. The term Calcedon is derived from the name of the Greek city Chalkedon in Asia Minor.

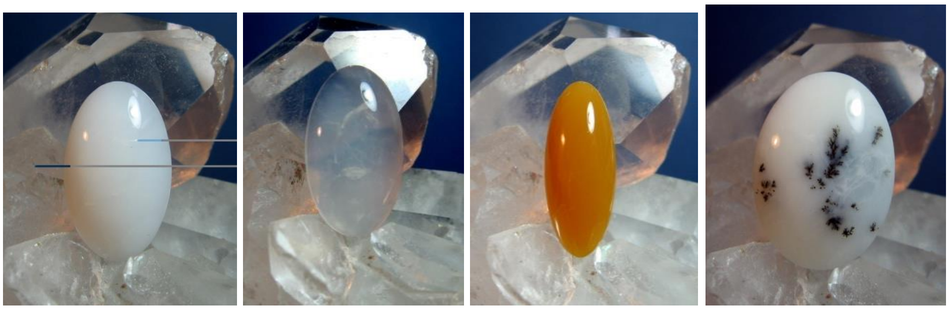

Figure 2 *Milky white and transparent opal, orange Chalcedon and kahapong-GO_4 from Goles deposite [3]*

A rare gemstone of chrysopras in Kosovo and Metohija-can be found on the mountain Goles, 15 kilometers away from Pristina, which is at an altitude of 1.119 meters. In addition to Western Australia, chrysopras can also be found in Germany, Madagascar, Zimbabwe, Tanzania, India, Kazakhstan, South Africa, Poland, California, Arizona, USA, Brazil, Russia and Oregon. The price of this gemstone in the world is ranging from 10-300 euros per kilogram. Chrysopras had been mentioned since the first century of the new era, but it was not excavated in large quantities until the second half of the 18th century. The Helen, Romans and Egyptians used it for jewelry and decorative items.

The Prussian king Friedrich the Great decorated his palace with objects that were partly or entirely made of this stone. His favorite ring (according to the tradition he never removes it) had a large central chrysopras surrounded by fifteen diamonds, and he wore a stick with a ball of chrysopras. Otherwise, the cost of chrysopras in Kosovo and Metohija is 50.000 euros per ton for mixed quality non-commercial type and 45.000 euros for mixed quality commercial type. It is economically profitable taking into account only the cost, costs of research andexploitation of these minerals. In truth, the deposits of expensive minerals-raw materials of the first and second class have not been discovered until now in Serbia and Kosovo and Metohija, but only those cheaper III, IV and V class (including chalcedony). Nevertheless their exploitation can be profitable. The following confirms the justification of re-engineering as a strategic development option for the company [4].

Table 2 *Deposits and types of jewelry minerals in Kosovo and Metohija [5]*

Deposit	Chalcedony-varieties of brown, green, red, greyand white Opal-variety of brown
Klobukar near Novo Brdo-Kosovo and Metohija	Silicon mass predominantly black in color
Crni kamen near Strezovaca	Magnesite-silicachertpale yellowto pink color, silicified dolomite of brown color
Magnesite deposit near Strezovaca	Opal varieties of different colors; Chalcedonyvarieties ofdifferent colors; Quartz variety jasper
Leposavic-Donje Jerinje, Kremenjacki potok	Quartz variety mountain crystal, rhodocrosite, pyrite, sphalerite-variety, marmatite
Deposit Pb-Zn Stari Trg, Trepca Kosovo i Metohija	Deposits Ni Cikatovo and Baks (opal variety of greenand other colors; Chalcedony-chrysoprase variety, occurrence Gladno selo (silicified wood)
A group of deposits and occurrences in Drenica	Kosovo and Metohija (opal-brown variety)
Occurrence Mirena on Goles, Kosovo and Metohija	Opal milky white variety, kaholong
Occurrence Medvece in Kosovu and Metohija	Opal-variety Chrysopal, honey opal, milky white opal, kaholong i others; chalcedony variety of Chrysoprase
Deposit Ni Glavica in Kosovo and Metohija	Deposit ofmarble onyx
Banjica near Pec	Chalcedony-varieties of brown, green, red, greyand white Opal-variety of brown

3 RESERVES OF METALLIC AND PRECIOUS MINERALS IN KOSOVO AND METOHIJA

The ancient Romans knew about the mineral resources of Trepca. This is also supported by an oil lamp found in the old underground mines. In addition to Trepca, the Romans also exploited the rich deposits in these areas, such as, for example, Srebrenica, Kopaonik, Gracanica, Socanica, etc. (Table 2). What is interesting about this site is the fact that the construction of a fortress in the Ibar valley was funded from silver obtained from this mine, and also the first Serbian silver Dinar (1412, despot Stefan Lazarevic) was minted from silver obtained from this mine. Known as a large deposit of lead-zinc ore, Trepca is distinguished by its diverse mineralogical composition. More than 60 different minerals have been identified. Due to the beauty of its crystals, many minerals from Trepca are found in many museums around the world [6].

The Trepca hydrothermal deposits of lead and zinc are an important source of basic metals and minerals in southern Europa [7]. The most productive mines in this business system are Stari Trg, Crnac, Belo Brdo, Kisnica and Ajvalija with production in the past of 60 million tons with 8% lead-Pb and zinc-Zn and more than 4,500 tons of silver-Ag [8]. The content of metals such as lead-Pb, zinc-Zn and silver-Ag in the deposits of the mine Crnac-northern Kosovo and Metohija, can be upgraded into a higher category B + C1 (Table 3) after the completion of research papers with reference to the ore reserves of these metals.

Table 3 *Reserves B + C1 category in "Crnac/east" [9]*

Category	Content of metal		
	Pb (%)	Zn (%)	Ag (g/t)
B + C1	8,25	2,33	93,5

Under the jurisdiction of Unmik, over the past seventeen years (2000-2017), only about 20,000 tons of lead was processed in the Trepca business system, while only 1,000-1,500 tons of waste and scraps of raw lead were refined in the refinery, mostly collected from the industrial facility of Trepca [10]. According to Unmik data from 2001 to this year 29,000,000 tons of ore were extracted in the business system Trepca-mine-Stari Trg, with variations of: 3.40-3.45% for lead-Pb, 2.23-2.36% for zinc-Zn, 74-81 grams, i.e. about 999,000 tons of lead-Pb, 670,000 tons of zinc-Zn and 2,200 tons of silver-Ag. It is estimated that partial revitalization, with only some improvements in this business system, will cost between US $ 15 and US $ 30 million [11]. The mine of Stari Trg at its deposits such as Meljanica, Mazic, Zijac and other surrounding deposits has reserves of around 35,081,000 million tons with significant massive deposits of sulphide ores or if expressed through the quantity of metals in the ores it is 1,349,579 tons of lead-Pb, 1,080,504 tons of zinc-Zn and 2,280,224 kg of gold-Au [12].

It is impossible to determine precisely the value of the main minerals at the Stari Trg mine because there were no more precise researches on their reserves conducted by the former Trepca business system (Table 4). The mine Stari Trg is one of the world's largest deposite of galenite (Pbs), which is the dominant lead ore in this mine. Galenite is mineralogical and auction-interesting because galenite and sphalerite together crystallize in more than 30 nicely crystallized minerals. After all, lead absorbs radiation and is used for protection in hospitals and in the nuclear industry. Another very usable mineral is pyrite (FeS_2), whose presence in a lesser extant was confirmed by a microsonde research in the ore at Stari Trg mine. The name of this mineral comes from the Greek word pyr, meaning fire, because it creates sparks when struck. This mineral is a raw material for the production of sulfuric acid.

Table 4 *Presumed mining reserves, total mine usable reservs and resource potential of Stari Trg Trepca mine [13]*

Mining reserves	**Tones**	**Pb (%)**	**Zn (%)**	**Ag (g/t)**
Proven reserves	120.340	5,14	5,13	88,0
Presumed reserves	311.660	5,10	3,17	80,5
Total mineral usable reserves	432.000	5,10	3,17	80,5
Total resources	12.488.000	3,21	2,21	56,4

From 1931 to 1998 Trepca business system produced bismuth in the amount of 4.118 tons with other related metal minerals, such as antimony, cadmium, gold and silver. The main minerals in Stari Trg are galenite, pyrite and sphalerite, which are associated with a small amount of mineral bismuth with sulfosalts gold-Au, silver-Ag and lead-Pb (Pictures 3 and 4). Mining deposits, such as Kisnica, Novo Brdo and Draznje in the east of Kosovo and Metohija have not been studied in detail, but the composition of the ore, textural and structural characteristics of the ore is similar to those in Stari Trg as shown by a similar hydrothermal source [12]. This is confirmed by the mineral reserves in Crnac area in northern Kosovo and Metohija with a high content of lead Pb 8.25%, zinc Zn 2.33% and silver Ag 93.5% g/t [14].

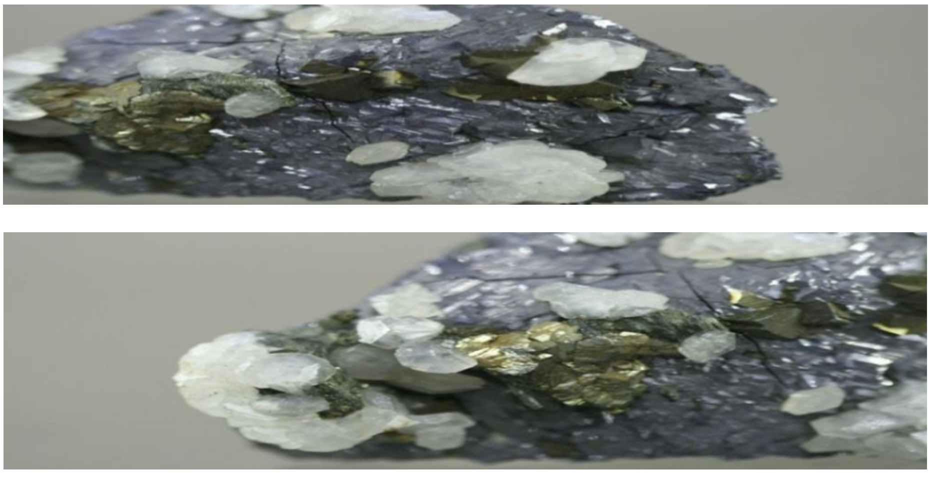

Figure 3 *Galenite, arsenopyrite and pyrite from Trepca [15]*

Figure 4 *Vivianite-siderite pyrite from Trepca-Stari Trg [16]*

The renewed research zones on zinc, lead and silver were carried out by the Canadian company "Altair Resources" from Vancouver, even in the period of the ex-Yugoslav government during the 1980s. Also, the research of the newer period from May to June 2016 refered to the Crepulja region, 17 kilometers west of the city of Mitrovica in the northern part of northern Kosovo and Metohija. Based on this research, the following data are present (Table 5).

Table 5 *Research zone "Crepulja" [17]*

Trench	Trench length (m)	Sample	From	To	Length	Zn (%)	Pb (%)
8	15	14	3,1	5,2	2,1	35,8	2,77
		15	5,2	7,7	2,5	37,02	1,75
9	14	Non-mineralized terrain					
10	12,5	18	1,7	3,4	1,7	36,57	3,95
11	20,5	6	0	6,4	6,4	1,69	0,43
		5	6,4	7,3	0,9	41,39	2,27
		4	13,5	15	1,5	34,79	3,66
12	17,7	3	11	11,8	0,8	28,9	5,21
		2	13	14,6	1,6	1,09	1,53
		1	15,6	16,5	0,9	4,53	2,13
Occurrences on the surface	n/a	19	n/a	n/a	n/a	38,28	1,8

These data only show that this area is highly mineralized in certain zones, and has a high quality level of zinc lead mineralization up to 41.39% of zinc Zn and up to 5.21% of lead-Pb. Surface excavations of mineralized high quality zinc were sampled and amounts 38.28% of zinc-Zn and 1.8% of lead-Pb. The parts of trenches, explored in 1974, were re-activated in 2016 and confirmed the high presence of zinc-Zn, up to 37.98%, and lead-Pb, up to 4.78% [16]. In the 1950s, the excavations and explorations of the Crepulja region were carried out by the Trepca business system. This was confirmed by the latest gravity research in March 2017, again by Altair Resources from

Vancouver that this area of the targeted zone, 5 km long and 200-300 meters wide, indicated a lead-mineralization zone of a high quality between 17 and 35% of zinc-Zn and lead-Pb [18].

4 RESOURCE POTENTIALS OF PRECIOUS METALS - GOLD AND SILVER IN KOSOVO AND METOHIJA

Kosovo and Metohija is another region rich in precious metals, gold and silver, above all. The potentials of economic resources in terms of lead, zinc, as well as gold, silver, and other rare and critical metals still exist today. Stari Trg in Kosovo and Metohija is one of the most important historical and mining districts in Europe for lead, zinc and silver [19]. Gold in Kosovo and Metohija is often found accompanied with the other minerals such as zinc, copper, lead and silver, although the alluvial reserves have been found along the rivers. For many years now, gold in Kosovo and Metohija has been mostly exploited in the Novo Brdo mine that operated between 1939 and 1989. It was the mine with the highest content of gold in the whole of ex-Yugoslavia. Before closing, the mine produced about 11.9 tons of gold. In 2005, the Independent commission for mines and minerals of Kosovo and Metohija, under the jurisdiction of Unmik, estimated that the share of the Trepca mine was estimated at around 3 billion euros. The remaining ore capacity is 29 million tons, out of which 990,000 tons is lead, 670,000 tons is zinc-Zn, and 2.200 tons is gold-Au. Table 6 shows the high percentage of gold and silver in the mines of Belo Brdo and Crnac in the north of Kosovo and Metohija [20].

Today, the largest gold mine in Kosovo and Metohija is a mine located in Malisevo, the municipality of Prizren (Figure 5). It is estimated that the Malishevo mine contains gold reserves of about 120 million tons with gold contents of 1.18 g/t.

Table 6 *Reserve of precious metals in Kosovo and Metohija [21] and [22]*

<table>
<tr><th>Location</th><th>Gold (Au) g/t</th><th>Silver (Ag) g/t</th><th>Silver/kg</th><th>The price of silver per kg 2018 [23]</th><th>Financial value of silver (in dollars)</th><th>Platinum</th></tr>
<tr><td>Stari Trg</td><td>0,6</td><td>76,00</td><td>1.577.304</td><td rowspan="8">530,66 USD</td><td>837.012,14</td><td rowspan="8">There is no available research on presence of platinum group metals. Reasearches are planned to be carried out in mountain massif of Djakovica</td></tr>
<tr><td>Belo Brdo</td><td>0,7</td><td rowspan="2">96,13</td><td rowspan="2">725.256</td><td rowspan="2">384.864,35</td></tr>
<tr><td>Crnac</td><td>1,0</td></tr>
<tr><td>Ajvalija</td><td>0,5</td><td rowspan="4">89,91</td><td rowspan="4">1.441.879</td><td rowspan="4">765.147,51</td></tr>
<tr><td>Kisnica</td><td>1,1</td></tr>
<tr><td>Badovac</td><td>0,25</td></tr>
<tr><td>Novo Brdo</td><td>1,6</td></tr>
<tr><td>Crepulja</td><td>0,13</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Draznja</td><td>-</td><td>39,66</td><td>-</td><td></td><td>-</td><td></td></tr>
</table>

This means that the reserves are estimated at about 142 tons of gold [24]. This area was explored in the 80s of the last century, but according to data a gold testing was not conducted. This project was recognized in 2007 after the Lydian program of Lydian International Ltd from Canada, when tests were carried out on a sample from 18 meters depth, and it was found 0.86 g/t of gold, while from 13 meters depth 1.8 g/t of gold was found (in 2008, 1.25 g/t of gold was found at 51 meters depth, and 1.08 g/t of gold at 38 meters depth) [25].

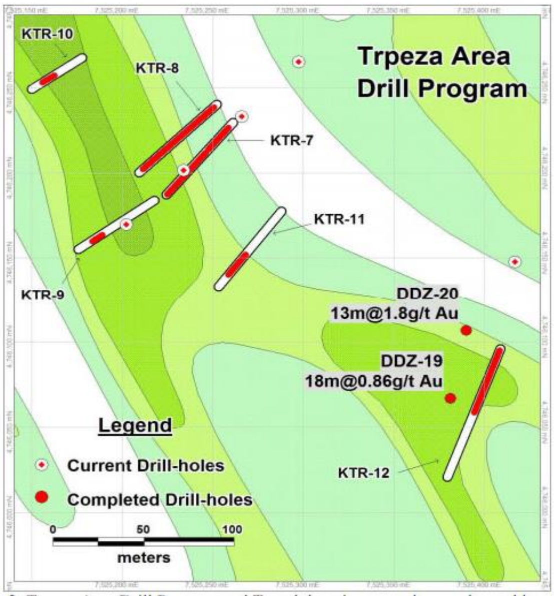

Figure 5 *Explored area of Malisevo near Prizren "Drazinje project" of a potential gold mine [26]*

When it comes to gold, there are several more projects underway. This includes the exploration of primarily the wider area of Pristina, Slivovo that is 15 kilometers far away. This is a joint venture between the Government of Kosovo and Metohija and Avrupa Minerals Ltd. from Canada, which together with Bymecut International Ltd. from Australia joined this research project. The research was concentrated on the Slivovo region, which showed the signs of golden deposits at 126.6 meters of the rock depth. The proof is a recently completed initial resource model, and the assessment of the Slivo project "Avrupa Minerals Ltd." (Table 7). This company has two projects in Kosovo and Metohija in the length of 47 km^2 and in mid-2016, it showed that within 640,000,000 million tons of ore were found, 4.8 g/t of gold and 14.68 g /t of silver.

Table 7 *Research project "Slivovo" [27]*

Explored area	Grams/t of gold	Grams/t of silver	%copper	% lead	% zinc
Slivovo	6,2	15,0	0,092	0,16	0,45

Therefore, the marked mineral resources of the project "Slivovo" amount to 98.700 ounces of gold and 302.000 ounces of silver. The estimated cost for the full three-phase research program amounts to approximately $ 8.3 million [28]. Cooperation with the foreign companies in the exploration and exploitation of gold and silver in Kosovo and Metohija is necessary because the lack of investment funds is one of the main issues to be addressed [29].

CONCLUSION

It is obvious that almost all deposits of jewelry minerals in Kosovo and Metohija are not well known and have not been sufficiently explored. Many countries and regions around the world traditionally encourage the processing of quality gemstones and, in general, the jewelry minerals - raw materials. To this day, there has been no systematic research into jewelry mineral resources in the territory of Kosovo and Metohija. It remains unknown that as per the market of Kosovo and Metohija for expensive and semiprecious stones-jewelry minerals-raw materials, there are no fairs and legal procedures for them. To begin the exploitation of these jewelry minerals, according to the expert estimates, no more than 10,000 euros is required. However, in order to begin the exploitation of jewelry mineral resources in Kosovo and Metohija, we must take a concession and pass procedures just like for the exploitation of gold and other precious ores.

Economically exploitable and primarily proven amounts of metallic resources and precious metals in Kosovo and Metohija are of particular interest for foreign companies and investors, based on the profit available in target mines and deposits. First of all, the economically profitable and exploitable reserves of magnesite mines at Goles and Strezovac basin are reffered here, as well as the research project of lead, zinc and silver in the Crepulja region and gold in the Slivovo region. According to the calculations of a Turkish company for the project exploitation and from the point of view of investors in mineral resource, there should be 30,000 tons of reserves of ore (lead, zinc and silver) in comparison to about 40 million euros of investments. Hence, the answer is got to the question that mining is an area in which foreign investors have an interest to invest. Some previous experience with the research of mineral resources conducted by the foreign companies shows that through such investments the investor invested at least 10 euros per hectare in the first year, 20 euros per hectare in the second year and 30 euros per hectare in the third year of research. Such mineral raw materials research requires a total foreign investment in mineral resource research of about 150 million euros, on average in three years, separately. Based on the previous research, the foreign companies are interested in the new mineral resource deposits, but also those located between the old deposits. Those sites that have been already known are not particularly interesting.

On the whole, Kosovo and Metohija is generally accessible, geographically and mineralogically compact area where the jewelry minerals, metallic reserves and precious metals are quite comparatively distributed. In the other words, Kosovo and Metohija has a total area of less than 10.000 square kilometers. This area is connected with 630 km of main roads and 330 km of railway infrastructure system. Although in the last five years, a lot has been done in terms of building a traffic infrastructure in the territory of Kosovo and Metohija and a wider region (Pristina-Djeneral Jankovic road with FYR of Macedonia, the highway of Kosovo and Metohija with Albania, etc.), the investments should be directed to the construction of local and regional roads to the mining sites and locations that are not quite in a prosperous state. The economic and especially unresolved political status of certain mining companies and their poor privatization, associated with the poor socio-economic situation of the domicile population, expressed primarily through a poor living standard, will not contribute to the development of the resource industrial complex of the region of Kosovo and Metohija. The lack of a concrete and targeted government policy with the unresolved political and economic status of some mining companies, for example, Trepca dealing with development of mining the precious and metallic resources and jewelry minerals-raw materials of Kosovo and Metohija, contributes only to a hyper stagnation of this sector. This is confirmed and estimated by the US Agency for International Development that the Trepca South business system is deeply in crisis because it functions with just 1/5 of its total production capacity from 2000 to 2012 [30]. In 2013, the Trepca North business system produced 11,000 tons of lead-Pb concentrate and 8,000 tons of zinc-Zn concentrates, which is only 15% of its capacity [31].

Natural minerals, first of all zinc, lead, silver and gold, and jewelry raw materials should not only attract the attention of foreign corporate investors, but especially the cooperation of the local self-government and those ones on whose territory those raw materials are located. Hence, the mining sector should be the primary sector of a wider region of Kosovo and Metohija, Serbia and the Balkans, where these raw materials are located.

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HUMAN POTENTIAL DEVELOPMENT IN THE MINING COMPANIES

Abstract

The new century has inaugurated a number of changes that can be attributed to the process of globalization of the world economy. Globalization with its influence brings a number of technological, economic, educational, social, and political and many other changes that have transformed the world economy, and have a significant impact on the business environment. The process of globalization brings a completely new concept of intellectual capital, with a clear and strong focus on the human potential, as its key component, pointing to its role and place in economic life. This paper presents the most important component of intellectual capital, which is the human potential. This is because of the role and significance of knowledge that becomes the central resource and bases of intellectual capital, and is the carrier of development and overall creativity. The knowledge and its application become the key form of material, spiritual, and every other social wealth. Rightfully, today's economy is called the "knowledge economy" because the creativity is based on the knowledge and innovation. Depending on the environment, defined by the economic horizon, the companies are referred to a strategic approach to the business development on the basis of strategy of developing their human potential, so these two strategies become compatible and inseparable. For the strategy of human resources development, as the most important segment of the social strategy, it is necessary to improve and promote the market for education and professional development. Today, instead of the global objective of education to provide the individual with a lifelong knowledge, in the foreground, the objective of education is to teach an individual to acquire the knowledge throughout his/her life, i.e. permanently educate and develop. The aim of this paper is to point out the importance, role and place of intellectual capital in companies with an emphasis on its progressive and constant change, i.e., development. By an empirical research, the role and development of knowledge will be proven in the Serbian mining companies which are part of the global economy.

Keywords*: human resources, intellectual capital, knowledge, permanent education, mining company, mining development in Serbia*

1 INTRODUCTION

The most developed countries of the world have highlighted the human potential as the newest and most important competitive factors of economic success. The fast economic development requires a new functional knowledge, and hence education and training have a key role and importance for further development. In order to be a part of the business world, to create it, we should continue to develop economically, we need to increase our arsenal of knowledge and develop the human potential of our mining companies. The European experiences tell us that during the human lifetime, the technology changes up to 10 times, and with this an employee changes own profession at least 5 to 6 times, which is not the case in the mining companies because of the very na

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ture of those jobs. This tells us that once learned, it can only serve as a start, where it quickly becomes insufficient. The transition economy in which the Serbian economy still exists has a new dimension in which there is a possibility that a large number of employees will lose their jobs for which they have been educated, and are forced to accept another job for which there is a need for society. Such conditions, as well as the ever-faster development of science and technology, as well as the changing conditions in the market and the environment, imply a growing need for permanent development of employees. That is why the all educational institutions and centers are assigned to find out how to help the employee in gaining a new and innovating the existing knowledge and skills. The answer lies in the fact that today it is necessary for the entire educational and scientific system to be oriented towards the production and diffusion of intensive knowledge, as well as the flexible disposal and use the existing knowledge and its continuous improvement. The classic role of companies is changing. Today, in addition to their work role, the companies have an educational role as well. Such education can give good effects in development the human resources. Today, there is a well-developed informal form of education serving the development of human resources in the companies. These are various forms of training and education that can be realized in addition to the classical methods of realization through the Internet, E-education, M-education, and other forms of distance learning, which will be discussed in this paper.

2 HUMAN POTENTIALS - FACTOR OF COMPETITIVE ADVANTAGE

Human potential is the only initiator of intellectual capital in the company. It relates to the accumulated value of investment in education, skills and future of all employees and their ability to transform their knowledge, skills and experience into the active creation of added value for the mining company.

Intellectual capital is a thermonuclear competitive weapon of the present, [1] telling us a lot and reflecting the power of human potential and their functional knowledge. In order to maximally and efficiently use this power of intellectual capital for the sake of further development and prosperity, it is necessary to fully understand its essence, role and way in which it develops. Companies are biology-sociological-economic organisms, which, in addition to the material basis, consist of people who, with their knowledge, abilities and skills, give meaning, purpose and useful value to all material elements as well as the mining company itself. Human being is confirmed as the most important factor of the company and its basic factor, the initiator and creator of new values, as well as the carrier and creator of all the changes that occur in an environment and company itself. Human is the one who gives the essence of life to the company and gives meaning and goals to the overall creative activities that occur and are carried out.

Human potential - a human being with knowledge, abilities, skills, creativity, motivation, attitudes, and working energy is primary in the development of the economy. A man represents the motor power, social and economic changes and is an inventive and creative factor in the process of creativity and management of companies regardless of their nature of work. Human potential is all that people know, for what are capable and skilled, experience that help them to anticipate the outcome and possible mistakes during work and management. Human potential is a part of the intellectual capital which leaves the company after the end of working hours. Today, in a developed economic world, the human potential and human capitals are explained as the wealth of a country, a region, a region. It is at the same time a country's competitiveness and competence in the international market, not just in goods and services, but also the intellectual capital, knowledge and skills. Therefore, instead of a business based on formerly tangible assets, the companies must develop a sense of creating, transferring, integrating protection and rational use of their intangible intellectual property, or the most valuable form of capital they own. Due to the nature of work, the mining companies have to manage the knowledge in a proper way if they want to use it maximally.

Everything defined as resources or capital has to be managed in the way to use it efficiently and rationally. Resources, whether they are in natural, financial, energy, information, are basic condition for the proper performance of business and only human resource (potential, capital) has no alternative and has the ability to give meaning, purpose and use value to all resources. It is the only rational resource from which everything begins and on which each activity is based. Human resources, in order to be efficient, should also be managed, which is the primary task of human resources management. Human resources management is a part of the organization's science and it deals with the management of human work and their development.

3 KNOWLEDGE-BASED ECONOMY

An economy, based on intellectual capital - knowledge is a modern economy and includes the value of total produced and realized goods and services created on the basis of applied knowledge. It is emphasized that the today's world has entered a new era - a period of knowledge and innovation. The basic infrastructural elements for prosperity in the knowledge economy are: knowledge as a source of economic development and innovation-as the most valuable source of creating new values and making changes. The age of knowledge sets the foundation for a new economic order and the chance of creating a new future, which is increasingly reliant on the value of human potential.

A new economic era is defined by many scientists, one of which is Peter Drucker, who points out that in the knowledge economy the natural resources and work are no longer the basic economic resources, but it is the intellectual capital that is defined as "knowledge that flows through technology and is found in humans" [2]

It follows from this that the knowledge is a priority factor of competitiveness. In the global business in the knowledge economy, competitiveness becomes tied to the individual economic entities, not to the national economies. Globalization as a universal process permeates all aspects of society, it breaks borders and establishes new connections and relationships creating conditions for faster and more efficient exchange of people, capital, goods, services, money, information and knowledge. Globalization of knowledge can be understood as the growth, development and knowledge exchange between different economic entities on a global basis.

In the knowledge economy, knowledge takes on some specifics and becomes the focus of interest in economic science and practice. Business in the knowledge economy is characterized by large and rapid changes at all levels and in all sectors and branches, business entities become more and more quality creators (new products, services, response to increased demands of consumers-markets), business has an international character, a new forms of cooperation between business systems, competition becomes more sophisticated and takes on new forms, the market is becoming more and more prominent, new demands of competitiveness are emerging.

The knowledge economy as a whole represents a transformed industrial economy where employees in the industrial economy are treated as a cost generator. In the knowledge economy, they are considered as generators of income and wealth and constitute the most valuable economic capital. The power of management in the industrial economy depends on the levels in the organizational hierarchy, but in the knowledge economy, the power of management depends on the level of knowledge it has at its disposal, i.e. of his competence.

The basic form of profit in the industrial economy was "tangible" - money, in the new economy the profit becomes "intangible", "invisible" - learning, new ideas, new qualities, standards, new customers and customers. The bottlenecks were money and skill which became time and knowledge in modern economy. The era of knowledge brings completely the new views on the world of economics, and inaugurates a completely new management. A man with his knowledge, abilities, habits, skills, creativity, motivation and energy is the most important factor in all human creativity and the bearer of the overall economic development at the present time. [3]

The economy of modern times and economic development are in a rapid rise and very complex and turbulent environment. In analyzing their competitive factors, the prevailing assumption is that a man with own values and position is not only a structure, but a basis from which everything starts and depends on . Changing the role and way of functioning of today's mining companies, as the subjects of industrial economy, is conditioned by a radical change in the role and importance of employees in them. Today, it is necessary to create the new, modern and high quality human resources, which can ensure the effective realization of business and development policy goals in conditions of the great economic uncertainty, rapid technological changes, dynamic transformation and change of the ownership relations.

The combination of labor and education, as well as their compatibility, has become an inevitable need of a modern and future businessman. The demand for developed and professional human potentials is changing faster than the human potential itself, hence there is a necessity of building a new human resource development strategy everywhere where they are present. The human resources development strategy is based on the "work and education", i.e. education in companies, which is a process of improvement leading to development and better quality of human potential [4]

Training programs should increase the flexibility of work and successfully overcome the rapid changes in any segment of mining companies, as well as to meet the legally prescribed requirements. The quality of human resources affects: behavior of people, change of working atmosphere, improvement of motivation for work, improvement of organizational culture, as well as change of working mentality and organizational behavior in a business system based on the ethical principles.

On the development and quality of employees, the US economist Peters T. said the following [5]

- Human capital should be invested as much as in the equipment,
- We train people from the first day and allow them to further improve whenever necessary,
- Comprehensive training includes the technical problem solving, so that people can contribute to the quality improvement,
- We organize training for people who transfer to the managers and continue to train them whenever they are transferred to a higher office,
- We use training as an incentive and strategic impulse,
- We insist that complete training is directed at people from the base, all programs should be based on the information from people from the base.

Training is progressing from the internal to dynamic; from a routine to a creative environment; from the "industry" of hierarchy, control and limiting compulsion to the "industry" of knowledge, cooperation, and intelligent choice of options. This approach to the professional and professional education and development of employees not only provides the high-level human potential, but also brings one message to every employee that is extremely important for their company. The new philosophy of development and business inevitably imposes an increasingly new attitude, it is necessary to understand how the

4 DEVELOPMENT OF THE HUMAN RESOURCES

The world is in so-called “intellectual revolution" that requires from every person to actively participate in the economic and social reality and its evolution. This is caused by a fact that development and survival of humans and society are conditioned by the knowledge and creativity of the human resources as developing resources that are a resource without limitations. This tells us that knowledge is a non-dynamic category and resource that is constantly evolving. Modern scientific and technical achievements will be defined in the companies at the speed and efficiency that the level of development of human potentials permits. The human resources development is a continuous process involving the formal education, work experience, relationships with other people and an assessment of personality and abilities, which enables the employee to prepare for future work. [6]

As one group of workers in New York stated in 1829 (A.Toffler, 1983) "With life and freedom, we consider education to be the greatest blessing that has been given to mankind."

The basic component of development the every human being and essential prerequisite of the human activity, both material and spiritual is education. Education is the carrier of every mental and manual work, as well as any spiritual and material creativity. The more education in a society, the less disorder and spontaneity in development, and more rationality and choices. Education - the process of knowledge acquiring is the most often exclusively related to the school education, which is a mistake. It is wider than this process and it lasts throughout lifetime, but it has different forms, content and methods. It is increasingly organized, in addition to the schools, in companies, factories and workplaces as an informal form of education that ensures the professional development of employees. The out-of-school human resource development programs are provided by the management training in companies, mass media, the Internet, scientific and artistic organizations and other organizational forms. In the process of knowledge acquiring, it is necessary to invest, where such investment is considered the most profitable process. [7]

A permanent education system is the basic infrastructure for the growth and development of human resources. It is oriented to the present and future, or to the training of human potentials for contemporary changes and changes in the future. Permanent education is a real social process and a strategy for social development. Under the permanent development of intellectual capital, all organizational activities aimed at completing knowledge, retraining, additional qualifications and other forms of professional development should be understood.

The human resource development goals can be expressed in several points:

- Permanent adjustment of employees' qualifications to the changes in job requirements;
- Motivation of employees;
- Investments in future success with small material investments;
- Company's responsibility to society and the environment;
- Stability of the social status of employyees. In the modern economy on the market, the winning companies are those that learn and truly believe in the idea that people and their knowledge are the greatest and most valuable asset. Modern companies collect information from the environment and turn

them into knowledge, embed this knowledge into their organizational structure and respond adequately to the issues and problems arising from the environment.

Only "learning organizations" are able to adapt to the changes in their environment, but at the same time initiate changes that give them a competitive advantage. Accordingly, the investments in human resources development, i.e. in their education increases both the value of employees and the value of company as a whole. Development is based on the interaction of individual development objectives and company development goals.

The development of human resources as a factor of the company's success cannot be left up, it must be a targeted and well -thought process, and it is left to the management training in company.

4.1 Training

When it comes to the educational function in the company, i.e. development of human resources, it is usually thought of as training. Training is used as a general term related to all organizational activities and programs aimed at raising the level and development of knowledge, skills and abilities of employees. Training in company represents a certain kind of organized permanent education that is related to changes in specific knowledge, skills, attitudes or behavior of employees with the aim of preparing for a better job. This is a company's planned effort to improve the performance of employees at their workplaces. [8]

Investments in the professional development of the human resources in developed parts of the world have become the most profitable investment in the own future and development, and company is a place where they are constantly learning, educating and developing. Many researchers suggest that the competitive companies in the West invest annually between 3 and 5% of their income to the education and human resources development. Some of these investments may be even greater, in case of strategy change, the introduction of new products, etc. Knowledge is a key factor that makes the difference between the successful and unsuccessful. Whenever it is said that education is expensive, it must be known that a lack of knowledge is much more expensive

The training aims to provide all employyees with the necessary skills to perform their roles in the business process. The state is obliged, through public funding of education, to provide the new participants in the labor market with appropriate qualifications. The companies and individuals are in competence for the continuation of training. The theory of training relies on the learning theories. With this way of acquiring knowledge, the employees of the company can respond correctly and timely to changing the environmental factors that influence the change of company strategies and goals.

The training itself as part of development process in the company is a complex, dynamic, synchronized and coordinated system of interconnected and scientifically determined and professional, predominantly creative and complex activities that take place chronologically at certain stages.

The stages of training as a process in the company are: discovering and determining the training needs, determining the goal, designing the way of realization, realization of the program, evaluating the results, as well as assessing the new values gained by the training. The phases are present in all forms of permanent education and training, and they must be mutually essentially settled, and are carried out according to a predetermined functional order. Only good and professionally designed training will give the good results in development the human resources.

Fitts and Posner (1967) defined a three-phase system that explains the process of acquiring skills. The phases occur in the following order: the cognitive phase in which an individual understands the nature of the job and how it occurs, associative phase in which an individual connects the input with the corresponding activities without great influence of the external environment, and autonomous phase in which an individual performs tasks independently without the need for cooperation.

The process of organizing the training is a very complex and responsible function of the human resources management or its sector (management training). But the form and method of training realization today is facilitated by development of information technologies, primarily those in education. Internet and new technologies in the field of information and communication are considered as the introductory in the new century, so investments in their development are very costly because they bring positive effects, both in the educational as well as in the economic and social system. The rapid development of information technology led to a change in education, as well as the very way of learning and acquiring a new knowledge. Electronic learning is increasingly complementing the classic forms of training and development, and in many cases their replacement. Thus, different forms of distance education enable the new ways of learning and acquiring knowledge that takes place separately in time and space between the lecturers and program users. The users have the opportunity to choose both timing and content of the program that will be adopted at very low cost. These forms are integral parts of training that take place in companies, making it more quality and efficient in their realization. [9]

Electronic learning has become an indispensable solution that helps companies applying this approach to development through the Information Communication Technology, and take advantage of the opportunities it provides. The strategy of today's educational centers as well as the company should be based on the fact that most of the activities in acquiring knowledge and human resources development taking place in a classroom are replaced by the interactive learning in a virtual classroom. The big world companies do 80% of their development and training through E- education, most often through the Internet (online training). Regardless of company activity, the education becomes the most important investment in future and development of every company which is more and more place for learning and developing.

5 RESEARCH METHODOLOGY

Today's scientific and technological progress has brought and imposed the new forms of work, management, new forms of organizational structures and important changes in treatment of developmental factors. Today's economy, besides investment capital and material resources, requires the good and quality human resources in which development should be invested much more.

Research was carried out in the mining companies of different types of activities, as well as with different number and structure of employees.

In this research, there were two hypotheses:

1. The hypothesis that education is not a process that takes place exclusively in the classrooms, but it is a permanent process that takes place, and continuously takes place in various informal forms of education.
2. The hypothesis that the Serbian mining companies increasingly recognize the role and importance of developing their employees as an important development factor.

The aim of the empirical part of the research is to identify the extent to which education and human resources development are represented in the Serbian mining companies, along with all other factors that condition the business in the transition process.

By the method of the questionnaire, the employees and their managers are examined in certain mining companies in the Republic of Serbia. The questionnaires were sent to the e-mail address of the director of business systems, and the data thus obtained were returned to the database.

The target group of the research is composed of the mining business systems (mining and processing of mineral sourcing) in the Republic of Serbia during the period of conducting this research. For the needs of research, based on the literature in the field of human resources development and the author's experience, a questionnaire with 30 questions was developed (this is not a standardized questionnaire model, but a personal projection).

In addition to the general questions about age, years of service, education and vocational training, the respondents answered the question of whether they are doing the job for which they have been educated and whether they have a sufficient knowledge to carry it out. The rest of the questionnaire relates to their advancement in companies, how often they attend training, what are the links between companies with the educational institutions, how much companies invest in their development, and how much in a new technology. The important question is: Do you want to acquire a new knowledge to keep your company alive?, and many others. 78% of the planned sample responded to the survey as follows:

The data are processed and sorted by the descriptive statistical methods and the results are the following:

Table 1 *Educational structure and strategy of development the mining companies*

Future company strategy	**Educational structure**					
	Unskilled	**Skilled**	**Secondary education**	**High education**	**Masters Doctorates**	**Total**
Closure of companies	0.9	4.5	1.2	0.4	-	7
Training of employees	2.8	14.1	3.8	1.3	-	22
Process of reorganization	3.5	17.2	4.7	1.6	-	27
Investing in a new technology	3.5	17.2	4.7	1.6	-	27
Cooperation of professional houses	2.2	10.8	3.0	1.0	-	17
Total	13	64	17	6	-	100

Based on these results, the following can be clearly seen: Training of employees as a strategic way of employee development is given a great importance by the employees in the amount of 22%, while the process of reorganization of the mining processes is given as much as 27%, as well as the investments in a new technology also 27%. It is almost a unique goal of all employees to continue working in the mining companies, regardless of difficulties and ownership transformation.

The educational structure of mining employees and future development strategy of the company, based on the obtained frequencies, the results are as follows: 17.2% of the qualified workforce is in favor of the strategy of reorganization of the process, the same is for investing in a new technology, while 14.1% of the qualified structure employees see training and development of their employees as one of the main strategies for the future development.

Table 2 *Number of employees and their skills*

Employees number problem	Problem of employees expertise			
	Employment of new experts	**Training of employees**	**Other way**	**Total %**
Dismissal %	3.3	13.13	3.13	19.6
Reorganization of working places %	12	47.30	11.30	70.6
No action %	1.7	5.65	1.57	9.8
Total %	17	67	16	100

From the networked data, it can be noticed that solving the problem of insufficient professional skills of employees is seen in the development - training as a model of acquiring a new knowledge and developing the new skills, even in 67% of cases, while a small percentage considers that problem of expertise should be solved by employing the new professionals 17%. However, solving the lack of expertise in the mining company employees see at 47.30% in the reorganization of workplaces and training of employees in the company.

Since the training itself as a process is a very complex and responsible function of human resources management or its sector, the question arises who will carry this responsible job in the company, or it will be entrusted to the other educational institutions or educational centers.

Table 3 *Attitude towards training and realization of training*

Attitude towards training	Time of training organization				
	In the last six months	**In the last year**	**5 years ago**	**10 years ago**	**Total %**
Yes	14.0	28.0	17.5	10.5	70
No	6.0	12.0	7.5	4.5	30
Total %	20	40	25	15	100

By analyzing the data the attitude of the employees towards the training and its organization and realization over a certain period in the companies is the following: The attitude of the employees towards the organization and realization of the training is positive at amounts to 70%, with the emphasis that the companies do not have enough professional people to conduct this process, so the specialists must be hired.

Viewed over time, there is a noticeable increase in frequency of the training implementation in the Serbian mining companies, but this is still not satisfactory. The attitude of employees towards training and other factors of company development is analyzed, as shown in the following Table.

Table 4 *Training and other factors of company development*

Attitude towards training	Development factors			
	Financial resources	**Human resources**	**Science and technology**	**Total %**
Yes	29.4	24.5	16.1	70
No	12.6	10.5	6.9	30
Total%	42	35	23	100

The employees in the Serbian mining companies consider for development factors: the financial resources with 42% in the overall structure of development factors, human capital and knowledge with 35%, science and technology with 23%. As the science development is component that refers to the human potentials and their knowledge, it can be said that the companies based their development on human resources, 58% (35% + 23%) and 42% on financial assets.

CONCLUSION

The mining production, as much as it prefers to provide the material resources in its operation, it cannot base its further development without intangible resources, i.e. without a new knowledge, innovation, quality, standards, and other values that exclusively relate to the employees, or human resources. Research has shown that it is understood that the quality human resources in the mining companies can enable their explicit growth. If companies have professional and educated human potentials that are ready to innovate and risk in line with market needs, they will succeed in achieving the economic growth and development, not only by the individual functions and organizational parts, but in general. The intellectual capital employed by the employees is a dominant determinant of the value of companies' capital at a given time, which is confirmed by our researches conducted in the Serbian companies that are engaged in the production and processing of ore. Companies that provide a permanent development of their human potential through different forms of training and education create better intellectual capital, have the opportunity for the market expansion, an advantage over the compe-tition, the ability to expand and conquer the new markets, and the opportunity to provide additional capital for their own development. People's proverb says: "If you want to harvest fruit forever then the people have to learn." The same is the case with the companies, those that invest in development of their employees in order to acquire the new knowledge and skills and believe that the knowledge is a key development resource, become the "learning organizations", and provide the better business future. The bases for development in the Serbian mining companies and companies of the developed world is in intellectual capital, but in our practice this indicator of development is not at an enviable level that obliges this problem to become a permanent social concern with much better and more responsible approach.

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ECONOMY MANAGEMENT WITH A FOCUS TO THE PRODUCTIVITY

Abstract

Knowing the essence of productivity and its importance for the economy of the company, but also for the national economy is a prerequisite for successful management in these spheres, as well as the implementation of productivity principles as one of the basic principles of economy. Productivity is viewed as a component of economic growth with the help of production function. Many theoretical interpretations point to the differentiated concepts of factor productivity at the enterprise level. The analyzed complex models for measuring the productivity of enterprises indicates that the productivity has been placed in the focus of economic management. The paper highlights the theoretical methodological problems in the application of certain models and ways to overcome them. The main goals of institutionalization in this area are harmonization the methodology for measuring the productivity of enterprises and national economy and enabling affirmation and importance of the productivity. The productivity of the national economy is most often measured by the real GDP per capita, often being the subject of analysis and composition of the GDP as different types of expenditures.The main goal of this paper is to enable better management to the economy of industrial enterprises, especially the mining companies, through improvement the productivity measurement.

Keywords*: productivity measurements, productivity indicators, productivity approaches, economic growth*

1 INTRODUCTION

Bearing in mind the constant orientation of the society to meet the greatest number of social needs in concrete conditions, there is a demand at the first place for production to be as productive as possible. Increasing productivity has become a constant task as well as a logical follower of increase in the social standards and continued advancement of society.

Countries with the productivity is at a higher level are far more favorable in the international trade because the world trade, and, as a rule, domestic trade do not take into account a low productivity and high production costs. The comparative advantages of the economically most developed economies of the world are primarily on the achieved productivity (an example of the Japan economy)

Productivity is one of the basic principles of economics without whose implementation there is no successful management of the economy, i.e. economic and social development.

Productivity as an economic principle is defined differently depending on what is meant by the economic content that it includes, or what it expresses as a measure of

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economy success. In this relation, two extremes occur: the broader and narrower theoretical concept of productivity comprehension.

On the one hand, there are the economic theoreticians stating that the productivity is a measure of overall economic efficiency, and thus it is an expression of overall state of the economy, expressed in the terms of output / input = productivity, where the inputs are available resources (labor, capital, land, material, energy, and even information), used in the production and trade of various goods and services.

Products and services are taken as the outputs either naturally or financially at various aggregate levels (individual, company, sector, industry, economy as a whole).

On the other hand, there are the authors who treat the productivity as the productivity of labor, since they assume that the productivity only expresses the efficiency of current work. This means that the productivity is treated as a partial measure of efficiency, or state of economy, as partial rather than as a universal economic principle. The productivity thus understood is usually expressed in terms of the labor productivity = production / current work.

The analysis of the essence of these concepts, the concepts of productivity, points to differences in the goals that should be achieved, nature and breadth of treatment of productivity treatment as an economic principle, economic content and economic categories that include productivity as an economic phenomenon. At the end, there are big differences in terms of measuring the productivity and applying the principles in the economy management. [1]

2 INSTITUTIONALIZATION AND PRODUCTIVITY MEASUREMENT

In theory and practice, this problem is often seen from different aspects and goals, and hence there are different opinions about the concept of productivity. Just because historical and other facts have influenced the definition of the concept of productivity, there are different understanding about the essence of this notion. Socially, politically, economically and other factors have influenced the definition of productivity.

A closer definition of this term is given by the physicists of the 18th century as “ability to produce”. At the beginning of the 20th century, the term productivity was used by the economists in the sense of relationship between the products and factors. In this sense, defining the concept of productivity as a global relationship between the output and input has been accepted by the Western economists and Organization for European Economic cooperation (OEEC), which has been worked since 1961 as the Organization for Economic Co-operation and Development (OECD). This understanding is seen in the latest works of the International Labor Office (ILO) from Geneva. [2]

As the relevant institution of measurement and analysis the productivity in Europe, the OECD in its reports [3] defines the national level of productivity measurements with the social gross product and / or added value, as the relevant outputs and certain alternatives to the inputs, hours of work, work effort (quality of work) and number employees. Of course, the OECD experts make difference between the quantitative and price aspect of productivity measurement. Although the financial way of productivity tracking is favored, it is mandatory to suggest the use of fixed price methods. The valid conclusion of the OECD study relates to a qualitative and quantitative approach in analyzing the working hours or effective working hours. It is quite clear that the number of working hours is a formal indicator (quantitative nature), and the actual utilization of employees in the working time is a vital indicator of productivity (qualitative aspect of productivity). The quantitative aspect of working hours (working time) can vary widely from country to country, from company to company (in the same country) from the nature of business, from the time of year (seasonal variations), etc. On the other hand, the qualitative aspect of productivity measurement relates to the quality of daily work activities in a single workplace, which belongs to a domain of human resources management, that is, the monitoring and evaluation the employees by the executives in all organizational units of the company. [4]

At the level of USA economy, the labor productivity is monitored analytically at the level of each enterprise, industry, and American economy as a whole. These monitoring and analysis are of a financial nature and are done through a chain or base indices, with different outputs and inputs depending on: 1) Whether the analysis is performed at the enterprise level as a whole or some of its units and 2) which aspect of productivity is monitored and analyzed. Reports on quarterly or annual aggregate productivity trends in the USA have been published within the Bureau of Labor Statistics since 1947. [5] In addition, this leading world house of statistics productivity (not only labor) in principle analyzes the productivity from three aspects [5]:

Work productivity which has a working input in its basis; productivity is monitored at the level of the economy as a whole (all enterprises, i.e. the economy and non-business are expressed in our terms), but it is particularly expressed in the agriculture, non-financial institutions, production corporations etc. The labor productivity indicator is monitored quarterly.

Multifactor productivity - inputs and labor are the inputs for the analysis and monitoring of this aspect of productivity; this indicator is monitored on an annual basis.

The KLEMS model of multifactor productivity - this is a complex model of productivity tracking, where besides work and capital the following inputs are specially specified: energy, materials and services; this indicator is particularly interesting only for the manufacturing companies, and is monitored on an annual basis.

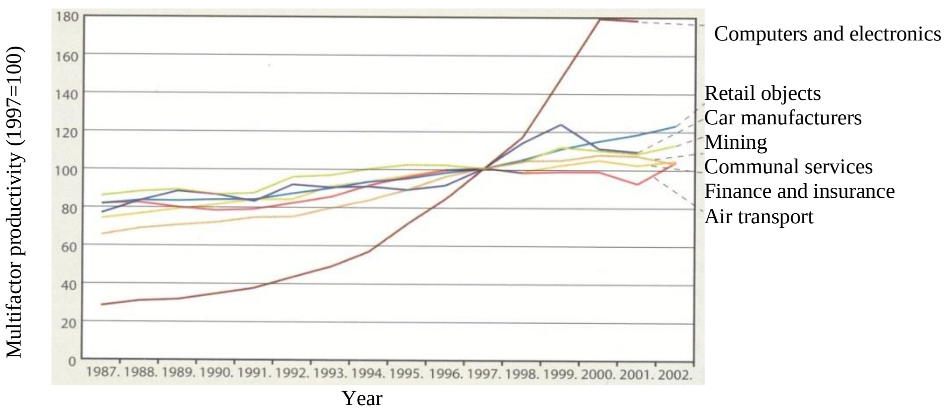

Fig. 1 *Growth of multifactor productivity in different industries*

Source: "Productivity and Costs", Bureau of Labor Statistics, available at http//data bls.gov/cgi-bin [6]

In the example shown in Figure 1, there are trends related to the multifactorial productivity in several branches of the US economy from 1997-2002, with an increase of 78% in the period from 1997 (which is equal to 100%) to 2001 (when the level reached 178), and with almost six times increase since 1987 the growth of multifactorial productivity in the computer and electronics sector has far exceeded productivity growth in the retail, car manufacturing, mining, utilities, finance and insurance, air transport and most other branches.

Should Managers Use the Multifactorial or Partial Productivity Measures? Generally speaking, they should use both measures. Multifactor productivity shows the overall productivity level of the company compared to its competitors. In the end, that is the most important thing. However, the measures of multifactorial productivity do not show how much the individual contribution that work, capital, material or energy give to the total productivity. In order to analyze the contributions of these individual components, the managers must use the partial productivity measures. This will help them to determine which factors need to be corrected, or in which areas the correction can most likely reflect on the total productivity. [7]

3 PRODUCTIVITY CENTERS - OUR EXPERIENCES

The main objective of institutional measurements the productivity was to harmonize and standardize the methodology for measuring productivity so that the productivity of national economies would be comparable, that is, each country could determine whether its productivity is increasing or not in relation to the productivity of other countries.

In parallel with the start of institutional and systematic measurement of the productivity of national economies, productivity centers (firstly in the countries of Western Europe, then in Japan) are being formed in many countries of the world, whose goal is to promote and improve the productivity in enterprises. The main goals of productivity centers are to promote the importance of productivity, and to improve the methodology for measuring productivity of enterprises through the harmonization. [8]

In our country, it is understood, the experiences of other countries are used, but some own results have been achieved, especially in the work of the Federal Institute of Labor Productivity (which was established in October 1957), which are a serious contribution to the problem of measuring labor productivity. The institution is financed from the budget. At that time, very useful cooperation with the European Productivity Agency (EPA) in Paris was developed. After several changes in the name, the stagnation and problems in the economy were very strong in the work of the institute. In 2005, after the privatization and transition to the ownership of a consortium of employees, the legal form was changed into a joint stock company and soon in the limited liability company. Today it is the Institute of Business Improvement Ltd. Belgrade.

4 PRODUCTIVITY, PROFIT AND ECONOMIC GROWTH

Productivity and profit are two sides of the same phenomenon, two angles of looking at the same process "the process of continuous and successful business". For businesses, a higher productivity - that is, to achieve more with less resource - means lower costs, lower prices, quick service, higher market share and higher profits.

According to Professor Drucker, the productivity represents the wealth of people, as it allows a part of the newly created value to flow into the increased quality of life of the broad social levels. This confirms and states that the "civilization and productivity go hand in hand". This is the reason why in all, and especially in highly developed countries, research is being carried out and ways to increase the labor productivity are found.

Every growth of the economy can be achieved [9]: 1) through the additional input, 2) through the productivity growth.

By help of the production function, it is possible to describe simply the mechanism of economic growth. Economic growth is a production increase achieved by an economic community. It is usually expressed as the annual growth percentage depicting (real) growth of the national product. Economic growth is created by two factors, so that it is appropriate to talk about the components of growth. These components are an increase in the production input, and increase in the productivity.

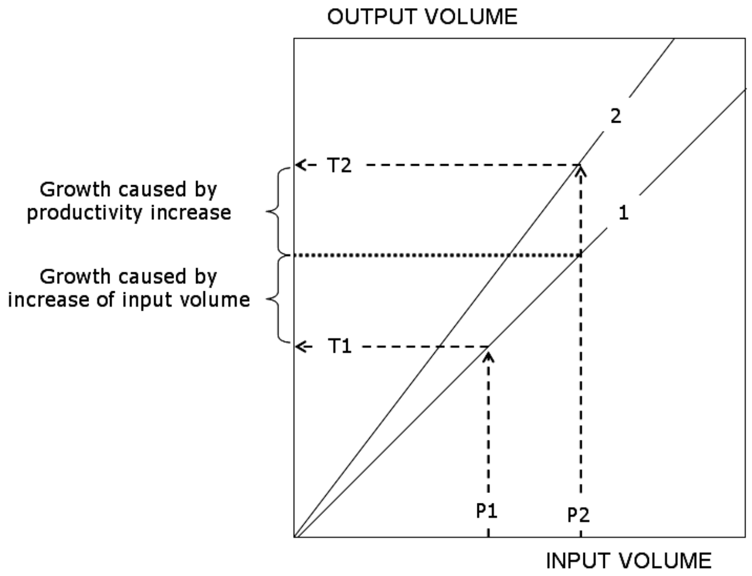

Fig. 2 *Components of economic growth*

Source: Seppo, S 2006, Productivity: Theory and Measurement in Business, University of Applied Sciences, Finland [10]

As shown in Figure 2, it becomes evident that the production increases from T1 to T2. Measured in absolute terms, the economic growth is T2-T1, while speaking proportionally it is T2-T1/T1. At the same time, increasing the value from P1 to P2 is measured in the use of production input. Now, both years can be represented by a graph of the production function, each function is related to a particular year, e.g. 1 and 2. Two components differ in the output growth: growth caused by input and growth due to increase in the productivity. A profit based increase is determined by moving along the production function for a certain input increment, e.g. from P1 to P2. The growth characteristics affected by the increase in input are that the relationship between the output and imprint remains unchanged. An increase in output means the change of production function simultaneously with the change in the output / input ratio. In the other words, the growth of output corresponds to a shift in production function, generated by an increase in productivity.

Therefore, the increase in productivity is characterized by the shift of the production function to the output / input ratio. The total productivity formula that follows is:

Total productivity = output quantity/ input quantity

According to this formula, the changes in input and output must be measured including both quantitative and qualitative changes.

In practice, the quantitative and qualitative changes occur when the relative quantities and relative prices of different input and output factors change. In order to emphasize the qualitative changes in the output and input of the total productivity formula, the following will be given:

Total productivity = Output quality and quantity / Input quality and quantity

Model of the national economy - In order to measure the productivity of nation or industry, it is necessary to operationalize the same concept of productivity as in the business, yet, the object of modeling is substantially wider and the information more aggregate. Calculations of the total productivity of nation or industry are based on the time series of the SNA, System of National Accounts, formulated and developed for half a century. National accounting is a system based on the recommendations of the UN (SNA 93) to measure the total production and total income of a nation and how they are used. Measurement of productivity is at its most accurate in business because othe availability of all elementary data of the quantities and prices of the inputs and output in production. We want to analyze more comprehensive entity by measurements, more data need to be aggregated. In the productivity measurement, combining and aggregating the data always involves the reduced measurement accuracy.

5 INDICATORS OF PRODUCTIVITY OF THE NATIONAL ECONOMY

Productivity is considered as the basic statistical information for many international comparisons and country performance assessments, and there is a great interest in comparing them internationally.

The productivity of the national economy is measured by the amount of the gross domestic product (GNP) per capita.

The Internationally Recognized Standards: The National Accounts System 2008 (SNA 2008) and the European System of Accounts 2010 (ESA-2010) are the basic methodological framework in terms of defining and evaluating categories, applied classifications and method of calculation. The annual macroeconomic accounts and the most important macro-economic aggregates for the Republic of Serbia are published in accordance with these internationally recognized standards. The published data are available since 1995.

The most well-known and most used aggregate of the National Account System is the gross domestic product (GDP), which is an indicator of the total economic activities at the country level. Gross domestic product is the market value of all final goods and services produced in one country for a specific period of time. The GDP is calculated at the current and constant prices. The calculation of the GDP at constant prices aims to show the real dynamic and structural changes arising independently of the impact of prices.

If the GDP is viewed from the point of view of total expenditures, it can be explained by the components: consumer spending (C), investments (I), government expenditure (G), and net exports (NX).

In addition to the national currency calculation, for the purposes of international comparisons, the calculation of the GDP, and other macroeconomic aggregates in USD and EUR is made at the average annual rate.

There are three approaches to the calculation of the GDP, production, processing and revenue (contained in chapter 6, national accounts, and methodological bases of the national accounts system) [11].

Gross domestic product, GDP, calculated according to the production method is the sum of gross value added (GVA) of all resident institutional units plus the amount of product tax and reduced by the amount of subsidies on products. Gross value added is obtained by the production method, as a difference between the total output (production value) and inter-phase consumption.

According to the expense approach, the aggregate forests: the final consumption (households, non-profit institutions that provide services to households and the state) invest in the basic funds changes in supply and export values minus the value of imports of goods and services. Spending of goods and services in the production process (inter-phase consumption) and investments do not have the character of final consumption.

The GDP can also be accounted by the income method as a sum of gross salaries of employees, business surplus / mixed income and taxes reduced for subsidies on products and on production.

The productivity of the national economy is measured by the gross domestic product per capita (GDP per capita) in current and fixed prices. When the nominal GDP is calculated, the current prices are used. When calculating the real GDP, the fixed base year prices are used and based on them the value of production of goods and services in that economy is attributed. Since real GDP does not affect price changes, changes in real GDP reflect only changes in the quantities produced. When it comes to the growth of the economy, this growth is expressed as a percentage change in the real GDP.

The Serbia's Gross Domestic Product (GDP) in 2016 amounted to RSD 4,261 billion at current prices and was 5.4% higher than in the previous year, while the real growth, calculated at fixed prices, was 2.8%, the Statistical Office of the Republic of Serbia reports.

By activity, in 2016, at fixed prices in the agriculture, forestry and fisheries sector, the growth of gross value added was 8.1%, the sector of processing industry 2.2%, the wholesale and retail sector and motor vehicles repair 3%, the sector information communication 5.8%,and in the electricity, gas and steam sector, 6.3%. The real fall in gross value added was recorded in the mining sector of 3.7%.

In the use of GDP, the share of expenses for personal consumption of households was 71.4%, expenses for final consumption of the state 16%, gross investment in basic funds 17.7%, exports of goods and services 50% and imports of goods and services 57.5%.

6 PRODUCTIVITY OF THE COMPANY

Many works dedicated to the global productivity of factors and labor productivity have contributed to the improvement of enterprise productivity measurement. In this way, support was provided in more efficient management of the company's economy.

Global productivity (factor productivity) or total resources implies that productivity expresses the overall efficiency of the economic system as the state of economy expresses the relationship between the total output and input. On the contrary, the productivity of work only partially expresses the efficiency of economic system, since it includes only one aspect of input, current work.

Jean Fourastie, in his book (La Productiva, page 53-65 [12]) as a member of the Committee for the Study and Measuring Productivity of the National Committee for productivity of France, gives a "recapitulation of productivity concepts" and systematizes them into the following productivity indicators derived from the Theory of Productivity factors:

First, productivity in relation to work = Production / Current work

Second, productivity in relation to any other factor = Production / Quantity of this factor

Third, global productivity factors = Production / all factors

Fourth, integral labor productivity = Production / Integrated work (current + tangible)

Fifth, net productivity = net product / (production-external factors) current work

With the abandonment of the value theory and change in theoretical thinking about productivity, the prevailing opinion was that capital, along with work and land, has an equally important role in creating products, and an effort to increase productivity. This was the basis for the emergence of the concept of production function and the measurement of total factor productivity. Measurement of the production function and total productivity of factors, through the relationship between products and all invested factors of production, began in the middle of the 20^{th} century.

7 MEASURING PRODUCTIVITY OF THE COMPANY

When we express or measure productivity of a company, we notice two groups of problems: 1) the problem of expressing output and 2) the problem of measuring the input. Classical production productivity can be measured by the ratio of the output quantity, volume of production, and quantity of work invested. If the output is defined in one type of product, then

$$P = Q / L$$

where

- Q is the quantity of usable values of products and services expressed by physical units of measure, and the L-amount of invested work is expressed in the number of employees or hours spent.

In order to be able to measure the outputs in processes with a heterogeneous production program, two measurement approaches can be used. The first is the application of coefficient of equivalence by which the quantity of different products is reduced to one conditional product. The conditional product is one of products from the assortment of company and presents the results of management decision. The equivalence coefficient is calculated as the ratio of the number of norms of hours needed to produce the conditional product and the norm of hours needed for production of the observed product

$$Kei = Nsi/Nsu$$

- Nsi - the norm of hours of the i-th product,
- Nsu - the norm of hours of conditionnal product.

Then the total output is:

$$\Sigma \; Kei \odot Nsi \odot Q:$$

where

- Qi- number of product pieces of i-th product

Another approach to expressing an output quantity in the case of a heterogeneous product or service program is based on the use of value units or prices. When using this approach, there may be some doubts about whether internal ones are used, for example, cost price, or market price. Bearing in mind that the prices of some products are very variable, and that some prices are formed in the conditions of dominance in the market, some companies decide to show the amount of the output at internal prices (cost price).

Productivity in these cases is measured by:

$P = \Sigma Q \cdot Cq/L$

where

- Q - Produced quantity,
- Cq - market price per unit of product.

$P = \Sigma Q \cdot Tq/L$

where

- Tq- cost price per unit of product.

These methodological problems can be overcome using the fixed prices. By calculation the physical product in the regular chains of the selected base period, a change in the quantity of products and services is expressed, not a change in prices.

With regard to determining the size of the input except for the work, or any other individual input factor, the input costs can be summarized as the labor inputs, material costs, energy costs, amortization costs, interest costs and the multifactor productivity is [13].

$P = \Sigma Kei \cdot Nsi \cdot Qi/ Tr + Tm + Te + + Ta + Tk$

Where

- Tr - labor costs
- Tm - material costs
- Te - energy costs
- Ta - amortization costs
- Tk - interest costs

Inputs can be calculated by fixed price method where some elements are calculated differently.

7.1 The Kurosawa Structural Approach

Kacukio Kurosawa, a professor at the Tokyo University, supports that the productivity measurement system is to be built in accordance with the hierarchy of leadership. In his works, he places productivity at the focus of economy management.

A very precisely defined working time structure is used to define the labor productivity measurement ratios.

In implementing his structural concept for measuring productivity at the enterprise level, Kurosawa combines the added value with various physical parameters and other related variables. The added value of the company can take several forms. Management objectives dictate the choice of form of added value.

Real added value = $\Sigma Pi \cdot Qi/ Ip - \Sigma Si \cdot li/Is$

$\Sigma Pi \cdot Qi$ - gross output in the current period at current prices

$\Sigma Si \cdot li$ - industrial costs in the current period at current prices,

- Ip - product price index,
- Is - average input price index.

7.2 The Lolor Approach

Alan Lolor treats productivity as a comprehensive measure of the efficiency and effectiveness of the company and looks at it from the point of view of objectives, efficiency, effectiveness, comparability from the point of view of trends.

In Lolorov's approach, there are two levels in measuring productivity within the company: primary and secondary. The primary level shows the total earnings productivity expressed by the ratio of total earnings / cost of conversion. The conversion costs include the total personal income (v), total purchased services (Ps) and depreciation (K)

E = total income/ conversion costs = T/C

At the second level, it expresses the profitability of profitability as a ratio of profit and total conversion costs.

Ep = profit/conversation costs = P/C or since $P = T - C$

$Ep = E - 1$

The total cost of conversion contains the costs when resources are productively used, and costs of unused resources. True production work, in contrast to the auxiliary work, directly adds value to the raw materials. Lolor uses two more secondary productivity measures: working capital and productivity of supplies.

Potential of the total enterprise income is earnings that would be obtained if the entire input was fully utilized without the cost of unused capacity. In the other words, Cd = CC. For that matter:

Potential earnings Tpot = T / Total Cd x C

7.3 The Approach of National Authors

On this occasion, it is necessary to emphasize the special contribution of Prof. Dr D. Radunović in the study on productivity of the company. By giving contribution in the analysis of the productivity of mining companies (coal mines), Radunović has developed his own concept for applying productivity in this business. Although this is a homogeneity - uniformity of assortments in the mining production, and here the theoretical and methodological problems arise. Four methods are applied: natural, natural-conditional, working and monetary method, as well as a combination of natural-conditioned methods. In his approach, he chose the productivity of current work. He analyzed factors in the mining production.

Prof. Dr Stevan Kukoleca, although his approach is based on the concept of labor productivity, uses only the term productivity because he rejects the thesis about factor productivity. He treats the productivity as one of the three economic principles in addition to the economics and profitability, each focused on a particular economic content. The principle of productivity is viewed as the principle of economic work whose content is focused on the relevant relationship between the products and labor costs. In order for productivity to be a feature of a specific measure of the quality of the company's economy, only the quantity of product that is being realized or, more precisely, which has been realized should be taken into account. In this way, an increase in the consumption potential and living standards is ensured which contributes to the level of macroeconomics.

Measuring productivity also implies the qualitative and quantitative expression of changes under the influence of a certain factor, not only the product and the cost of labor, but also their mutual relationship.

CONCLUSIONS

Productivity is undoubtedly at the center of both theoretical research and concrete economic practices, whether it is a national economy or the economy of a company. This is shown by extensive literature devoted to the productivity, which is in the focus of interest not only of some scientists and researchers, teams of specialists but also national and international institutions dealing with productivity improvement. When adding all those working on productivity problems in specific companies all around the world economy, then a really good picture of this significant economic phenomenon is obtained.

Productivity is not interpreted in the literature uniquely and different models for its measurement appear. Based on the differrence in economic sustainability that it encompasses, or what it expresses as a measure of the success of the economy, two concepts exist in the contemporary literature. The first concept of labor productivity is a relationship between the product and invested work as an input. This is the oldest and most frequently used indicator of partial productivity. Quality management of the organization through the labor productivity model implies increasing the level of results while reducing the effective working hours needed to achieve these results. It is also necessary to discover causes that affect the efficiency and effectiveness of the company.

Another concept of the productivity of all factors is the relationship between products and all inputs. The fixed price method is the standard productivity measurement method. By the method of fixed prices, heterogeneous products and inputs are reduced to a monetary value, thus overcoming the problem of their incompatibility.

By determining the multifactor productivity, we do not get knowledge on contribution the certain factors to overall productivity. Multifactor productivity as a synthetic indicator is not an analytical instrument that enables an adequate diagnosis of the condition and cause for taking the appropriate management actions accordingly.

Measuring the levels and productivity changes (single-factor productivity), while monitoring changes in the scope and structure of individual factors, can provide conclusions about which measures reducing consumption or input lead to the highest growth in results.

At the national economy level, it is necessary to operationalize the same concept of productivity as in business, but the goal of modeling is much wider and the information is more aggregate. It is usual that the productivity of a national economy is expressed as a gross domestic product per capita. Institutionalization has contributed to data comparability, which is a step to increase productivity.

The increase in productivity can be due to the savings made in the use of other inputs, which cannot be shown by a partial expression of labor productivity. The net saving of all inputs and the resulting increase in total productivity can only be expressed when the product is compared with all inputs, which means measuring the overall productivity of factors. Productivity as a measure of success is important for the mining companies.

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VERIFICATION OF A DEEP WELL PUMP FOR THE INDUSTRIAL WATER SUPPLY SYSTEM

Abstract

This paper gives a procedure of calculation verification the technical characteristics of the pump under given operating conditions in an example of the existing installation of a deep well pump for the technical water supply of the Nisal factory, The calculation was done analytically and graphically.

It also presents a scheme of industrial water supply, disposition of a deep well pump installation, as well as its technical characteristics.

***Key words**: deep well pump, calculation, disposition, technical characteristics*

1 INTRODUCTION

Deep well pumps are used in the water supply facilities, industry, construction and mining to reduce or maintain the water levels [1]. Three reservoirs R1, R2 and R3 are used for the needs of the technological process of the “Nisal” factory in Nis. The reservoirs are supplied with water from three artesian wells for the technical water B1, B2 and B3. The B1 well is Ø1600 mm in diameter, about 20 m in depth, and water is pumped from it by means of a deep well pump made by the ”Jastrebac“ Nis, with label BP-150-4. The B2 and B3 wells are Ø1200 mm in diameter, about 7 m in depth, and water is pumped from them by means of a deep well pump made by the “Jastrebac“ Nis, with label BP-100-2. All reservoirs are connected in the “ring” in case of failure of individual deep well pump by the buried steel pipelines A case of supply o the reservoirs R1, R2 and R3 from the B2 well will be analyzed in this paper. The scheme of industrial water supply from the B2 well with designated sections is shown in Figure 1.

2 TECHNICAL DESCRIPTION

Vertical deep well pump construction consists of the discharge head, fixed discharge pipe section, discharge pipe sections, hydraulic sections and suction bell [2]. The cross section drawing of the deep well pump is shown in Figure 2. A flanged electromotor with electrically driven pumps is assembled on a discharge head, while a discharge head itself contains the axial and radial bearing, shaft, elastic coupling, manometer, shaft sealing and discharge connection. Fixed discharge pipe section serves as a connection of discharge head with the discharge pipe sections. Discharge pipe sections make the necessary pump height. Hydraulic part of the pump consists of the suction and discharge cases, as well as a certain number of impellers with diffusers through which the shaft on rubber bearings passes. Suction bell consists of the suction strainer and check valve. Deep well pump BP-100-2 is a two-stage semi-axial vertical deep well pump driven by electromotor made by the “Jastrebac“ Nis the with following technical characteristics:

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- power: $P = 3\ [kW]$
- speed: $n = 2900 \left[\frac{1}{min}\right]$
- discharge connection: DN100 PN10

Disposition of deep well pump BP-100-2 in the B2 well is shown in Figure 3.

Performance curve of the pump is shown in Figures 4 and 5.

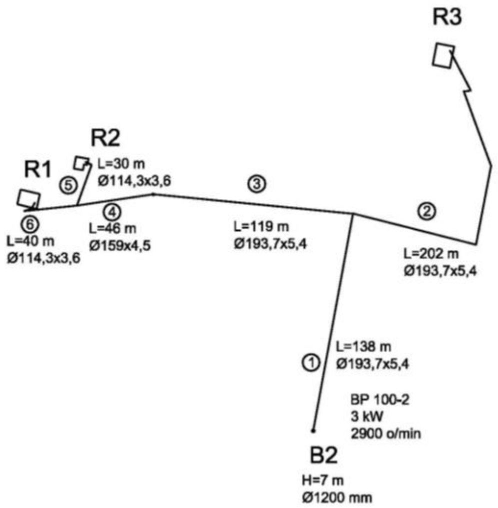

Figure 1 *Scheme of the industrial water supply from the B2 well*

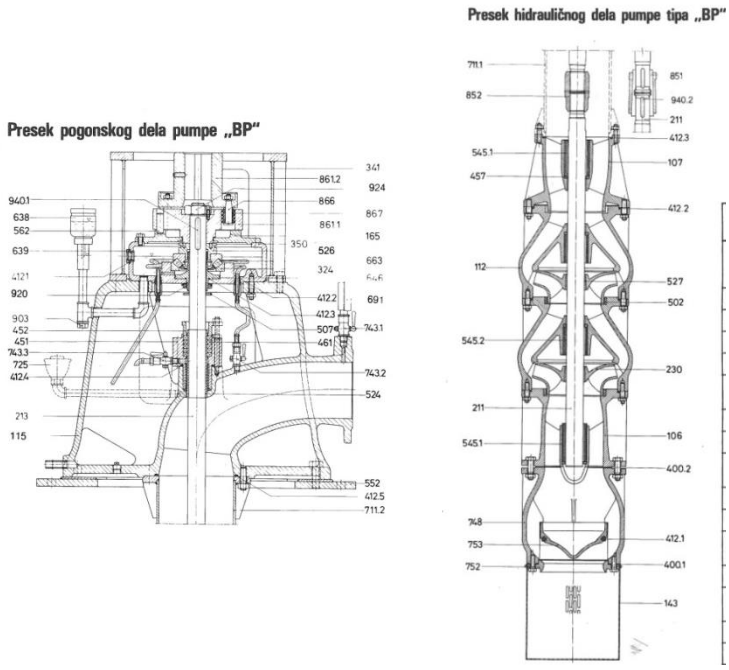

Figure 2 *Cross section of the BP deep well pump*

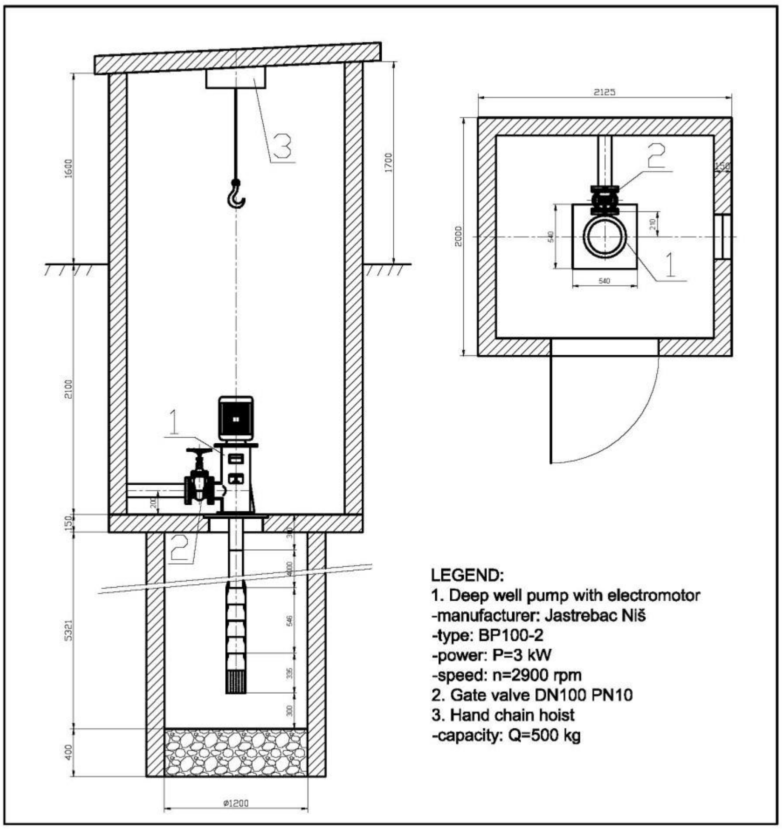

Figure 3 *Disposition of the deep well pump BP-100-2 in the B2 well*

3 CALCULATION

Hydraulic calculation of the industrial water system of Nisal was done for the purpose of verifying the BP-100-2 deep well pump that transports water from the well B2 into the reservoirs R1, R2 and R3 for the needs of the technological process, and it is given according to [3]. The calculation results are the flow rates for every section, and afterwards comparison with the required flow rates for each reservoir is done.

The input data:

1. Minimum height difference between the water level in the B2 well and the reservoirs R1, R2 and R3 amounts H=7 m at the equal water level in all reservoirs

2. Maximum height difference between the water level in the B2 well and the reservoirs R1, R2 and R3 amounts H=14 m at the equal water level in all reservoirs

3. $\delta = 0.2\ [mm]$ - absolute roughness of the steel pipe

4. $\upsilon = 1.306 \cdot 10^{-6} \left[\frac{m^2}{s}\right]$ - kinematic viscosity of water

5. Local losses amounts 20% from friction losses

6. $L\ [m]$ - length of section

7. $D\ [m]$ - internal diameter of section

8. $v\ \left[\frac{m}{s}\right]$ - water velocity in section

9. $\varsigma\ [-]$ - coefficient of local losses

The following calculation formulae are used in the calculation:

1. $Re = \frac{v \cdot D}{\nu}$ - Reynolds number

2. $\lambda = 0.11 \cdot \left(\frac{\delta}{D} + \frac{68}{Re}\right)^{0.25}$ - friction coefficient of a section according to the Altsule

3. $m = \frac{8}{\pi^2 \cdot D^4}\left(\lambda \cdot \frac{L}{D} + \sum \varsigma\right) \left[\frac{J/kg}{m^3/s}\right]$ - resistance coefficient of a section

4. $Y_g = g \cdot H + m \cdot Q^2 \left[\frac{J}{kg}\right]$ - pressure loss curve of a section

where

$g = 9.81 \left[\frac{m}{s^2}\right]$ - gravitational constant

$Q \left[\frac{m^3}{s}\right]$ - flow rate in section

5. $Y_p \left[\frac{J}{kg}\right]$ - pump performance curve given by a pump supplier

On the basis of resistance coefficients of each section and the scheme of pipe network (see Fig. 1) by appropriate addition of the pressure loss curves of sections, taking into account whether the sections are connected in series or parallel the cumulative pipeline pressure loss curve is determined. At the intersection of this curve and pump performance curve in Y-Q diagram, the operating point of pump is placed which simultaneously determines the flow rate through the section 1. Then the flow rates for all other sections are determined based on the known pressure loss curves. The calculation is carried out iteratively which means that at first the velocities in sections are assumed, and the calculation is repeated until the calculated velocities match the ones in the previous iteration. The results of the calculation are tabulated in Tables 1 and 2, while the operating points of the pump are shown in Figures 4 and 5 for both cases of adopted height differences between the water level in the well B2 and the reservoirs R1, R2 and R3.

Table 1 *Flow rates and velocities at height difference of H_{min}=7[m]*

SECTION NUMBER	SECTION LENGTH	INTERNAL PIPE DIAMETER	VELOCITY	REYNOLDS NUMBER	FRICTION COEFFICIENT	RESISTANCE COEFFICIENT	ACTUAL FLOW RATE	ACTUAL VELOCITY
-	L	D	v	Re	λ	m	Q	v
-	m	mm	m/s	-	-	(J/kg)/(m^3/s)	l/s	m/s
1	138	182.9	0.61	85428	0.023	15040	16.00	0.61
2	202	182.9	0.36	50417	0.024	23474	9.34	0.36
3	119	182.9	0.25	35011	0.026	14602	6.66	0.25
4	46	150	0.38	43645	0.026	15029	6.66	0.38
5	30	107.1	0.4	32802	0.028	57072	3.59	0.40
6	40	107.1	0.34	27882	0.028	77804	3.07	0.34

Table 2 *Flow rates and velocities at height difference of Hmax=14[m]*

SECTION NUMBER	SECTION LENGTH	INTERNAL PIPE DIAMETER	VELOCITY	REYNOLDS NUMBER	FRICTION COEFFICIENT	RESISTANCE COEFFICIENT	ACTUAL FLOW RATE	ACTUAL VELOCITY
-	L	D	v	Re	λ	m	Q	v
-	m	mm	m/s	-	-	(J/kg)/(m^3/s)	l/s	m/s
1	138	182.9	0.45	62365	0.024	15595	11.60	0.44
2	202	182.9	0.26	36582	0.026	24614	6.87	0.26
3	119	182.9	0.19	26249	0.027	15326	4.90	0.19
4	46	150	0.28	32006	0.027	15717	4.90	0.28
5	30	107.1	0.29	24022	0.029	59637	2.64	0.29
6	40	107.1	0.25	20804	0.029	81308	2.26	0.25

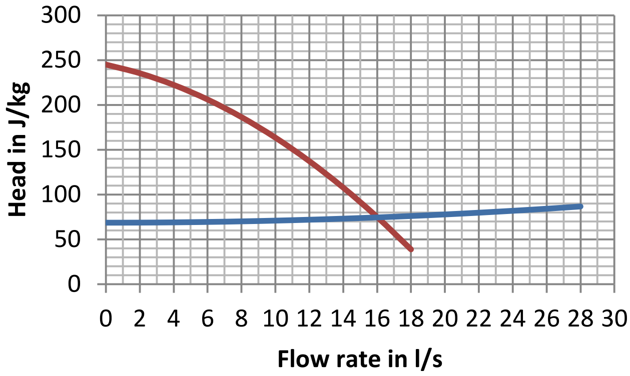

Figure 4 *Operating point of the pump at height difference of H_{min}=7* [*m*]

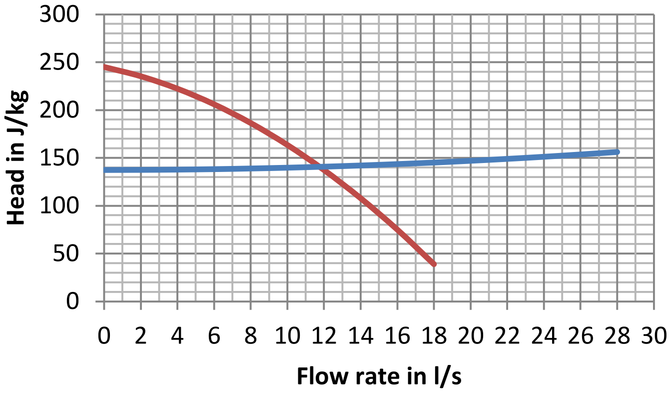

Figure 5 *Operating point of the pump at height difference of H_{max}=14* [*m*]

4 DISCUSSION OF CALCULATION

As it can be seen from the calculation, when operating the pump in the most unfavorable variant, which means that the deep well pump B2 itself supplies all three reservoirs at the maximum height difference between the water level in the well and the reservoirs, the flow rate in each of the reservoirs will be greater than the required minimum flow rate. Corresponding values are given in Tables 3 and 4. The problem that has been solved here is to determine the flow rates through the sections for the given geometry of the complex pipeline consisting of 6 sections when the pump operates in section 1 with a given performance characteristic. Alternatively, it is possible to solve the problem of pump verification in such a way that, based on the values of the required inflows in the reservoirs, the values of the required flow rates in all sections are determined and for them the value of the total pressure drop for the most unfavorable circuit is calculated. This value represents the required pump head. If the available pump head is greater than the required pump head for the given total flow rate the pump may be verified.

Table 3 *Flow rates at height difference of* H_{min}=7 [*m*]

TECHNICAL WATER SUPPLY OF RESERVOIRS R1, R2 AND R3 FROM WELL B2 AT H_{min}=7m		
Pump operating point: head Y=74,57 J/kg; flow rate Q=16 l/s		
Reservoir	Calculated inflow in l/s	Required inflow in l/s
R1	3.07	2.15
R2	3.59	0.116
R3	9.34	5.56

Table 4 *Flow rates at height difference of* H_{max}=14[*m*]

TECHNICAL WATER SUPPLY OF RESERVOIRS R1, R2 AND R3 FROM WELL B2 AT H_{max}=14m		
Pump operating point: head Y=140,6 J/kg; flow rate Q=11,6 l/s		
Reservoir	Calculated inflow in l/s	Required inflow in l/s
R1	2.26	2.15
R2	2.64	0.116
R3	6.87	5.56

CONCLUSION

The exposed methodology of the hydraulic calculation of the complex pipeline is a grapho-analytical method for determining the operating point of the pump which, as can be seen, is not simple even when it comes to the complex pipelines with only a few sections, and when certain simplifications are used. Although it can be implemented for simpler cases of complex pipelines, a perspective is certainly in the application of specialized software.

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RELATIONSHIP BETWEEN THE ORGANIZATIONAL STRUCTURE AND CULTURE – CASE STUDIES OF THE MINING COMPANIES IN SERBIA

Abstract

Organizational culture and organizational structure have a correlated inter-relationship. Structure determines the behaviors, attitudes, dispositions and ethics that create the work culture. In this paper, the authors analyze the inter-relationship between the organizational structure and culture in the mining companies in Eastern Serbia. Investigation was conducted in two companies, with 138 participants in the survey. The research was conducted at the beginning of 2016. The questionnaires included 50 questions concerning the organizational structure and culture, and were anonymous. The results confirmed a significant correlation between the organizational structure and culture in the investigated organizations.

Keywords: *organizational culture, organizational structure, national culture, mining companies*

1 INTRODUCTION

Organizational culture is based on values, expectations, experiences and behaviors of the members of an organization which contribute to the unique social and psychological environment of that organization. It is expressed as an image, interactions with the outside world, future expectations, and is based on shared attitudes, beliefs and customs, written and unwritten rules that have been developed over the time, and are considered valid. It is interrelated with national culture and organizations have been found to operate at the optimal level when there is alignment between national and organizational culture.

Organizational structure depends on the organization's objectives and strategy. It defines how the roles, power and responsibilities are assigned and how hierarchical arrangement of lines of authority, communications, rights and duties are defined in an organization. It regulates control and coordination of information flows among the different levels of management. Organizational culture and organizational structure have a correlated inter-relationship. Structure determines the behaviors, attitudes, dispositions and ethics that create the work culture.

2 ORGANIZATIONAL CULTURE

Organizational culture could be defined as a system of assumptions, values, norms and attitudes manifested through symbols which the members of an organization have established and adopted through shared experience, which helps them define the meaning of the outside world and the way they interact with it [1]. Organizational culture defines the character of interpersonal rela-

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tions in the organization, improves motivation of employees, defines a leadership style, reduces the number of conflicts and improves the coordination in the organization [2], [3].

Zheng and associates investigated the relationship between the organizational culture, structure, strategy and organizational effectiveness, as well as the role of knowledge management in linking these elements [4]. The results of their study shows that the organizational culture, structure, strategy and organizational effectiveness have noticeable inter- relationships [4]. Management of each organization creates a specific, unique culture. National culture also has a great influence on the creation of organizational culture and management. Employees come to the organization with a certain, already well-defined value system based on their national culture, and which is the foundation of an organizational culture. The influence of national culture on organizational culture and management is established through various studies. During the last few decades, a number of national culture frameworks have been developed, but the most frequently used and replicated has been Hofstede's [5], [6], [7]. Hofstede primarily identified the most commonly used dimensions of national culture: individualism vs. collectivism, power distance, uncertainty avoidance and masculinity vs. femininity [5]. Later, in his further investigations in cooperation with Michael Bond and Michael Minkov, Hofstede identified two additional dimensions: the short-term vs. long-term orientation [8] and indulgence versus restraint [9]. National culture dimensions framework can be used to better understand the organizational culture, the structure and the management in different companies [10]. Paunkovic emphasized the importance of the national culture in defining the optimal organizational structure for the implementation of sustainable development projects in Eastern Serbia, as well as in managing sustainable development projects. Studies regarding the organizational and national culture aspects the important published [11], [12].

As well as the national, organizational culture has its own dimension. The IRIC (Institute for Research on Intercultural Cooperation) identified six independent dimensions of practices: the process-oriented versus results-oriented, job-oriented versus employee-oriented, professional versus parochial, open systems versus closed systems, tightly versus loosely controlled, and pragmatic versus – normative [13].

The mainstream successful companies in the world, and in Serbia also, have very recognizable and strong organizational cultures [14], [15]. Strong culture has a positive impact on motivation and loyalty of the employees, makes coordination and control of organization easier, reduces conflicts and enhances creativity [16], [17], [18].

3 ORGANIZATIONAL STRUCTURE

Every organization, system or company has its own structure, system of internal links and relationships. Investigation of the organizational structure of a certain company begins by analyzing and defining the general task which should be realized through the overall business, and then by decomposition it into the partial and individual tasks. This decomposition defines a large number of partial tasks that the company performs and according to which the organization should be structured. The appropriate organizational units should be defined in order that the optimal realization of the entire business process is enabled. Organizational structure is the result of the organizational process and is a modus of effectively achieving business goals. It represents the way in which business leaders are unified for the realization of certain tasks. A good organizational structure must provide coordination at all levels. When managing an organization, both internal and external factors that create an adequate organizational structure enabling organizational goals to be achieved, must be considered. The most influential internal factors are the organizational culture and strategy [4].

There is a relationship between the organizational culture and structure. Organizational culture has a great impact on the selection and implementation of an organizational structure. A new organizational structure can have an impact on the existing organizational culture consolidating or changing it. Culture is an important factor of organizational structure. Culture is a completely different component which can significantly contribute to the functioning of organization and affects the other mentioned components of the organization, including the structure. Investigations have revealed and partly explained the nature of the impact of national cultures on organizational structure [6], [19], leadership styles [2], [20], managing organizational changes [21], [22], job satisfaction [3], organizational culture [23], human resource management [24]. Organizational models differ from each other according to a degree of formalization and centralization. Different organizational cultures also implicate the use of different organizational models.

4 RESEARCH

In order to explore the relationship between the organizational culture and structure in the mining companies, an investigation was conducted on the territory of Eastern Serbia. The study included 138 employees from the companies working in the mining sector, located in the municipality of Bor. Although management of the both companies has approved the process of investigation, we did not get the permission to reveal the identity of the investigated organizations in publications. For that reason, they will be referred to as: the Company 1 and Company 2. One of the companies is publicly owned, engaged in research and development in mining sector, and the other one is a private company. Total of 138 participants (84 from the Company 1 and 54 from the Company 2) have completed questioners used for this analysis.

The research in these companies was conducted at the beginning of 2016. The investigation was anonymous. The questionnaire consisted of 50 questions, divided into four groups. Participants in the study were asked to grade (1 - not important; 5 - very important) 11 questions on a scale of 1 to 5 in the questionnaire. For the purpose of this paper, the groups of questions related to the organizational culture and organizational structure were delineated.

5 RESEARCH RESULTS

The general hypothesis for this research was: There is a relationship between the organizational culture and structure.

The following tables represent the average marks, obtained from the questionnaires. The research was conducted in two companies, and the results are presented for both of them.

Regression analysis was used to determine a connectivity between two variables: the organizational culture and organizational structure. Previously, Kolmogorov - Smirnov test was performed. The test explored the fulfillment of conditions for parametric statistical tests. The following tables show the regression parameters of the two investigated phenomena (organizational culture and organizational structure).

Table 1 *Organizational culture and structure*

Questions - organizational culture	*	**	Questions – organizational structure	*	**
The employees have the new (better) ideas for doing business	3.43	3.98	There is a clear and precise sharing of work tasks of employees in the organization	3.54	4.41
The employees are ready to take risks while implementing their ideas	2.77	3.67	Activities and work assignments are grouped	3.67	4.24
The work is organized as a teamwork	3.77	4.52	There is a well-defined line of authority – who is responsible to whom	4.23	4.39
Management takes into account the needs of employees	2.69	4.44	One manager manages a large number of employees	3.51	3.56
A strong competitive spirit of employees is expressed	3.25	3.31	The main strategic decisions are made by the top management without participation of managers from lower levels and employees	3.82	3.09
Due to strongly expressed competitive spirit, there is sometimes a lack of cooperation among the employees	3.24	2.65	Decisions are made at all levels of the organization with the participation of all employees	2.30	3.39
More importance is attached to the results than the way they are achieved – the ends justify the means	3.70	2.48	The organization provides the detailed work instructions and jobs are well-standardized	3.10	4.24
The employees are precise, analytical and detailed when performing delegated tasks	3.56	4.19	The behavior of employees is precisely defined by the certain rules and procedures	3.96	4.48
The employees in organization are encouraged to have respect for others	2.51	4.43	At last, the employees agree with what their superior says, although they do not share his/her thoughts	3.86	3.52
The organization shows loyalty towards its employees	2.65	4.74	Employees in the organization have two or more superiors	3.67	3.33
In this organization, people in principle have a great respect for others	2.44	4.26	There is a good communication among employees at the same levels	3.08	4.30

***** *Average mark – Company 1*
****** *Average mark - Company 2*

Table 2 *Regression parameters of the strength of correlation between two determinants*

Regression parameters	R	Coefficient of determination	Corrected coefficient of determination	Standard error of the estimate
	0.572	0.327	0.319	2.77041

Calculated correlation coefficient (R) is 0.572 and it is positive. It means that there is a direct positive correlation between these two investigated phenomena (organizational culture and organizational structure). Taking into account that the value of R is between 0.50 and 0.75, it means that there is a moderate to good correlation between organizational structure and organizational culture.

Corrected coefficient of determination is 0.319, and it can be concluded that the organizational culture affects the developing organizational structure in 32% of the cases. The rest of 68% of the total variability is not explained by the regression line, and it is under the influence of some other unidentified factors. Small probability of error and statistically significant value of F test shows that the value of coefficient of determination is very important for predicting the variances between variables. Since determination is high, which is statistically very significant, it is further necessary to analyze the shape and strength of a link between the indicators. Parameters from the statistical model, offset and inclination ($\beta0$ and $\beta1$), are checked by the T-test. Null hypothesis is set which says that there is no linear link H0: $\beta = 0$ between the variances of investigated phenomena in the basic set, and two-way alternative hypothesis H1: $\beta \neq 0$.The next table shows statistical parameters of the model of regression analysis.

Table 3 *Statistical parametric model of regression analysis for the organizational culture and organizational structure*

Statistical parameters of the model	Non-standardized coefficients		Standardized coefficients	t	Probability of error
	B	Standard error	ß		
Cult/constant	10.570	0.886		11.931	0.000
Org. culture-inclination	0.531	0.084	0.572	6.310	0.000

It can be seen from Table that β_1 =10.570. Since this value is not null, regression line can be used for prediction. Probability of the error value is less than adopted (0.05), and the value of the T-test for estimation of inclination is statistically significant. This means that the null hypothesis is rejected, and the alternative H1: $\beta \neq 0$ is adopted. Regression line can be used to predict a variation between these phenomena. In the particular case, the equation of regression line is y=0.531x+10.57. The next diagram shows the link between two variables (organizational culture and organizational structure).

The next diagram shows that there is a quantitative correlation between variables of investigated phenomena. Coefficient of determination shows that the organizational structure is the result of existing organizational culture in 32 % of the cases. This confirms the starting hypothesis: "There is a relationship between the organizational culture and structure. "

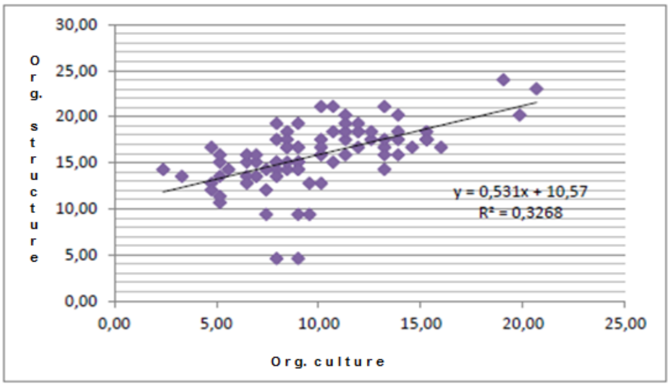

Diagram 1 *Dispersion diagram for two variables: the organizational culture and organizational structure*

5 RESULTS AND DISCUSSION

Organizational structure is affected by a number of factors such as technology, the activity that an organization performs in the economy, the size of organization and many other factors. Among those factors that influence developing of the organizational structure, a special place is occupied by the organizational culture. The assumptions, values and beliefs of management and employees affect the acceptance or rejection of the certain organizational models. According to [19], a certain organizational culture can contribute to development of the organizational structure, which is unexpected considering other relevant factors.

By comparison the results related to organizational culture of the investigated companies (presented in the tables above), it is evident that the average mark of the respondents from Company 1 does not exceed 3.5, except for the question No.7 (“More importance is attached to the results than the way they are achieved - the ends justify the means”) and the question No. 8 (“The employees are precise, analytical and detailed when performing the delegated tasks“). On the other hand, majority of the respondents from the Company 2 gave an average mark higher than 4, except for the question No. 6 (“Due to strongly expressed competitive spirit, there is a lack of cooperation among employees“, and the question No. 7. According to these results, the organizational culture in the Company 2 was recognized by the respondents as more satisfactory in comparison with the organizational culture of the Company 1.

The average mark of 4.23 for the question No. 25, which belongs to the questions related to organizational structure, shows that there is a well-defined line of authority (“who is responsible to whom”) in the Company 1. However, based on the average mark of 2.3 for the claim that the decisions are made at all levels of the organization with the participation of all employees, it can be concluded that the structure of this organization is quite centralized. On the other hand, the average marks for the same questions in the Company 2 is 3.5 and 4.5 so the conclusion could be that this organization has a clearly defined formal structure where behavior of employees is precisely defined by the certain rules and procedures, but also that the employees have possibility to take part in some business related decisions. The high average marks show that there is a good communication among employees at all levels.

The existence of a direct positive correlation between the organizational culture and organizational structure is confirmed by the correlation coefficient of 0.572. Coefficient of determination shows that the organizational structure is the result of existing organizational culture in 32% of the cases.

Organizational culture primarily affects two dimensions of organizational structure – the level of formalization and level of centralization of decision-making. In this case, the research has shown that the organizational culture of the second com-pany organizational culture was recognized by the employees as more satisfactory in comparison with the organizational culture of the Company 1. The work in the second company is organized as a teamwork, managers pay attention to the needs of the employees, and employees have respect for their colleagues. Based on this, it is expected that the organizational structure of the second company should be less centralized. The obtained data justified the expectations, and it is shown by the average marks for the claim: the main strategic decisions for the company as well as the other decisions related to the business of the organization are made by the top management without participation of managers from lower levels and employees. As far as the first organization is concerned, the average mark for this claim is almost 4.0 (3.82), and for the second organization is 3.0. Based on the obtained average marks and on correlation coefficient and coefficient of determination, obtained by the regression analysis, the starting hypotheses that there is a correlation between the organizational culture and structure is confirmed.

Nevertheless, the average mark of 3.0 for the claim that the main, strategic decisions for the company, as well as the other decisions related to the business of the organization, are made by the top management, without participation of managers from lower levels and employees, shows an indecisiveness of the employees of the second company. It could be interpreted as if the employees from the second company did not want to make a statement about this claim, and it shows that the structure of the second company is also centralized. These results corroborate Hofstede's research on the national culture dimensions [12], [13]. According to Hofstde, the nationnal culture of Serbia is characterized by the high Power Distance Index (PDI), and consequently, the organizations are generally expected to have a centralized form of organizational structure.

CONCLUSION

The mining companies in Serbia are in a very demanding position. Their business is characterized by a work of great complexity, obsolete and complex organizational structure, as well as a hardly adequate management practice, work and functioning. This situation could be improved creating such an organizational culture that supports the adequate organizational structure. Adequate structure and culture alignment could enable companies to become more profitable and improve the market position. It is necessary that the management of these companies understand this complex inter-relationship between the organizational structure and culture, as well as the national culture influence on organizational performance.

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PREVENTION OF THE ENVIRONMENTAL RISKS FOSTERING IMPLEMENTATION OF THE REACH REGULATION IN THE REPUBLIC OF SERBIA****

Abstract

The chemical industry has a great importance in implementation the sustainable development strategy. The environmental protection from different risks from the mining and metallurgical industry, in which the use of chemical is the basic precondition for production, is the primary goal in the EU and Serbia, also. The European Commission's specific Chemical Strategy (Registration, Evaluation, and Authorization of Chemicals-REACH) legislation is the one among many of the most important environmental regulations. Hence, is it an urgent need of policy makers in Serbia and all stakeholders to understand how the future REACH implementation could prevent ecological risks in the mining industry and strengthening economy? Hence, this is the topic of this paper. Conclusion of the work presents the recommendations that have been given as a result of performed analysis. It is clear at the end that REACH could mitigate the ecological risks in mining and metallurgy, and improve competitiveness of the Serbian chemical industry on the EU market.

Keywords: *environments, risks, contamination, REACH regulation, chemical industry*

1 INTRODUCTION

The chemical industry is one of the world's most competitive and successful industries. Chemicals are widely acknowledged as important for the mining and metallurgy industries in the Republic of Serbia. In one of his work, Jenk and co-author stated that as a result of its extremely strategic nature connected to numerous sectors essential for modern-day society, and as a manufacturing industry which substantially transforms raw materials into products, the chemical industry is fully involved in the problems relating to industrial sustainability [1].

World chemicals sales in 2016 are valued at 3.360 billion of Euros, grew by 12.8 billion of Euros only compared with 2015. The European Union chemical industry ranks as the second (15.1%), along with the United States (14.2%) in the total

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sales. The EU countries and non-European countries total sales reached 597 billion of Euros in 2016 or 17.8% of the world chemical sales. Chemical companies in the EU in 2016 employed the total staff of about 1.14 million. The sector generated an even greater number of indirect jobs, up to three times higher than through direct employment. Direct employment average annual rate in the EU chemical industry decreased by 1.5% from 2000 to 2016. Hence, the EU chemical industry promised based on data that chemical sector grew 3.1% during the first half of 2017, compared to the same period of 2016. The challenge to provide an adequate safety in the EU chemical sector is always paramount. Created to ensure the safety of chemicals throughout EU, the EU chemical regulation REACH, is one of the most advanced pieces of chemical legislation in the world [2].

In the 20^{th} century, the environmental protection starts to be one of the greatest concerns in the global world, and seriously affected chemical, and mining and metallurgical industries. In the ongoing efforts of the Republic of Serbia to join the EU, this issue is one among the most important. Regardless our country joins or not the EU, the mining companies should comply with the environmental standards and appropriate environmental legislation [3]. Therefore, the European and Serbian chemical and mining industry have contr-ibuted to the society capacity to reduce the green gases emissions (GHG), and imple-ment the accepted overall environmental friendly concept. In the Serbian towns, like Bor and Kosovska Mitrovica, they are recognized as the histo-rical pollution hot spots, and remediation measures are still missed [4].

Chemicals used in the mining and metallurgical process, as well in many other occasions caused the contamination of soil, water and air, and create a great problem for the competent authority and citizens. These problems have become the priority in the municipalities like Pancevo, Bor and Kosovska Mitrovica. There are number of reasons why contamination happens. The most common are the landfills from different kind of abandon and unmaintained industrial facilities, mine waste, which failed in the extreme weather conditions, illegal dumpsites (few of them recently fined in the towns of Obrenovac and Novi Sad), disposal of toxic wastewater in the rivers, underground spillage of oil, accidental spills, etc. Chemical contaminations happened during various natural and anthropogenic disasters, and cause the unprecedented consequences in few cases, like in the mine Stolice [5].

2 BRIEF HISTORY OF THE REACH REGULATION

To address the global sustainability goals, the modern society will require innovations enabled through sustainable industry, especially in the chemical sector. Through its processes and product, the chemical sector is a major driving force for innovation in Europe and essential for smart and sustainable growth across all sectors [6]. The REACH regulation undoubtedly has enormous contribution in achievement of sustainability goals. The REACH was proposed in 2003 after a long consultation period resulting from the publication of the White Paper on the Strategy for the Future Chemicals Policy in 2001 [7,8]. It is needed to state that the REACH was the reason to establish the European Chemicals Agency ECHA based in Helsinki with a task to implement REACH in practice.

Acceptation of the REACH regulations is a part of wider the nontoxic environmental strategy as a part of the 7th European Action Programme to 2020 [9]. The rapid adoption of the Regulation for the registration, evaluation, authorization and restriction of chemicals (REACH) was considered as a milestone in the Review of the EU Sustainable Development Strategy which requires that by 2020 the chemicals are produced and used in ways that do not threaten the human health and environment [10]. The REACH furthermore give a greater responsibility to the chemical and mining industry to manage the risks from chemicals and to provide the safety information that will be passed down the supply chain. There are the realistic expectations that the REACH will contribute to the fulfillment of the World Summit of the Sustainable Development Goals 2030 [11].

Registration is one of the key elements of risk management in the REACH. It is staggered across three different deadlines – 2010, 2013, and 2018. At the beginning of its implementation in one report based on presented data on the deadline of 30 November 2010, the total of 4,300 substances were registered under the REACH chemicals regulation [12]. According to Article 117(4) of REACH the Commission has to report on functioning the REACH every five years starting from 1 June 2012. Therefore, there was a legal obligation for the Commission to create a report in 1 June 2017. This report has to be carried out by the Member States, the European Chemical Agency and the Commission. Due to collecting information from all interested parties, a public consultation was carried out from 28 October until January 2017. A specific consultation on SMS relevant issues was carried out through the Europe Enterprise Network (EEN). The expected report has to cover the five compulsory evaluation criteria: effectiveness efficiency, relevance coherence and added value, and put emphasizes on potentials for burden reduction and simplification [13]. Meanwhile, the report suffered three delays, and due to that it was in a big delay because of numerous reasons, and it is expected, based on the statement the ECHA's director of registration Christel Musset in REACH 2018 Stakeholders' Day in Helsinki "by the end of February or in March" of 2018 [14].

3 THE EUROPEAN EXPERIENCES IN THE PROCESS OF THE REACH IMPLEMENTATION

Discussion in the public and scientific communities all over the world showed without any doubt that the REACH regulation is of enormous importance for EU and whole global community. Industry despite all achievements still is worrying that the REACH is too bureaucratic, inflexible and costly, and could lead to a decline in competitiveness and job losses. At the beginning of the REACH implementation, due to similar doubt, a special assessment was created to present some data against the presumptive impact of regulation. Numerous participants address concerns about increasing the costs in this process. The European Commission Extended Impact Assessment calculated the cost of the REACH to the chemical industry for testing and registration costs of the REACH will be approximately 2.3 billion Euros over the period of 11 years (including Agency fees of 2.3 billion). The total costs are estimated to 3.5 billion of Euros[15]. This corresponds to around 50 cent per EU citizen per year – or less than the cost of a chocolate bar [16]. Various interesting studies could be find in the literature, which have estimated the costs from one side, and social, health and environmental benefits from the other side. One of the most detailed and worth to be considered regarding this issue is a book edited by Ackerman and Massey [17].

The uneven distribution of costs towards small and medium enterprises (SME) was another issue worrying industry. Concerns have been expressed about increases in the cost base of the companies, which may forces smaller firms out of market, or exhibit entry of the new ones and reduce the overall supplier base of the industry. Analysis of the REACH proposal shows that there are a number of “SME friendly” initiatives provided from the EU regarding this purpose, as well as many other benefits for SME [18].

The European Commission is permanently concerned about population perceived change in safety of chemicals and periodically organized specific survey regarding this matter. According to the special Eurobarometer survey regarding chemicals, 61% of Europeans thought that the chemicals were safer than 10 years ago [19]. In the last Eurobarometer report, the EU citizens express their opinion that they more likely to say that the safety of products containing chemical has improved, stayed about the same or deteriorated, compared with 10 to 15 years ago. More than two in five EU citizens (44%) think that the product safety has improved over this period, while one in six (16%) think it has deteriorated. One in three (32%) says that it has stayed about the same [20].

Although, the REACH has no precedent in the history of the chemical industry, and was the major step forward in the safe use of chemicals, a concern has been expressed by some chemical producers and companies that some industrial supply chains could be disrupted by the registration process, and the important industrial production could move outside of the EU due to the REACH registration requirements. Due to these reasons and many others caused by the global economic crises, and political situations regarding the Russian sanctions, and overall global security issues, the European Commission has taken a special care to provide as much assistance as possible to the businesses – and especially the SME – to ensure that they are able to meet their obligations. In 2010, for example, the European Commission has taken action to reduce fees for the SME. These reductions amount to 90% for micro-enterprises, 60% for small companies and 30% for medium-sized companies [21]. The European Chemicals Agency (ECHA) announced that by the first phase REACH registration deadline, applied to the most hazardous substances, manufactured or imported in quantities of one tone/year or more per company, and substances very toxic to the aquatic environment, manufactured or imported in quantities of 100 tons/year or more per company, 24,675 registration dossiers had been successfully submitted [22]. However, it is expected that the registration deadline of 31 May 2018 will be quite different from the two previous ones, in terms both the number of registrations and type of registrants [23]. This deadline concerns companies that manufacture or import the chemical substances in small volumes, between 1-100 tons per year. The ECHA expects to receive up to 60 000 registrations for up to 25 000 substances manufactured or imported in those volumes. The REACH 2018 will complete the gathering of data on chemical substances on the European market, resulting in the most comprehensive chemicals database in the world.

Industry remains concerned over data sharing the requirements that could result in a loss of confidentiality or competitiveness. It is obvious that data sharing are encouraged under the REACH, but it does not include any confidential data. Safety related data such as toxicity information will never be confidential because of the public right to be informed. However, the exact tonnages and formulae will remain fully confidential due to many security issues (ecological risks and terrorist possibility of abuse chemicals) [24].

The above mentioned are just a briefly author analyze of experiences, which were useful and should be followed in Serbia in the future process of the REACH application. Some examples of positive practice should be very useful for undeveloped and non-EU countries, like Serbia to apply the gained experiences in implementation the REACH regulation. One of that could be activity of the Directors' Contact Group (DCG). The DCG made an enormous contribution to the successful completion of registration. Their achievements, lessons learned and recommendations are valuable for all stakeholders [25]. It is concerned in the last report the Directors' Contact Group (DCG) that the cost burden on SMEs for accessing data and jointly submitting their registration dossiers has created the risks to successful conduct the REACH 2018 registration [26].

4 THE CURRENT STATE OF THE SERBIAN CHEMICAL INDUSTRY

The actual state of the Serbian industry is far from the predicted in the past. In the project, led by the Government of Serbia and Prime Minister personally (2001-2003), the all competitive weaknesses and advantages of domestic chemical industry have been evaluated in the sub-project ``Chemical Industry,`` which was an integral part of the global project named: "The Strategy of Economy Development in Serbia up to 2010" [27]. The conducted analysis has proved that despite all, the chemical industry should be classified in the group of domestic industrial sectors having the best chances in realization the export oriented development strategy. Conclusion was that the Serbian chemical industry is probably a "small player" at the world or European scale, but should be considered as a "very important player" in the region of South-East Europe [28]. This statement is going to be proved in the next years.

The chemical industry in Serbia is the most development in Vojvodina where it create 35% of the GDP of total, after that in the region of Belgrade 25% and at the third place is the Šumadija region with 16%. The future of chemical industry has been given from the bright side. The positive prediction of the chemical industry is presented in the expected percentage of growth rate in GDP from 7.7 % in 2008 to 10% in 2020 [29].

Unfortunately, all that expectations about chemical industry like driving force of development fell down due to the negative impacts of privatization and many other unexpected obstacles. Process of privatezation jeopardizes safety of citizens which face with the long term consequences and fear, because competent authorities neglected or misunderstood its role in the emergency management in changed circumstances [30].

In few cases, an inadequate maintenance of chemical facilities and chemical in general caused serious accidents which jeopardize the environment and population health. Hence, the public awareness of risk perception about chemical industry signifycantly increased after serious of accidents (Viskoza fire, explosion in Galenika phytopharmacy factory, etc.). It could be stated that the loss of trust in some cases (the air pollution in city of Pancevo was one among many others) caused demonstration of citizens who addressed their basic human right on clean environmental guaranteed by the Constitution of the Republic of Serbia [31].

Chemical industry in Serbia is made up of 1,500 companies, which in 2014 contributed to the GDP by 2.2%, and employed over 32,000 people. Unlike the average of the Serbian economy, these companies, in addition to being more ready for the impact of the global financial crisis, proved to be more dynamic and healthier. Industrial production and exports continue their growth in the entire post-crisis period. The chemical industry, in addition to a solid foothold in Serbia, spills over its effects of development into the rest of the economy - the products are often used as a raw material source in the production process of a large number of related sectors. In this regard, the chemical industry is centrally positioned in the value chain of processing industry. The largest number of sectors of the chemical industry is identified in the segment of high development potentials. As much as 9 out of 13 sectors demonstrated a high development potential [32].

It is important to address that the chemical industry is recognized as the most important sector for increasing the regional employment, greater GDP, and increased export in the South Banat region, Pirotski and Jablanicki region. The second importance this sector is recognized in the Macva region, Bor, Middle Banat, Sremski, Moravicki, Rasinski, and Sumadijski region [33].

The aim of the Serbian chemical industry is to retain or improve its place in the national economy and achieve a satisfactory return on capital. To this end, its objective is to supply its customers with the highest quality products, at the lowest competitive cost, in a healthy and environmentally sustainable fashion and on a long-term basis. Hence, the "recovery of the whole chemical industry", as well as of the industry in general, necessitates many favorable presumptions from the environment, as well as strategic, systematic and operative measures, of the state within social industry policy, as well as of the very companies which deal with chemical industry [34].

In 2017, the trends showed that the industrial production in Serbia increased by 6.9 percent compared to 2016. Manufacturing industry grew the most -- by 6.4 percent, while the energy sector fell by 6.2 percent. Manufacture of machinery and equipment, rubber and plastic products, chemicals and chemical products, and metal products had the largest influence on the industrial production growth [35].

Competitiveness and sustainable development of the chemical industry in Serbia is threatened by a combination of factors, higher energy prices; in a few cases the corruption is mentioned as well as the political influence, higher logistics costs and a business environment that generally does not invest enough in research of development activities. On the other hand, the industry itself has the power to increase its competitiveness by restructuring and improving its operational performance, by making use of improved market - sales excellence and more market and customer orientation, and by own invest in innovation and sustainable development. The public private partnership could be very useful, but till now the results were humble in this area. The chemical industry could be an important player on the South European market and EU if the Serbian government would be able to create the adequate transformation programs and increase the efforts to strengthen the chemical and mining industry.

5 ACCEPTANCE THE CHALLENGE AND ENGAGEMENT THE REACH REGULATION

All issues. considering the competetiveness of the Serbian chemical industry in adaptation of the REACH regulation, has to be taken with a multiplicity of audiences in mind. By adoption the Law on Chemicals [36], a foundation for preparation the implementation of Regulation (EC) No. 1907/2006 was created. The provisions of the REACH, related to the centralized procedures implemented in the ECHA, are not transposed, but approximated with the aim of better preparation the domestic industry for the REACH implementation. The competent Authority for chemicals management in the Republic of Serbia - The Chemicals Agency is established in 2009. National help desk is also established, and by informing, answering the questions, and preparation the guidelines for industry, guides industry to proper implementation of all obligations arising from the national regulations and REACH; building the capacities of the Chemicals Agency as well as education and informing of industry, in order to prepare them for fulfillment the future obligations pursuant to the REACH provisions, was in the progress after its establishment. Serbia plans to implement the Regulation by 2020 with the exception of certain provisions for which Serbia intends to request the transitional periods [37].

The positive achievement in the area of chemical management in Serbia was among other also a project financed by EU titled "Assistance in the Implementation of

Serbian Chemicals Management System," financed with amount about 10 million euro. In the period from 2008-2012, many useful actions happened, like realization of project about Integral system for monitoring transport of hazardous materials, education of employees in judicial system about environmental protection and criminal acts against environmental, etc.

Despite all, from this point of view it looks pretty unreasonable when after two and half year the Serbian Government decides to shut down the Serbian Chemical Agency with explanation about budget constraints. It can be seen as a giant leap back having in mind the current state of chemical waste on the illegal dumpsites found in the Serbian cities Novi Sad and Obrenovac. In the EU Report about the Serbian process to fulfill the conditions for membership in 2016, a certain concern is stated about Serbian ability to ensure the adequate administrate and surveillance capacities in order to implement the EU REACH regulative and the classification and packaging substances and mixtures in the fifth chapter. Therefore, in same document (page 34). there is a sentence that the competent authorities have to work on harmonization and adoption the secondary regulation and adequate implementing capacities area, and force an effective implementation of the REACH [38].

To meet the REACH challenges, the industry needs to take specific actions. Some actions are currently underway and need reinforcing; but some new initiatives are required. There is the basic need in the current macroeconomic state in the country to help in the process of the identification and detailing of the concern raised by the industry, and also tp take into account the ecological barriers of growth and development influencing the general quality of society life. The process of identification and developing solutions to a number of issues will help a smooth way to a successful completion of registration before the registration deadline. Maybe in the recent future, the policy makers should take into consideration development some of high impact national programs to assist the companies to prepare for registration, (which has evaluated like very successful in France and Belgium). These and other initiatives and approaches, e.g. pooling consultants for multiple companies, should be more presented in future. It is important to appoint that the future REACH implementation process in Serbia, like everywhere else, has to provide all kind of opportunities to create a dynamic environment for information exchange among the representatives of governmental institutions, non-governmental organizations, and industry, scientists and chemical experts.

Promotion the concept of corporate social responsibility (CSR) is of exceptional importance in the EU. [39]. Almost every multinational company and many smaller companies have adopted voluntary the CSR initiatives, which can include codes of conducting, auditing and monitoring strategies, social and eco labels, as well as the philanthropy [40]. The role of CSR has been found to be multifaceted, covering the areas such as transparency, environmental issues and corporate sustainability. In the current circumstances, a significant gap between policy makers and industry representatives exists in the Serbian society. Years after involvement the corporate social responsibility (CSR) concept in Serbia, there is still a lot of room for improvement. The Serbian environment is equally jeopardized as it used to be. The historical pollution remains an equally discussable question. Since the Serbian privatization process is evaluated as unsuccessful, now the society bears the scars of that wrong decision and in the area of solving historical pollution and remediation of contaminated sites, it is still far from an optimal solution. Therefore, the new concept of corporate sustainability and responsibility (CSR2.0 which covering not only the social responsibility, but also the organization sustainability - therefore the abbreviation with 2.0 means those two S), expanded in the scientific public is even hard to implement in the Serbian practice. Policy makers and top business management are not still organized within the scope to be effective in this significant area. The Serbian business community is hard to admit that and despite all efforts there is a doubt that the CSR2.0 in Serbia will soon become much more highly engaged in the area of disaster management because the system of integral disaster often lacks a comprehensive knowledge about its role in disaster [41].

From that point and taking into account the current status of chemical industry, there is a fear that it would not be so easy to apply the REACH regulation. In addition, the Serbian chemical industry has been already challenged with the consequences of inadequately privatization process and future focused around an integrated approach to the pollution control (IPC), and need to provide an integral license (this deadline is extended by recently law changes). The Serbian Government and all stakeholders must consider some limitation factors, already notified in EU. It is very useful to have knowledge about the REACH implement-tation in other countries. From that point data presented in the study prepared by the ECORYS of the Netherlands, which pre-sents overview of 36 studies on the impact of the new EU chemicals policy (REACH) on society and business, could be extremely useful [42].

Another activity, which would be helpful to the policy makers to make the REACH implementation process more successful, could be establishing of some specific body like it was the Directors' Contact Group (DCG) in EU. At the end, it is needed that after all highlight enor-mous benefit for the environmental and human health of the REACH implement-tation. It is expected that the REACH will help in avoidance severe health effects up to 50 billion Euros; impro-ved reuse of sewage sludge up to 2.6 million Euros and clean drinking water 34 million Euros. Having in mind a long path of Serbia to fulfill the environmental regulation, which is in power in EU, this regulation will obviously lead in the right direction [43].

CONCLUSION

Chemicals industry has been responsible for the diffusion of new technologies and positive spillover effects to a wide range of other industries. In this process it has fulfill different environmental standards. The REACH could lead to a brand stands for the highest ecological and social standards. But also, the fact is that the REACH will undoubtedly affect the competitiveness of the Serbian chemical industry creates the additional costs. The problem in future will arise from the fact that the importers, who did not apply the REACH, would be away from the European market. In Serbia, there is an additional need to adapt it and remove the general thoughts about chemical industry like unfavorable, help its renewal, arise the number of employee and thus drive the chemical industry forward. A stronger regulatory framework would protect the companies against the future liability claims and prosecutions due to a possibility of chemical accidents and environmental damage. The REACH will in future, without any doubt, brought multi benefits to the public and chemical industry. The public will have safer chemicals and have access to more sophisticated information on the products they consume. Due to a shortage of human and financial resources in Serbia, it should be pointed that everyone needs to work together-from enterprise level to the national and EU level. Although the REACH in Serbia is not so well recognized, and still looks like the new environmental legislation, its adaptation in greater scope would help chemical industry in shaping sustainable future accordingly to the experience of the European Union. The main task for all stakeholders should be to careful access strength and weakness of implementation in terms of conditions and structure of the market, user choice, compliance costs, and administrative procedure. The results of the article confirmed that if the approach of chemical management is changed in practice, Serbia would avoid being the object of numerous scientific and institutional reports presenting Serbian insufficient capacity to cope with the ecological risk like chemical contamination in different perils and contribute to the sustainable development of country.

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SELECTION OF THE MOTIVATION STRATEGY FOR EMPLOYEES IN THE MINING INDUSTRY USING THE GRA METHOD

Abstract

Human resources in an organization are one of the most important resources. Their motivation and satisfaction is a tool in achieving and retaining the organization's competitive advantage. The motivation of employees motivation is one of the main goals of the human resource management, since it has a direct impact on the performance itself, productivity of employees and the overall organizational performance. The aim of this paper is to propose an approach to the selection of motivation strategy for employees based on the multi-criteria decision-making. The approach is based on the GRA method, i.e. gray relational analysis. An illustrative numerical example was carried out in this paper. The proposed approach, based on the gray relational analysis, was successfully applied for selection the motivation strategy for employees in the mining industry.

Keywords: *VKO, GRA, motivation, performance, mining industry, motivation strategies*

INTRODUCTION

The most important resources of every organization are employees. They are a resource through which an organization achieves a competitive advantage and business success; they are a resource whose work results directly depend on their motivation. Employees are often, not only the most valuable, but also the most expensive organizational resource, so managing them must be a long-term and strategically well planned process.

One of the key issues gaining momentum in recent times is the motivation of employees. The organizations pay a great attention to this problem, because motivation and employees' satisfaction affect performance of an organization. Therefore, the motivation of employees and creation the conditions for their satisfaction are the most important tasks of management aimed to create a successful organization [13]. Motivation is a process through which it is possible not only to achieve the organizational goals, but also to provide the employees with the opportunity to satisfy their needs through work. The process of motivation is affected by a variety of factors, external and internal, such as: the individual characteristics of an employee, the characteristics of the job that an individual performs, management styles, organizational culture, social and economic development, as well as the external social environment. The motivational factors include job, progress and responsibility. These factors are related to the positive feelings of an individual toward the work itself and t content of that work, achievements, recognition and responsibility.

Since motivation is a very complex and dynamic factor of successful business, it is

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necessary to establish an adequate motivation system for the proper management of human potential in order to achieve better performance and higher productivity. One of the biggest problems of the motivation system is the resistance of the workers themselves, who often do not believe in the system of stimulating rewards, in its objectivity and justice. Therefore, it is essential to gain the confidence of employees in this system.

The motivation system should be designed to provide three important steps: attracting employees while securing their staying with the organization, employees performing tasks and responsibilities appropriately and employees' self-development in the field of innovation and creativity. A large number of business problems arise as a result of an ineffective system of motivation. Decreased employees' interest, poor response of the candidates in the recruitment process, inefficient trainings, poor interpersonal relationships, high fluctuation percentage and inefficient cooperation within different sectors are the result of the unregulated HR processes. The reason for these unregulated conditions may also be the failure to comply with the basic principles of business ethics, as well as the application of inadequate motivation strategies [4].

Managers have the possibility to use various types of strategies, techniques and methods for motivating employees in the company. Each strategy is aimed to achieve the organization goals, and to meet the employees' needs. Managers can apply the material motivation strategies, non-material motivation strategies and integrated ones, i.e. combined strategies of motivation. The strategy managers will apply depends exclusively on identification the employees' needs. Urošević et al. [13,14] point out that the motivation of employees depends partly on the managers' skills, their competencies to foster motivation and ability to create such organizational climate that will ultimately result in the employees' satisfaction.

The aim of this paper is to propose an approach for selection a motivation strategy for employees in the mining industry based on the multi-criteria decision-making. This approach is based on the use of gray relational analysis. Accordingly, the paper is structured as the following: Section 1 represents the introductory considerations; Section 2 offers the key elements of motivation; Section 3 specifies the employees' motivation in the organizations of the mining industry; Section 4 shows the applied methodology, i.e. gray relational analysis; Section 5 suggests an illustrative numerical example. Finally, the last section represents the conclusion of this paper.

CONCEPT OF MOTIVATION

Researchers and managers have always been interested in motivators that drive employees and elements that affect the employees' motivation. The answer to that question is significant from the aspect of better employees' performance and better productivity.

Motivation represents the process of initiating and directing the human behavior in a certain direction. Most authors [8,12], agree that the motivation is primarily a psychological process of the inner feelings or incentives. Luthan (1998) defines the motivation "as a process that begins with the physiological disadvantages or with the need to activate the certain behaviour", in other words it is "the goal of stimulating the goal" [12]. According to Minner, Ebrahim and Watchel (1995), the motivation is characterized by three elements: needs, movement and rewards [12]. In other words, an unmet need creates tension, motivates an action and meeting of that need.

Theories of motivation have developed, as the result of the process of determining the different needs, the causes and mechanisms that initiate the human activity. The first group of theories is focused on discovering the needs and motives that drive people in an organization. The most important theories regarding the content of motivation are: Theory of Hierarchy of Needs by Abraham Maslow; Theory X and Y by McGregor; Alderfer's ERG Model of Motivation; Herzberg's Two-Factor Theory; Mccalleland's Theory of Needs. The second group of theories seeks to discover the motivation process making people to take a certain action. The most important theories of the motivation process are the following: Goal Setting Theory, Theory of Equality and Theory of Expectations.

There are three dimensions of motivation necessary for understanding its essence and its impact on the employees' performance. They include direction, intensity and persistence. In order for the employee to be motivated in the right way, his/her motivation must have a certain direction. People in an organization can be motivated in the wrong direction, too. The intensity of motivation determines the amount of effort that someone will invest in an amount of time required to meet their needs. If the motivation intensity is higher, the employees will put more effort into achieving their tasks and their performance. Finally, the stability of motivation shows the time and a certain level of effort invested in a particular direction. For example, one can be motivated at an extremely high level in a short period of time, while another employee can be motivated with lower intensity, but for a longer period of time [5].

Motivation has a direct impact on the performance of employees. Therefore, the performance of the employees depends on the employees' ability to do the job, on their competencies, the appropriate work conditions and motivation. It may happen that an employee has competencies for a particular job and that the organization provides the necessary conditions, but if he/she is not motivated, the results will be lacking. In order to maximize the employees' productivity, the managers need to know what the employees' needs are. We are all different and we all have different needs. The diversity of human nature is the reason why someone is more oriented towards the career and some is more interested towards the securing material resources. Therefore, it is extremely important to identify the needs of each employee.

MOTIVATION OF THE EMPLOYEES IN THE MINING INDUSTRY ORGANIZATIONS

Working in the mining industry organizations is difficult, often unhealthy and unsafe. Employees in the mining industry organizations face risks specific only to this profession. The aggravating circumstances may include poor working conditions, poor management, lack of skilled personnel, inadequate equipment, outdated technology and unsustainable tools, lack of training, exposure to extreme temperatures, biological and chemical agents, noise, radiation and stress, which increase the risk of accidents, possible in the mining industry. In addition to poor working conditions, if there is a partial and unfair system of rewarding and an ineffective motivation system, the workers will not be motivated to work. The absence of employees' motivation implies the reduced performance and employees' productivity, which definitely reflects on the business success of the organization, on attracting the new and retaining the existing staff. In order to increase the productivity of employees, it is necessary to provide a motivational system based on the fair system of valuation and rewarding. In addition, the managers must create trust of the employees in the motivation system. In order to determine the correct motivation system or, in other words, to select the best motivation strategy that will give the biggest effect in productivity, it is necessary firstly to determine the needs of employees. All the motives and needs of the employees can be classified into four categories:

- Material motives (material rewards, bonuses, salaries, scholarships for education, paid life insurance);
- Non-material motives (praises and acknowledgments, the possibility of career advancement, the possibility of education through training programs, achievement and personal success);
- Work related motives (dynamic and challenging job, good working conditions, job security, clearly set goals and objectives, modern work equipment, acceptance of responsibilities, participation in decision-making and goal setting processes, feedback on achieved results);
- Motives related to the work environment (good relationship with the manager, good interpersonal relationships, respect from colleagues and management).

Motives related to work and motives related to the work environment represent the subcategories of non-material motives.

Managers can apply different motivation strategies:

- Material strategy of motivation (managers apply the different material incentives according to the ranked identified motives);
- Non-material motivational strategies (managers apply the different non-material incentives according to the ranked identified motives);
- Integrated or combined motivation strategies (managers apply a combination of various material and non-material incentives according to the ranked identified motives).

The motivation strategy mangers will choose to apply depends on identifying the employees' needs, because the basic starting point for creating the employees' motivation is meeting the different needs.

METHODOLOGY

The theory of gray systems was proposed by Deng (1989) with the aim to model non-deterministic systems in situations where information is incomplete, unreliable and insecure. Within this theory, it was developed the gray relational analysis (GRA). The gray relational analysis is suitable for solving many problems characterized by uncertainty, which include discrete data and incomplete information, multi-criteria problems and optimization problems. As Lin & Lin (2002) [7] emphasize, gray relational analysis can be applied to solve effectively the complex interrelations between the multiple performance characteristics.

The justification for application the gray relational analysis lies in a fact that the method has been so far used, and successfully applied to solve various problems, such as: investigation the human error factors of civil aircraft pilots based on the gray relational analysis [3], selection of the mining tourism development strategy [9], measuring the quality of web sites in the hotel industry using the gray relational analysis [11], and others.

Mathematical interpretation of the gray rational analysis can be shown in the following way [9,11]: may $A = \{A_1, A_2, ..., A_m\}$ be discrete set of alternatives, $C = \{C_1, C_2, ..., C_n\}$ set of criteria and $w = \{w_1, w_2, ..., w_n\}$ vector of weight, where is $w_j = [0,1]$ and $\sum_{j=1}^{n} w_j = 1$. After that, there is a determination of the most acceptable alternative using a gray relational analysis through the following steps:

Step 1: Determination of the ideal solution. An ideal solution (reference point) is a solution that maximizes the revenue and minimizes the expense criteria, and it can be determined applying the following formula:

$$A^* = \{r_1^*, r_2^*, \ldots, r_n^*\} = \{(\max_i r_{ij} \mid j \in \Omega_{\max}), (\min_i r_{ij} \mid j \in \Omega_{\min})\}, \qquad (1)$$

In the equation A^* is an ideal solution, r_j^* is j coordinate of the ideal solution, r_{ij} is normalized rating of the i alternative to j criteria, $\Omega_{\max}$ and $\Omega_{\min}$ are sets of the na-tural and expense criteria.

Step 2: Calculation of the gray relational coefficient. In the second step, it is necessary to calculate the gray relational coefficient for each alternative of the ideal solution using the following formula:

$$\xi_{ij} = \frac{\min_i \min_j | r_j^* - r_{ij} | + \varsigma \max_i \max_j | r_j^* - r_{ij} |}{| r_j^* - r_{ij} | + \varsigma \max_i \max_j | r_j^* - r_{ij} |}, \qquad (2)$$

In the equation, ξ_{ij} is the gray rational coefficient of the i alternative to j criteria, ς is coefficient of the difference and $\varsigma \in [0.1]$.

Step 3: Calculation of the gray relational grade. In this step, the gray relationnal grade is calculated for each alternative from the ideal solution using the following formula:

$$G_i = \frac{1}{n} \sum_{j=1}^{n} w_j \xi_{ij}, \qquad (3)$$

In the equation G_i is gray rational grade from i alternative, w_j is weight of the j criteria.

Step 4: Ranking alternatives and choosing the best one. In this step, it is necessary to rank the considered alternatives and choose the best one in accordance with G_i. The alternatives with higher G_i are better ranked and alternatives with G_i are the most acceptable/desirable.

ILLUSTRATIVE NUMERICAL EXAMPLE

In order to show, in the best way possible, the justification, efficiency, effectiveness and usability of the proposed approach based on the use of the gray relational analysis, this section will show an illustrative numerical example: the selection of motivation strategies for employees in the mining industry. For the suggested motivation strategies in our case the alternatives are: A_1 – material motivation strategies; A_2 – non-material motivation strategies and A_3 – integrated motivation strategy. For the evaluation of these strategies, it will be applied four criteria of equal assigned weight of 0.25. Criteria for evaluating the strategy are as following: C_1 – feasibility of strategy implementation, C_2 – strategy implementation speed, C_3 – compliance of strategy with mission and vision of the organization and C_4 – acceptability of strategy by the employees.

Therefore, let us assume that the HR manager should decide on an adequate motivation strategy from the three offered, designated as A_1, A_2 and A_3 in relation to the four evaluation criteria designated as C_1, C_2, C_3 and C_4.

At the very beginning of the evaluation, the HR manager conducts an evaluation of the strategies in relation to the four evaluation criteria. The grades of considered alternatives are shown in Table 1.

Table 1 *Grades of the considered strategies*

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

Then, we approach to determination the ideal point applying formula 1. The ideal point A^* and the distance of the alternative to the ideal point is shown in Table 2.

Table 2 *The ideal point and the distance between the alternative and ideal point*

	C_1	C_2	C_3	C_4
A^*	5	5	5	4
A_1	2	1	2	0
A_2	1	2	1	0
A_3	0	0	0	0

In the next step, applying formula 2, the gray relational coefficient is calculated for each of the alternatives to the ideal point. Table 3 shows the gray relational coefficients for each alternative to the ideal point. In this case, ς is set to 0.5.

Table 3 *Gray relational coefficients for each alternative to the ideal point*

	C_1	C_2	C_3	C_4
A_1	0.33	0.50	0.33	1.00
A_2	0.50	0.33	0.50	1.00
A_3	1.00	1.00	1.00	1.00

Finally, using formula 3, the gray relational grade is calculated for each alternative. The gray relational grades and the order of alternatives' ranking are shown in Table 4.

Table 4 *Gray rational grades and the ranking order*

	G_i	***Rank***
A_1	0.54	3
A_2	0.58	2
A_3	1.00	**1**

Data in Table 4 indicate that the alternative designated as A_3 is the best-ranked alternative or, in our case, the best-ranked strategy.

CONCLUSION

Multi-criteria decision making greatly facilitates the decision-making process and adoption the sustainable solutions. From the illustrative numerical example, it can be concluded that the proposed application of the gray relational analysis is justified, and it was successfully used in the selection of motivation strategy for the employees in the mining industry. The best ranked alternative is the one marked as A_3, which represents an integrated motivation strategy for employees (material and non-material motivation).

In order to achieve better performance and business success, the managers need to discover what triggers the human activity, and what the needs of employees are. When their needs are satisfied, the employees achieve better performance and higher productivity, which leads to accomplishing the organizational goals and business success. The selection of motivation strategy depends on the employees, whether they are more focused on meeting the basic existential needs or directed toward higher needs, such as improvement, career advancement, etc. The results of this research indicate that variables like the life expectancy, education, work experience and tjob position of respondents in the organization influence the choice of work motives. The results of empirical research indicate that the employees are focused on the material and non-material needs. That is why it is recommended to the managers to apply the inte grated (combined) motivation strategies that involve the material and non-material stimulus.

Therefore, in order to raise the level of employees' motivation, besides the material incentives (wages, bonuses for night shifts, overtime and high performance, pension and disability insurance, private pension fund and life insurance, paid leave, etc.), which are universal motivators, and can satisfy the needs to a certain level, especially the existential ones, there are also the non-material motivators (education, praise and recognition, various forms of employees' participation in the processes, career advancement, etc.) that have a deeper and longer-term effect on motivation. An effective method of motivation can be an occasional job rotation, as well as keeping the work interesting in order to avoid the monotony and routine. Given that work in the mining industry is difficult and unsafe, the employees need to have better working conditions, more modern equipment and job security. As the process of motivation is influenced by the work results, the employees should be provided with a feedback on their work, as well as on achieving the set goals. Also, for raising the motivation level of employees in the mining industry organizations, the good examples from foreign and domestic companies practice can be used, such as: special productivity bonuses, different actions for employee, paid recreation, company's hotels, organized excursions, professional excursions, paid kindergartens for employees' children, gifts for holidays, birthdays, etc.

Application of an adequate motivation strategy can raise the employees' level of motivation and self-confidence, which leads to achieving better efficiency and effectiveness in the workplace; it keeps the existing workers in the company and attracts a new staff, which is difficult to achieve in this specific field of work. Therefore, an effective motivation system should represent an optimal combination of the material and non-material incentives. Because of the hard working conditions in the mining industry, it is necessary to find constantly the new techniques and methods for motivating the employees, because the expectations and needs of employees change over time.

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