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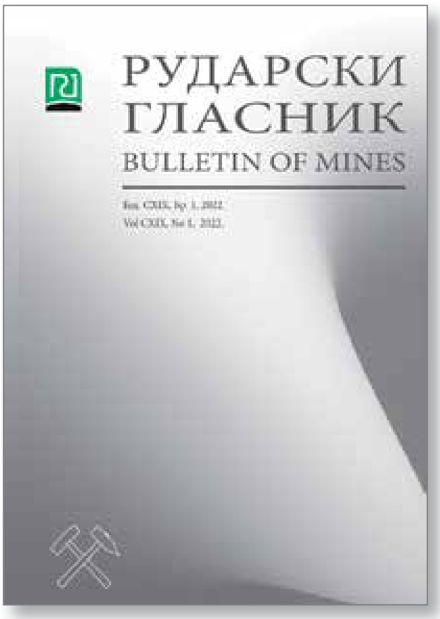
У организацији Рударског института одржан је 8. Балкански рударски конгрес у Београду 28-30. септембар 2022. У најави Конгреса саопштено је да ће према мишљењу учесника 10 најбоље изложених радова бити публиковани у часопису Рударски гласник. Поштујући најаву, у овом броју Рударског гласника публиковани су најбоље рангирани радова на Конгресу, изузимајући последњи рад.

The 8th Balkan Mining Congress was held in Belgrade on September 28-30, 2022, organized by the Mining Institute. The Congress announced that the ten best among the presented papers, as selected by the participants, would be published in the Bulletin of Mines. As per the announcement, the best-ranked papers at the Congress, excluding the last paper, were published in this issue of Bulletin of Mines.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INNOVATIVE PROCESSES FOR THE RECOVERY OF RARE AND RARE EARTH ELEMENTS FROM COMPLEX ORES

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Abstract: *Through the analysis of data collected by IR spectroscopy, SEM and other state-of-the-art physical and chemical research methods, the mechanism of change was described in the structural (morphology, surface defects) and process properties of eudialyte, perovskite, ash and slag waste, and molybdenite when exposed to high power nanosecond pulses (HPEMP), low-temperature dielectric barrier discharge plasma (LT DBDP), and ultrasound. It was found that the breakage of the structure and modification of the mineral surface with the formation of deep cracks intensifies leaching processes.*

The rational parameters (acid concentration, treatment time, temperature, S:L ratio) of nitric acid leaching of rare and rare earth elements when exposed to physicochemical and energy impacts (electric field strength, frequency and duration of energy pulses, duration of treatment, pressure) were identified theoretically and experimentally to achieve the following:

- for eudialyte concentrate, increase in zirconium recovery by 4.3% from 86.65% to 90.9% and REE recovery by 1.8% from 87.7% to 89.5%; for ash and slag waste, increase in REE recovery by 4-18% from 50.2% to 54.2–68.4%; for molybdenum concentrate, increase in rhenium recovery by 29.1% from 68.5% to 97.6%.

Key words: RARE AND RARE EARTH ELEMENTS, EUDIALYTE, PEROVSKITE, MOLYBDENITE, ASH AND SLAG WASTE, RECOVERY, ENERGY IMPACT METHODS, LEACHING

INTRODUCTION

The development of high-tech industries, including nuclear engineering, radio electronics, aircraft manufacturing, space industry, green energy, requires sufficient supply of strategic metals, including: U, Mn, Cr, Ti, Al, Zr, Hf, Be, Li, Re, yttrium REEs, Bi, Cd, Ga. A study of the existing mineral resource base of rare earth element deposits identified eudialyte ores of the Lovozero deposit, perovskite-titanomagnetite ores of the Afrikanda deposit, copper-molybdenum ores and ash and slag waste as the most promising mineral feeds for the recovery of rare and rare earth elements [1,2,8-10].

Potential solutions to the challenges involved in the hydrometallurgical processing of these mineral resources include exposing mineral suspensions to energy impacts (ultrasound, high-voltage pulses, plasma and electrochemical treatment, etc.), which improves the unlocking and breakage performance of fine-grained mineral complexes and the recovery of non-ferrous and precious metal micro- and nanoparticles in the downstream ore processing circuits [3-7,11].

MATERIALS AND METHODS

MATERIALS

The following mineral samples were studied: perovskite in the form of individual grains isolated from perovskite ore samples from the Afrikanda deposit (Kola Peninsula, Russia), eudialyte from the Lovozero deposit in the form of monomineral fractions, samples of eudialyte concentrate — ash and slag waste generated by the Irkutsk thermal power plant, copper-molybdenum ore and molybdenum concentrate.

METHODS

The morphology and elemental composition of the mineral surfaces were studied by SEM-EDX and ASEM (microscopes LEO 1420VP INCA 350, Carl Zeiss; Ntegra Prima, NT-MDT SI; VK-9700, EDXRF Olympus X-5000). To identify the chemical composition of the mineral surfaces and assess the semi-quantitative adsorption performance of flotation reagents, infrared spectroscopy with the Fourier transform was employed (IR-Fourier spectrometer IR-Affinity, Shimadzu, and Diffuse IR unit, Pike Technologies). Energy treatment of the minerals was carried out with the following parameters: HPEMP (voltage pulse amplitude 70 kV; field strength $1.75x10^7$ V/m; pulse frequency 375 Hz; pulse duration 50 ns); DBD (leading edge of the pulse duration 250-300 ns; pulse duration 8 μs; voltage amplitude 20 kV; pulse frequency 16 kHz); ultrasound (frequency 20±1.65 kHz; oscillation amplitude 2.5-5 μm) using experimental lab-scale equipment (IPKON RAS; NPP FON LLC, Ryazan).

EFFECT OF COMBINED PHYSICOCHEMICAL AND ENERGY IMPACTS ON THE STRUCTURAL AND CHEMICAL, MORPHOLOGICAL, AND PROCESS PROPERTIES OF THE SURFACE OF RARE AND REE MINERALS

PEROVSKITE

According to the SEM-EDX data, as a result of electromagnetic pulsed and plasma treatment of crystals, the structure was broken down and the perovskite surface was modified (Figure 1), which led to an increase in the sorption of the reagent and an increase in the flotation recovery of perovskite by 10–15%.

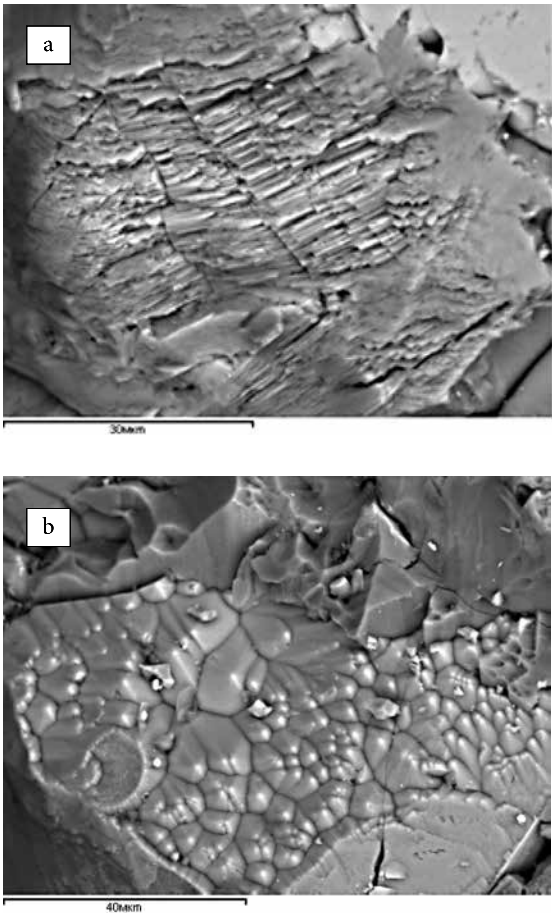

Figure 1, Perovskite surface after exposure to HPEMP (a) and DBD (b)

EUDIALYTE CONCENTRATE

Based on the SEM-EDX data, exposing the eudialyte to HPEMP caused breakage of the surface of a significant part of the mineral grains with the formation of new surface types: depending on the treatment time, from parallel fractured at 30 s (Figure 2a) to polygonal fractured at 60 s and 90 s (Figure 2b, c), which led to the formation of microcracks, and as a result predetermined the subsequent leaching performance of the concentrate.

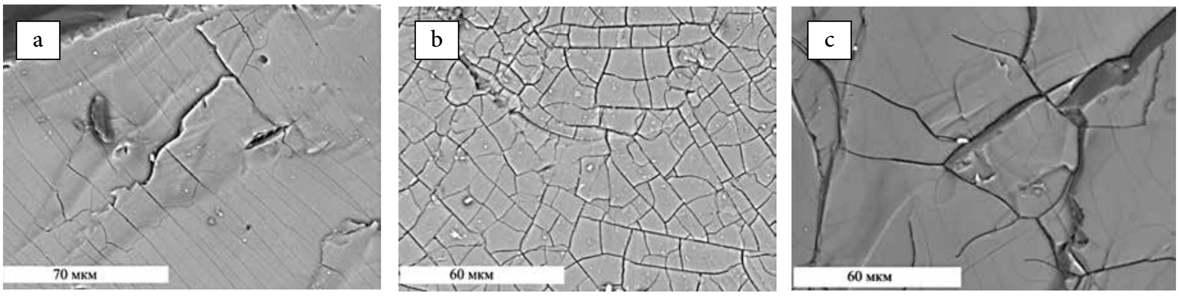

Figure 2, Images of the eudialyte surface after HPEMP treatment for 30 s (a), 60 s (b) and 90 s (c)

ASH AND SLAG WASTE

HPEMP and US treatments were found to cause significant breakage to the structural state of the surface of ash and slag waste, contributing to the formation of a significant number of damaged, split microspheres (Figure 3), which subsequently should ensure the intensification of the dissolution of microspheres in nitric acid and, as a result, an increase in the REE recovery into the pregnant solution.

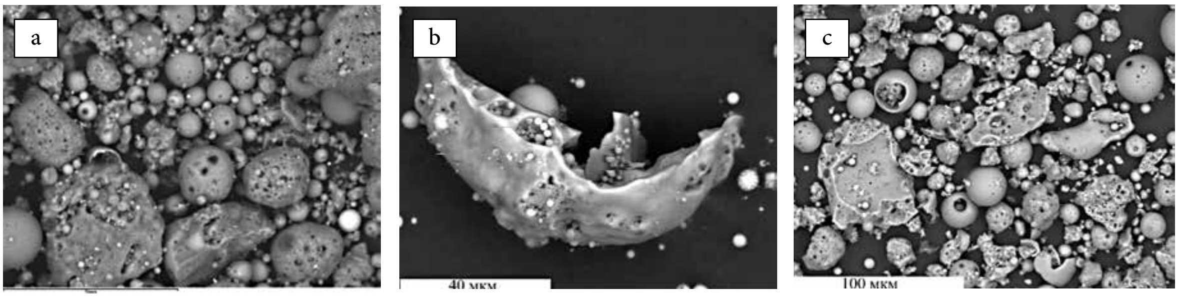

Figure 3, Images of particles of ash and slag samples after exposure to HPEMP (a, b) and ultrasound (c)

OPTIMIZING THE LEACHING CONDITIONS OF RARE AND RARE EARTH ELEMENTS FROM EUDIALYTE CONCENTRATE, ASH AND SLAG WASTE, AND MOLYBDENUM CONCENTRATE WHEN EXPOSED TO COMBINED PHYSICAL, CHEMICAL AND ENERGY IMPACTS

At the first stage of the study, based on a literature review and experimental studies, *optimal leaching modes were identified* for *eudialyte concentrate* – temperature 80°C, duration 1 hour, nitric acid concentration 7.2 mol/dm^3, ratio of solid mineral phase to leaching solution (S:L) 1:20, mixing speed 500 min^{-1}; *ash and slag waste* – temperature 130°C, duration 3 hours, nitric acid concentration 7.2 mol/dm^3, S:L ratio 1:10; mixing speed 500 min^{-1}; *molybdenum concentrate* – temperature 130°C, duration 5 hours, nitric acid concentration 3.2 mol/dm^3, S:L ratio 1:10, mixing speed 500 min^{-1}, pressure 63 atm.

EUDIALYTE CONCENTRATE

Analysis of the findings of studies of the process of nitric acid leaching of eudialyte concentrate when exposed to energy impacts made it possible to establish that pretreatment with HPEMP provides an increase in Zr recovery into the pregnant solution by 3.4-4.3%, while pretreatment with DBD — by 4.0% (Table 1). The maximum increase in the recovery of Zr (4.3%) was achieved as a result of HPEMP treatment of the concentrate with an exposure time of t_{treat} =60 sec.

Table 1, Effect of HPEMP and DBD on the leaching performance of eudialyte concentrate

Treatment conditions	Recovery, %						Average REE recovery, %	Increase in REE recovery, %
	Zr	Ce	Hf	La	Nd	Y		
No treatment	86.6	87.5	84.9	86.2	88.4	89.7	87.7	-
HPEMP (30 s)	89.9	88.4	89.9	87.2	89.9	92.4	89.5	1.8
HPEMP (60 s)	90.9	88.2	90.7	85.7	90.1	92.8	89.4	1.7
HPEMP (90 s)	90.2	87.6	89.5	85.8	89.4	92.3	88.9	1.2
DBD (30 s)	90.6	87.9	89.4	85.9	89.9	92.8	89.2	1.5

ASH AND SLAG WASTE

The impact of HPEMP and ultrasound on the process of nitric acid leaching of ash and slag wastes brought an increase in the recovery of rare earth elements in the pregnant solution from 50.2% to 54.2% and up to 68.4% when exposed to ultrasound (Table 2).

Table 2, Effect of HPEMP and US on the ash leaching performance

Treatment conditions	t, min	Recovery, %				REE recovery, %	Increase in REE recovery, %
		Ce	La	Nd	Y		
No treatment		43.9	48.3	45.6	64.0	50.2	-
HPEMP	0.5	44.0	48.5	46.8	66.3	51.2	1.0
	1.0	50.8	48.4	47.5	67.4	54.2	4.0
	1.5	49.0	50.8	50.0	66.8	54.2	4.0
US (water)	5	56.0	47.5	53.2	65.3	54.3	4.1
	10	60.5	50.4	53.4	64.9	58.6	8.4
	20	60.1	46.7	57.5	66.0	59.1	8.9
	30	56.1	54.2	56.5	65.2	58.3	8.1
US (HNO_3)	10	73.2	52.5	72.1	67.9	68.4	18.2

MOLYBDENUM CONCENTRATE

Experimental studies of the leaching process of molybdenum concentrate with a 20% nitric acid solution demonstrated an increase in the maximum recovery of rhenium from 68.5% to 97.65% when pressure leached for 5 hours at 63 atm.

CONCLUSIONS

Using state-of-the-art methods to study the impacts of high-power nanosecond electromagnetic pulses (HPEMP), dielectric barrier discharge (DBD), ultrasound, and pressure leaching on the structural and chemical, mechanical and physico-chemical properties of eudialyte and molybdenite concentrates and ash and slag waste during acid leaching, the mechanism was described behind the intensification of the recovery process of Zr, Re and REEs, which consists in the softening and breakage of minerals, bringing a 5-30% increase in the recovery of valuable components.

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УПОТРЕБА ЕКОЛОГИЈЕ ЗА ДЕСТРУКЦИЈУ РУДАРСТВА

USE OF ECOLOGY FOR THE DESTRUCTION OF MINING

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Сажетак: *Рударство са репутицајом еколошки „прљаве" индустрије, изложено је предрасудама, подозрењу, сумњама, неразумевању, заблудама, критикама, ограничавањима, условљавањима итд. Проблем утицаја рударских радова на животну и радну средину продубљује и чини сложенијим него што јесте, непознавање фазности рударства и притисци јавности проблематично мотивисани и стручно неутемељени. Екологија као наука, не дефинише шта је „исправно" а шта „неисправно", не дефинише ни оквире своје научне меріторности. То у данашњем амбијенту „свезнања", односно поистовећивања „знања" и „незнања", производи конфликте са материјализованим исходом у облику штете нанете економији и развоју друштва. Рад је посвећен феномену аутоштете, односно (зло)употребе екологије у деструкцији рударства.*

Кључне речи: РУДАРСТВО, ЗАШТИТА СРЕДИНЕ, ЕКОЛОГИЈА, ДЕСТРУКЦИЈА

Abstract: *With its reputation as an ecologically "dirty" industry, mining is subjected to prejudices, doubts, misunderstandings, misconceptions, criticisms, limitations, conditioning, etc. Lack of knowledge about mining phases and problematically motivated and professionally unfounded public pressures deepen and make the issue of the impact of mining operations on the living and working environment even more complex than it is. Ecology, as a science, does not define "adequate" and "inadequate," nor does it define the framework of its scientific meritoriousness. In today's environment of "omniscience," or equating of "knowledge" and "ignorance," it produces conflicts with a materialized outcome in the form of damage to the economy and social development. The paper is dedicated to the phenomenon of autodamage, that is, the (mis)use of ecology in the destruction of mining.*

Key words: MINING, ENVIRONMENTAL PROTECTION, ECOLOGY, DESTRUCTION

ЗАШТО ОВА ТЕМА

Неке рударске активности нестручно и непажљиво вођене могу створити проблем у окружењу. Последице непажње нису увек исте, нити су одмах видљиве.

WHY THIS TOPIC

Some unprofessionally and carelessly carried out mining activities can create an environmental problem. The aftermath of carelessness is not always the same, nor is it immediately visible.

Да би сагледавање утицаја рударских радова на животну средину било мериторно, потребна је вишеетапна мултидисциплинарна стручност, а надзор стања средине у зони утицаја рударских радова, мора полазити од (утврђеног) природног фона. Сагледавање стања насталог под утицајем рударских радова и решења за отклањање или ублажавање последица, обухвата планирање и правовремено спровођења мера баланса рударских активности, заштите, неге и уређења предела експлоатационог поља. У сагласју с тим, већ у фази пројектовања отварања рудника, неопходно је дефинисати концепцију заштите животне средине и динамику спровођења. То није статичан – проблем постојаног стања, већ проблем вишедеценијског трајања и неминовних амбијенталних промена тржишта, економије, политике, законске и нормативне регулативе, урбанизма, социјалних и еколошких захтева, итд. Дакле, заштита животне и радне средине је интерактивна, вишезначно осетљива, сложена, и стручно високо захтевна тема.

Комплексност проблема, могућа површност у дијагностици и решавању, недовољна посвећеност проблему, скромна стручност носиоца задатка и притисци јавности проблематично мотивисани и стручно неутемељени, стварају затегнутост и конфликтне ситуације које наносе економску штету и успоравају развој [1,3,5].

УТИЦАЈИ РУДАРСТВА НА ЖИВОТНУ И РАДНУ СРЕДИНУ

Резолутно, животну средину рударство може угрозити на један од начина: *исцрпљивање ресурса, разарање и загађивање средине* [1].

Експлоатација минералних сировина одвија се фазно, те се и утицаји на животну средину истоветно генеришу. Диференцирање еколошких утицаја технолошких процеса експлоатације и прераде чврстих минералних сировина, захтевало би много обимнији а неважан текст. Зато су у функцији теме рада и целовитијег сагледавања проблема, у наставку приказана обележјима утицаји на

In order for the assessment of the impact of mining on the environment to be meritorious, multi-stage multidisciplinary expertise is needed, and monitoring the condition of the environment in the mining impact zone must start from the (established) natural background (condition). Reviewing the situation created under the influence of mining and creating solutions for eliminating or mitigating the consequences includes planning and timely implementation of measures aimed at balancing mining activities, protection, care, and arrangement of the exploitation field. In this regard, it is necessary to define the concept of environmental protection and the dynamics of its implementation already in the mine opening design phase. It is not a static or permanent problem but a decades-long problem of inevitable ambient changes in the market, economics, politics, legal and normative regulations, urban planning, social and environmental requirements, etc. Therefore, living and working environment protection is an interactive, ambiguously sensitive, complex, and professionally highly demanding topic.

The problem complexity, possible superficiality in diagnosis and solution, insufficient dedication, modest expertise of the task owner, and problematically motivated and professionally unfounded public pressures create tension and conflict situations that cause economic damage and delay the development [1,3,5].

IMPACTS OF MINING ON LIVING AND WORKING ENVIRONMENT

Resolutely, mining can threaten the environment in one of the following ways: *depletion of resources, destruction and pollution of the environment* [1].

The exploitation of mineral resources takes place in phases, so the environmental impacts also come in phases. Differentiating between the environmental impacts of the technological processes of exploitation and processing of solid mineral resources would require a much more extensive and irrelevant text. That is why the impacts on the living and working environment of the key mining activities are shown below животну и радну средине кључних рударских активности: геолошко истраживање, експлоатација и припрема минералних сировина и одлагање јаловине.

Геолошко истраживање претходи експлоатацији минералних сировина, поступно је и фазно условљено (реализација наредне фазе истраживања зависи од исхода претходне) и дуготрајно од проспекцијских, геофизичких до детаљних геолошких истраживања – истражним бушењем, подземним или комбинованим истражним радовима, узорковањем, инситу и лабораторијским испитивањима, синтезе резултата, оцене, елборације, контроле и провере, итд.

Геолошким истражним радовима не деградира се и не контаминира земљиште, и не квари визуелни ефекат крајолика. Подземним истражним радовима извесне количине откопне јалове стенске масе одлажу се на површини терена. То су мала одлагалишта, не мењају морфологију терена, а рекултивација је лако изводљива, није материјално захтевна, најчешће није ни потребна пошто је природа спонтано и ефикасно обавља. Генерализована оцена ефеката гелошких истражних радова по окружење, своди се на констатацију да је реч о еколошки безазленој активности [1,2].

Подземна експлоатација не деградира земљишне површине и не оставља негативан визуелних ефеката, што је посебно значајно за урбане и заштићене пределе као што су национални и паркови природе, туристички, рекреациони центри, бање, историјски споменици, археолошка налазишта итд. Пошто се експлоатациони радови изводе у дубини тла, нема технолошких утицаја на окружење, као што су сеизмички ефекти, бука, прашина, гасови итд. Нежељени ефекти могу бити: ограничене промене морфологије као последице слегања терена, испуштање у атмосферу истрошеног јамског ваздуха, испуштања рудничке воде повећане минерализације у отворени водоток, потенцијално загађење подземне воде у контакту са флотацијском јаловином коришћеном за запуњавање јамских просторија итд. [1]

to contribute to the paper topic and provide a more comprehensive overview of the problem: geological research, mineral exploitation and processing, and tailings disposal.

Geological exploration precedes the exploitation of mineral resources, is gradual and phase-conditioned (the next phase of research depends on the outcome of the previous one), and lengthy - from prospecting and geophysical to detailed geological research - by exploratory drilling, underground or combined exploratory works, sampling, in-situ and laboratory tests, synthesis of results, evaluations, studies, controls and checks, etc.

Geological exploratory works do not degrade or contaminate the soil and do not spoil the visual effect of the landscape. Through underground exploratory works, a certain amount of excavated barren rock mass is deposited on the terrain's surface. These are small landfills that do not change the terrain's morphology. Their reclamation is easily feasible, not materially demanding, and most of the time, it is not even necessary since nature does it spontaneously and efficiently. A generalized evaluation of the effects of the geological exploratory works on the environment comes down to the conclusion that it is an environmentally harmless activity. [1,2]

Underground exploitation does not degrade land surfaces and does not leave negative visual effects, which is especially important for urban and protected areas such as national and nature parks, tourist and recreation centers, spas, historical monuments, archaeological sites, etc. Since exploitation works are carried out deep in the ground, there are no technological impacts on the environment, such as seismic effects, noise, dust, gases, etc. Adverse effects include limited changes in morphology as a result of ground subsidence, release of pit air into the atmosphere, release of mine water with increased mineral content into an open watercourse, potential pollution of groundwater in contact with flotation tailings used to fill pit chambers, etc.[1]

Површинска експлоатација, данас доминирајући облик експлоатације минералних сировина, веће је потенцијалности за проблеме еколошке природе. Чињеница је и да се овом облику експлоатације приписује се много више негативног него што стварно јесте. Разлози негативне перцепције су: визуелни ефекат, заузимање и деградирање земљишта, пошумљених површина итд. Заборавља се, не зна или не жели да зна, да је деградација површине захваћене експлоатационим радовима привремена, да се може успешно ревитализовати и рекултивисати.

Од технологије површинске експлоатације, зависе пратећи утицаји на околину и трајање њиховог деловања. Код минирања то су сеизмички ефекти, бука, ваздушни удари, прашина и гасови. Код утовара, транспорта, депоновања руде и одлагања јаловине, то су бука, прашина и издувни гасови из мотора за покретање машина и опреме, могућа је и прашина коју подиже и развејава по околини ветар.

Утицаји рударских радова на ближу и ширу околину површинских копова манифестују се: заузимањем земљишта, променама морфологије терена, одлагањем јаловине стварањем стерилних површина, измештањем водотокова, могућим микроклиматским променама, могућом иницијализацијом ерозионих процеса, снижавањем нивоа и променама режима струјања подземних вода, појаве померања тла, прекида ланца исхране и других промена биоценозе, миграција популације, измештање насеља, индустријских објеката, археолошких и историјских споменика итд. Ови ефекти зависе од какрактеристика радне средине, од примењене технике и технологије експлоатације, од садржаја и стања у окружењу, а пре свега од стручног и моралног односа менаџмента рудника према заштити животне и радне средине. Правила нема, утицаји и последице мењају се од рудника до рудника, подложни су просторним и временским променама, често стохастично због комплексности односа у систему природа – човек – техниика и технологија [1,4].

Разликује се обим и интезитет утицаја на животну и радну средину површинске ек-

Open-pit exploitation, today the dominant form of mineral resources exploitation, has greater potential for ecological problems. Also, a much more negative picture is attached to this form of exploitation than it really is the case. The reasons for negative perception are the visual effect, occupation and degradation of land, forested areas, etc. However, people forget, do not know or do not want to know that the degradation of the surface affected by exploitation works is temporary and can be successfully revitalized and reclaimed.

The accompanying impacts on the environment and the duration of their effect depend on the open-pit exploitation technology. In blasting, these are seismic effects, noise, air blasts, dust and gases. When loading, transporting, depositing ore and disposing of tailings, these are noise, dust and exhaust gases from machine and equipment engines; dust that is raised and blown around by the wind is also possible.

The impacts of mining operations on the immediate and wider environment of open-pit mines are manifested by land occupation, changes in terrain morphology, disposal of tailings, creation of barren areas, displacement of watercourses, possible microclimatic changes, possible initialization of erosion processes, lowering of the level and changes in the groundwater flow regime, the occurrence of ground movement, interruption of the food chain and other changes in the biocenosis, population migration, displacement of settlements, industrial facilities, archaeological and historical monuments, etc. These effects depend on the working environment characteristics, the applied exploitation technique and technology, the content and condition of the environment, and primarily the professional and moral attitude of the mine management towards the protection of the living environment and working environment. There are no rules - impacts and consequences change from mine to mine; mines are subject to spatial and temporal changes, often stochastically due to the complex nature - man - technique and technology system relationship. [1,4]

The extent and intensity of the impacts of the open-pit exploitation of energy, non-metallic сплоатације енергетских, неметаличних и металичних минералних сировина.

Површинска експлоатација неметаличних минералних сировина у принципу нема значајнији поремећајни утицај на животну и радну средину.

Површински копови металичних минералних сировина и угља, знатно већег захвата у плану и по дубини, у принципу антропогено девастирају земљиште. Знатна количина рудничке и флотацијске јаловине захтева адекватан депонијски простор за смештај, што може утицати на компоненте екосистема – вегетацију, едафон, површинске и подземне воде итд. [2,4]

and metallic mineral resources on the living and working environment differ.

The open-pit exploitation of non-metallic mineral resources does not, in principle, have a significant disruptive impact on the living and working environment.

Open-pit mines of metallic mineral resources and coal, considerably larger in plan and depth, devastate the soil anthropogenically in principle. A significant amount of mine and flotation tailings requires adequate landfill space for accommodation, which can affect the ecosystem components - vegetation, edaphon, surface and underground water, etc.[2,4]

Слика 1, Рударски басен Колубара, Површински коп угља „Тамнава Западно поље",
истражни археолошки радови [1]

Figure 1, Kolubara Mining Basin, Open-Pit Coal Mine "Tamnava Zapadno Polje,"
exploratory archaeological works [1]

Специфичност интеракције површинске експлоатације и археологије, објашњива је старом кинеском пословицом „*Никада се не зна зашто је нешто добро*". Да није површинске експлоатације, данас бисмо били ускраћени за више значајних археолошких налазишта, слика 1.

The specificity of the open-pit exploitation and archeology interaction is explained by the old Chinese proverb, "It is impossible to tell if anything is good or bad." If it were not for open-pit exploitation, today, we would be deprived of several important archaeological sites, Figure 1.

Ако се изузме флотирање руде и депоновање флотацијске јаловине, као технолошких сегмената који нису увек пратиоци површинске (или подземне) експлоатације, генерализовани закључак је да се површинском експлоатацијом у принципу не стварају токсични продукти нити се радна средина контаминира. Деградација површина захваћених рударским радовма је привремена. Враћање природних функција простору изводи се биолошком рекултивацијом, успостављањем нових садржаја, намена и економских вредности, слика 2.

Подводна експлоатација је знатно мање заступљена у односу на површинску и подземну експлоатацију. Негативни еколошки ефекти данашњих технологија подводне експлоатације своде се на: механичко замуљивање воде у непосредној зони радова, зависно од минералне сировине која се откопава могуће је и повећање минерализације воде [2,5].

Бушотинска експлоатација заузима и деградира мале површине земљишта, нема буке, прашине, издувних гасова, нема јаловине, а пепео и шљака као продукти сагоревања код подземне гасификације угља, остају под земљом, итд. Услед дефицита стенске масе у лежишту настале током експлоатације, могуће су појаве слегања и мања трусна померања терена, локалне промене струјања подземне воде, и зависно од примењене технологије деградирање мањих површина на којима се формирају таложници.

Припрема минералних сировина (ПМС) је готово неизбежна технолошка фаза у експлоатацији металичних минералних сировина, присутна је и у експлоатацији угља уколико се угаљ чисти. Нестручно и неодговорно вођење процеса, овај сегмент рударства може учинити потенцијално опасним за околину, а последице су дуготрајне и веома штетне. Савремени флотацијски системи високо су поуздани, сигурни и еколошки безбедни. Ексцеси који су се повремено догађали, потврђују да је у технолошком ланцу човек најнепоузданија карика [1].

Одлагање јаловине настале експлоатационим радовима, из постројења за ПМС, или

If we exclude ore flotation and depositing flotation tailings, as technological segments that are not always companions of open-pit (or underground) exploitation, the generalized conclusion is that open-pit exploitation in principle does not create toxic products or contaminate the working environment. Degradation of areas affected by mining operations is temporary. Restoration of natural functions of space is carried out by biological reclamation, establishment of new contents, purposes and economic values, Figure 2.

Underwater exploitation is significantly less prevalent than open-pit and underground exploitation. The adverse environmental effects of today's underwater exploitation technologies are reduced to mechanical silting of water in the immediate area of the works; depending on the mineral resource that is mined, an increase in water mineralization is also possible. [2,5]

Drilling exploitation occupies and degrades small areas of land, there is no noise, dust, exhaust gases, no tailings, and ash and slag, as combustion products during underground gasification of coal, remain underground, etc. Due to the deficit of the rock mass in the deposit created during exploitation, subsidence and minor ground movements, local changes in groundwater flow, and depending on the applied technology, the degradation of smaller areas on which sediments are formed are possible.

Mineral processing (MP) is an almost inevitable technological stage in exploiting metallic mineral resources. It is also found in coal exploitation if the coal is cleaned. Incompetent and irresponsible process management can make this mining segment potentially dangerous for the environment, with long-lasting and very harmful consequences. Modern flotation systems are highly reliable, safe, and environmentally friendly. However, occasional accidents confirm that man is the most unreliable link in the technological chain. [1]

Disposal of tailings from exploitation works from MP plants or ash and slag from thermal пепела и шљаке из термоелектрана, представља значајан инжењерски проблем у еколошком и економском смислу. На површинским коповима јаловина се одлаже ван контуре, унутар контуре или комбиновано [1].

power plants are a significant engineering problem in an ecological and economic sense. In open-pit mines, tailings are disposed outside the contour strip, inside the contour strip, or combined. [1]

Слика 2, Рударски басен Колубара, расадник и воћњак на јаловишту Површинског копа угља „Поље Д“ [1]

Figure 2, Kolubara Mining Basin, nursery and orchard on the tailings pit of the Open-Pit Coal Mine «Polje D» [1]

Одлагање ван контуре подразумева заузимање нових земљишних површина, што еколошки и економски предност даје одлагању унутар контуре. Код изостајања мера заштите одлагалишта су потенцијални извори прашине. Овакве могућности превентивно се отклањају адекватном синхронизованом рекултивацијом. Пожељно је третирање јаловинског материјала као „техногене минералне сировине“, то конвертује јаловину из трошковне у профитну категорију и умањује нежељену еколошку потенцијалност.

За разлику од рудничке јаловине настале експлоатационим радовима, која се може одлагати на било ком погодном месту, јаловина из ПМС постројења у принципу се одлаже у изоловане просторе, природно погодне, као што су нпр. депресије и увале, или вештачки изграђени и слично. Флотацијска јаловина се у облику пулпе хидраулички транспортује на јаловиште, где се таложењем раздваја течна и чврста фаза; Течна фаза – вода, у принципу се рециклира и поново користи у флотацијском процесу, може се препустити испаравању или после пречишћавања испустити у водотокове.

Disposal outside the contour strip implies the occupation of new land areas, which gives an ecological and economic advantage to disposal within the contour strip. In the absence of protective measures, landfills are potential sources of dust. Such possibilities are preventively eliminated by adequate synchronized reclamation. It is preferable to treat tailings as “technogenic mineral resources”; it converts tailings from a cost to a profit category and reduces unwanted environmental aspect.

In contrast to mine tailings created by exploitation works, which can be disposed of in any suitable place, tailings from MP plants are in principle disposed of in isolated areas, naturally suitable, such as, for example, depressions and bays, or artificially constructed and similar. Flotation tailings in the form of pulp are hydraulically transported to the tailings pit, where liquid and solid phases are separated by sedimentation; the liquid phase - water, is generally recycled and reused in the flotation process, can be left to evaporate, or discharged into waterways after purification.

ДЕСТРУКЦИЈА РУДАРСТВА

Рударство као једна од најстаријих људских делатности, од својих почетака пре око осам миленијума, суочава се са проблемом очувања животне средине. Да овај проблем прати рударство и да су људи од давнина свесни његовог утицаја и значаја говоре историјски записи.

Агрикола на пример у свом делу „De Re Metallica" 1556. пише: „*Противници рударских радова аргументују свој став тиме што, наводно, копање руде опустошује поља, сече шуме и гајеве, ... било за подземне објекте, рударске уређаје, било топљење руде, бескрајно захтевају дрво. Сечење гајева и шума разгони птице и звери од којих многе служе човеку за укусну храну. Испирање руде трује потоке и реке, убија или прогони рибе ....*". Дакле, проблем није нов, техника и природа, индустрија и предео, у принципу су одувек у супротстављеном односу.

Али Агрикола објашњава и потребу за рударством: „*Рудари већим делом раскопавају горе које не доносе никакве плодове и које се налазе на неплодним местима. Штета од рудника не превазилази штету од других послова човека, његових насеља и градова, од војних дејстава ...*".

Ове речи као да су писане данас, указују на конфликт рударства и поборника „чисте природе". На неприхватљивост незнања као аргумента, о потреби стручног тумачења рударства, објективном сагледавању последица у животној средини, али и о заштити, рекултивацији и ревитализацији експлоатацијом оштећеног предела. Агриколине речи коинцидирају са мишљењем да се рударство и данас прозива више и чешће него што за то има оправданих разлога.

DESTRUCTION OF MINING

Mining, as one of the oldest human activities, has been facing the problem of environmental protection since its beginnings about eight millennia ago. Historical records show that this problem follows mining and that people have been aware of its influence and importance since ancient times.

For example, Agricola, in his work "De Re Metallica" in 1556 writes:" *The argument of the detractors is that the fields are devastated by mining operations, for which reason formerly Italians were warned by law that no one should dig the earth for metals and so injure their very fertile fields, their vineyards, and their olive groves. Also they argue that the woods and groves are cut down, for there is need of an endless amount of wood for timbers, machines, and the smelting of metals. And when the woods and groves are felled, then are exterminated the beasts and birds, very many of which furnish a pleasant and agreeable food for man. Further, when the ores are washed, the water which has been used poisons the brooks and streams, and either destroys the fish or drives them away....*". Therefore, the problem is not new; technology and nature, industry and landscape, in principle, have always been in an opposing relationship.

By Agricola's account, mining was a need. He claimed miners, for the most part, excavated mountains that do not bear any fruit and that are located in barren places, and that the damage from the mines did not exceed that of other human activities, settlements and cities, military operations.

These words, as if they have been written today, point to the conflict between mining and supporters of "clean nature." To the inadmissibility of ignorance as an argument, the need for an expert interpretation of mining, an objective assessment of the consequences in the environment, but also the protection, reclamation, and revitalization of the landscape damaged by exploitation. Agricola's words coincide with the opinion that even today, mining is called out more and more often than there are justified reasons for it.

Минералне сировине су необновљиви ресурси, без њих нема суверенитета земље нити технолошког напретка. Да ли савремен човек може замислити живот без електричне енергије, топлих просторија зими, мобилног телефона, телевизора, кућне и рачунарске технике, превозних средстава (аутомобила, бродова, железнице, авиона), разних направа и машина и других техничко-технолошких угодности данашњег времена, чије рађање почиње у рудницима угља, уранијума, нафте и гаса, руда гвожђа, бакра, олова, цинка, алуминијума, никла, литијума, сребра, злата, платине, силицијума, неметала итд. Гласови против експлоатације енергетских минералних сировина и термоелектрана, утихнули би одмах после престанка производње и снабдевања електричном и топлотном енергијом домова, фабрика, болница, школа итд., а најгласнији говорници за „нетакнуту природу" постали би неми.

Данас је на сцени свезнање. Свезнајући на основу пословних, политичких и других личних или задатих интересних мотива, оспоравају оно што не знају. У подстицању таквог односа удео има природа и ширина садржаја еколошке тематике која свезнајућим обезбеђује алиби да без последица неодговорно импровизују и износе неистине.

Еколошки еснаф, не знајући или не желећи да зна да су геолошка истрживања еколошки безазелена и без обзира на исход инвентарски корисна активност за земљу, упозорава да ће терен на коме се изводе истражни радови опустошти и постати безводан. Да није штете која се оваквим иступима прави друштву, карикатурално би било гледати еснафлије с цигаретом у устима током протеста против загађивања ваздуха спаљивањем угља у термоелектранама, или с накитом од злата на себи у протестном казивању против експлоатације руда племенитих метала. Врхунац „компетенције" свезнајућих су расправе о еколошким аспектима експлоатције угља, руда обојених и племенитих метала, литијума, борних минерала итд., на којима је непожељно присуство рударских стручњака.

Mineral resources are non-renewable; without them, there is no sovereignty or technological progress in a country. Can a modern man imagine life without electricity, warm rooms in winter, mobile phone, television, household appliances and computer equipment, means of transport (cars, ships, railways, planes), various devices and machines and other technical and technological comforts of today, whose birth begins in the mines of coal, uranium, oil and gas, ores of iron, copper, lead, zinc, aluminum, nickel, lithium, silver, gold, platinum, silicon, non-metals, etc. Voices against the exploitation of energy minerals and thermal power plants would fall silent immediately after the production and supply of electricity and heat energy to homes, factories, hospitals, schools, etc. ends, and the loudest advocates for "intact nature" would become mute.

Today, omniscience is on stage. Those omniscient on the basis of business, political and other personal or vested interest motives dispute what they do not know. The nature and breadth of the content of the environmental topic plays a role in encouraging such a relationship, providing the omniscient with an alibi to irresponsibly improvise and present untruths without facing the consequences.

The ecological guild, not knowing or not wanting to know that geological explorations are an ecologically insignificant and, regardless of the outcome, a useful activity for the country in terms of its inventory, warns that the explored terrain will become desolate and waterless. If it weren't for the damage done to society by such actions, seeing guild members with a cigarette in their mouth during a protest against air pollution by burning coal in thermal power plants, or wearing gold jewelry during a protest against the exploitation of precious metal ores would be cartoonish. The pinnacle of the "competence" of omniscient is the discussions on the environmental aspects of the exploitation of coal, non-ferrous and precious metal ores, lithium, boron minerals, etc., where the presence of mining experts is undesirable.

Да би се оваква одступања (неспоразуми) избегла, морамо се чути, саслушати и прихватити да је могуће успоставити баланс између еколошких, привредно-економских и развојних циљева друштва. Прилаз претпоставља познавање фазности геолошко-рударских активности, стручност, аналитичност, објективност, и да последице могу бити ублажене или отклоњене током извођења радова, синхронизованом заштитом животне и радне средине и постексплотационим уређењем предела.

ЗАКЉУЧАК

Неинформисаношћу, нестручношћу, непознавањем рударских технолошких процеса, доминацијом визуелне перцепције, формира се површна слика о утицају рударских радова на животну средину, изводи погрешна оцена и закључци. Исходи су конфликти и нереални еколошки захтеви.

Рударске технологије негативног еколошког потенцијала, штетне ефекте оставиће само уколико се основни и логистички процеси неодговорно или нестручни воде, погрешно примењују или не спроводе мере заштите. Дакле, еколошки праг толеранције не сме се прекорачити.

У том контексту, често слушани термини „*зелено рударство*“, „*зелена транзиција*“ и слично, губе логичку упору, смисао и своде на празне речи.

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In order to avoid such deviations (misunderstandings), we must hear each other, listen and accept that it is possible to establish a balance between the ecological, economic and development goals of society. The approach assumes knowledge of the geological-mining activities phasing, expertise, analyticity, objectivity, and that the consequences can be mitigated or eliminated during the execution of works by synchronized protection of the living and working environment and post-exploitation landscaping.

CONCLUSION

Due to a lack of information, expertise, and knowledge of mining technological processes, the dominance of visual perception forms a superficial picture of the mining impact on the environment, leading to wrong assessments and conclusions. The outcomes are conflicts and unrealistic environmental requirements.

Mining technologies with a negative ecological potential will leave harmful effects only if basic and logistics processes are carried out irresponsibly or if those lacking expertise incorrectly apply or fail to apply protection measures. Therefore, the ecological threshold of tolerance must not be exceeded.

In this context, the often heard terms “green mining,” “green transition,” and the like become illogical, senseless, and are reduced to empty words.

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MULTIPLE UTILIZATION OF THE INTERNAL LANDFILLS OF THE KOSTOLAC COAL BASIN IN THE FUNCTION OF REPURPOSING OF LANDFILL SPACE

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Abstract: *The increasing development of industrial production, not only in our country but also in the world, imposes the need to increase energy capacities. The result of such demands is reflected in the utilization of available ore reserves to the greatest extent possible. Using project solutions in accordance with the spatial plan of the Kostolac coal basin, the concept of development, spatial planning, protection, etc. have been defined, all with the objective of preventing further degradation of space and preserving the environment.*

The creation of project documentation is defined by legal regulation and planned by the economic program of the area in question. Multidisciplinary analysis, expert opinions, acquired experiences implemented in verified project solutions have the expected effect only in case of application in the planned period. Project solutions from their beginning, initiation, through planning, implementation, monitoring and control, until the very completion, are the basis for the implementation of conceptual solutions, and it often happens that they are not fully implemented due to changes that occurred during the execution of works.

Key words: SM (SURFACE MINE) KLENOVNIK, SM ĆIRIKOVAC, SM DRMNO, DISPOSAL, ASH AND SLAG, GYPSUM

INTRODUCTION

The economic and industrial prosperity of the city municipality of Kostolac, Pozarevac as its administrative center and the Branicevo district is based on the industrial development of the mining and energy complex Thermal Power Plants and Mines (TE-KO) Kostolac. In the zones of influence of large systems, the economic, social, technical and technological, and ecological aspects are considered, and the project basis is based on the results of research and analyzes in different thematic areas. During planning and spatial planning, project activities have the obligation to apply laws, by-laws and regulations in the fields of mining, energy, industry, agriculture, water management, environment, nature protection, protection of cultural monuments, etc.

The areas of mining and energy systems are conditioned by changes of natural ecosystems as a consequence of exploitation processes. In the area of the Kostolac coal basin, coal exploitation is currently active at SM «Drmno», while the area of the internal landfill of SM

«Ćirikovac» is used for the disposal of ash and slag from the Thermal Power Plants «Kostolac B1 and B2». At SM «Klenovnik», after the permanent suspension, no works were carried out according to the project documentation [2], and the possibility of mining the remaining coal reserves is currently being considered.

In order to preserve the environment, as well as to strive for as little degradation as possible of areas where surface exploitation is carried out in the Kostolac coal basin, planning activities and project solutions envisage the spatial planning of surface mines and the utilization of the potential of internal landfills and the repurposing of landfill areas.

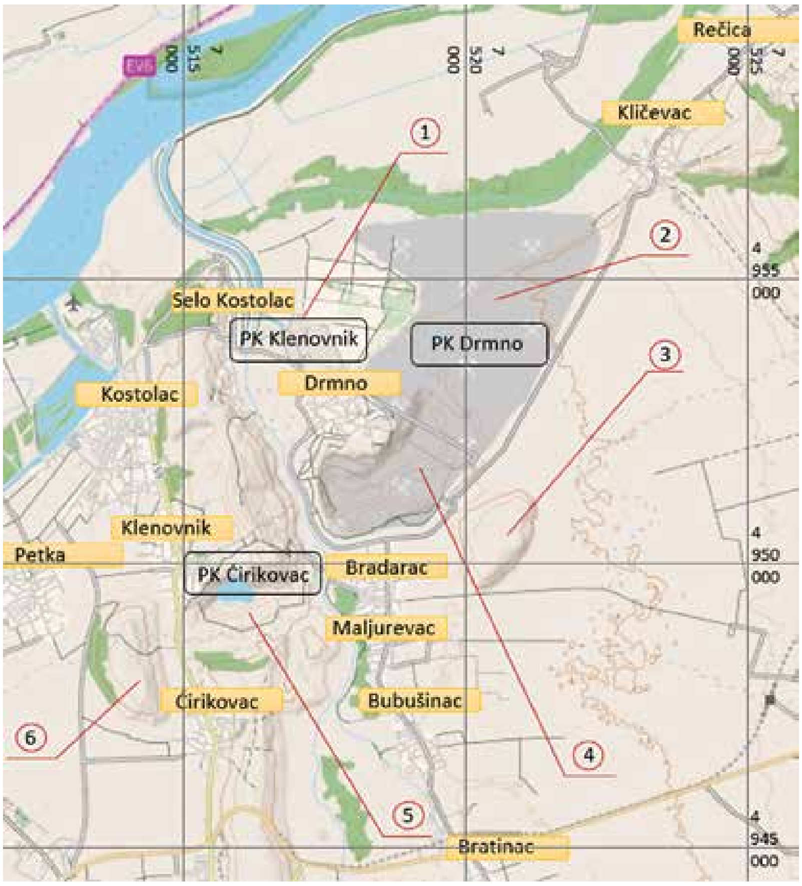

Figure 1, Locations of surface mines "Klenovnik", "Ćirikovac" and "Drmno"

Legend: 1 - External landfill SM "Klenovnik"; 2 - Excavation front SM "Drmno"; 3 - External landfill SM "Drmno"; 4 - Internal landfill SM "Drmno"; 5 - Internal landfill SM "Ćirikovac" 6 - External landfill SM "Ćirikovac".

"DRMNO" SURFACE MINE

In order to preserve the environment, as well as in accordance with EU norms for the purpose of Flue Gases Desulfurization (FGD) from Thermal Power Plants "Kostolac B1 and B2", a system was designed and built for the collection and disposal of gypsum, which is created as a by-product in the process of binding sulfur from flue gases with limestone [4].

Project solutions defined the landfill construction technology with all constructive parameters, as well as the method of disposal of gypsum, all in accordance with European practice and positive European and domestic legislation, while respecting all prescribed conditions of competent ministries and institutions. In the preparation of the document, the harmonization of the technical and technological and capacity capabilities of the entire thermoenergetic complex was processed [8].

Space for storing FGD gypsum, is provided at the internal landfill of the "Drmno" Surface Mine. Dried, i.e. filtered gypsum from the flue gases desulphurization process of blocks "B1 and B2" is transported by a system of four serially connected conveyors with a rubber conveyor belt from the power plant to the transfer station at the end of the last conveyor. From the transfer station, gypsum is deposited by a conveyor belt into cassette 1, the bottom and sides of which are waterproofed with a double geomembrane and has a storage space for one year's production of gypsum. Cassette 2 is located next to cassette 1 and is intended to have storage space for five years of gypsum production, i.e. until the FGD gypsum transport system is connected with the system for the transport of moistened ash and slag from the "Kostolac B3" TPP block, after which the gypsum will be directed to joint landfill of ash, slag and gypsum [6].

At the moment, at SM "Drmno" coal production is ensured for the installed thermal energy capacities in Kostolac and Drmno, while in the area of the internal landfill, in addition to the disposal of tailings, gypsum is also deposited, cassette 1., while cassette 2 is in the construction phase. The planning documentation provides for the construction of the cassettes for accommodating ash and slag with a gypsum mixture.

Figure 2, Gypsum disposal site at SM "Drmno" [6]

Legend: 1 - Orientation landfill area for gypsum, 2 - Existing cassette for disposal of gypsum.

"ĆIRIKOVAC" SURFACE MINE

The production of electrical energy in Kostolac is carried out in four blocks, TPP "Kostolac A1 and A2" and TPP "Kostolac B1 and B2". In the initial phase, the landfill "Middle Kostolac Island" was formed for the purpose of storing ash as a product of the thermal energy process, on an area of about 70 ha, which was later expanded to about 240 ha. According to the planning documentation, the closure of the landfill is planned to be carried out successively until 2017, however, the landfill is still active. After the reconstruction of the system of collection, transport and disposal of ash and slag from the blocks of TPP "Kostolac B", the location of the future landfill was defined, the internal landfill of SM "Ćirikovac", which will be used in the future for the disposal of ash from the blocks of TPP "Kostolac A". With the cessation of pit production in 1974, surface exploitation of the "Ćirikovac" coal deposit continued, and during 2009, coal exploitation was suspended at the surface mine based on the project documentation [1] and activities were started on the landscaping and construction of infrastructure objects for the formation of an ash and slag landfill. After the termination of the exploitation works, landslide occurred on the northern slope of the surface mine. On the basis of the solutions adopted in order to rehabilitate the areas affected by the landslide, work on the rehabilitation of the same has begun. The final appearance of the surface mine "Ćirikovac" was designed in accordance with the limitations of the surface mine, the physical and mechanical characteristics of the environment and the intended system of exploitation [7]. The problems related to the landslide on the northern slope of the SM "Ćirikovac" landfill significantly affected the changes and the selection of the solutions given in the technical documentation [1]. These problems also affected the capacity utilization of the storage area of the landfill, as well as the dynamics of works' execution. With the completion of the necessary infrastructure objects, the landfill became active in 2010. The construction and use of the landfill was accompanied by a series of problems resulting from the length of time it took to rehabilitate the landslide on the northern slope [3]. The designed technology of ash and slag disposal is intended to be carried out in two cassettes, which are divided by a barrier embankment, with alternate filling of the sedimentation. The formation of this landfill originally meant the disposal of ash and slag only for the needs of the "Kostolac B" TPP, so that in the middle of 2016, hydromix from the blocks of the "Kostolac A" TPP would also be deposited in the storage area of the SM "Ćirikovac". Activities on the formation of cassette 1 related to the depositing of ash and slag were carried out in parallel with the execution of works on the spatial planning of the northern slope. As a result, decanting was carried out exclusively in cassette 2, which caused the formation of a barrier embankment more than 20 m in comparison to cassette 1. During 2017, the conditions were created, after the northern slope was partially rehabilitated, and cassette 1 was formed. The technological procedure of depositing is carried out through the distribution pipeline and formed decanters in stages, into the prepared storage area. It includes the planning of the foundation, the installation of a waterproof barrier, the superstructure of the barrier embankment and the evacuation organs of underground and process water. Based on the classification of industrial waste landfills, proposed by the USACE (2), based on the size of the storage space or the height of the embankment, this landfill is classified in the category of medium landfills, on both grounds. The transport pipeline from the Thermal Power Plant TPP "Kostolac B" to the landfill is about 5 km long, while the length of the transport from TPP "Kostolac A" to the landfill is about 5.2 km. In accordance with the project documentation [5], the development plan for the expansion of the ash and slag landfill at SM "Ćirikovac", the newly designed working life of the landfill with the expansion of the storage space to about 200 ha is foreseen until 2031.

The specificity of this space is characterized by the unorganized northern slope in order to permanently suspend the works while in the function of stabilizing the space below which ash and slag disposal activities are carried out. Preparation of the terrain above the northern slope for the installation of wind generators is underway. In any case, this fact should initiate activities on the formation of the projected final slopes, in order to ensure the stability of the foundation for the installation of the projected objects and the wider area as well, the northern slope.

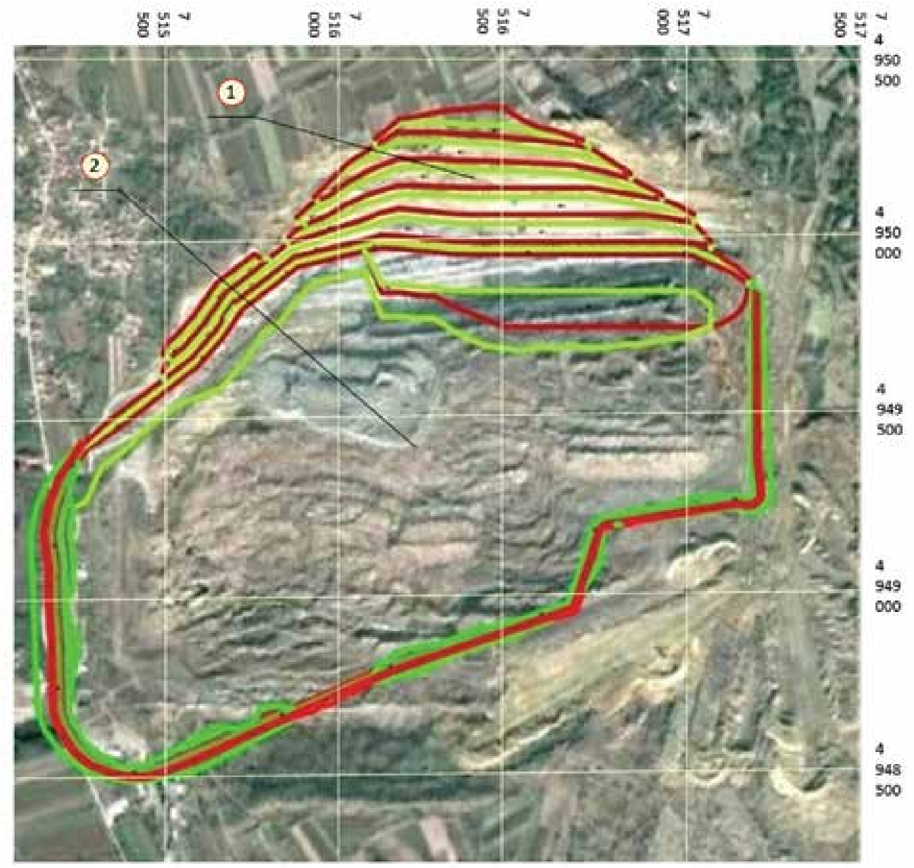

Figure 3, Projected final contour of SM "Ćirikovac", 2012 [1]

Legend: 1 - Northern slope of SM "Ćirikovac";
2 - Internal landfill - landfill area for disposal of ash and slag.

SURFACE MINE "KLENOVNIK"

Termination of exploitation works, backlog of mining works and closure of mine with elementary consequences of degradation of the area left to the influence of natural processes, are a very common case in our mining practice. One example is the "Klenovnik" Mine, where coal mining ceased in 2008. In the area of damaged surfaces, the contents of the landscaping of the subject area are defined by the current project documentation. The spatial planning of the area of the "Klenovnik" Surface Mine envisages the construction of an Art Colony in the northern part of the surface mine. The western part is planned for the construction of a Mining Museum and an Education and Accommodation Complex. The central part of the surface mine envisages the construction of a Sports and Recreation Complex. The internal landfill is intended for biological recultivation and return of land to its original purpose, Figure 4.

The Mining Museum, which is intended as an exhibition space where the development of mining should be presented, as well as the life and work of miners from the beginning of mining to the present day, is only one of the existing projects, which needs to be implemented in order to utilize existing opportunities. In the same space, all archival materials, as well as objects and mining machines, which show the period of mining in the area of the Kostolac mines, would be exhibited and kept. It is necessary to mention that part of the equipment is located on the site in question and has been partially restored, which means that it is necessary to continue with the planned activities according to the content of the project documentation. In this context, in the annual plans, it is necessary to foresee capacities for continuous execution of works according to project solutions [2]. Installing solar panels on a steel substructure, which would be a canopy and at the same time sun protection for parked vehicles, is one of the solutions. The entire complex is protected by a fire protection road. Along with the newly planned railway, the current project documentation stipulates that the area between the parking lot and the square in front of the Mining Museum will remain grassed. The central open space is the Square in front of the museum building, which represents the starting point for a visit to the entire site, which is also a meeting and gathering place. A stepped fountain with a bust of Djordje Weifert is planned for the Square itself. An Open Amphitheater was designed next to the Square with the possibility of being covered with a removable canopy. There is also a Geological Column on the Square, as well as an Info Panel with detailed explanations of the area. The space between the Museum and the Education and Accommodation Complex is organized as a green area, which is crossed by a railway, intended for the restoration of the former transport track in a new function, i.e. for the transport of tourists from the pier on the Danube and the archaeological site - Viminacium to the Mining Museum - Kostolac. The green area would be formed as a lawn, and the project also provides for pedestrian communications, and those that would appear over time as alternative directions could also fit into the original concept of the project. The Accommodation and Education Complex represents a great potential for the education of the youth, precisely in the place where coal has been exploited for decades. In addition to an insight into the historical development and exhibited machines within the Mining Museum and open-air museum exhibits, students who would be accommodated within the Accommodation and Education Center, would have classrooms and laboratories at their disposal. Large green areas within the Education and Accommodation Complex itself, a gymnasium and playgrounds for children, as well as the Sports and Recreation Center, which is attached to the location of the Education and Accommodation Complex, represent facilities for sports, that is, relaxation activities of visitors [2]. It is necessary to point out that when designing each of these spaces, care was taken of the existing condition in the field, functional and programmatic requirements, the character of the newly planned objects, economy and energy efficiency.

By building such complexes, the idea of decentralization and unburdening the main city centers from content is supported, which, according to their theme and connection to a specific area, can be of much greater use, with better contents, spatially and functionally better organized. In order to provide the most complete tourist offers, the described projected contents must first of all be realized and connected with the contents in these areas, i.e. the Archaeological Site of Viminacium, the Rukumija Monastery, the Art Gallery of Milena Pavlovic-Barili and the entire existing tourist potential in the wider area of Kostolac. This would create the conditions for new investments, the creation of new jobs, more meaningful and better living conditions.

The current situation in the energy sector necessitated the use of available resources, so that project documentation for the continuation of the exploitation of the remaining coal reserves at SM “Klenovnik” is currently underway.

During the preparation of the project documentation for the permanent suspension of works, not only legal obligations were taken into account, but also the need to create conditions for the eventual continuation of exploitation. The objects and spatial planning envisaged by the project solutions were designed on the basis of the spatial representation of coal reserves. The project solutions provide for the spatial planning with a very manipulative approach in the area of the remaining reserves, which is a very important fact from today’s point of view, even though to date no activities have been initiated according to the valid project documentation. In the area where coal exploitation would continue, objects were designed in order to stabilize the slopes and where the construction of stationary objects is not foreseen. In this respect, it is necessary to look at as many aspects as possible when creating project solutions in order to achieve high-quality long-term plans.

Figure 4, Projected content for SM "Klenovnik", 2013 [9]

Legend: 1 - Lookout; 2 - Sports grounds; 3 - Tracks for BMX and motocross; 4 - Accumulation lakes; 5 - Agricultural areas; 6 - Orchards; 7 - Forest; 8 - Grassy areas; 9 - Accommodation and Education Complex; 10 - Parking lot; 11 - Mining Museum; 12 - Recreational meadows; 13 - Green areas left to natural development; 14 - Sports grounds; 15 - Art Colony.

SUMMARY

The main objective of creating conceptual solutions is to present the analyzed development possibilities with accompanying effects. On the basis of input parameters, such solutions should be combined with synthesized research carried out and project solutions for the purpose of industrial and economic development. The design of degraded areas is defined in accordance with the surrounding conditions of nature, the requirements of improving and preserving the quality of the environment and safety in the form of reducing risks and damages.

The center of gravity of planned project activities must be oriented at the area of the mining basin. It should be emphasized that project solutions based on a longer period of time, which refers to the state of works at the end of exploitation with the intended concept and adopted solutions, must be carried out or harmonized with the existing project documentation and development strategy. Applicable solutions for the spatial planning in the zones of influence of large mining and energy systems can be provided through the creation and adoption of temporary plans as well as spatial plans for narrower spatial entities, such as the open pit zone or the energy complex as a whole.

In the zone of influence of production systems, project solutions should synthesize a whole set of phenomena and relationships in order to mitigate the consequences of surface coal exploitation and conceptually harmonized with the development plans of mining and energy systems, as well as with the plans of local communities, plans of other economic organizations.

Causal consequences of performing works that are not in accordance with project solutions are based on several grounds:

- Short-term analysis of the development strategy and planning intentions,
- Insufficient communication of expert opinions of the engineering staff from the field of the production sector with the project team,
- Non-compliance of project documentation with the situation in the field,
- Repurposing of degraded spaces, etc.

CONCLUSION

The disorganization and neglect of degraded areas are often the result of the unprofessional attitude of professional managers on the one hand and the passivity of local communities on the other. These are just some of the causes that prevent the application of verified project solutions. In this respect, it is necessary to initiate activities on the rehabilitation of all neglected areas, which were left to their natural existence after industrial use. Permanent stabilization, spatial planning and matching with the landscape features of the surrounding terrain precedes the establishment of ecological balance.

Expert opinions and solutions must in any case be the starting point for the development of project solutions, which as such should be carried out according to the plan and program defined by the Projected Task and implemented within the project documentation. All changes and deviations must be completed with implemented solutions based on the preservation of the working and living environment.

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ANALYSIS OF THE POSSIBILITY OF EXPANDING THE EXPLOITATION FIELD OF THE KOVIN MINE

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Abstract: *Underwater exploitation of coal, gravel and sand on the Kovin mine is performed within the approved exploitation field in which the reserves of mineral raw materials allow exploitation until 2024. The subject of this article is expanding current exploitation zone within coal field "A" of Kovin's deposit.*

Key words: UNDERWATER EXPLOITATION, EXPLOITATION FIELD, EXPANDING

INTRODUCTION

Kovin coal mine and deposit are located on the Danube River coast, at a distance of approximately 10 km downstream and approximately 20 km by land roads (across the place Gaj) from the town of Kovin. The coal deposit "Kovin" consists of 2 coal fields: "A" and "B", Figure 1.

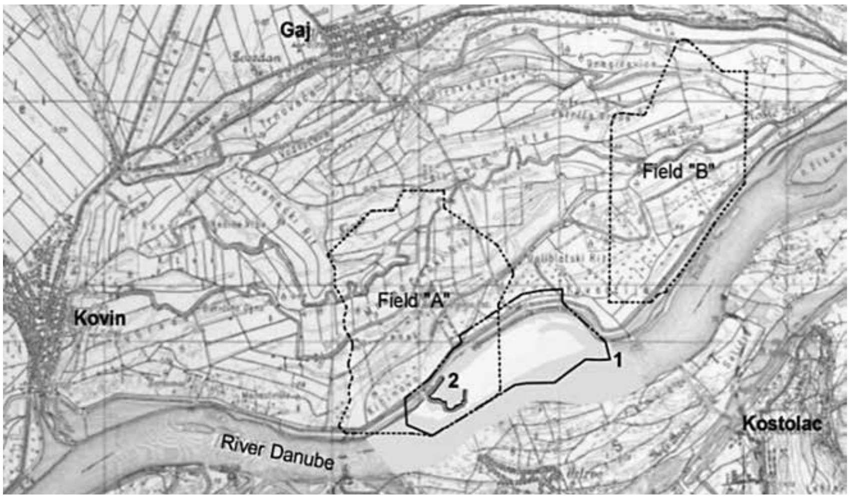

Figure 1, Coal fields "A" and "B" of Kovin's deposit

Legend:1 - Existing, approved exploitation field of Kovin mine;
2 - Current state of mining operations.

Underwater exploitation of coal and associated sediments (sand and gravel) on Kovin's deposit has been taking place since 1992, in the southeastern part of Field “A”, within the approved exploitation field (contour 1 in Figure 1).

During the construction and development of Kovin mine, the facilities necessary for the exploitation and functioning of the mine were constructed: navigable and terrestrial roads, electric network, hydrant network, coal processing plant, coal and gravel loading plant in barges, coal settling basin and others.

According to the current Main Mining Project (MI, 2018), exploitation works within the approved exploitation field, with an annual production of mine of 400.000 t of open-pit coal (250.000 t of commercial one) have been projected by mid-2024.

At Kovin mine, during 2019, a plan for the development of the mine and the extension of exploitation boundaries were started.

As the first strategic task, the extension of the boundaries of the existing exploitation field in the 500 m wide belt is defined, in the manner envisaged by the Law on Mining and Geological Surveys.

EXPANDING EXPLOITATION FIELD AND MINEBOUNDARIES

In order to define expanding the boundaries of exploitation, Mining Institute Belgrade in 2019 designed a “Study of the Expanding the Existing Exploitation Field of Kovin Mine within the Coal Field “A” of Kovin deposit.”

By analyzing possible directions of exploitation operation development, by Study the concept of expanding the existing exploitation field within field A, in the north direction was selected.

Expanding the exploitation field was prevented in the east and south directions, due to the coal pinch-out on the east side and the safety distances from the international Danube waterway on the south side (Figure 2).

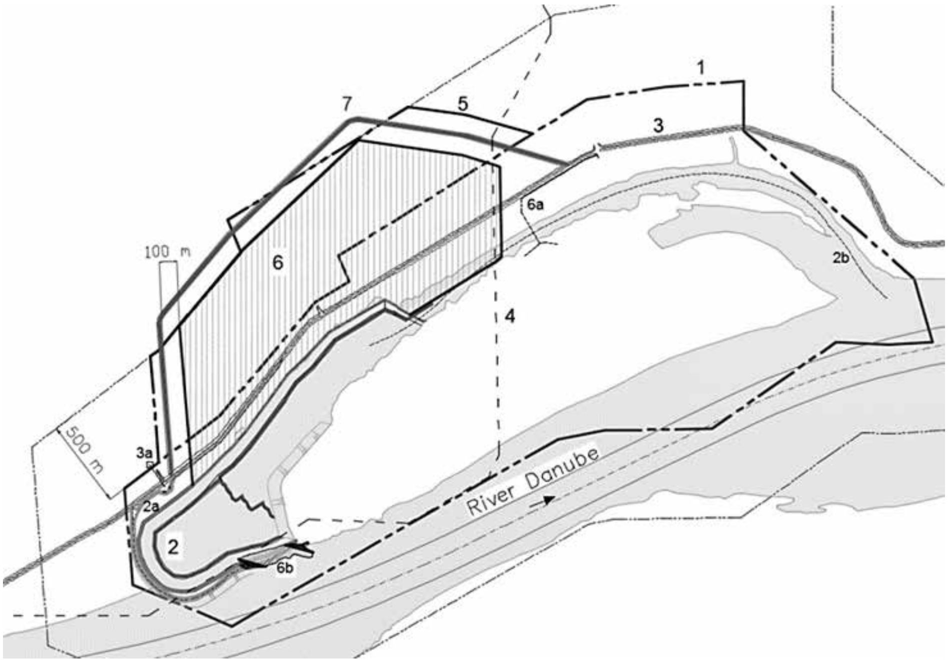

Figure 2, Expanding the Exploitation Field and Open-pit of Kovin Mine

Legend: 1 - Approved exploitation field; 2 - Designed contour of mine in 2024, 2a (2b) of the mine roads;
3 – Danube defensive embankment, 3a pumping station „Malo Bavanište“; 4 - Boundaries of the field „A“;
5 - Extended contour of the exploitation field; 6 - Expending the underwater mine, 6a (6b) of the new mine roads;
7 - New route of the defensive embankment.

Expanding the exploitation field in the west and southwest direction is excluded, because it is estimated that the economic effects of exploitation in these zones would be unfavorable for the following reasons:

- Layer of coal in the Kovin's deposit at greater depths than the maximum digging depth of the of Kovin dredger (> 45m) and expensive and uncertain reconstruction of the excavator, as well as;
- High cost of moving the pumping station „Malo Bavanište".

Expanding (5 in Figure 2) the contour of the approved exploitation field by 500 m northwards, from the west side to the pumping station (3a) and from the east side to the boundaries of the field A (4), enables expanding the mine (6) on area of P = 154.5 ha.

MASS BALANCES, OVERBURDEN COEFFICIENT AND EXPLOITATION LIFE IN THE NEW CONTOUR

Within the expending the exploitation field of Kovin mine in the north direction and the expanded contour of the mine, the quantities of individual sediments were calculated, from the surface of the terrain to the level k + 25.

Table 1, Coal reserves and Associated Sediments of Kovin Deposit, in Expanding the Exploitation Field

Sediments		Geological reserves (m^3)	Feasible reserves (m^3) (m^3)	Exploitation reserves	
				(t)	
Overburden	Sand (s1)	11.907.900			
	Gravel (g)	18.891.500		17.946.900	
	Sand (s2)	5.037.200			
	Σ	35.836.600	35.836.600		
Coal (c)		12.775.700	12.762.300	12.124.200	14.306.500

The middle coefficient of the overburden (with gravel in overburden which is partially launched on the market) in the expanded contour of the mine is:

$$K_O = \frac{\sum(Vs1+Vs2+Vg)}{Vc} = \frac{35.836.600 m^3}{14.306.500 t} = 2,5 m^3/t$$

Working life of the mine in the planned expansion of the exploitation field of Kovin mine (from the middle of 2024) is:

$$T = \frac{\sum V}{Qg} = \frac{14.306.500 t}{400.000 t/year} = 35,8 \text{ years.}$$

REQUIRED INVESTMENT WORKS AS A CONDITION FOR EXPANDING THE EXPLOITATION FIELD

For the planned expansion of the existing exploitation field of Kovin mine, 500 m northwards, it is necessary to provide financial resources to create conditions for undisturbed underwater exploitation, while at the same time to protect agricultural land outside the exploitation field from the high water of the Danube.

Necessary investment activities are:

- Purchase of 240 ha arable land and 30 buildings of different purposes on the planned area;
- Rationalization and significant shortening of land and navigable mine roads: the land roads instead of the current route around the contour of the mine, will be shortened by the construction of an embankment across the current waterway; the new waterway will be shortened by opening the passage from the lake to the Danube (6a and 6b in Figure 2.);
- Relocation (demolition of part of the current and construction of a new) defense embankment at a length of 3.680 m;

- Interventions in the form of earthwork on one part of the canal network of the first drainage line, whereby the length of the canals will not change, as well as the mode of operation of the pumping stations.

The estimated investment in the planned investment works, as a condition for expanding the mine and continued exploitation, is € 3.770.000.

CONCLUSION

In the continued exploitation in the expanded exploitation field of Kovin mine will not change the concept of operation of the Mine, the location and function of the constructed mining facilities (except roads), as well as so far applied technology of underwater coal mining and associated sediments.

By expanding the mine and underwater exploitation in unchanged conditions, the values of the environmental impact parameters will be retained as well.

After the exploitation is completed, by recultivation of the entire area, development of tourism will be enabled, which includes hunting, fishing, water sports and other similar contents.

Economic analysis has shown favorable economic effects of continued exploitation in the planned expansion of the exploitation field for a period of 35,8 years: positive business performance in all years, satisfactory liquidity, invested funds retrieval period of 6 years, etc.

The exploitation conditions, applied technologies and the effects of exploitation have shown that underwater exploitation of coal and gravel on Kovin deposit, and in the planned expansion of the exploitation field and mine, in addition to the necessary large-scale investment activities, is a favorable and justified project and that it should certainly continue with activities that will enable further exploitation on this extremely favorable part of the deposit.

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FLYROCK INDUCED BY BLASTING IN SURFACE MINING

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Abstract: *Rock blasting in surface mining is still the most efficient and cheapest method of extraction large amounts of solid mineral raw materials. The energy of explosion is used for the fragmentation of solid rock mass to require granulation. In addition to positive effects of rock blasting, there are certain side effects of each blasting process which may occur, and these are: ground vibration, flyrock, airblast, toxic and suffocating fumes and dust. Flyrock is the uncontrolled propelling of fragments of blasted rocks and represents one of the main sources of material damage and harm to people. This paper presents the causes of flyrock, accidents that occurred because of flyrock and measures to prevent flyrock during the blasting operation in surface mining.*

Key words: FLYROCK, DRILLING, BLASTING, SURFACE MINING, SAFETY, ACCIDENT

INTRODUCTION

Flyrock, also called rock throw, is the uncontrolled propelling of rock fragments produced in blasting operation and constitutes one of the main sources of material damage and harm to people [1]. Institute of Makers of Explosives (*IME*) has defined flyrock as the rock propelled beyond the blast area by the force of an explosion [2]. A flyrock related injury is sustained when a blast propels rock beyond the blast area and it injures someone.

Flyrock from blasting can result from three key mechanisms due to lack of confinement of the energy in the explosive column. Flyrock can occur if there is insufficient burden for the hole diameter of a zone of weak rock occurs in the face. Figure 1 shows an illustration of each mechanism [3]:

- Face burst: burden conditions usually control flyrock distances in front of the face;
- Cratering: if the stemming height to hole diameter ratio is too small or the collar rock is weak flyrock can be projected in any direction from a crater at the hole collar;
- Rifling: if there is insufficient stemming height of inappropriate stemming material is used, flyrock at a high trajectory can result from rifling the ejection of stemming material and loose rocks from the collar.

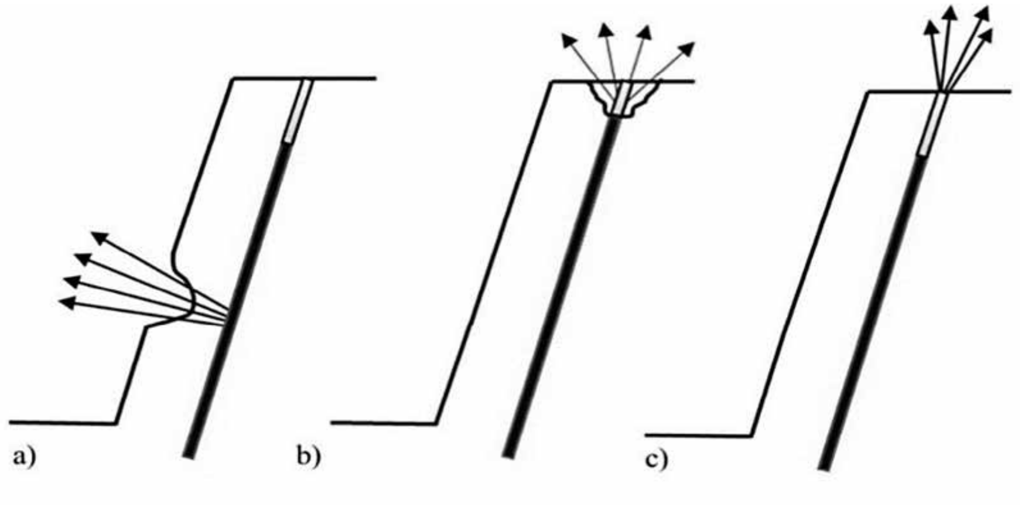

Figure 1, Flyrock mechanisms: a) face burst, b) cratering, c) rifling [3]

CAUSES OF FLYROCK

Generally, flyrock is caused by a mismatch of the explosive energy with the geomechanical strength of the rock mass surrounding the explosive charge. Factors responsible for this mismatch include [4]:

- Abrupt decrease in rock resistance due to joint systems, bedding layers, fracture planes, geological faults, mud seams, voids, localized weakness of the rock mass, etc.
- High explosive concentrations leading to localized high energy density;
- Inadequate delay between holes in the same row, or between rows;
- Inappropriate blast design;
- Deviation of blast holes from its intended direction;
- Improper loading and firing practices, including secondary blasting of boulders and toe holes.

Primary blasting in surface operations can often produce boulders too large to be handled directly by loading and hauling equipment and the crushing plant. Secondary blasting is a common source of flyrock. To control flyrock, it is recommended that the boulders be removed to areas where they do not disturb the operation [1]. Previously, oversized boulders have been broken by blasting with:

- Drilling a hole into the boulder, which will be charged and blasted (pop shooting);
- Placing a charge on the surface of the boulder and shooting it (plaster shooting).

In order to reduce the risks of flyrock, plaster shooting is prohibited. Lately, secondary blasting is increasingly being replaced by hydraulic breakers mounted on excavators mostly due to flyrock hazards.

THE PREDICTION OF MAXIMUM THROW DISTANCE IN FRONT OF A FREE FACE

Lundborg developed semi-empirical formulae which were obtained from the research at the Swedish Detonic Research Foundation (*Sve De Fo*) [5] for the prediction of maximum throw and optimum projectile size of flyrock. For a specific charge (powder factor) ≤ 0.2 kg/m^3, the maximum throw is expressed by:

$$L = 143\ d \cdot (\ q - 0.2),\ (m) \qquad (1)$$

where: L Maximum throw (m),
q Specific charge (kg/m^3),
d Hole diameter (in).

The optimum size of the rock thrown is given by:

$$\phi = 0.1 \cdot d^{\ 2/3},\ (m) \qquad (2)$$

where: ϕ - Boulder diameter (m),
d - Hole diameter (in).

This introduces the concept that the distance that a boulder is thrown depends on momentum (rock size and density) and aerodynamic principles (rock shape, smoothness, air resistance), and that a certain spheroidal size (most aerodynamic) has optimal momentum and air resistance characteristics [3].

In an underburdened or understemmed blasthole, the optimum sized boulder would be thrown a maximum distance of:

$$L_{max} = 260 \cdot d^{2/3}, (m) \qquad (3)$$

The maximum throw and throw of boulders at sizes other than the optimum can be determined from Figure 2.

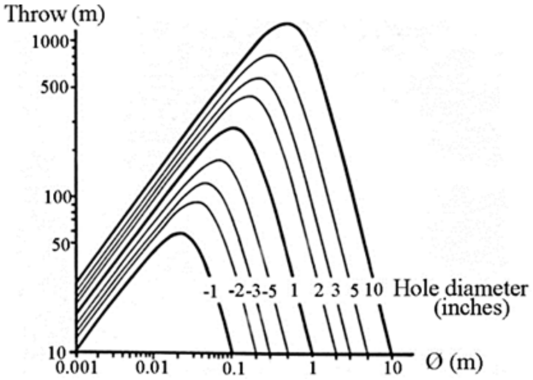

Figure 2, Maximum throw of boulders [5]

FLYROCK ACCIDENTS

Mine Safety and Health Administration (*MSHA*) accident data reveal [6] that most blasting accidents in surface and underground mines occur during scheduled blasting and are due to inadequate blast area security. The functional task-elements of a blast area security system are:

- Estimate the flyrock zone based on shot conditions, and add a factor of safety to determine the bounds of the blast area;
- Clear all employees, contractors, and visitors from the blast area;
- Post guards at the access points to prevent unauthorized entry;
- Use adequate blasting shelters for employees whose presence is required in the blast area;
- Maintain effective communication with guards, mine foreman, and other employees.

The hazards of surface blasting are primarily due to lack of blast area security, flyrock, premature blast, and misfire [7]. Table 1 illustrates the contribution of flyrock and lack of blast area security in surface mining operations.

Table 1, Trends in flyrock and lack of blast area security injuries in surface mining, 1978– 98 [8]

Activity or cause	Fatal and nonfatal injuries						
	1978–81	1982–85	1986– 89	1990– 93	1994– 97	1998	Total
Lack of blast area security	51	28	43	25	17	3	167
Flyrock	26	22	29	24	10	3	114
Total	77	50	72	49	27	6	281

Table 2 shows flyrock - related accidents according to Mine Safety and Health Administration (MSHA) [6].

Table 2, Flyrock - related accidents according to (MSHA) [6]

July 16, 2007.	A mechanic with 20 years of mining experience was fatally injured at a surface mine when he was struck by flyrock from blasting operations. The victim and another mechanic had just completed their shift in an equipment parking/service area approximately 457.2 m from the area being blasted.
December 4, 2013.	A 63-year-old lead man with 16 years of experience was killed at a crushed stone mine. The victim initiated a blast and was struck by flyrock from the blast. He was standing 46.6 m from the nearest blast hole and was struck by rock as large as 48.3 cm long, 35.6 cm wide and 17.8 cm thick.
January 12, 2016.	Flyrock left the mine site during a blast and struck the windshield of a pick-up truck traveling by on a public road near the mine site. The driver and the passenger both received minor injuries.

Figures 3a and 3b show the external view of the residential object and the internal view of the restaurant damaged by the flyrocks during the blasting accident occurred at an andesite quarry in Serbia. The fragments of blasted rocks were propelled almost 300 m from the centre of blasting causing extensive damages to the surrounding objects. A total of 4 467 kg of explosives was used. The parameters of the largest section - blasting section II were: bench height 13.6 m, blasthole length 15.5 m, sub-drilling 1 m, burden 2.8 m, spacing between blastholes in a same row 3 m, spacing between rows 2.8 m, blasthole diameter 89 mm, and angle of blastholes 70 degrees [9].

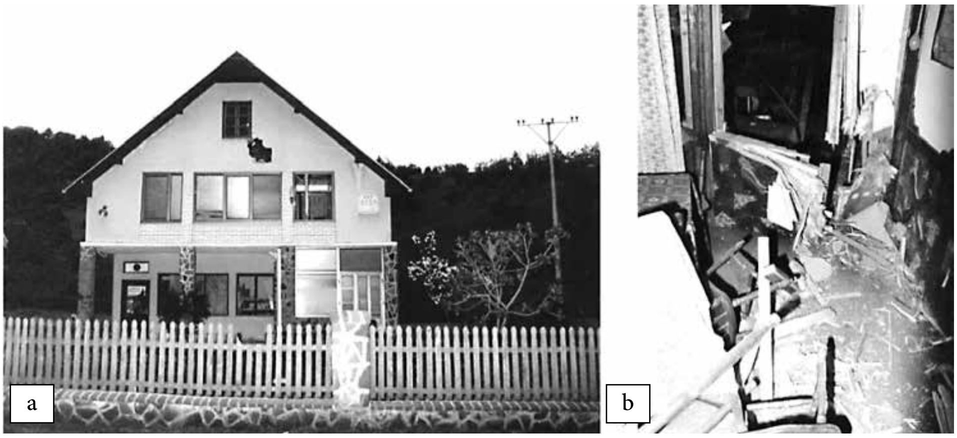

Figure 3, a) External view of the residential object; and b) internal view of the restaurant damaged by the flyrocks [9]

The consequences of the flyrock during this blasting operation were material damage to the residential and other buildings located near the surface mine. Fortunately, there were no human casualties.

MEASURES TO PREVENT FLYROCK

Flyrock by blasting in surface mining can be prevented by the application of certain measures, including:

- Orient quarry faces away from potentially sensitive objects or areas;
- Ensure stemming material and height are adequate;
- Choose a sufficient length of burden to reduce the possibility of flyrock;
- Take special care when carrying out secondary blasting to avoid rock throw;
- Cover the rock to be blasted with suitable material to control flyrock;
- Ensure the correct delay time of initiation systems and the order of initiation;
- Provide the adequate blast area security.

MSHA [6] recommends blasting best practices to prevent flyrock induced by blasting:

- Conduct effective workplace examinations. Identify all hazards and take action to correct them;
- Ensure all miners are trained to identify all potential hazards and emergency procedures, including evacuation procedures;
- Guard or barricade all access routes to the blasting area to prevent the passage of persons or vehicles;
- Clear and remove all persons from the blast area unless suitable blasting shelters are provided to protect persons from flyrock;
- Consider mine specific conditions and rock strata when designing blasts to prevent flyrock;
- Maintain and use all available methods of communication, such as sirens and radios, to warn persons of impending blasting operations;
- Use a central blasting system and schedule blasting between shifts or on off-shifts when no one is present;
- Closely follow mine policies and procedures through all phases of the blasting operation.

ANGLE AND HOLE DEPTH MEASURING INSTRUMENT

The latest drill rigs can be equipped with measuring instruments to improve drilling results, reduce deviation, prevent flyrock and improve overall blasting results. Angle measuring instrument is the electronic angle indication system consisting of an angle sensor on the boom and feed, sight, and graphic presentation on an LCD display [10]. The sight makes it possible to drill parallel holes by selecting a reference point before the first hole is drilled. This reference point is then maintained throughout the entire round or if the direction of movement is the same.

To maintain control over the drilled depth, drill metres and penetration rate, the system is equipped with a drilled depth sensor. The drill rig can be equipped with one of the following alternatives:

- Angle and depth measurement instruments with sight;
- Angle, depth, and laser plane instruments with sight.

AUTOMATIC FEED POSITIONING

The automatic feed positioning function avoids mistakes during setting of the feed angle and cancels out operator error. The operator simply can press a button in his cab and hold it until the feed is set to the correct angle. Automatic feed positioning reduces set-up time and ensures parallel holes without deviation resulting in better blasting and smoother bench bottoms [11].

HOLE NAVIGATION SYSTEM

Satellite-based Hole Navigation System (HNS) [10] for surface drill rigs employs Real Time Kinematic (RTK) GPS to improve the positioning accuracy of drill rig. There is no need to mark out holes, and the accuracy is such that all holes can be parallel, or different holes in each round can be drilled in a predetermined direction, according to the blasting pattern. The result is a controllable product, with better fragmentation, fewer boulders, without drill hole deviation and flyrock.

THE BOREHOLE DEVIATION MEASUREMENT SYSTEMS

To improve the accuracy of drilled holes and reduce their deviation from designed one, borehole deviation measurement systems can be used. The borehole deviation measurement systems are used for measuring the deviation of boreholes drilled in underground mines or on the surface in quarries or open-pit mines. Figure 4a shows the Boretrak2 [12] borehole deviation measurement gyro-based system.

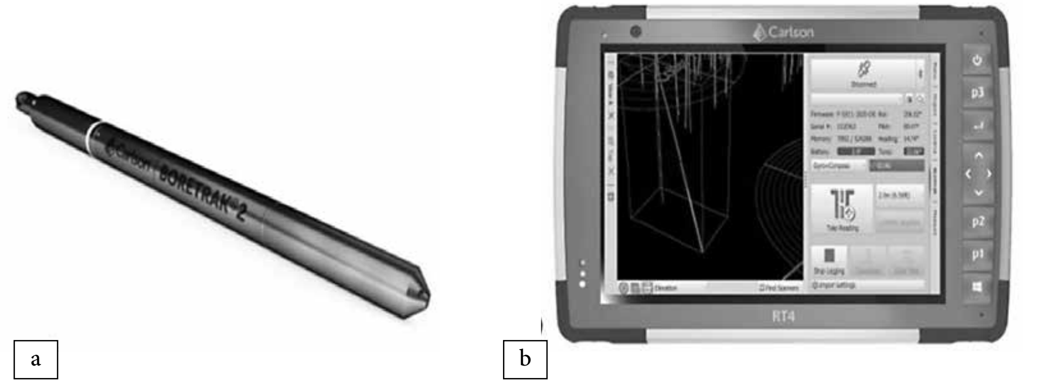

Figure 4, a) The Boretrak2 borehole deviation measurement system,
b) The Carlson Boretrak software [12]

System enables accurately measurement of borehole deviation and effective application the data to plan projects safely and in compliance with auditing requirements. System also record and visualize 3D data on drilling activity from ground level or underground site optimizing blasting and engineering works. The Carlson Boretrak software (shown in Figure

4b) can be used to set up the project, import hole coordinates, setup design holes, and import third-party data to form a background to the collected Boretrak2 data.

Currently, there are many similar borehole deviation measurement systems on the market such as: The Blasthole Probe Mk3 and Micro Probe Mk3 for boreholes from 35 mm diameter [13], Rodded Boretrak and Cabled Boretrak borehole deviation measurement systems [14], etc.

COVERINGS

Good blast design, generally, is primary method of avoiding flyrock; however, it often is not enough, and the blaster must resort to methods of containing the flyrock: (1) covering the field with heavy blast mats and (2) backfilling [15]. Coverings are all the elements used to cover the blasting site to avoid rock throw or any other material that could harm people, buildings etc. [1].

BLASTING MATS

Blasting mats are used when explosives are detonated in places such as quarries or construction sites to prevent flying rocks, reduce of shock wave and noise, suppress dust to protect people, structures, or the environment in proximity to the blast site. The most common materials that are used for making blasting mats are strips of old tires held together by steel cables, mats woven from manila rope or wire cables or conveyor belts. Figures 5 and 6 show blast field covered with blasting mats and the initiation of blasting charges covered with blasting mats produced from the most wear resistant parts of recycled truck tires and sewn together with galvanized steel wires.

Figure 5, Blast field covered with blasting mats [16]

Figure 6, Initiation of blasting charges covered with blasting mats [16]

CONCLUSION

Flyrock occurs as a mismatch of the distribution of explosive energy, confinement of the explosive charge, and mechanical strength of the rock. During the blasting operations in rock masses where discontinuities in the geology and rock structure exist, it is very important to properly adjust drilling parameters and blasting design to reduce the chances for flyrock.

The efficiency of the drilling process greatly affects the quality of blasting results. During drilling process, the hole deviation must be reduced to a minimum. All drilling parameters regarding the changes in the characteristics of rock mass along the entire length of holes need to be monitored. Key element to a safe blasting operation is good communication especially between driller and blasting manager. The application of modern drill rigs enables the improvement of drilling process.

Before charging, each blast hole needs to be inspected. The borehole deviation measurement systems are very useful for this purpose. The inspection must also be carried out regarding the collapse of the walls of drill holes. The quantities and type of explosives must be selected according to working conditions in the blast field. Special attention should be paid to the zones of weak rock or reduced burden in any part of the bench face. The stemming material should be adequately selected, and stemming must be properly made with optimum height according to blast design. Proper blast design and an effective blasting plan reduce the chances for flyrock.

During blasting operation all employees should be removed from the blast area to a safe location. All entrances to the blast area should be securely guarded to prevent inadvertent entry of employees or visitors. To control flyrock, blast field may be covered with suitable material. If there is a need for secondary blasting, special care should be taken to avoid rock throw. It would be desirable to use hydraulic breakers mounted on the excavators instead of explosives in fragmentation of boulders.

Training and education of personnel involved in blasting operations is very important in preventing flyrock accidents.

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APPLICATION OF THE FUZZY THEORY IN THE EVALUATION OF OPERATING PARAMETERS OF AUXILIARY MECHANIZATION ON OPEN-CAST COAL MINE, CASE STUDY: PIPELAYERS

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Abstract: *Achieved operating parameters are the main indicator of the work quality and selection of mining machines. The effectiveness of a coal mine is correlated with the availability of basic and auxiliary machines. The main task of auxiliary machines in lignite mines is to achieve optimal working conditions. From an economic point of view, auxiliary machines generate up to 20% of the lignite mines' total costs. These are the primary reasons for analyzing their current work and making decisions in the selection of equipment. In this paper, a method based on fuzzy theory was used for analyzing the archived operating data of machines. A case study was done on pipelayers as one of the most used machines.*

Key words: QUALITY OF SERVICE, FUZZY THEORY, MINING MACHINES

INTRODUCTION

Mining machines on open-cast lignite mines consist of basic and auxiliary machines. Basic machines are bucket wheel excavators, bucket chain excavators, belt conveyers, and spreaders, while auxiliary machines are hydraulic excavators, dragline excavators, dozers, pipelayers, wheel loaders, etc. The operation of auxiliary machines directly affects the operation of the basic machines, as it provides optimal working conditions which is a requirement for adequate time and capacity utilization of basic machines. This ensures a high level of safety for people and equipment and uninterrupted work [1]. The activities performed by pipelayers on lignite mines are moving the belt conveyor, assembly and disassembly of conveyor elements, lifting works, drainage works, pulling other machines, etc.

The procedure of machine evaluation consists of two steps. In the first step, it is necessary to choose the overall indicator (OI) that describes the quality of the service of the engineering system (ES) and defines its structure. In the second step, it is necessary to choose a mathematical and conceptual model that has a join character and that will follow the structure of OI. In the papers [1-3] dependability and availability as OI concepts were used for the evaluation of ES. Effectiveness was used by different authors [4] as an OI concept. By standards [2, 3], OI is usually contained of reliability, maintainability, supportability, and functionality. For specific ES, it is often necessary to define specific partial parameters (PP) to obtain usable OI. This paper presents a model for the evaluation of the working parameters of pipelayers to define operational and maintenance ability as equivalent to service quality. PP are average working hours (WH), average numbers of failures (AF), technical availability (TA), and total working cost (TC) [5]. In this paper, the umbrella term that synthesized mentioned parameters is named serviceability (SP). Selection of the parameters was made according to the experience of employees and accessibility of the service documentation. Considering that the parameters are mostly uncertain, imprecise, multiplicity, and difficult to measure, it is suitable to use fuzzy sets to identify them [6]. For their composition at the level of OI, fuzzy logical inference and fuzzy composition are used.

Three different types of pipelayers that operate under similar conditions at Electric Power Industry of Serbia (EPS) lignite mines are analyzed. For the optimal evaluation, a new fuzzy model (FM) was developed. The model is designed to provide a comparative analysis of different machines. It can be a useful tool for company managers to optimize future purchases according to specific conditions.

DEVELOPMENT OF FUZZY INFERENCE MODEL FOR EVALUATION OF ES

FM contains a fuzzy proposition of PP, their composition to the level of SP, and identifications. The concept of the model can be presented as an algorithm (Figure 1). The elements of the algorithm are explained below.

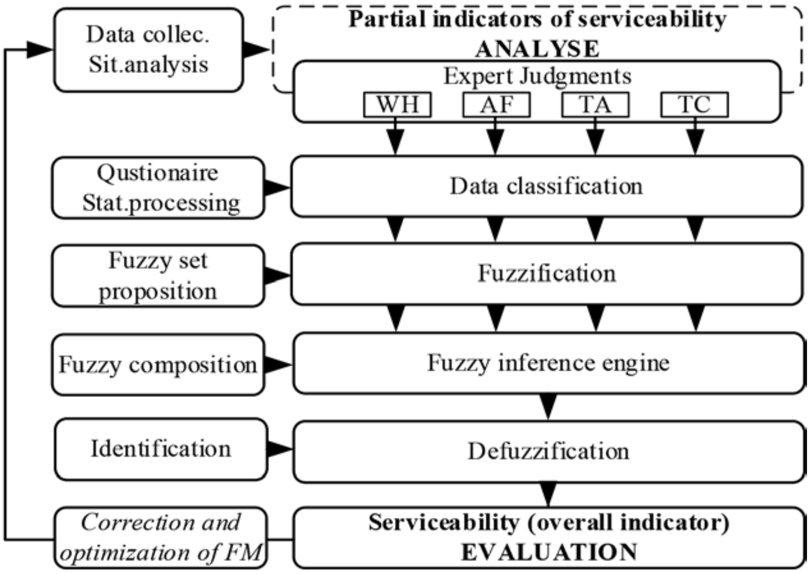

Figure 1, Algorithm of the fuzzy inference model

In the proposition procedure, five fuzzy sets (‘*A*’ to ‘*E*’) are defined as grades of quality of parameters, where ‘*A*’ grade represent a high quality of service and ‘*E*’ is the opposite. The used fuzzy sets (FS) in the model are a combination of trapezoidal and triangular shapes. Figure 2 shows that the first (‘*A*’) and last (‘*E*’) fuzzy sets are trapezoidal sets, while the others are triangular. FS (1) are defined according to values of the membership function μ (where μ = 0 to 1) and class j as a measure of mentioned quality (where j = 1 to n = 7):

$$FS = \mu_{(j=1)}, \ldots, \mu_{(j=7)} \tag{1}$$

The value of the j-scale in this model represents the units of measurement for the machine’s operating parameters (working hours, number of failures, €/wh) [5]. The PP are displayed as numerical values on the j-scale. Membership functions of those fuzzy sets are:

$$'A' = 0_{(j=1)},\ \dots,\ 0_{(j=5)},\ 1_{(j=6)},\ 1_{(j=7)};$$
$$'B' = 0_{(j=1)},\ \dots,\ 0_{(j=4)},\ 1_{(j=5)},\ 0_{(j=6)},\ 0_{(j=7)};$$
$$'C' = 0_{(j=1)},\ \dots,\ 0_{(j=3)},\ 1_{(j=4)},\ 0_{(j=5)},\ \dots,\ 0_{(j=7)};$$
$$'D' = 0_{(j=1)},\ 0_{(j=2)},\ 1_{(j=3)},\ 0_{(j=4)},\ \dots,\ 0_{(j=7)};$$
$$'E' = 1_{(j=1)},\ 1_{(j=2)}, 0_{(j=3)},\ \dots,\ 0_{(j=7)};$$

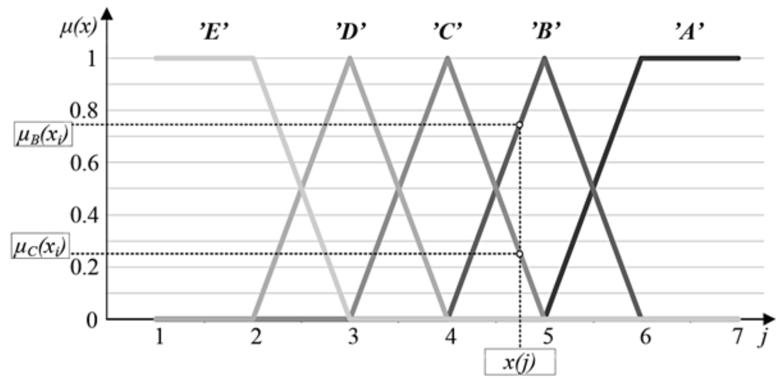

Figure 2, Fuzzy sets [7]

The data representing PP, which are used in the FM are in numerical form. They were obtained based on monitoring the operation of machines and appropriate technical documentation. Data used in the model must be converted into a fuzzy form through a process of fuzzification [4, 7]. Figure 2 shows an example where the numerical data (number *x*) is mapped in the fuzzy number *X* (2):

$$X = 0/'A',\ \mu_{B(x_i)}/'B',\ \mu_{C(x_i)}/'C',\ 0/'D',\ 0/'E' \quad (2)$$

In the next step, it is necessary to form a composition to combine the PP of the analysis. This paper uses the max-min model of composition [1, 3, 4, 7, 8], also called the pessimistic composition. The best solution can be found from the set of the worst combination of outcomes in this model. The max-min model identifies the best solution from the set of the worst combination of outcomes (3). This type of composition is used for phenomena where a positive outcome is expected, as are: dependability, availability, and effectiveness [1, 3, 4, 7, 8].

$$SAi = \max\{\min(WH_i,\ AF_i,\ TA_i,\ TC_i)\} \quad (3)$$

The analysis observes 4 PP (WH, AF, TA, TC). The synthesis parameter is represented as the Fuzzy composition of the PP is denoted by *SP*. The outcome (4) defines each combination (*c*) of the screening composition model as:

$$J_c = \left(j_{(\mu_{WH})c} + j_{(\mu AF)c} + j_{(\mu_{TA})c} + j_{(\mu_{TC})c}\right)/4 \quad (4)$$

CASE STUDY – PIPELAYERS EVALUATION

The total number of machines that are analyzed (three manufacturers) is 32. Operational (partial) parameters required for the analysis of EPS pipelayers are presented in Table 1. For each PP in the analysis are given preference (MIN/MAX), overall minimal and maximal calculated values for all machines, and calculated average value for each machine according to the particular PP.

Table 1. Data for analysis, referent values

Type of machine	WH, hours	AF, per years	TA, 0 … 1	TC, €/mh
Preferences	MAX	MIN	MAX	MIN
Overall minimum	705	2.32	0.6293	56.45
Overall maximum	2121	8.08	0.9824	87.59
Dressta TD25 CS-3	1085	5.98	0.8106	63.55
Liebherr RL52	1305	4.37	0.8810	82.46
Dressta SB60	1501	5.11	0.8550	68.83

The operational parameters are mapped into the μ - j coordinate system (Figure 1). Classes j=1 and j=7 are defined according to the maximum and minimum measured values for all machines. Due to the complexity of the calculation, only a representative example (*Liebherr* RL52) of the calculation will be given, while the results of the analysis for other machines will be shown in Table 2. In the mentioned example the layout of the scale with the associated membership functions ($\mu_{WH(C)} = 0.54$ and $\mu_{WH(D)} = 0.46$) is given in Figure 3. The same principle was used for all machines and parameters. The data for the *Liebherr* RL52 machine is a representative example shown in Figures 3-6. Membership function of Fuzzy sets for *Liebherr* RL52 pipelayer takes the following form: $\mu_{WH\ RL52}$ = (0/'*A*', 0/'*B*', 0.54/'*C*', 0.46/'*D*', 0/'*E*'); $\mu_{AF\ RL52}$ = (0.12/'*A*', 0.88/'*B*', 0/'*C*', 0/'*D*', 0/'*E*'); $\mu_{TA\ RL52}$ = (0.29/'*A*', 0.71/'*B*', 0/'*C*', 0/'*D*', 0/'*E*'); $\mu_{TC\ RL52}$ = (0/'*A*', 0/'*B*', 0/'*C*', 1.0/'*D*', 0/'*E*');

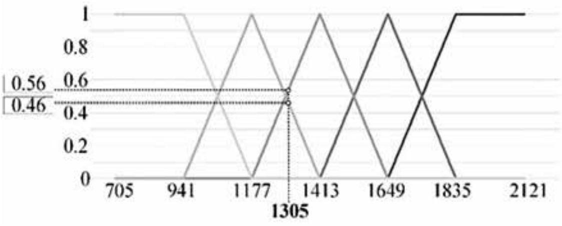

Figure 3, Fuzzy sets for parameter WH (for RL52)

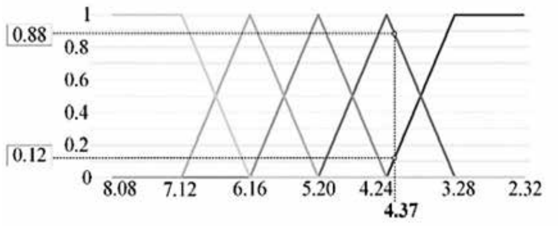

Figure 4, Fuzzy sets for parameter AF (for RL52)

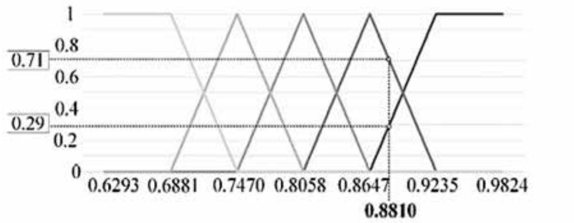

Figure 5, Fuzzy sets for parameter TA (for RL52)

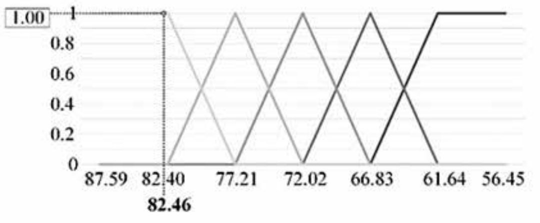

Figure 6, Fuzzy sets for parameter TC (for RL52)

Finally, defined membership functions are fuzzificated in the form (1). For the mentioned example:

$$\mu_{WH\ RL52} = (0,\ 0,\ 0.54,\ 0.46,\ 0) \times \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} = (0,\ 0,\ 0.46,\ 0.54,\ 0,\ 0,\ 0)$$

The next step is a fuzzy composition of the fuzzy relations. The number of combinations that need to be formed is $C = 7^4 = 2401$. For each combination for which every $\mu \neq 0$ outcomes J_c (4) is calculated. Further, seek the minimum value of membership functions among outcomes; and finally, outcomes are grouped by value J_c. The final expression for the machine *Liebherr* RL52 membership function can be presented as:

$$\mu_{RL52} = (0,\ 0,\ 0,\ 0.54,\ 0.29,\ 0,\ 0)$$

To obtain a final grade, it is necessary to carry out the process of identification with „*best-fit*" method, where the membership function μ depends on j-scale returns in the form that is related to FS as an exponent of quality of service. This method is generally accepted [1, 3, 4, 7, 8] for mapping numerical values (j-scale) into linguistic ones (FS). The mentioned example of the calculation is given below, while the results for all machines are presented in Table 2.

$$\left(0_{(j=1)}, 0_{(j=2)}, 0_{(j=3)}, 0.54_{(j=4)}, 0.29_{(j=5)}, 0_{(j=6)}, 0_{(j=7)}\right) \Rightarrow \left(0.127/A,\ 0.219/B,\ 0.360/C,\ 0.167/D,\ 0.127/E\right)$$

where: '*A*' – high, '*B*' – good, '*C*' – medium, '*D*' – adequate, and '*E*' – low quality of service.

Table 2, Final results

Manufacturer	Type	'A'	'B'	'C'	'D'	'E'	*Rang*
Liebherr	RL52	0.12696	0.21938	0.35986	0.16684	0.12696	2
Dressta	SB60	0.12831	0.31203	0.26580	0.16556	0.12830	1
Dressta	TD25 CS-3	0.12437	0.18350	0.34455	0.22320	0.12438	3

For a more precise comparative analysis of these machines, it is necessary to defazzificate the obtained results by the center of the mass point calculation [1, 7, 8]. Results are presented in Figure 6. It can be observed that the best-evaluated machine is *Dressta* SB60, followed by *Liebherr* RL52 and the lowest rated machine is *Dressta* TD25 CS-3. The diagram shows the structure of the results as well as the values calculated by the process of defuzzification.

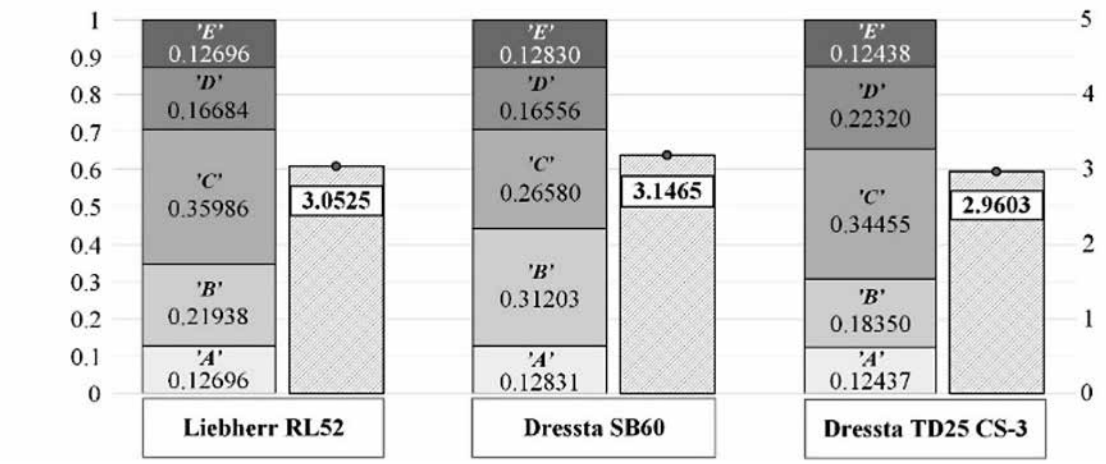

Figure 6, Results of the analysis

CONCLUSION

Pipelayers are auxiliary machines that provide adequate working conditions for basic mining machines. The lifetime of these machines is usually several times shorter than the lifetime of the mine. That indicates that investment in the purchase is more frequent. The decisions must be supported by adequate evaluations and analysis.

This paper is presented a detailed assessment of the chosen pipelayers' working parameters and the model for their composition in one overall. The conceptual model is based on the fuzzy inference concept with fuzzification of the input numerical data. Three types of pipelayers with observed input data are analyzed in this case study. The most serviceable pipelayer for the specific conditions is selected based on the results of the analysis.

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GOLD: PROPERTIES, MINERALS, ALLOYS AND USES

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Abstract: *The work presents a brief history of Bronze Age gold to the Middle Ages, as well as its properties, minerals and gold deposits and the world's major reserves.*

Key words: GOLD, PROPERTIES, MINERALS, DEPOSITS

SHORT HISTORY

Gold has always fascinated people, enriching some or ruining others, provoking wars or facilitating alliances, and leading to the rise of some empires or the disappearance of others. It has been so present in human life that it is mentioned 417 times in 189 verses of Holy Scripture, beginning with Genesis 2:11 and ending with Revelation 21:18. It was one of the three gifts that the Magi gave to Baby Jesus, along with myrrh and frankincense: gold like a king, incense like a God, and myrrh like a man who was to die and be embalmed. U.S. researchers, whose professional integrity cannot be questioned, say there is evidence of the use of gold as early as 6,000 years ago, citing the following more important data [1]:

- 4000 B.C. A culture, centered in what is today Eastern Europe, begins to use gold to fashion decorative objects. The gold was probably mined in the Transylvanian Alps or the Mount Pangaion area in Thrace.
- 3000 B.C. The Sumer civilization of southern Iraq uses gold to create a wide range of jewelry, often using sophisticated and varied styles still worn today.
- 2500 B.C. Gold jewelry is buried in the Tomb of Djer, king of the First Egyptian Dynasty, at Abydos, Egypt.
- 1500 B.C. The immense gold-bearing regions of Nubia make Egypt a wealthy nation, as gold becomes the recognized standard medium of exchange for international trade. The Shekel, a coin originally weighing 11.3 grams of gold, becomes a standard unit of measure in the Middle East. It contained a naturally occurring alloy called electrum that was approximately two-thirds gold and one-third silver.
- 1350 B.C. The Babylonians begin to use fire assay to test the purity of gold.
- 1200 B.C. The Egyptians master the art of beating gold into leaf to extend its use, as well as alloying it with other metals for hardness and color variations. They also start casting gold using the lost-wax tech-

nique that today is still at the heart of jewelry making. Unshorn sheepskin is used to recover gold dust from river sands on the eastern shores of the Black Sea. After slucing the sands through the sheepskins, they are dried and shaken out to dislodge the gold particles. The practice is most likely the inspiration for the „Golden Fleece".

- 1091 B.C. Little squares of gold are legalized in China as a form of money.
- 560 B.C. The first coins made purely from gold are minted in Lydia, Asia Minor.
- 344 B.C. Alexander the Great crosses the Hellespont with 40,000 men, beginning one of the most extraordinary campaigns in military history and seizing vast quantities of gold from the Persian Empire.
- 300 B.C. Greeks and Jews of ancient Alexandria begin to practice alchemy, the quest of turning base metals into gold. The search reaches its pinnacle from the late Dark Ages through the Renaissance. 218–202 B.C. During the second Punic War with Carthage, the Romans gain access to the gold mining region of Spain and recover gold through stream gravels and hard rock mining. 58 B.C. After a victorious campaign in Gaul, Julius Caesar brings back enough gold to give 200 coins to each of his soldiers and repay all of Rome's debts.
- 50 B.C. Romans begin issuing a gold coin called the Aureus.
- 476 A.D. The Goths depose Emperor Augustus, marking the fall of the Roman Empire.
- 600–699 A.D. The Byzantine Empire resumes gold mining in central Europe and France, an area untouched since the fall of the Roman Empire.
- 742–814 A.D. Charlemagne overruns the Avars and plunders their vast quantities of gold, making it possible for him to take control over much of Western Europe.
- 1066 A.D. With the Norman Conquest, a metallic currency standard is finally re-established in Great Britain with the introduction of a system of pounds, shillings, and pence. The pound is literally a pound of sterling silver.
- 1250–1299 A.D. Marco Polo writes of his travels to the Far East, where the „gold wealth was almost unlimited".
- 1284 A.D. Venice introduces the gold Ducat, which soon becomes the most popular coin in the world and remains so for more than five centuries.
- 1284 A.D. Great Britain issues its first major gold coin, the Florin. This is followed shortly by the Noble, and later by the Angel, Crown, and Guinea.
- 1377 A.D. Great Britain shifts to a monetary system based on gold and silver. 1511 A.D. King Ferdinand of Spain says to explorers, "Get gold, humanely if you can, but all hazards, get gold," launching massive expeditions to the newly discovered lands of the Western Hemisphere.

PROPERTIES OF GOLD

Gold was one of the first metals used by man, along with copper, the name being given by the Romans (*aurum*), where *aura* means *gold,* brightness or light. It has a bright yellow colour, warm and pleasant, being the most malleable and ductile of all metals. So malleable that a 1 m^2 semi-transparent sheet can be beaten from a gram of gold and so ductile that it can be pulled into extremely small thick wires. It is a good conductor of heat and electricity, melts at 1,064°C, boils at 2,970°C and has a density of 19.30 g/cm^3, close to that of tungsten (19.25). As a result, tungsten was used to counterfeit gold, by plating it with noble metal or by drilling a gold ingot and plugging the hole with a tungsten rod. As a miscellaneous fact, of all metals, the lowest density is lithium (0.53 g/cm^3) and the highest is osmium (22.59 g/cm^3).

Like all metals, solid gold has a crystalline structure, meaning that its atoms are distributed in the nodes of an elementary crystal cell called a cubic lattice with cantered faces. This network consists of 14 atoms, of which 8 in the corners of the elementary cell and 6 in the canters of the faces of the cube. The density of the atoms in the network is 75% (Figure 1).

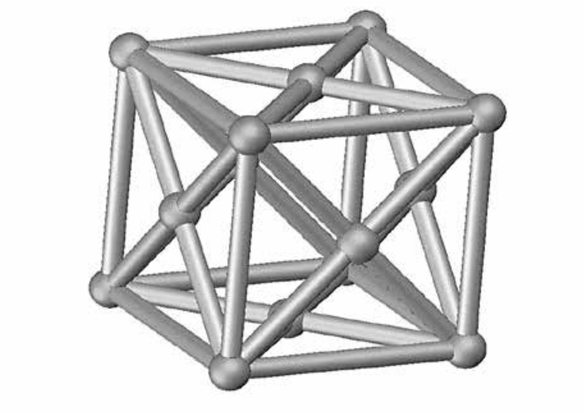

Figure 1, Crystal lattice of gold

Gold is resistant to the oxidizing and corrosive action of most chemicals, being attacked only by royal water, a mixture of nitric acid and hydrochloric acid, in a volume ratio of 1: 3. It is insoluble in nitric acid, which dissolves silver and base metals, a property used for refining gold and confirming it in various metal objects (*acid test).* It dissolves in alkaline sodium cyanide solutions, a property on which its extraction from poor ores is based by the cyanide process, invented in 1887 in Glasgow, which ensures an extraction yield of 97%. Also based on this property is the coating of metal objects with a thin layer of gold, through the electrochemical galvanizing process. Based on this method, some workers in the electrolytic refining sectors of gold during communism in our country have subtilized significant amounts of noble metal through a simple disarming trick. The operator only had to own a gold cigarette case, which he declared at the entrance in exchange, then tied it to the cathode of the electrolysis tank. A layer of 24 carat gold was quickly deposited on the cigar case. No one weighed the tobacconists at the entrance or exit of the exchange, so modern holoangars only had to turn to complicit jewellers to supply them with other tobacconists. This object was used because it had a larger volume and mass than jewellery, less worn by men. Gold dissolves in mercury, forming a solid solution called amalgam, which is an older extraction process with an extraction yield of 60–75%. The amalgam is heated in a retort, the mercury is evaporated and a spongy material containing gold and silver, called *burnt gold,* is obtained.

The mechanical properties of gold are weak except for plasticity. Instead, the technological ones are goods, it can be processed by casting, plastic deformation and light gluing, using copper or silver, and as a protective flux borax.

GOLD MINERALS AND DEPOSITS

Gold is found in the earth's crust, especially in its native state, but also in the form of combinations with silver, platinum and tellurium. The main minerals of gold are:

- Calavera ($AuTe_2$): Au – 43,6%, Te – 56,4%, Ag – 1%.
- Silvanit [$(AuAg)_2Te_4$]: Au – 34,37%, Ag – 6,27%, Te – 59,36%.
- Nagyágit [$Pb_3(PbSb)_3S_6(AuTe)_3$]: Au – 8,18%, Te – 15,89%,
- Sb – 5,06%, Pb – 60,22%, S – 10,65%.
- Krennerit (Au_3AgTe_8): Au – 34,37%, Ag – 6,27%, Te – 59,36%.
- Petzit (Ag_3AuTe_2) : Au – 25,38%, Ag – 41,71%, Te – 32,90%.

All these minerals were discovered in the sec. XIX in the Săcărâmb gold deposit, except for the calavera that was highlighted in 1861 in the Calaveras region of California. The silvanite was discovered in 1835 by the Swiss geographer and crystallographer Lois Necker de Saussure, the petzite in 1842 by the Austrian chemist Wilhelm Petz, the nagyágite in 1845 by the Austrian naturalist Franz Müller, and the krennerite in 1848 by the Hungarian mineralogist Joseph Krenner.

Two types of deposits are known to contain significant amounts of gold, namely primary deposits and secondary deposits. The primary deposits are of hydrothermal origin, being associated with quartz and pyrite (*stupid gold!)* and are presented in the form of veins or as gold scattered in rocks. They were formed by the crystallization of hot solutions produced in the process of cooling magma from inside the Earth.

The secondary deposits were formed by the erosion in the superficial area of the terrestrial crust of the filonian or disseminated type deposits, accumulating in the sedimentary deposits at the level of the alluvial terraces or in the sediments at the bottom of the rivers and seas. In addition to gold, there are other metals or precious stones in these alluvial deposits with densities higher than those of quartz (2.65) with which they are associated: uranium, thorium, tin, zirconium, titanium, ruby, sapphire and diamond. As with other useful substances, these alluvial accumulations become ore deposits. The alluvial deposits found along the watercourses were the main sources of gold in antiquity for Egypt, Mesopotamia, Lydia (today in Turkey), Persia, India and China.

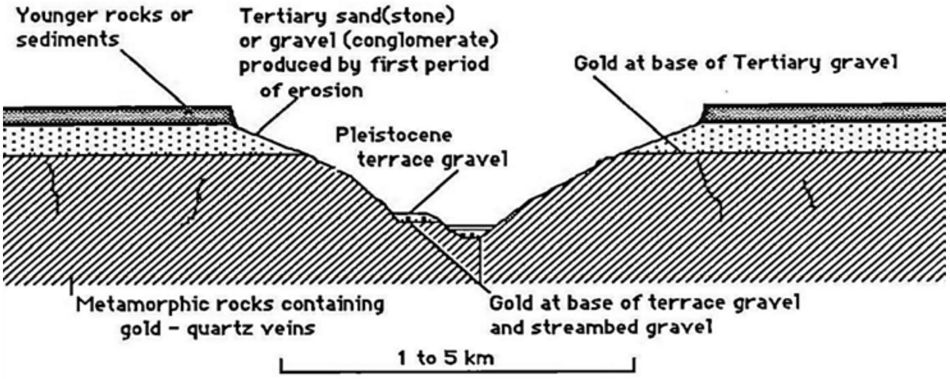

Figure 2, Formation of an alluvial deposit

Experts estimate that the world's gold reserves are currently about 50,000 tons, of which almost 70% are located in 10 countries (Figure 3, Table 1). In Romania, the gold mines were closed, as unprofitable, in 2006, but in the basement of the country there are still important reserves in the Gold Quadrangle of the Apuseni Mountains and in the Baia Mare mining basin. In the absence of official data, it is difficult to assess the gold reserve left in the basement, which is certainly quite significant.

In Romania, about 2,070 tons of gold were extracted over time, as follows: pre-Roman period (before 106 A.D.) 10%; Roman period (106-270) 24%; the Middle Ages (270-1492) 24%; period of the Austro-Hungarian Empire (1492-1918) 27%; the interwar period (1918-1945) 4%; the communist period (1945-1989) 9%; post-communist period (1989-2006) 2%.

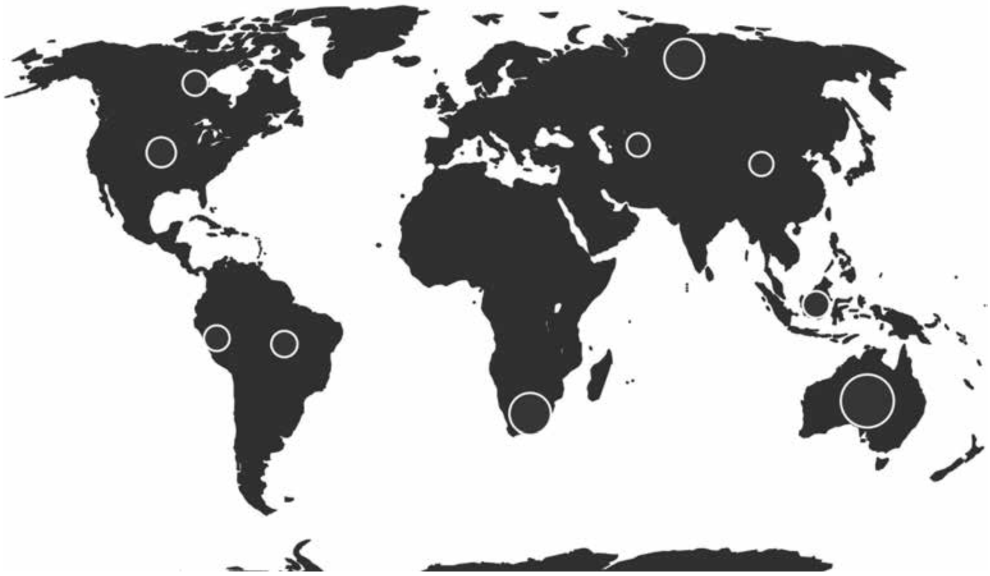

Figure 3, The world's major gold reserves

Table 1, The world's major gold reserves

No. crt.	Country	Reserves, t	No. crt.	Country	Reserves, t
1.	Australia	10.000	6.	Brazil	2.400
2.	Russia	5.300	7.	Peru	2.100
3.	South Africa	3.200	8.	China	2.000
4.	USA	3.000	9.	Canada	1.900
5.	Indonesia	2.600	10.	Uzbekistan	1.800

GOLD ALLOYS

Because gold is too soft to withstand long-term use, it is alloyed with other metals to increase hardness and wear resistance. Also, the alloying elements lead to a variety of shades or colors.

The amount of gold in an alloy equal to 24th of the total mass is called the carat. So 24 carat gold is pure gold (Table 1).

Table 1, Gold content in a carat

Carats	24	22	20	18	16	14	12	10	8	6	4	2	0
% Au	99,99	91,67	83,34	75,01	66,68	58,35	50,02	41,69	33,36	25,03	16,7	8,37	0
Thousandths	999	917	833	750	667	584	500	417	337	250	167	84	0

Silver and copper are the main metals with which gold is alloyed, but it can also be alloyed with platinum, nickel, zinc, manganese and palladium, obtaining alloys with different destinations, properties and colors. Only 24 and 18 carat alloys are recognized as universal. The others are considered to be specific to the culture of certain countries or regions of the world, as follows: They have 22k - UK, Asia; Au 20k - Asia; They have 15k (625 ‰) - Great Britain, Australia, New Zealand; Au 14k - Europe, Asia, USA, Turkey; At 12 k - USA, South Africa; Au 10k - USA, South Africa; Au 9k (375 ‰) - Europe, Australia, New Zealand; Au 8k - Germany.

GOLD ALLOYS FOR JEWELRY

Pure gold cannot be used in the manufacture of jewelry, having a very high malleability. To increase the hardness and resistance to breakage and wear, it is especially alloyed with copper and silver, but also with zinc, iron or aluminum. The first jewelry made of gold and silver alloys appeared in ancient and then pre-Columbian civilizations. Today, most gold jewelry is made of 18 carat alloys, with 9 different shades:

– Yellow gold: Au – 75%, Ag – 12.5%, Cu – 12.5%.
– Rose gold: Au – 75%, Cu – 20%, Ag – 5%.
– White gold: Au – 75%, Ag – 18.5%, Zn – 5.5%, Cu – 1%.
– Gray gold: Au – 75%, Fe – 17%, Cu – 8%.
– Red gold: Au – 75%, Cu – 25%.
– Green gold: Au – 75%, Ag – 25%.
– Blue gold: Au – 75%, Fe – 24.4%, Ni – 0.6%.
– Purple gold: Au – 75%, Al – 21% (can be assimilated with Au 18k).
– Black gold: White gold plated by rhodium plating.

Currently about 53% of world gold production (3,300 t/year) is used in jewelry manufacturing. As nickel used in the alloys of watch cases and bracelets has been found to cause contact dermatitis in one in ten people, the European Union recommends giving it up.

DENTAL GOLD ALLOY

Dental alloys are standardized internationally by the standards established by ISO 22674: 2016. Based on this standard, the following dental gold alloys have been standardized in Germany (Table 2).

Table 2, Dental gold alloys standardized in Germany

Type	Gold, %	Silver, %	Platinum, %	Palladium, %	Copper, %	Zinc, %
A	87,5	11,5	–	1.0	–	–
B	75,8	15,0	1,4	3,3	4,1	0,4
S	79,3	12,3	0,3	1,6	5,5	1,0
M	74,8	13,5	4,4	2,0	4,1	1,2
M0	65,6	14,0	8,9	1,0	10,0	0,5

They melt at 860–1,080°C, have a breaking strength of 30–59 kg/mm^2, a density of 15.6–17.4 g/cm^3 and a relative elongation at break of 34–43%.

USES OF GOLD

Due to its rarity, beauty and properties, gold has been used as an exchange since ancient times. Early transactions were made with gold or silver pieces, easily portable and divisible. Later, gold coins were minted, which circulated even after the printing of paper banknotes. The banknotes were backed by a safe-keeping stockpile of gold, as the United States did by using *the gold standard,* storing a quantity of precious metal for paper dollars in circulation. According to this standard, anyone could exchange the banknote with its gold plating, but the process proved to be too cumbersome and was abandoned. Gold coins are no longer used in financial transactions, but are popular ways of investing or are issued for commemorative purposes. Today, much of the world's gold reserves are held in national banks in the form of bullion, so that in the event of a financial crisis it can be converted into foreign currency, guaranteeing the liquidity of the holding countries. The official gold reserves of over 100 tons were thus distributed in March 2022 (Table 3).

Table 3, The official gold reserves of over 100 tons in world

Country	Reserves, t	Country	Reserves, t	Country	Reserves, t
USA	8 133	Portugal	383	Venezuela	161
Germany	3 358	Kazakhtan	368	Philippines	156
Italy	2 452	Uzbekistan	337	Singapore	154
France	2 436	Saudi Arabia	323	Brazil	130
Russia	2 302	United Kington	310	Sweden	126
China	1 948	Lebanon	287	South Africa	125
Switzerland	1 040	Spain	280	Egypt	125
Japan	846	Austria	280	Mexico	120
India	760	Thailand	244	Libya	117
Netherlands	612	Poland	229	Greece	114
Turkey	431	Belgium	227	South Korea	104
Taiwan	424	Algeria	174	Roumania	104

Gold also has many industrial uses, the most important being in the manufacture of electronic products. They operate with very low voltages and currents, which can be easily interrupted by corrosion at the contact points. With very good electrical conductivity and corrosion resistance, gold is an extremely reliable element used in connectors, switching contacts, printed circuits, relays, solder joints and wires or conductive strips. All of this can be found in mobile phones, standard computers, laptops, camcorders, memory cards, global positioning systems (GPS) and satellites. About 200 tons of gold are consumed annually for the manufacture of these products, from which almost nothing is recovered. Almost a billion mobile phones are produced every year, with a lifespan of about two and very few being recycled. The cost of gold in a mobile phone is 50 cents, so recovering it is not cost effective. The same is true of other electronic products.

The construction of satellites or spacecraft, in which the possibility of lubrication, maintenance and repair is ruled out, could not be achieved without the use of gold, which is a reliable conductor and connector. Many parts of spacecraft are also covered with gold-plated polyester foil, which reflects infrared radiation, ensuring the stability of the interior temperature. Without this protection, the dark parts of the vehicles would absorb too much heat. Gold also reduces the friction of moving mechanical parts, replacing organic lubricants, which would volatilize in the presence of cosmic radiation. With a very low shear strength, the gold atoms slide easily on the surfaces of moving parts, ensuring very good lubrication.

Gold has applications even in medicine, not only in dentistry, but also as a medicine. Injections with weak solutions of sodium aurothiolate ($C_4H_4AuNaO_5S$) or aurothioglucose ($C_6H_{11}AuO_5S$) are used to treat rheumatoid arthritis, pemphigus vulgaris (autoimmune disease that causes fluid bubbles and skin ulcers) and dermatitis. The particles of a radioactive gold isotope are implanted in tissues for the treatment of certain types of cancer. Also, small amounts of gold are used to treat lagophthalmia, a condition that is manifested by the inability of the upper eyelid to cover the eye, which remains open during sleep. The gravitational force of the gold particles helps the eyelid to close completely. Many surgical instruments, electronic equipment, and life support devices contain small amounts of gold, which is extremely reliable and compatible with living tissues. The list of gold uses can continue with the medals of the winners of major sports competitions and school Olympics, Nobel, Oscar, Grammy or other awards, but also with some church objects of worship. The snobbery of the rich has gone so far that some people drink champagne with 24-carat (0.000125 mm) inert organic gold microparticles at exorbitant prices or order gold dusted food, especially in luxury restaurants in Saudi Arabia, France. and the USA. Saudi princes drive gold-plated luxury cars, which defies any ethics. It is estimated that today there are about 200,000 tons of gold above the ground, which would fill a cube with a side of 21.8 meters.

GOLD RECYCLING

It is estimated that about 1,100 tons of gold are recycled annually, which is 33% of the world's 3,300 tons of consumption. 90% of jewelry, ingots, coins and dental gold and 10% of industrial waste are recycled. Recovering gold from industrial waste costs less than extracting it from ores and is less polluting, but 2/3 of what could be recycled is dumped in landfills. There are countries that do not have gold deposits, but recover the precious metal from waste, covering their domestic consumption. Most European industrial waste from which gold could be mined, as well as other deficient metals, is shipped for nothing to Asia or Africa, losing billions of euros.

Table 4, Recycled gold in world (tons)

Country	Recycled gold, t	Country	Recycled gold, t
China	222,1	Japan	48,2
India	103,1	Egypt	45,9
Turkey	77,4	United Kington	40,7
Italy	67,5	Russia	37,6
United States	56,4	South Korea	32,9

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CREATION AND DEPOSITION OF GYPSUM FROM THE DESULFURIZATION OF TPP KOSTOLAC B FLUE GAS AT DRMNO OPEN-PIT MINE

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Abstract: *The ever-accelerating application of modern technologies and the rapid technological development of society can cause harmful effects on human health and ecosystems, so paying more attention to preserving the environment is imperative. In this sense, the harmonization and application of our legal regulations with the European Union regulations have been initiated, leading to the implementation of measures and activities necessary for the preservation of the environment, especially the air, by reducing the emission of harmful substances and bringing them to set limit values.*

Thus, for the purposes of desulfurization of flue gases from blocks B1 and B2 of the «Kostolac» thermal power plant, a system was created for transportation and disposal of gypsum created as a by-product in the process of binding sulfur from flue gases with limestone. The initial gypsum disposal area is Cassette 1, constructed at the internal disposal site of the «Drmno» open-pit mine.

Key words: FLUE GAS DESULFURIZATION, GYPSUM, TRANSPORT, DEPOSITION, LIMESTONE

INTRODUCTION

Flue gas desulfurization (FGD) plants have been used to reduce sulfur dioxide (SO_2) emissions from coal-fired power plants since the late 1960s. The first plants of this type were installed in North America, Europe and Japan, due to the occurrence of acid rain in these parts of the world, as a result of increasing SO_2 emissions, which have very adverse effects on the ecosystem. There are different FGD systems, but the market is dominated by wet FGD systems, where synthetic gypsum is obtained as a by-product, the use of which is constantly increasing. Gypsum is mainly used as source material for products in industries such as agriculture and construction, but it also has other commercial applications.

The Environmental Protection Law, which entered into force in 2004 and the Law on the Ratification of the Agreement on the Energy Community of Southeast Europe, stipulate the obligations of harmonizing the operation of thermal power plants with the EU requirements regarding air protection. Given that thermal power plants are major air polluters (sulfur dioxide, nitrogen oxides and dusty substances), it was necessary to approach reducing their emissions. The wet limestone-gypsum process was chosen as the optimal flue gas desulphurization technology for lignite-fired units with a power above 300 MW.

TPP «Kostolac» was taken as the facility where the desulphurization plant construction gives the best results in terms of reducing SO_2 emissions and estimated costs. That is why this thermal power plant is the first where the FGS project was implemented. TPP «Kostolac B» is located near the «Drmno» open-pit mine in the village of the same name and near the archaeological site of Viminacium. The thermal power plant is located on the territory of the Municipality of Požarevac, in the Braničevo District, about 2.5 km from the Danube banks, and about 11 km from the city of Požarevac, which has about 70,000 inhabitants. The distance between the TPP Kostolac and Belgrade is about 60 km in the east-southeast direction.

DESIGN PARAMETERS OF THE FGD PLANT FOR BLOCKS B1 AND B2

The basic parameters for designing the FGD plant are the characteristics of the flue gas at the entrance and exit of the plant, as well as the quality of the by-products. Tables 1 and 2 show the design parameters of the incoming and outgoing flue gas. [1]

Table 1, Design parameters of the incoming flue gas (per block)

Parameter	Unit	Block B1/B2
Flue gas temperature	°C	175
Flue gas flow rate (STP, dry gas)	m^3/h	1.469.000
Flue gas flow rate (STP, wet gas)	m^3/h	1.830.530
Flue gas flow rate (realni 170 °C)	m^3/h	2.970.000
H_2O (STP, wet base, oxygen)	Volumetrically %	19,75
O_2 (STP, dry gas)	Volumetrically %	8,0
SO_2 (STP, dry gas)	Volumetrically %	11,46
Concentration SO_2 (STP, dry gas, 6% O_2)	mg/Nm^3	7.661
Concentration of ash (STP, dry gas, 6% O_2)	mg/Nm^3	50
Concentration SO_3 (STP, dry gas, 6% O_2)	mg/Nm^3	50
Concentration HCl (STP, dry gas, 6% O_2)	mg/Nm^3	50
Concentration HF (STP, dry gas, 6% O_2)	mg/Nm^3	30

Table 2, Design parameters of the outgoing flue gas

Parameter	Unit	Block B1/B2
Concentration SO_2 (STP, dry gas, 6% O_2)	mg/Nm^3	<200
Concentration of ash (STP, dry gas, 6% O_2)	mg/Nm^3	<30
Concentration of droplets in the flue gas at the outlet of the droplet eliminator	mg/Nm^3	<75
Flue gas temperature at the entrance to the chimney	°C	~66.2

TECHNICAL DESCRIPTION OF THE FGD PLANT

The flue gas desulfurization plant consists of the following systems: [1]

- absorber system,
- flue gas system,
- limestone reception and storage system,
- system for preparing limestone suspension including a limestone suspension delivery and storage system,
- gypsum suspension drainage system,
- drainage systems,
- gypsum transport and disposal system,
- auxiliary systems (for power supply, control, service water system, compressed air system, thermotechnical and hydrotechnical installations).

BRIEF DESCRIPTION OF THE FLUE GAS DESULFURAZATION TECHNOLOGICAL PROCESS

The wet flue gas desulfurization technology, with the use of limestone as a reagent and wet treatment of flue gases, is the most commonly applied technology for reducing the content of sulfur dioxide (SO_2) in flue gases emitted from plants with boilers of more than 300 MW. [1]

The wet flue gas desulfurization process is considered a commercial technology with a large number of users today. Desulphurization is carried out after purification in an electrofiltration plant. The dusted flue gas is directed to the flue gas fans and booster fans, and then to the absorbers, where it is purified. The purified flue gas is then released into the atmosphere through a suitable chimney. The very flue gas purification is caused by the contact of the flue gas with the limestone suspension, which takes place in the desulfurization system absorber. The flow of flue gas and suspension in the absorber is in the opposite direction: The gas is introduced into the absorber in the downstream part and flows upwards, coming into contact with the sprayed limestone suspension, which falls downwards from several spray levels. The suspension circulating in the absorber is directed to the spray nozzles by recirculation pumps. The suspension droplets absorb SO_2 from the flue gas through the reaction that takes place between SO_2 and the reagent, i.e. sorbent from the suspension. Hydrogen chloride (HCl), present in flue gas, is also absorbed and neutralized by reacting with limestone, forming soluble salts, which leads to the accumulation of chloride ions in the suspension. The purified flue gas passes through a droplet eliminator that removes water droplets before the gas entering the chimney. When entering the absorber, the flue gas cools rapidly in contact with water, and a certain amount of water evaporates, so the flue gas is saturated with moisture while exiting the absorber. The flue gas temperature at the absorber outlet ranges from 64 to 66°C.

In the wet limestone/gypsum process, flue gas desulfurization takes place according to the equation:

$$CaCO_3 + SO_2 + 2H_2O + 1/2O_2 \rightarrow CaSO_4 \cdot 2H_2O + CO_2$$

The first step in the process of removing sulfur dioxide from the flue gas is its absorption by the absorption suspension. Once in suspension, sulfur dioxide produces sulfite and bisulfite ions.

The result of the sulfur dioxide absorption process is increased concentration of hydrogen ions (H+), leading to a decrease in the pH value of the suspension.

A low pH value (high concentration of hydrogen ions) reduces SO_2 absorption, so neutralization is a key part of the wet flue gas desulfurization process. The SO_2 absorption process taking place in the absorber is the process of SO_2 transition from the gas phase into the liquid phase. With the absorption of SO_2 comes the absorption of halides, primarily hydrogen chloride. The content of hydrogen chloride in flue gas depends on the content of chlorine in the fuel:

$$CaCO_3 + 2HCl \leftrightarrow Ca^{2+} + 2Cl^- + CO_2 + H_2O$$

The neutralization reaction in the wet flue gas desulfurization process can be shown as follows:

$$H + OH^{-} \rightarrow H_2O$$

where in:

H+ acid gas absorption product,
OH– limestone dissolution reaction product.

Sulfates are obtained by the secondary absorption in the reaction pool of the absorber from sulfite and bisulfite:

$$HSO_{3^-} + 1/2O_{2(aq)} \rightarrow SO_4^{\ 2-} + H^+$$

$$SO_3^{\ 2-} + 1/2O_{2(aq)} \rightarrow SO_4^{\ 2-}$$

All the reactions shown in the above process can be grouped into three general categories:

- gas-liquid reactions,
- liquid-liquid reactions,
- liquid-solid reaction.

The degree of sulfur dioxide removal in the desulfurization process can be controlled or limited by the degree of progress of any of the previously shown reactions.

Figure 1 shows an illustrative view of the wet flue gas desulphurization technology.

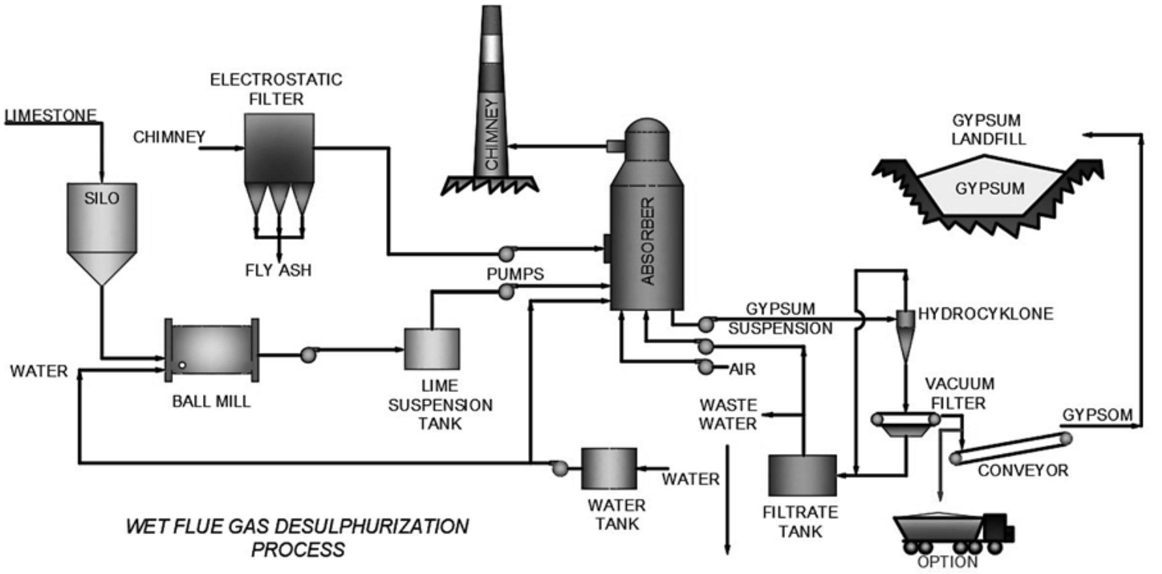

Figure 1, Schematic representation of the flue gas desulfurization process

DESCRIPTION OF THE GYPSUM LANDFILL

Gypsum is produced as a final by-product of the desulphurization process, and a system for its transport and disposal was created for the needs of this process. The initial gypsum disposal area is Cassette 1, constructed at the internal disposal site of the "Drmno" open-pit mine (Figure 2). The cassette dimensions (approximate) are 275 x 137 m and its depositing depth is 12 m. [2]

The initial basis for forming the gypsum depositing cassette was the design annual gypsum production, the coordinates of the point from which the transported gypsum is taken and the available equipment for the technological procedure. For the cassette construction, a dragline excavator was used to excavate the deposited mine tailings, and then embankments were built from the excavated material and slopes and berms were shaped. The excavated masses provided material for the construction of the perimeter embankment of the 8.0 m high cassette. The internal cassette slope was formed in two levels, the first 4.0 m high, the second 8.0 m high, with a slope of 1:3 and a 2.0 m wide berm between the levels.

Figure 2, Gypsum disposal cassette 1

Gypsum from the plant, dominated by calcium sulfate, is a non-hazardous waste. To deposit such material, current regulations require that the landfill has an appropriate geological barrier. For this reason, the watertight HDPE film was installed. Gypsum disposal at the landfill is carried out by a dumper (Figure 3) so as to ensure the stability of the masses and coherent structure of the deposited material, especially in terms of preventing landslides. The leveling of gypsum inside the cassette is done with a bulldozer.

Figure 3, Gypsum dumper at the landfill

The underground and surface water landfill protection system serves to evacuate these waters from the landfill and comprises:

- drain carpet,
- drain channels,
- perimeter channel OK-1,
- leachate drain system,
- water collector.

Figure 4 shows the site plan of Cassette 1 with accompanying elements.

In addition to protecting the cassette from the inflow of surface water, the OK-1

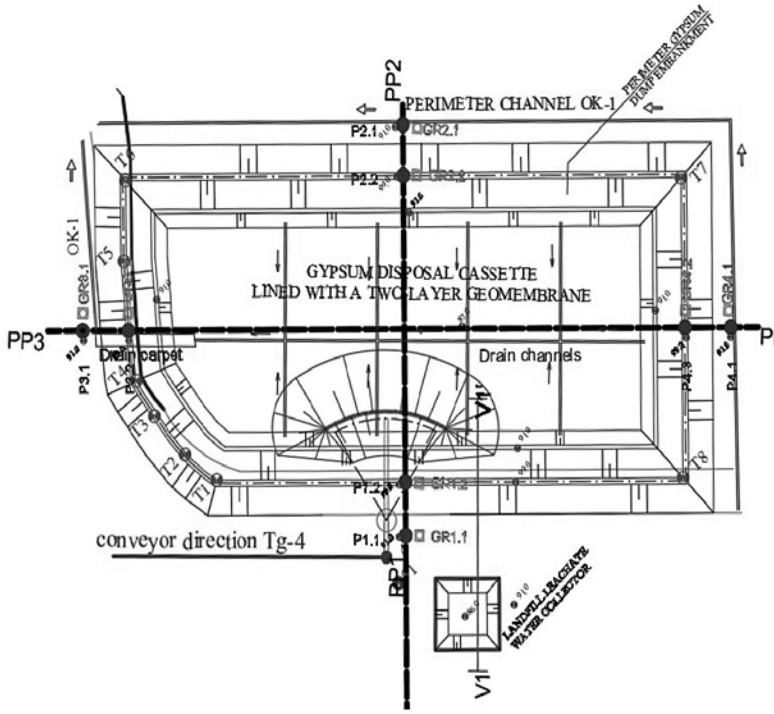

Figure 4, Cassette 1 site plan

perimeter channel also receives water drained from the drain channels and the drain carpet. Collected water is drained to the lowest point in the pit, i.e. to the main water collector MWC. A drain layer was designed on the bottom of the cassette to collect storm water inflow into the gypsum landfill. The drain pipe flows into the collector pipe that leads through the embankment to the water collector located at the bottom of the cassette (Figure 5). [3]

Figure 5, Leachate water collector

To monitor seepage water through the landfill embankment, characteristic control profiles were selected to place piezometers.

During landfill construction and exploitation process, various changes are made related to the method and conditions of transportation, deposition, environmental protection, water removal, changes in the underground water levels in the surrounding terrain, etc. Since it is not possible to predict all the impacts of the landfill on the environment and vice versa, it is necessary to observe the landfill throughout its exploitation as an object that is influenced and reflects all natural events in the environment and all events caused by human activities.

Certain measures have been foreseen to monitor the landfill and measure the necessary parameters so that under the specified conditions the landfill is a stable hydro-construction building that does not pose a threat to or pollute the environment, and at the same time fully meets its purpose. [4]

CONCLUSION

The installation of the FGD plant in the Kostolac B thermal power plant resulted in the reduction of harmful gas emissions from blocks B1 and B2 and the harmonization of the thermal power plant's operation with EU regulations. As a result, air quality has improved in terms of the concentration of sulfur oxides, and there is also positive effect on the environment through a reduced possibility of the formation of acid depositions. An additional effect of the application of wet flue gas desulfurization technology is the reduction of the content of dusty substances and acidic halogen gas components (HCl and HF) in the flue gases. Also, gypsum, which is produced as a by-product and whose disposal process is an integral part of this system, which gives the possibility of its exclusion, can be used for commercial purposes.

However, although the deposited gypsum from the plant is non-hazardous waste, after its disposal, the landfill is to be sealed, that is, after the end of each cassette exploitation, permanent closure and reclamation must be carried out.

It should also be noted that the construction of a flue gas desulphurization plant together with a gypsum transport and disposal system is in progress within other thermal power plants. This primarily refers to TENT-A and TENT-B as well as the new block B3 within TPP "Kostolac B".

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SOLIDIFICATION / STABILIZATION TECHNOLOGY OF BY PRODUCTS (ASH) FROM POWER PLANTS

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Abstract: *Treatments of by-products from industrial plants should be primarily environmentally and then economically acceptable. Solidification is a by-product treatment that goal to turn waste into a form that reduces contact with the environment with easier handling and disposal. This is achieved by various technological procedures by creating physically strong and durable substances that maintain the integrity of the solidified matrix for a longer period of time. When choosing a stabilizing additive, special attention should be paid to the availability in the immediate vicinity of the plant, which significantly reduces the overall costs treatment and disposal.*

Key words: SOLIDIFICATION, ADDITIVE, BY PRODUCTS, DISPOSAL, INDUSTRIAL PLANTS

INTRODUCTION

Solidification/Stabilization (S/S) is an important physical-chemical method for the treatment of industrial solid and sludge waste and contaminated materials. Stabilization changes the chemical characteristics of hazardous constituents in waste by converting into less soluble, less mobile or less toxic forms. Solidification changes the physical characteristics of waste such as increasing compressive strength, reducing permeability and physical encapsulation of hazardous substances [1].

Solidification or "hardening" is a well known method in worldwide science and practice for agglomerate and transform fine grain material into a technologically and ecologically stable form. There are numerous ways to achieve solidification and methods are divided into six basic groups [2]:

1. Solidification based on the addition of lime or cement (addition of lime and/or cement results in obtaining very stable material);
2. Self-locking solidification (the natural characteristics of the waste material are used to achieve solidification in controlled conditions);
3. Solidification based on the addition of silicates (silica gel and cement are suitable for inorganic waste with low heavy metal content);
4. Solidification based on thermoplastic impregnation (additives such as asphalt, bitumen, paraffin, polyethylene, etc.);

5. Solidification based on impregnation with organic polymers (urea-formaldehyde is used for the polymerization mostly of nuclear waste);
6. Solidification based on inorganic precipitation (ferry ions such as $Na_2Fe_3(SO_4)_2(OH)_6$ and $Na_2Fe(SO_4)_2(OH)\cdot 3H_2O$) [3].

During the S/S process, the waste or contaminated material is mixed with the stabilizing agent (additive) with resulting physical-chemical processes between them. The obtained binding or cementation properties serve to completely stabilize the treated material (ash) and above all the contact surface of the deposited material. Suitable binding agents are selected for specific application and contaminants based on a set of criteria, which are mainly dependent on the characteristics of the end products as well as the set goals and possibilities. Immobilization agents can generally be divided into two large groups: primary and secondary stabilizing agents. These agents can be substances of organic and inorganic origin [13].

The most commonly used solidification agents are portland cement, various types of puzzolans (flying ash, high-furnace slag, cement kiln dust) and lime [4]. They are mostly used for curing nuclear and hazardous waste [3]. These materials chemically react with water, creating a hydrated matrix that improves the physical characteristics of the waste. Also, the pH of the waste increases, improving the precipitation of metals and their immobilization [5, 6].

SOLIDIFICATION/STABILIZATION TECHNOLOGY

Solidification refers to a technique in which waste is compacted into a monolithic solid matter of high structural integrity. Solidification does not include the obligatory chemical interaction between wastes and reagents used for solidification, but the waste is safely mechanically bound to the binding agent [7]. The migration of the contaminant is limited by reducing the surface area exposed to leaching and/or isolating waste into the capsule, which results in a reduction in permeability leading to a decrease in water penetration to contaminants, and therefore also reduces their migration. Usually, the main goal of solidification is to convert the waste into a form that is easier to handle and dispose of, while minimizing harmful potential by reducing the surface of the waste that is in contact with the environment, complying with legal regulations and requirements and feasible practical implementation [1,8]. Moreover, solidified waste reduces the risk of waste particles dissipation during handling, storage, transport and disposal, and therefore increases the safety of workers who come into contact with waste, as well as enhancing environmental protection. The development of specific technologies procedures for different types of waste began in the late 1960s and early 1970s [9, 10].

Most of the technologies used for solidification are created to provide physically strong and durable materials that retain the integrity of the solid matrix over a long period of time [11].

The effectiveness of physical changes depends on numerous factors. For example, systems that use cement depend on the temperature of formation and the moisture content. It is generally accepted that higher temperatures accelerate the bonding processes of solidified material, while the moisture content above or below the optimum results in less matrix strength and less durability. In addition, many chemical reactions can lead to shrinkage, swelling or changes in the time required to stabilize the solidified material. Weather conditions, such as freezing and melting, dry and wet weather cycles or erosion can also lead to a significant reduction in the physical integrity of the matrix [12,13].

The process of solidification usually results in chemical changes that incorporate free water into a solid matrix.

ASH SOLIDIFICATION

The hardening or solidification of ash by addition of additive/s was not found to be widespread. The reason, probably, lies in the limited and small negative impact on the environment and the high costs of such process, especially in terms of the amount of ash to be converted into a solid state.

Polish scientists [14] developed the ash hardening method by adding one of the additives: CaO, $CaCl_2 \cdot H_2O$, KNO_3, $NaHSO_4$ and $KHSO_4$. In relation to the weight of ash, the share of these additives is about 7.5%. The ash with added additive/s is mixed with water in a ratio of 1: 1 (when transported as a hydromixture) or 3: 1 (when transported as a paste). Over time, curing takes place (maximum 10 days) where the formed mass shows water permeability of not more than 1 x 10^{-6} m/s and a compressive strength of not less than 0.3 MPa. This disposal system was tested through semi-industrial application at TE "Lagiša" (Poland) where depositing was carried out in the excavated areas of the nearby mining pits. Relatively fast curing, good geo-mechanical properties and absence of free water classified this solidified ash into good material for filling the excavated mining voids [15].

The researchers of the Mining Institute determined the conditions for solidification of silicate ash from TPP "Kostolac-B" through several tests. One of the first testing was based on the use of lime and bentonite. Positive results were obtained in the case when the share of additives was 5, i.e. 10%. The experiments carried out for the innovation project of the Ministry of Education, Science and Technological Development aimed to determine the influence of additives on the solidification process in terms of aeolian erosion of particles of deposited material (ash and slag) on the air and soil in the vicinity of the TPP Kostolac landfill. Different mass fractions of additives and water were tested on the samples. The results showed that the optimal additive and water content for reducing aeolian erosion and improving the properties of the deposited material is 3% and 15%, respectively. Also, in addition to these ashes, ashes from thermal energy plants TPP Gacko and TPP Kosovo were examined, characterized by (with particularities) controlled self-solidification, which as such is rarely encountered in practice. The original technology of controlled self-solidification was applied at the TPP Gacko ash landfill. CaO (66-90%) dominates the composition of ash from TPP Gacko, with the free CaO share ranging from 12 to 49%. CaO comes from marl, which is exploited as interlayer tailings and is "burned" together with coal. After crushing and burning, marl is decomposed into CaO, which goes with the ash, and CO2 , which leaves as a gas through the chimney. The self-solidification technology is designed in such a way that by controlled addition of water, with good mixing and depositing in thin layers, a reversible chemical reaction is performed, i.e. the formation of $CaCO_3$. In the TPP Kosovo ash, the content of CaO (35-40%) also prevails, but with a higher content of SiO_2 (29-32%) compared to the ash of TPP Gacko [17]. When ash comes into contact with water at the landfill, the ash compounds are hydrated. The process begins with carbonation conditioned by the share of active CaO, forming $Ca(OH)_2$, which in the presence of CO_2 from the air, forms $CaCO_3$. The process does not end there, but very complex hydration reactions of other components participating in the structure of ash continue with the end result of forming four new minerals, all with calcium as a carrier element, with the dominant participation of tobermorite and ettringite groups minerals. The landfill solidification process of TPP Kosovo ash usually takes about 22 days.

In the literature dealing with the hardening of mineral materials [19,20,21] there are papers in which solidification process is studied in relation to obtain a commercial products, not from the aspect of disposal. The American scientist Minik [21] studied the process of hydration of ash from eight thermal power plants with addition of additive - a lime purchased as a standard commercial product from five different manufacturers. The lime to ash ratio was defined as 1:2. Dry components were firstly mixed and then water was added to this mixture with manual stirring for 5 minutes, or until a homogeneous mixture was obtained. From each mixture, test probes were made in the molds for further testing. After detailed investigation, it was found that the reaction of ash, lime and water is very complex not only because of the large number of reactions, but also because there is a variety of products of potential reactions (especially in the case of hydration of aluminates and silicates and combinations that can occur). Minik showed the following chemical reactions with the remark that this is only a minor part of the reactions that can take place:

a) $CaO + H_2O = Ca(OH)_2 + heat$

b) $CaO + H_2O + CO_2 = CaCO_3 + H_2O + heat$

c) $Ca(OH)_2 + CO_2 = CaCO_3 + H_2O + heat$

d) $Ca(OH)_2 + SiO_2 + H_2O = xCaO\ ySiO_2\ z\ H_2O$

e) $Ca(OH)_2 + A1_2O_3 + H_2O = xCaO\ yA1_2O_3\ zH_2O$

f) $Ca(OH)_2 + A1_2O_3 + SiO_2 + H_2O = xCaO\ yA1_2O_3\ zSiO_2\ wH_2O$

g) $Ca(OH)_2+SO_3+ A1_2O_3+H_2O = xCaO\ yA1_2O_3\ zCaSO_4\ wH_2O$

Analyzes have shown that the present CaO hydrates in contact with water (reaction under a) in a very short period of time by creating $Ca(OH)_2$ which is very usable for reaction with other ash component. Analyzes of the resulting compounds confirmed that minerals from the group of tobermorite and etringite (reactions under f and g) should be sought among the cement minerals [3].

Malviya and Chaudhary in their review [22] state that unconfined compressive strength (UCS) provides basic information whether the waste material is stabled or not. The minimum required value of UCS should be determined on the basis of further works related to solidification. USEPA recommends that the minimum required UCS for solidification intended for disposal is 0.35 MPa, as sufficient strength for a stable base to withstand material that is deposited over treated waste at disposal sites. Determination of UCS is performed at different time intervals, after 1, 3, 7, 14, 28, 90, etc. days in order to monitor the effect of changes in the mineral composition of the treated waste during the exposure time to the environment.

It was concluded that the lower ratio of waste to the additive leads to better physical and chemical characteristics of the solidified material, while a higher share of water in solidified material reduces UCS. This is due to the larger size of the pores and visible holes in the structure of solidified material in the presence of a larger amount of water.

The UCS also affects the particle size, therefore the material with different sizes of particles will have higher UCS, since particles of different sizes and shapes fill pores in the mixture of waste/additive resulting in an increase in UCS [22].

Pozzolans refers to materials that have high content of SiO_2 and Al_2O_3 with a large specific surface, which is available for the hydration reaction with alkaline and earth alkaline metal hydroxides in the presence of water at room temperature, whereby cement products are formed: calcium-silicate hydrates (CSH) and calcium-aluminate hydrates (CAH) [23]. As already mentioned, flying ash (FA) of class F is a puzzolan material, which has cementation characteristics and can be self-solidified in the presence of water, without the addition of alkalis. [24, 25].

The most important FA characteristics are the CaO content that provides alkalinity to the system and the content of $SiO_2 + Al_2O_3 + Fe_2O_3$ [26]. The content of calcium in FA class F varies from 1 to 12%, mainly in the form of $Ca(OH)_2$ i $CaSO_4$.

Šešlija et al. [27] have demonstrated their experimental investigation of the physico-mechanical properties of flying ash from the TPP Nikola Tesla A (TENT A) and Nikola Tesla B (TENT B) and stabilized ash with the addition of lime and cement suitable for application in road construction. The amount of additive in the mixture was 2, 4 and 6% relative to the total mass of fly ash. After the tests, it is noticeable that ash mixture without additives and with the addition of additives can be used for the production of soil base, embankments and beddings, while for the supporting structures it is not recommended.

When choosing a method, costs are one of the greatest interests in selecting technologies for the treatment or disposal of waste. S/S is one of the most popular technologies due to its low cost compared to other technologies [28].

A study published by L. Rafalko and J. Giacinto in June 2010 refers to cost estimation of the stabilizing of ash class F by using various types of additives available in the area [29].

The price of stabilization of the fly ash from Curtis Bay, Maryland, USA, during the closure of the nearby Perryville open pit mine, was estimated for five different additives: lime, cement kiln dust (CKD), lime dust (LKD), portland cement and granulated furnace slag (GGBFS). The estimate of the necessary costs was made only for the stabilization of the ash.

The following factors have been taken into account for cost estimation:

- Designing of complete technology from the delivery, storage and mixing of components to transport and landfill while developing a study of treatment options;
- Materials include used additives (ash and water are not included in the costs);
- Equipment includes complete facilities for preparation and transport (internal and external), machinery at the landfill, construction facilities (buildings and silos, bunkers and storage for materials used in the process);
- Work to be applied in the plant and at the landfill, depending on the selected technological process and additives (It is necessary to anticipate investigation, engineering supervision and preparation of reports).

Additives available in the immediate vicinity of the plant can significantly reduce the cost of treatment due to the minor material costs that need to be allocated for transport. If the amount of additive increases, transport costs become primary in total costs. Thus, when selecting the additive, attention should be paid to the indicated fact and be taken into account.

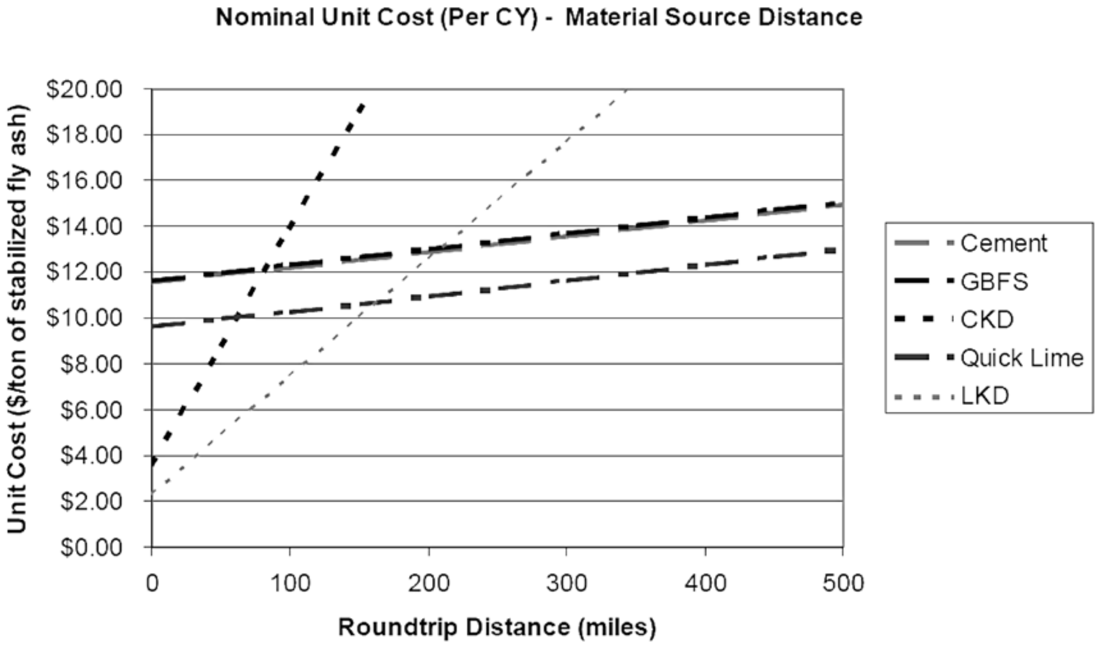

Figure 1, Increase of the nominal cost per ton of stabilized ash relative to the distance

The illustrated diagram shows that transport costs at larger distances are lower in total material costs for additives that have a lower consumption per ton of ash.

All of these additives have similar physical properties and can be treated with similar equipment, although higher quantities are required when using CKD and LKD, and therefore larger equipment capacity is required.

In the following table, the ash stabilization costs evaluated in the mentioned Study are presented.

Table 1, Percentage share of costs in ash class F stabilization at Curtis Bay

Costs	Percentage in total costs				
Additives	Designing	Material	Transport	Equipment	Work
lime	0.4	72.5	14.6	1.6	11.0
CKD	0.3	9.6	57.4	1.2	31.6
LKD	0.5	9.1	54.6	2.2	33.6
GGBFS	0.4	88.1	3.4	1.5	6.7
Portland cement	0.4	84.1	6.5	1.5	7.6

The level of solidification/stabilization and associated total costs should be analyzed and processed through a site-specific study, additive (or additives) and ash [29].

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CONCLUSION

Adequate and complex knowledge of the starting raw material is of great importance for the proper stabilization of waste products and therefore ash in landfills, on the basis of which the appropriate technological procedure is chosen, with the use of one or more reagents (additives). With the self-solidification of certain rare types of ash, the prevailing opinion of the authors dealing with these issues is that adding CaO to initiate the stabilization/solidification process, through carbonization, plays a key role in the ash solidification process. The reactions between ash, lime and water are very complex. It is obvious that subjecting the ash to additives and hydration causes significant changes in the mineral composition, in such a way that new minerals such as tobermorite, ettringite, gypsum and braunmillerite are built. As already emphasized, choosing the technological procedure and therefore additives is influenced by market availability, production capacities, transport costs (local producers), price, the most favorable characteristics for solidification, i.e. stabilization.

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THE INFLUENCE OF ADDITIVE QUANTITY ON THE TEMPERATURE CHANGE IN ASH AND SLAG MIX FOR SOLIDIFICATION PURPOSES

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Abstract: *The aim of this study is to determine the possibility of solidification/stabilization of ash from the Kostolac thermal power plant. Solidification is a process that should enable, suppress or reduce aeolian erosion at the future landfill. The solidification process involves combining chemical and mechanical methods, i.e. adding optimal quantities of a suitable binder and water and compacting the formed mixture before the binding process starts. The binder and water reaction in the mixture is monitored by temperature changes, and part of the test results related to this change is presented in this paper.*

Key words: SOLIDIFICATION, ASH, SLAG, BINDER, TEMPERATURE

INTRODUCTION

The treatment that involves mixing the binder with industrial plants by-products and contaminated material, resulting in the immobilization of hazardous substances contained in it and the reduction of potential negative environmental impact, is called solidification. Solidification is achieved by a chemical reaction between the waste and specific additives or mechanical processes.

Waste physical characteristics do not have to change during stabilization. If solidification refers to techniques that form a solid material, there is no chemical interaction between the contaminant and the additives that aid solidification. The waste solidification product may be a monolithic block, a clay-like material, granular particles, or another physical form that is usually considered solid.

Aeolian erosion on thermal power plant ash dumps can be reduced or even suppressed by applying some of the solidification methods. The negative environmental impact of ash is low and limited, and considering there is large quantity of ash to be solidified by adding additives, making the process even more expensive, this method is still not widely used.

It is generally accepted that higher temperatures accelerate the solidified material bonding processes, while the moisture content above or below the optimum results in lower mixture firmness and durability.

Carbonization is the basic process. Further on, the hydration continues, but due to the considerably subordinated share of aluminum, iron and sulfur salts, the further flow of hydration does not have a significant effect on the characteristics of the hardened material. Due to the high participation of the free CaO, process is exothermal and leads to an increase in temperature up to 96°C. As the carbonization process is unstable at elevated temperatures, the anhydrous hardened mass is susceptible to decomposition if it is immersed in water before the temperature drops to ambient temperature, which is the evidence that carbonization is the main hardening process. However, as the strength of the deposited material increases with time, it is evident that hydration is also present. Another proof of the hydration is an elevated temperature of water within the deposited material (up to 55°C) at a depth of 5-10 m below surface and without the presence of air. Application of this disposal technology enables minimization of the air pollution as well as water pollution because of the chemically bound water in a short period of time. Since material remains within the disposal site, no pollution of surrounding soil is recorded [2,3,4].

It is generally accepted that higher temperatures accelerate the solidified material bonding processes, while the moisture content above or below the optimum results in lower mixture firmness and durability [5,6].

EXPERIMENTAL PROGRAM

For the successful development of the joint ash and slag disposal technology, a detailed characterization of ash and slag samples was performed before all tests, which included determination of physical and chemical characteristics. The results are presented in the paper Characterization of ash, bottom ash and gypsum for the development of the technology of their disposal [7].

Afterward, a program was created to form test bodies, which, for the purposes of monitoring temperature changes, provided for the formation of three test body groups, namely:

- Test bodies with hydrated lime as an additive (ash, additive, water);
- Test bodies with quicklime as an additive (ash, additive, water) and
- Test bodies with slag (ash, slag, additive, water).

The percentage of added water was adopted as per a special examination of this research group so that the temperature change was monitored on samples with 10, 15 and 20% sample dry weight, while the adopted percentage of additives ranged from 1 to 3%.

The lime added as an additive releases heat in the reaction with water, so it was necessary to monitor temperature change to observe the possible impact on the further solidification process.

RESULTS AND DISCUSSION

The chemical exothermic reaction of the mixture of ash, binder (hydrated lime and quicklime) and water was analyzed based on the results obtained by measuring the temperature change during the ash, binder and water reaction. According to the research plan, the components ratio was determined. Water was added in relation to the 10, 15 and 20% dry matter. Binder, hydrated $Ca(OH)_2$ and quicklime CaO, was added in the ratio of 1, 2 and 3%. Sample was prepared and measured entirely in laboratory conditions, which means that the external factors of sample, water, and environment temperature had an equal influence, i.e. were the same for all measurements performed. Immediately before measuring the temperature, a certain amount of water was added to the dry prepared sample and continuously mixed for 4 minutes. Then continuous temperature measurement was started. The measurement was done using a calibrated thermometer AHLBORN Almemo 2020-1 type every 30 seconds for the first 5 minutes, and then every 1 minute until the end of 40 minutes. The following charts show characteristic values.

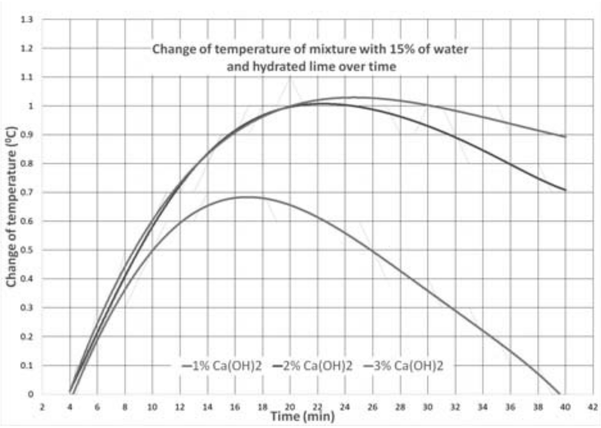

Figure 1, Change of temperature in ash mixture with 15% of water with hydrated lime

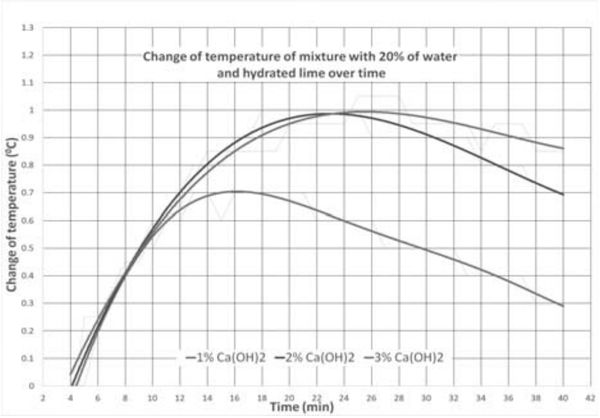

Figure 2, Change of temperature in ash mixture with 20% of water with hydrated lime

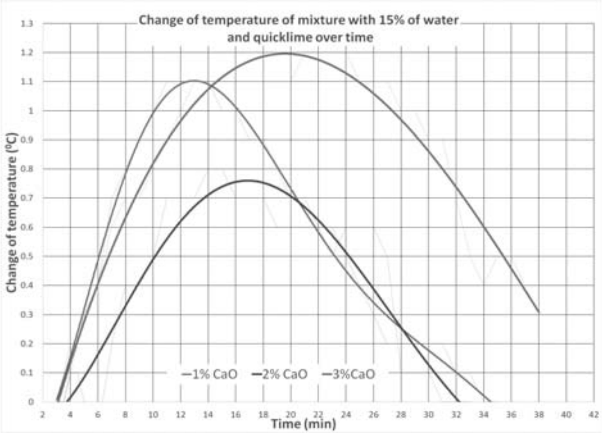

Figure 3, Change of temperature in ash mixture with 15% of water with quick lime

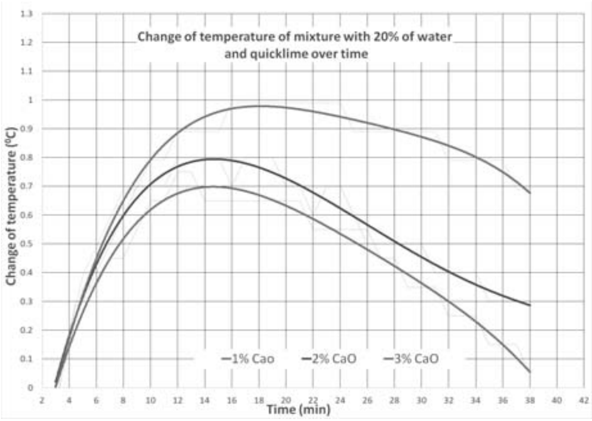

Figure 4, Change of temperature in ash mixture with 20% of water with quick lime

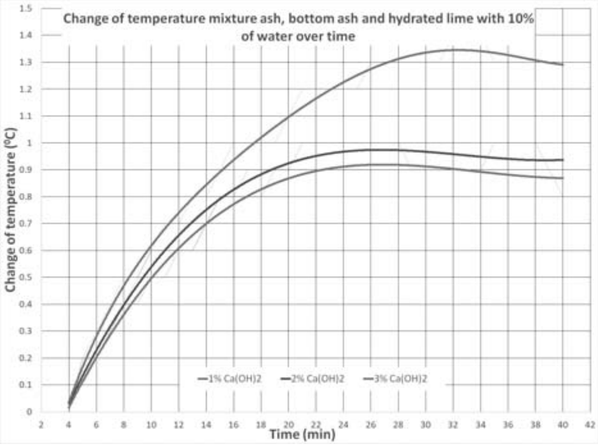

Figure 5, Change of temperature in fly and bottom ash mixture with 10% of water with hydrated lime

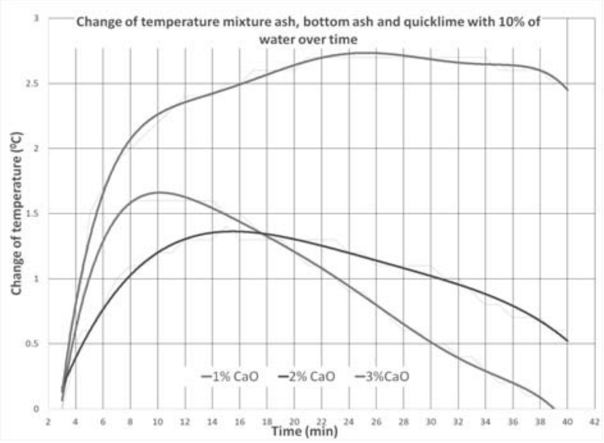

Figure 6, Change of temperature in fly and bottom ash mixture with 10% of water with quick lime

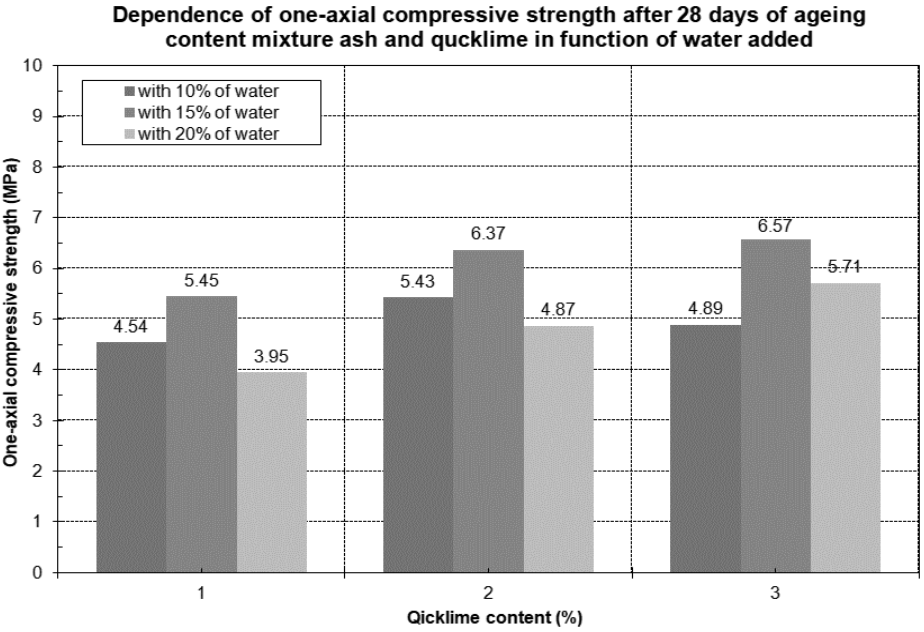

Figure 7, Dependence of one-axial compressive strength after 28 days of ageing on water and quick lime content for ash mixture

The reaction in all measured cases began and ended in the measured interval, i.e. between 4 and 40 minutes. The highest values were read in the period between 10 and 25 minutes, meaning that the reaction was most intense in that period. The mean value of the lowest (min) to highest (max) temperature readings difference (temperature increment) was about 1°C (0.7-1.2) for all the set ratios of the ash, $Ca(OH)_2$ binder and water mixture, while for the ash, slag, $Ca(OH)_2$ binder and water mixture, it was about 0.7-1.4°C. The highest temperature read when using the $Ca(OH)_2$ binder was 24.4°C.

The mean value of the temperature difference (temperature increment) when it comes to

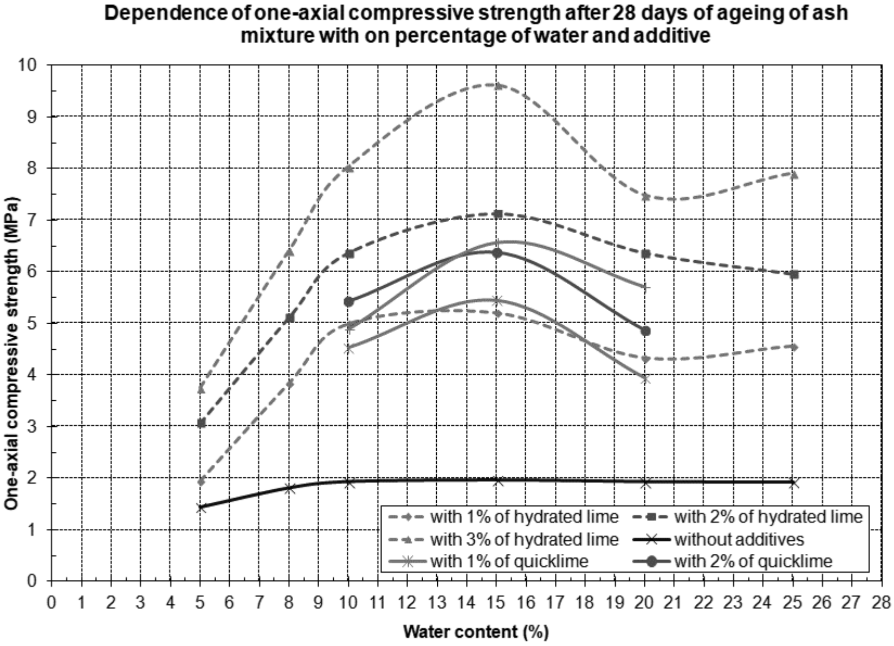

Figure 8, Dependence of one-axial compressive strength of ash mixture test probes on quantity of water after 28 days of ageing

CaO binder was about 1°C (0.8-1.3), while for the ash, slag, CaO binder and water mixture it was 0.5-2.7°C. The highest temperature read when using the CaO binder was 25.7°C, while in the presence of slag the reaction is more intense and is 26.7°C.

Study of the influence of the ash, $Ca(OH)_2$; CaO binder and water mixture ratio on the compressive strength of the compacted sample was carried out in an accredited geomechanical laboratory. The following characteristic charts show the uniaxial compressive strength dependence on the quantity of added water, added binder, the aging time of the ash and ash and slag compacted mixture. From the chart, it can be clearly seen that the compressive strength decreases with the addition of water beyond the optimal 15%, regardless of the type of binder.

From the chart, it can be clearly seen that the compressive strength decreases with the addition of water beyond the optimal 15%, regardless of the type of binder.

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This paper arose from the activities related to the innovation project of the Ministry of Education, Science and Technological Development, number of the Republic of Serbia in 2017 number 391-00-16/2017-16/25.

CONCLUSION

Testing was carried out on several occasions to determine the conditions for the preparation, transport and deposition, as well as the solidification of ash and slag from Kostolac A and B Thermal Power Plants. When it comes to ash and slag stabilization in landfills by adding additives, satisfactory results were obtained with 3% share of additives. To understand the necessity of ash and slag stabilization in landfills, it is crucial to have a proper and comprehensive understanding of the material being deposited. Complex reactions between ash, lime and water cause significant changes in the mineral composition by forming new minerals. Therefore, temperature change monitoring during the solidification process is only one of the parameters that is monitored and which is one of these processes indicators. Temperature change is in line with the tests of compressive strength, quantity of binder and quantity of water. As the binder content increases, the temperature and reaction time increase. The reaction starts and ends in an interval between 4 and 40 minutes. In the period between 10 and 25 minutes they reach the peak values. The mean value of the lowest (min) to highest (max) temperature difference, temperature increment, and temperature readings ranged from 0.7 to 1.4 °C for $Ca(OH)_2$ and between 0.5 and 2.7 °C for CaO. The recorded values for the tested samples have no significant influence on the compressive strengths. The highest temperature read with $Ca(OH)_2$ was 24.4°C, while for CaO it was 25.7°C. In the presence of slag, the reaction is more intense and the highest temperature read at that time was 26.7°C.

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О УТВРЂИВАЊУ МИНЕРАЛНИХ РЕСУРСА И РЕЗЕРВИ У ЛЕЖИШТИМА ЧВРСТИХ МИНЕРАЛНИХ СИРОВИНА

ABOUT ESTABLISHING OF MINERAL RESOURCES AND MINERAL RESERVES IN DEPOSITS OF SOLID MINERAL RAW MATERIALS

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Сажетак: *У раду је размотрена проблематика утврђивања минералних ресурса и резерви у лежиштима чврстих минералних сировина, што представља главни задатак геолошке фазе извођења минералних пројеката. Истакнуто је да се ресурси и резерве, иако геолошки тесно повезани, економски битно разликују. Ресурси се утврђују на основу података добијених геолошким истраживањима лежишта (најважнији су о количини и квалитету припадајуће минералне сировине), али се на бази тих података не може установити њихова експоатабилност; резерве се пак изводе из одговарајућих ресурса применом адекватних техничко-економских студија (које укључују разматрање модификујућих фактора) на бази којих се установљава њихова експлоатабилност. Због тога се они разврставају у посебне класе: ресурси у неексплоатабилну геолошку класу (са поткласама претпостављених, индицираних и измерених ресурса), а резерве у експлоатабилну економску класу (са поткласама вероватних и доказаних резерви). Добијени резултати резимирани су у релевантним закључцима и препорукама.*

Кључне речи: МИНЕРАЛНИ РЕСУРСИ, МИНЕРАЛНЕ РЕЗЕРВЕ, ЛЕЖИШТА, ЧВРСТЕ МИНЕРАЛНЕ СИ-

Abstract: *In this paper are considered problems of establishing of mineral resources and reserves in deposits of solid mineral raw materials what is the main task of the geological phase of performing of mineral projects. It is pointed out that the resources and the reserves, although closely related geologically, essentially differ economically. The resources are established on the basis of data obtained by geological exploration of the deposits (most important are data regarding quantity and quality of the belonging mineral raw material) but their exploitability could not be established; the reserves are derved from the corresponding resources by application of proper technical-economic studies (that include consideration of the modifying factors) on the basis of which their exploitability is ascertained. Therefore they are classified into separate classes: the resources into the nonexploitable geological class (which is divided into subclasses of inferred, indicated and measured resources) and the reserves into the exploitable economic class (which is divided into subclasses of probable and proved reserves). The results obtained are summarized in relevant conclusions and recommendations.*

Key words: MINERAL RESOURCES, MINERAL RESERVES, DEPOSITS, SOLID MINERAL RAW MATERIALS, GEOLOG-

РОВИНЕ, ГЕОЛОШКА ИСТРАЖИВАЊА, ГЛАВНА ОБЕЛЕЖЈА, ТЕХНИЧКО-ЕКОНОМСКЕ СТУДИЈЕ, МОДИФИКУЈУЋИ ФАКТОРИ, КЛАСИФИКОВАЊЕ, ЗАКЉУЧЦИ, ПРЕПОРУКЕ

УВОД

Утврђивање (процењивање од стране компетентних лица) минералних ресурса и из њих изведених минералних резерви у лежиштима чврстих минералних сировина (минералним лежиштима) представља главни задатак истраживања у геолошкој фази извођења минералних пројеката (у ширем смислу: рударских подухвата), како у свету тако и у Србији. Због тога смо у раду детаљније размотрили поменуту проблематику, а добијене резултате смо приказали у наредним поглављима.

У овом раду су коришћени подаци из релевантних светских кодекса и стандарда [1, 2, 3, 4, 5], из законске регулативе Републике Србије [6] и бивше СФР Југославије [7, 8], из публикованих радова [9, 10, 11, 12, 13, 14, 15, 16] и из праксе.

ИСТРАЖИВАЊА МИНЕРАЛНИХ ЛЕЖИШТА У ЦИЉУ УТВРЂИВАЊА РЕСУРСА И РЕЗЕРВИ, ИЗВЕШТАВАЊЕ О ДОБИЈЕНИМ РЕЗУЛТАТИМА И РЕГУЛАТИВА

У овом поглављу размотрени су: истраживања лежишта чврстих мнералних сировина намењена утврђивању минералних ресурса и резерви, извештавање о добијеним резултатима и одговарајућа регулатива (домаћа и светска).

Истраживања намењена утврђивању ресурса и резерви

Минерални пројекти, који имају за задатак утврђивање ресурса и резерви у минералним лежиштима у циљу одрживе експлоатације лежишта (односно технички ефикасне, економски профитабилне, а еколошки прихватљиве експлоатације утврђених резерви) у садашњим условима, по правилу се изводе поступно, у две

ICAL EXPLORATION, MAIN TRAITS, TECHNICAL-ECONOMIC STUDIES, MODIFYING FACTORS, CLASSIFICATION, CONCLUSIONS, RECOMMENDATONS

INTRODUCTION

Establishing (estimating by competent persons) of mineral resources and their derivatives - mineral reserves, in deposits of solid mineral raw materials (mineral deposits), is the main task of exploration in the geological phase of realization of mineral projects (mining enterprises), both in the world and Serbia. Therefore the issue of the paper is a detailed consideration of the problems and the results obtained are presented in the following chapters.

Data from relevant world codexes and standards [1, 2, 3, 4. 5], from regulations of the Republic of Serbia [6] and the former SFR Yugosalavia [7, 8], from published papers [9, 10, 11, 12, 13, 14, 15,16] and from practice are used in the paper.

EXPLORATION OF MINERAL DEPOSITS AIMED AT ESTABLISHING OF THE RESOURCES AND THE RESERVES, REPORTING OF THE RESULTS AND APPROPRIATE REGULATIONS

In this chapter are considered: exploration of mineral deposits aimed at establishing of the resources and the reserves, reporting of the results achieved and the appropriate regulations (both Serbian and world ones).

Exploration intended for establishing of the resources and the reserves

Mineral projects, assigned to establishing of the resources and the reserves in mineral deposits, aimed at sustainable exploitation (excavation) of the deposits (that is technically efficient, economically profitable and ecologically acceptable exploitation of the reserves established) in present conditions are, as a rule, фазе: првој, геолошкој (истражној или прединвестиционој) – од стране носилаца геолошких истраживања и другој, рударској (инвестиционој) – од стране носилаца експлоатације лежишта, и то само ако су у геолошкој фази добијени позитивни резултати.

Геолошка фаза се, по правилу, изводи у четири сукцесивна стадијума: иницијални стадијум рекогносцирања и наредне стадијуме проспекције, претходних (генералних) истраживања и детаљних истраживања. У сваком наредном стадијуму изводи се све већи број истражних радова (и по све гушћој мрежи), којим се утврђује количина минералне сировине, и узима се све већи број проба, чијим испитивањем се утврђује квалитет минералне сировине у лежишту које се истражује. На основу добијених података компетентно лице геолошке струке (са одговарајућом лиценцом) утврђује (процењује) минералне ресурсе које, по растућем нивоу (степену) геолошке проучености и поузданости, разврстава у поткласе претпостављених, индицираних и измерених ресурса. Индициране и измерене ресурсе, након примене адекватних техничко-економских струдија (претходне студије изводљивости и студије изводљивости), које укључују разматрање модификујућих фактора, компетентно лице рударске струке (са одговарајућом лиценцом) преводи (конвертује) у одговарајуће резерве: по растућем нивоу детаљности и поузданости ових студија – у вероватне и доказане резерве.

Рударска фаза се изводи у три сукцесивна стадијума: стадијум пројектовања (дизајнирања) рудника, стадијум изградње рудника и стадијум производње рудника. Стадијуми рударске фазе, као и посебна геолошка истраживања која се изводе у стадијуму производње рудника (експлоатациона истраживања) су у овом раду наведени, али нису разматрани јер нису обухваћени третираном темом.

Подела геолошке фазе на стадијуме целисходна је и са научног и са практичног аспекта. Она омогућава да се, на крају појединих стадијума, упоређују геолошким пројектом (планом) прогнозирани резултати и његовим извођењем добијени

performed gradually, in two phases: the primary geological (exploration or preinvestment) phase – by carriers of geological exploration and the following mining (investment) phase –by carriers of the exploitation – only in case of positive results obtained in the geological phase.

The geological phase, as a rule, is performed in four successive stages: the initial reconnaissance stage and the following prospecting, general (preliminary) exploration and detailed exploration stages. In every successive stage is performed an increasing number of exploratory workings (in denser gits) by which is established quantity of the mineral raw material and an increaing number of samples is taken for testing of the raw material in a deposit being explored. On the basis of the data obtained a competent person of geological profession (possessing a proper licence) estimates mineral resources and, according to an increasing level (degree) of geological knowledge and confidence, classifies them into subclasses of inferred, indicated and measured resources. Indicated and measured resources are, after application of adequate technical–economic studies (the preliminary feasibility study and the feasibility study), which include consideration of the modifying factors, a competent person of mining profession (possessing a proper licence) converts into the corresponding reserves: according to the increasing level of detailedness and confidence of the studies – into probable and proved reserves.

The mining phase is performed in three successive stages: the mine design stage, the mine construction stage and the mine production stage. The stages of the mining phase, as well as a special geological exploration performed in the mine production stage, are just mentioned but not considered in this paper because they are not included in the theme treated.

The division of the geological phase into stages is suitable both from scientific and practical aspects. It enables, at the end of any stage, a comparison between the results prognosticated by a geological project and the results obtained резултати, тако да се сваки наредни стадијум започне са неопходним корекцијама геолошког пројекта или се пак обуставља његова даља реализација (уколико су добијени резултати негативни).

Истраживања минералних лежишта кроз све стадјуме геолошке фазе поглавито се врше код великих и геолошки сложених лежишта, новопронађених или недовољно истражених. Код мањих и геолошки једноставних лежишта често се поједини стадијуми спајају (нпр. стадијуми проспекције и претходних истраживања, претходних и детаљних истраживања) ради уштеде времена и смањења трошкова, али само ако овај поступак даје задовољавајуће резултате.

У стадијуму рекогносцирања изводи се операција рекогносцирања изабраног региона са резултујућом минерагенетском анализом – у циљу идентификовања подручја са повишеном минералном потенцијалношћу (перспективних подручја) у којима ће се вршити проспекција. У том, иницијалном стадијуму геолошке фазе прикупљају се, селектују и анализирају подаци ранијих проучавања и истраживања (геолошких, геофизичких, геохемијских и даљинске детекције – нарочито специјалних авионских и сателитских снимака, укључујући контролне теренске опсервације и провере, као и коришћење дронова), под руководством компетентног лица геолошке струке. Минерагенетска анализа може да укаже на постојање минералних концентрација у перспективним подручјима. Због ниског нивоа геолошке проучености идентификованих перспективних подручја и поузданости постојећих података у овом стадијуму се не могу добити минерални ресурси, него се само дају „резултати истраживања“ (или, прецизније, резултати рекогносцирања).

Добијени резултати се приказују у одговарајућем документу (геолошком извештају о рекогносцирању са минерагенетском анализом потенцијалности) на основу којег се, уколико су резултати позитивни, пројектују (планирају) и изводе истражни радови у перспективним подручјима у следећем стадијуму проспекције.

by its realization so that every stage begins with necessary corrections of the project or the whole mineral project could be abandoned (in case of negative results).

Exploration of mineral deposts throughout all stages of the geological phase is applied mostly in case of big and geologically complex newly discovered or poorly explored depostits,. In case of small and geogically simple deposits some stages could be joined (e.g. stages of prospecting and preliminary exploration, preliminary and detailed explorations), in order to save time and reduce costs, but only if this act offers satisfactory results.

In the reconnaissance stage is carried out the reconnaissance operation in a chosen region with the resulting minerogenetic analysis of mineral potentiality, aimed at identifying areas of increased minareal potentiality (prospective areas) in which prospecting should be performed. In that, initial stage of the geological phase are gathered, selected and analysed data of previous studies and exploration (particularly geological, geophysical, geochemical and remote sensing – mainly special aerial and satelite images, followed by control field observations and checks, including application of drones), by a competent person of geological profession. The analysis could show that the area(s) contain mineral concentrations. Due to a low level of geological knowledge concerning prospective areas and confidence of the existing data, in this stage could not be obtained mineral resources but only„exploration results“ (or, more precisely, reconnaissance results).

The results obtained are presented in a proper geological document (the report on reconnaissance with the minerogenetic analysis of mineral potentiality) on the basis of which, if the results are positive (favourable), the following geological exploration (in the prospecting stage) is planned and performed in prospective areas.

У стадијуму проспекције, у идентификованом перспективним подручјима се обављају геолошким пројектом предвиђена геолошка, геофизичка и геохемијска истраживања и изводе истражни радови мањег обима, поглавито површински радови (раскопи, ровови, канали) и истражне бушотине. Из тих радова се узимају пробе за испитивање квалитета припадајуће минералне сировине – све у циљу лоцирања и грубог оконтуривања минералних концентрација у идентификованим перспективним подручјима и добијања првих података о битним особинама тих концентрација. На основу добијених резултата се процењује да ли нека од њих, првенствено у погледу количине и квалитета припадајуће минералне сировине, представља лежиште, у којем компетентно лице геолошке струке утврђује минералне ресурсе, које оконтурује, процењује и класификује као претпостављене ресурсе.

Због малог броја истражних радова и из њих узетих проба, ниво геолошке проучености и поузданости у овом стадијуму је знатно нижи него у наредном стадијуму претходних (генералних) истраживања, тако да се у одговарајућој техничко-економској студији (студији могућности), која има оријентациони карактер, не могу применити модификујући фактори и не може вршити превођење (конверзија) петпостављених ресурса у вероватне резерве. За то је неопходно да се, даљим истраживањима, претпостављени ресурси унапреде у индициране ресурсе, чија је конверзија у вероватне резерве могућа.

Претпостављени ресурси се приказују у одговарајућем геолошком извештају о проспекцији и у пратећој студији могућности и служе за пројектовање и извођење бројнијих истражних радова у наредним стадијумима (претходних и детаљних истраживања) у циљу добијања индицираних и измерених ресурса.

У стадијумима претходних (генералних) и детаљних истраживања изводи се велики број различитих истражних радова (праћених систематским опробавањем) предвиђених одговарајучим геолошким пројектом: површински радови (раскопи,

In the stage of prospecting, in the identified prospective areas are carried out, in accordance with a geological project, geological, geophysical and geochemical studies and a small number of exploratory workings: mainly surficial ones (ditches, trenches, channels) as well as expoloratory boreholes, which from are taken samples for testing quality of raw material, all in order to locate and delineate coarsly mineral concentrations in identified prospective areas and to get first data on their essential characteristics. On the basis of the results acieved it is estimated whether any of the concentrations, mainly regarding quantity and quality of the belonging mineral raw material, represents a deposit to which a competent person of geological profession determines boundaries and, inside them, establishes mineral resources which delineates, estimates and classifies as inferred resources.

Due to a minor number of exploratory workings and samples taken from them, the level of geological knowledge and confidence in the stage is considerably lower than in the next stage of preliminary (general) exploration so that, in the appropriate technical-economic study (the opportunity study), which has an orientational character, the modifying factors could not be applied and the conversion of inferred resources into pobable reserves is not possible. To make it possible an inferred resource must be upgraded by new exploratory workings up to the indicated resource.

The inferred resources are presented in an appropriate geological report on prospecting and the accompanying opportunity study and serve for projecting (planning) and performing of a greater number of exploratory workings in the following stages (of prelininary and detailed explorations) in order to obtain indicated and measured resources.

In the stages of preliminary (general) and detailed explorations a great number of various exploratory workings followed by systematic sampling (forseen in the appropriate geological project) is performed: surficial ones (ditches, trenches, channels, exploratory shafts, exploratory stages), expoloratory boreholes and ровови, канали, истражна окна, истражне етаже), истражне бушотине и подземни радови (истражни поткопи, истражни нископи) из којих се добијају подаци о битним особинама истраживаног лежишта (распрострањењу – хоризонталном и вертикалном, облику, пружању и паду; дебљини, минералном и хемијском саставу и запреминској маси минералне сировине) и њиховој променљивости, који служе као основ за валидно утврђивање граница лежишта, као и за оконтуривање, процену и класификовање минералних ресурса (у индициране и измерене) у лежишту.

Подаци добијени из изведених истражних радова (укључујући одговарајућа испитивања узетих проба), који морају бити репрезентативни (да имају задовољавајућу тачност и поузданост), разматрају се од стране компетентног лица геолошке струке, које оконтурује и процењује минералне ресурсе у истраживаном лежишту и, према растућем нивоу (степену) геолошке проучености и поузданости, класификује их у индициране и измерене. Ове ресурсе, потом, на основу одговарајућих техничко-економских студија (које укључују разматрање (вероватне и доказане). Ваља, међутим, истаћи да се код процене резерви, осим минералне сировине установљене истражним радовима у лежишту (in situ), узимају у обзир разблажења и губици који се јављају при експлоатацији.

Минерални ресурси, као и из њих изведене минералне резерве, у горе поменутим геолошким и техничко-економским документима, приказују се текстуално, графички (на картама, плановима, профилима и дијаграмима) и нумерички (у јединицама масе: t, kg, g/t или у јединици запремине: m^3).

Извештавање о добијеним резултатима и одговарајућа регулатива

Будући да су по Уставу Републике Србије рудна богатства (као и сва друга природна богатства) државна својина, носиоци истраживања минералних сировина у лежиштима

undergound ones (exploratory adits, exploratory winzes) from which are obtained data on essential characteristics of a deposit being explored (its spread – both horizontal and vertical, shape, strike and dip, thickness, mineral and chemical compositions and bulk density of the raw material) and their changeability (variance) which serve as a basis for valid establishing of the deposit's boundaries as well as for delineation, estimation and classification of the resources within the deposit (into indicated and measured ones).

The data obtained from exploratory workinngs (including proper testing of samples taken from them), which should be representative (of satisfactory accuracy and confidence), are considered by a competent person of geological profession who delineates and estimates mineral resources in the deposit being explored and, in accordance with an increasing level (degree) of geological knowledge and confidence, classifies them into indicated and measured ones. After that, on the basis of an appropriate technical-economic study (that includes consideration of the modifying factors) – the preliminary feasibility study (prefeasibility study) and the feasibilita study, a competent person of mininig profession converts the resources into the corresponding reserves (probable and proved ones). It is noteworthy that at the estimation of the resources, besides the mineral raw material established by exploratory workings in a deposit (*in situ*), dilutions and losses ocurring during exploitation are taken into consideration.

Mineral resources as well as the reserves derived from them, in geological and technical-economic documents mentioned above, are presented textually, graphically (in maps, plans and profiles) and numerically (in mass units: t, kg, g/t or in the volume unit: m^3).

Reporting of the results achieved and appropriate regulation

Since mineral wealth (as all other natural wealth) in the Republic of Serbia, according to its Constitution, represents state property, carна територији Србије (компаније, предузетници) - који поседују дозволу за геолошка истраживања у одређеном простору - истражном простору, законски [6] су обавезни да добијене резултате периодично приказују у адекватним извештајима (годишњим, завршном) и достављају ресорном Министарству (Министарству рударства и енергетике), односно повереном надлежном органу покрајине, за преглед и евиденцију. Након завршног извештаја о обављеним геолошким истраживањима носилац истих израђује елаборат о утврђеним (процењеним) минералним ресурсима и резервама и доставља га ресорном Министарству, односно надлежном покрајинском органу, који уз стручну помоћ експертских р*а*дних груп*а*, образованих посебним актом ресорног Министра (односно надлежног покрајинског органа) разматрају, прихватају (или одбијају) и верификују прихваћене ресурсе и резерве, које се евидентирају и укључују у државни биланс. За прихваћене и верификоване ресурсе и резерве издаје се одговарајућа потврда.

Верификоване минералне резерве (доказане и пратеће вероватне) у лежишту служе као основ за издавање компанијама и предузетницима дозволе за експлоатацију тих резерви у оквииру пројектованог експлпатационог поља. При томе приоритет имају они који су, као носиоци геолошких истраживања иста успешно обавили и прописно верификовали добијене резерве и ресурсе.

Носиоци геолошких истраживања минералних лежишта јавно обзнањују добијене резултате у виду сажетих приказа и информација у различитим медијима (штампаним, електронским) намењених инвеститорима, потенцијалним инвеститорима и њиховим саветницима, берзама, банкама и свима заинтересованим за минерални пројекат.

За извештавање о резултатима истраживања минералних лежишта и утврђеним минералним ресурсима и резервама у данашње време у свету се највише користе интернационални CRIRSCO Template [2], чији је европски члан PERC Стандард [1], i класификација Уједињених Нација - UNFC

riers of exploration of mineral raw materials in the deposits situated on the territory of Serbia (companies, enterprenours) that possess permit for geological exploration in a certain space - an exploration space (field), are legally [6] obliged to submit periodically the results obtained to the competent ministry (Ministry of Mining and Energy) or to the entrusted authorized organ of an autonomous region, presented in appropriate reports (annual, final) for inspection and file. After a final report on the geological exploration completed, the carriers make a report on established (estimated) mineral resources and reserves and submit it to the Ministry (or to the authorized (estimated)organ of an autonomous region) which, with the professional help of expert *Working Groups,* formed by the special act of the competent Minister (or of the authorized organ of an autonomous region), consider, accept (or reject) and verify the accepted resources and reserves which are filed away and assigned to the state ballance. For the accepted and verified resources and reserves a proper certificate is issued.

Verified mineral reserves (prooved and the accopanying probable) in a deposit serve as a basis for issuing permits (to companies and enterprenours) for exploitation (extraction) of the reserves in the frame of the projected exploitation field. In that respect priority have the ones that, as carriers of geological exploration, completed it successfully and verified legally the reserves acheived.

Carriers of geological exploration of mineral deposits announce in public the results obtained in the form of brief presentaioins and informations in various media (printed, electronic) intended for investors, potential investors and their advisers, stock markets, banks and for all interested in a mineral project.

For reporting of results of exploration of mineral deposits and of established resources and reserves in the world contemporary practice are mostly used the international CRIRSCO Template [2] includig its European member PERC Standard [1] and United Nations Clas-

[3], који су међусобно усаглашени. Наиме, доказаним резервама из [1,2] одговара код 111 из [3], вероватним резервама - код 112, измереним ресурсима - код 221, индицираним ресурсима - код 222, претпостављеним ресурсима - код 223, а резултатима истраживања из [1,2] - код 334 из [3].

Класификација Уједињених Нација [3] примењена је као основ за нацоналне класификације минералних ресурса и минералних резерви многих земаља (нпр. у Кини, Индији, Мексику) а примењује се и код свих минералних пројеката које финансира ова светска организација.

Ми сматрамо да Србија, као европска земља, своју регулативу у области геолошких истраживања и рударства треба да усагласи са одговарајућом регулативом Европске Уније: законима, кодексима, прописима, стандардима, директивама, који су ефикасни и признати у свету. То се односи на Закон о рударству и геолошким истраживањима Републике Србије [6] и на његове подзаконске акте (пре свега на будући Правилник *о извештавању о резултатима геолошких истраживања, ресурсима и резервама чврстих минералних сировина и њиховој класификацији*) које треба хармонизовати са паневропским PERC Стандардом [1]. Потоњи је, као члан „CRIRSCO фамиље“, у свету широко прихваћен (од стране водећих рударских компанија, банака, инвестиционих фондова, берзи, државних органа и других значајних институција већине земаља). Овој „фамилији“ иначе припадају још и аустралијски JORC Code, канадски CIM Guidelines, амерички SME Guidelines, јужноафрички SAMREC Code, руски NAEN Code и други национални кодекси и стандарди. У PERC Стандарду (као и у осталим члановима CRIRSCO „фамилије“) дате су темељне одредбе (минимум стандарда, препорука и упутства) за извештавање о резултатима истраживања, минералним ресурсима и минералним резервама, али се носиоцима истраживања и од њих ангажованим стручњацима дају значајна овлашћења (уз одговарајућу одговорност) за креативан приступ и оригинална решења код планирања истраживања, њиховог извођења и интерпретације добијених резултата.

sification - UNFC [3], which are mutually harmonized. Namely, proved reserves [1,2] respond to code 111 [3], probable reserves - to code 112, measured resources - to code 221, indicated resources - to code 222, inferred resources - to code 223, and exploration results [1,2] respond to code 334 [3].

The United Nations classification [3] has been adopted as the basis of national mineral resources/reserves clasification in many countries (e.g. in China, India, Mexico) and has been used in all mineral projects financed by this world organization.

We think that Serbia, as a European country, should harmonize its legislation in the field of geological exploration and mining with the corresponding EU legislation (laws, codes, regulations, standards, directives) which are efficient and recognized in the world. It refers to Serbian Law of Mining and Geological Exploration [6] and its accompanying acts (first of all to the future *Book of Regulations of Reporting Exploration Results, Resources and Reserves of Solid Mineral Raw Materials and Their Classification)* which should be harmonized with the Pan-European PERC Standard [1]. As a member of the “CRIRSCO family” the latter is widely accepted in the world (by the leading mining companies, banks, investment funds, stock markets, governmental agencies and other important institutions. To the “family” also belong Australian JORK Code, Canadian CIM Guidelines, USA SME Guidelines, South African SAMREC Code, Russian NAEN Code and other national codes and standards. The PERC Standard (as well as the other members of the CRIRSCO „family“) sets out principal rules (minimum standards, recommendations and directions) concerning reporting of exploration results, mineral resources and mineral reserves but significant authority (and resposability) is given to carriers of exploraton as well as to experts engaged by them for a creative approach and original solutions in planning of mineral exploration, its performing and interpreting of the results obtained.

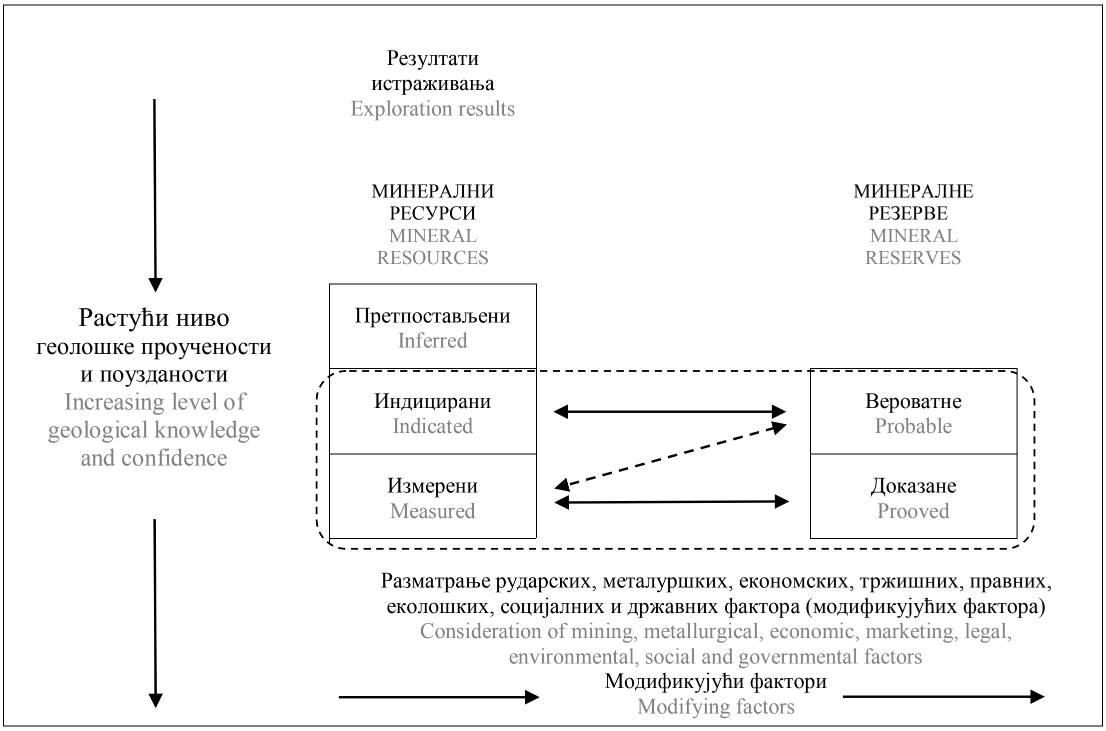
It should be stressed that both CRIRSCO Template and PERC Standard allow, after keeping

Важно је истаћи да PERC Стандард [1], као и CRIRSCO Template [2], дозвољавају да се, уз придржавање њихових истоветних темељних одредаба, у националне правилнике укључе и нека додатна упутства за поједине земље специфичне и/или значајне минералне сировине, типове њихових лежишта и методе њиховог истраживања, али под условом да та додатна упутства нису у колизији са неком од темељних одредаба поменутих кодекса. Таква додатна упутства свакако треба унети у будући српски Пр*а*вилник.

У актуелном Закону [6] само делимично је прихваћен PERC Standard [1], а још увек није донет горе поменути нови Пр*а*вилник. Стога се у пракси користи стари Правилник [7] везан за Закон [8] бивше СФР Југославије, који је застарео и превазиђен (сачињен је за ту социјалистичку државу), што проузрокује велике проблеме, нарочито у комуникацији са иностраним институцијама, компанијама и стручњацима. Због тога је неопходно доношење новог, савременог српског Пр*а*вилник*а*, хармонизованог са PERC Стандардом (чији су главни елементи приказани у т*абели 1).*

their principal rules, to include in national codes (books of regulations) some additional instructions for the countries' specific or significant mineral raw materials, types of their deposits and methods of their exploration but on condition that the instructions are not in collision with any of the rules. Such additional instructions should be included in the future Serbian *Book of Regulations.*

In the actual Serbian Law [6], the PERC Standard [1] is adopted partly as the *Book of Regulations* mentioned above has not passed up to now. Therefore in practice is used the Book of Regulations [7] bound to the Law [8] of the former SFR Yugoslavia, which is out-of-date and superseded (it was created for the socialist country) what causes big problems, especially in communication with foreign institutions, companies and experts. For that reason passing of a new, contemporary Serbian *Book of Regulations*, harmonized with the PERC Standard (main elements of which are presented in *Table 1*), is indispensable.



Табела 1, Генерални однос између резултата истраживања, минералних ресурса и минералних резерви, по PERC Стандарду [1]

Table 1, General relation between exploration results, mineral resources and mineral reserves according to the PERC Standard [1]

Правилник [7] садржи детаљна упутства за спровођење истражног процеса код лежишта чврстих минералних сировина, како заједничка (за све сировине) тако и посебна упутства (за 43 значајне сировине). Ова упутства се односе на пројектовање и извођење истражних радова, опробавање и испитивање минералне сировине, утврђивање „резерви" сировине у лежишту, класификацију и категоризацију утврђених „резерви" и вођење евиденције о њима.

Сходно Правилнику [7], „резерве" чврстих минералних сировина се, према степену истражености и степену познавања одговрајуће минералне сировине, разврставају у категорије А, В, C_1, C_2, D_1 и D_2, а, зависно од могућности рентабилне експлоатације, „резерве" А, В i C_1 категорије се разврставају у класе билансних и ванбилансних.

„Резерве" А, В и C_1 категорије се „прорачунавају", „резерве" C_2 категорије „процењују", а "резерве" D_1 и D_2 категорије „претпостављају". Највеће дозвољене грешке код „прорачуна резерви" (заправо процене ресурса и резерви) и одговарајуће вероватноће (поузданости) њиховог утврђивања прописане су: за А категорију ±15 % (са вероватноћом 85%), за В категорију ±30% (са вероватноћом 70%) и за C_1 категорију ±50% (са вероватноћом 50%).

Степен истражености лежишта одређује се односом утврђених „резерви" категорија А+В/ /А+В+C_1.

Код актуелних минералних пројеката у свету се обично тражи да највеће дозвољене грешке и одговарајуће вероватноће (поузданости) процене ресурса буду у интервалима: за измерене ресурсе ±10-15% (са вероватноћом 85-90%), за индициране ресурсе ±15-30% (са вероватноћом 70-85%), а за претпостављене ресурсе ±50-70% (са вероватноћом 30-50%).

Треба имати у виду да је југословенска регулатива у погледу минералних „резерви" [7, 8] била сачињена по угледу на одговарајућу регулативу тадашњег Совјетског Савеза [4] укључујући у њој коришћене дефиниције, класификацију и терминологију, у којој не

The Book of Regulations [7] contains detailed instructions for perfoming of exploration process at deposits of solid mineral raw materials, both common (for all the materials) and special (for 43 significant raw materials). The instructions relate on planning and carrying out of exploratory workings, sampling and testing of a raw material, establishing of "reserves" of a raw material in a deposit, classification and categorization of established "reserves" and on keeping files about them.

According to the Book of Regulations [7] "reserves" of solid mineral raw materials are divided, according to a degree of exploration and a degree of knowledge of the appropriate raw material, into categories A, B, C_1, C_2, D_1 and D_2 which, according to the possibility of profitable exploitation, are divided into balance and out-of-balance.

"Reserves" of categories A, B and C_1 are "calculated" "reserves" of C_2 category are "estimated" and "reserves" of D_1 and D_2 categories are "inferred". The prescribed accuracy of the "calculated categories", expressed by permitted errors, is: for the category A ±15% (at the probability of 85%), for the category B ±30% (at the probability of 70%) and for the category C_1 ±50% (at the probability of 50%).

The degree of exploration of a deposit is determined by the relation: A+B/A+B+C1 categories of „reserves" established.

As to contemporary mineral projects in the world it is usually demanded that the error limits and the corresponding probabilities (confidences) of estimation of mineral resources should be: for measured resources ±10-15% (at the probability level of 85-90%), for indicated resources ±15-30% (at the probability level of 70-85%) and for indicated resources ±50-70% (at the probability of 30-50%).

It should be kept in mind indicated resources ±15-30% (at the probability level of 70-85%) and for inferred resources ±50-70% (at the probability level of 30-50%).that Yugoslavian legislation concerning mineral "reserves" [7,8] was created using Soviet legislation of that time [4] as a model, including definitions, classification and terminology in which did фигурира појам (и термин) „ресурси“ него је исти обухваћен појмом (и термином) „резерве“. У регулативи потоње Руске Федерације - NAEN Code [5] задржане су ознаке за напред наведене категорије, али су њихове дефиниције и класификација усклађене са CRIRSCO Template [2] класификацијом: на претпостављене, индициране и измерене ресурсе и на вероватне и доказане резерве.

Но, ваља напоменути да је, поред наведених недостатака, Правилник [7] одиграо значајну улогу у истраживању, оцени, класификовању и евидентирању минералних сировина и у некадашњој Југославији и у Србији.

Табела 2 приказује корелацију између „резерви“ чврстих минералних сировина (A, B, C_1, C_2, D_1 и D_2 категорије) из Правилника [7] и резултата истраживања, минералних ресурса и минералних резеви из PERC Standarda [1] (из предложеног српског Правилника: 14, 15), као и карту (мапу) њихове конверзије. Ова карта конверзије је потребна када се разматрају и користе подаци ранијих (из друге половине XX века и почетка XXI века) геолошких истраживања минералних лежишта у Србији и Југославији.

Главни елементи предложеног српског Правилника [14, 15] приказани су у т*абели 3*.

not exist the concept (and term) “resources” which was encompassed by the concept (and term) “reserves”. In regulations of the later Russian Federation - the NAEN Code [5] the categories have been kept but their definitions and classification have been harmonized with the CRIRSCO Template [2] classification: into inferred, indicated and measured resources and probable and proved reserves.

However, it shold be pointed out that, besides its shortcomings mentioned afore, the Book of Regulations [7] played a significant role in exploration, classification and keeping file on mineral raw materials in former Yugoslavia and Serbia.

Table 2 depicts correlation between “reserves” (categories: A, B, C_1, C_2, D_1 and D_2) of solid mineral raw materials from the Book of Regulations [7] and mineral reserves, mineral resources and exploration results from the PERC Standard [1] from the proposed Serbian *Book of regulations* [14, 15] and a scheme (map) of their conversion. This conversion map is necessary if data of earlier (from the second part of XX century and the beginning of XXI century) are considered or used.

Main elements of the proposed Serbian *Book of Regulations* [14. 15] are presented in *Table 3*.

Табела 2, Корелација између “резерви” чврстих минералних сировина из југословенског Правилника [7] *везаног за Закон* [8] *и резултата истраживања, минералних ресурса и минералних резерви из PERC Стандарда* [1] *усвојених у предложеном српском Правилнику* [14, 15] *и карта (мапа) њихове конверзије*

Table 2, Correlation between “reserves” of solid mineral raw materials from Yugoslavian Book of Regulations [7] *tied up to to the Law* [8] *and exploration results, mineral resources and mineral reserves from the PERC Standard* [1] *accepted in the proposed Serbian Book of Regulations* [14, 15] *and a map of their conversion*

<table>
<tr><td rowspan="2">PERC Стандард [1] и на њему базиран предлог српског Правилника [14, 15] / PERC Standard [1] and the proposal of the Serbian Rulebook based on it [14, 15]</td><td rowspan="2">Резултати истраживања Results of exploration</td><td colspan="3">Минерални ресурси Mineral resources</td><td colspan="2">Минералне резерве Mineral reserves</td></tr>
<tr><td>Претпостављени Inferred</td><td>Индицирани Indicated</td><td>Измерени Measured</td><td>Вероватне Probable</td><td>Доказане Prooved</td></tr>
<tr><td rowspan="3">Југословенски Правилник [7] везан за Закон [8] / Yugoslav Rulebook [7] related to the Law [8]</td><td colspan="6">Резерве чврстих минералних сировина Reserves of solid mineral raw materials</td></tr>
<tr><td>Потенцијалне Potential</td><td>Потенцијалне Potential</td><td colspan="2">Ванбилансне Out-of-balance</td><td colspan="2">Билансне Balance</td></tr>
<tr><td>D_1, D_2</td><td>C_2</td><td>C_1</td><td>A, B</td><td>C_1</td><td>A, B</td></tr>
</table>

Табела 3, Шематски приказ главних елемената предложеног српског Правилника о извештавању о резултатима истраживања, минералним ресурсима и минералним резервама, према [14, 15], *са допунама аутора*

Table 3, A diagrammatic presentation of main elements of the proposed Serbian Book of regulations on exploration results, mineral resources and mineral reserves, according to [14, 15], *supplemened by the author*

МИНЕРАЛНИ ПРОЈЕКТИ / MINERAL PROJECTS		
ФАЗЕ, СТАДИЈУМИ PHASES, STAGES	ДОБИЈЕНИ РЕЗУЛТАТИ RESULTS OBTAINED	ДОКУМЕНТИ DOCUMENTS
ГЕОЛОШКА ФАЗА GEOLOGICAL PHASE Стадијуми Stages		
Стадијум рекогносцирања Reconnaissance stage	Резултати истраживања (рекогносцирања) Results of exploration (reconnaissance)	Геолошки извештај Geological report
Стадијум проспекције Prospecting stage	Претпостављени ресурси Inferred resources	Геолошки извештај и Студија могућности Geological report and Opportunity study
G ↓ Стадијум претходних истраживања Stage of preliminary exploration	Индицирани ресурси Indicated resources ⟷ MF ⟷ Вероватне резерве Probable reserves	Геолошки елаборат и Претходна студија изводљивости Geological study and Preliminary feasibility study TE ↓
	⤡ MF	
Стадијум детаљних истраживања Stage of detailed exploration	Измерени ресурси Measured resources ⟷ MF ⟷ Доказане резерве Prooved reserves	Геолошки елаборат и Студија изводљивости Geological study and Feasibility study
РУДАРСКА ФАЗА MINING PHASE Стадијуми Stages		
Стадијум пројектовања рудника Mine design stage	Доказане и вероватне резерве Prooved and probable reserves	Инвестициони (рударски) пројекат Investment (mining) project
Стадијум изградње рудника Mine construction stage	Доказане и вероватне резерве Prooved and probable reserves	Инвестициони (рударски) пројекат Investment (mining) project
Стадијум производње рудника Stage of mine production	Доказане и вероватне резерве Prooved and probable reserves	Инвестициони (рударски) пројекат Investment (mining) project

Тумач: G - *Растући ниво геолошке проучености (степен истражености) лежишта и поузданости добијених података; TE -* Растући ниво (степен) детаљности и *поузданости техничко-економских студија;* MF - *Модификујући фактори.*

Legend: G - Increasing level of geological knowledge (degree of exploration) of a deposit and confidence of the data obtained; TE - Increasing level (degree) of detailedness and confidence of technical-economic studies; MF - The modifying factors.

Имајући у виду величине напред поменутих дозвољених грешака, није разложно да се минерални ресурси и минералне резерве приказују прецизним цифрама (нпр. 1 939.811 t), већ се оне заокружују на прву значајну цифру (1 940.000 t).

Having in mind values of the errors it is not reasonable to present mineral resources and mineral reserves in very precise figures (e.g. 1 939 811 t) but they are rounded to the first significant figure (1 940 000 t).

ГЛАВНА ОБЕЛЕЖЈА И МЕЂУСОБНИ ОДНОС РЕСУРСА И РЕЗЕРВИ

У овом поглављу размотрени су главна обележја минералних ресурса и минералних резерви и њихов међусобни однос.

Главна обележја минералних ресурса

Минерални ресурси, као што је у претходним поглављима поменуто, представљају оне делове лежишта у којима су изведеним истраживањима добијени повољни резултати у погледу њихових битних особина (карактеристика), пре свега у погледу количине и квалитета припадајуће минералне сировине, али није установљена њихова експлоатабилност (изводљивост технички ефикасне, економски профитабилне а еколошки прихватљиве експлоатације у садашњим условима). На бази података истраживања, у лежишту се минерални ресурси оконтурују, процењују и класификују: у поткласе претпостављених, индицираних и измерених ресурса и приказују у одговарајућем документу (извештају или елаборату) и то од стране компетентног лица геолошке струке. У том документу се даје и осврт на постојеће податке о геолошким (минералошко-петрографским, структурно-тектонским, хидрогеолошким, инжењерско-геолошким и другим релевантним) особинама лежишта, као и о привредно-географским (инфраструктурним, енергетским, тржишним и другим релевантним) карактеристикама шире околине лежишта.

Треба имати у виду да подаци добијени истраживањима минералних лешишта садрже неизбежне грешке због мање-више удаљених тачака опсервације, мерења или узорковања, као и због њиховог субјективног интерпретирања. Међутим, те грешке морају бити у дозвољеним границама да би се постигла задовољавајућа тачност и поузданост добијених резултата.

Дугогодишња искуства стечена истраживањем великог броја лежишта различитих минералних сировина, како у свету тако и код нас, показала су да се највеће грешке код утврђивања минералних ресурса јављају због неадекват-

MAIN TRAITS AND MUTUAL RELATION OF THE RESOURCES AND THE RESERVES

In this chapter are considered main traits of the resources and the reserves and their mutual relation.

Main traits of the resources

Mineral resources, as mentioned in previous chapters, represent these parts of deposits exploration of which displayed favorable results regarding their essential characteristics, in the first place about quantity and quality of the belonging mineral raw material, but their exploitability (feasibility of technically efficient, economically profitable and ecologically acceptable exploitation) in present conditions has not been established. On the basis of exploration data, mineral resources are delineated, estimated and classified: into three subclasses: inferred, indicated and measured ones, and are presented in a proper document (report) by a competent person of geological profession. The report includes a review on the existing data on geological (mineralogical-petrologic, structural-tectonic, hydrogeological, engineering-geological and other relevant) characteristics of a deposit and on economic-geographic (infrastructural, energetic, market and other relevant) characteristics of a wider surroundings of the deposit.

It should be kept in mind that the data obtained by exploration of mineral deposits contain unavoidable errors because they are collected from more or less distant points of observation, measuring or sampling and are interpreted subjectively. However, these errors should be in permitted limits as to have a satisfactory accuracy and confidence of the results achieved.

The experience of a long-lasting exploration of a great number deposits of various mineral raw materials, both in the world and Serbia, have shown that the biggest errors in establishing of mineral resources occur because of inadequate projecting and/or performing of exploratory workings, wrong measurements (in the field or in corresponding graphical attachments):

ног пројетовања и/или извођења истражних радова, погрешних мерења (на терену или на одговарајућим графичким прилозима): дужина – пре свега дебљина (моћности) лежишта односно рудних тела и њихових површина, због погрешне интерполације и екстраполације добијених података, због погрешног опробавања (избора врсте и распореда проба, њиховог узимања и обраде) и потоњих испитивања (лабораторијских, индустријских) узетих проба (садржаја корисне компоненте и штетних компонената, запреминске густине минералне сировине итд.), као и због погрешног уношења добијених података у компјутерски програм. Збир ових парцијалних грешака чини јединствену (укупну) грешку утврђених ресурса.

Из горе наведених разлога, за утврђивање минералних ресурса много су значајнији геолошки него математички фактори, те је утврђивање ресурса превасходно геолошки задатак (геолошка процена), а не математички задатак (математички прорачун). Тако, на тачност утврђивања ресурса далеко већи утицај имају геолошки фактори, као што су: концепција и методика истраживања лежишта (које треба да буду усклађене са битним особинама лежишта и њиховом променљивошћу), пројектовање истражних радова, њихово извођење (укључујући опробавање), испитивање узетих проба и, коначно, геолошка интерпретација добијених података, него математички фактори, као што су: рачунске методе и одговарајуће технике. Због тога се у пракси тежи за тим да се истраживањем лежишта добију што тачнији подаци и да се изврши што веродостојнија њихова геолошка интерпретација, а да се потом примене што једноставније математичке методе и технике утврђивања („прорачуна“) ресурса.

Главна обележја минералних резерви

Минералне резерве (вероватне и доказане), као што је у претходним поглављима поменуто, представљају експлоатабилне делове одговарајућих минералних ресурса (индицираних и измерених) у лежиштима, добијене конверзијом (превођењем) поменутих ресурса у одговарајуће резерве. Оне се окон-

regarding lengths – mostly thicknesses of deposits (or ore bodies) and their surfaces, because of wrong interpolation and extrapolation of the data obtained, because of wrong sampling (of a wrong choice of a kind and distribution of samples, of their taking and of their processing) and of latter testing (laboratory, industrial) of the samples taken (of contents of useful and detrimental components, of bulk density of a raw material etc.) as well as because of taking wrong data in a computer program. Sum of these partial errors makes a unique (total) error of the resources' estimate.

For the reasons mentioned above, for establishment of mineral resources much more significant are geological factors than mathematical ones so that establishment of the resources is mainly geological task, not mathematical task ("calculation"). So, much more influence on the accuracy of the resources have geological factors, as conception and the method of exploration of a deposit which should be in accord with geological properties of the deposit and their changeability (variation), projecting of exploratory workings and their performing (including sampling), testing of samples and, finally, geological interpretation of the data obtained than mathematical factors, as mathematical methods and the appropriate techniques. For that reason it is longed in practice of exploration of mineral deposits to obtain most accurate data as possible and to do their best possible interpretation by using simplest mathematical methods and techniques of estimation ("calculation") of the resources.

Main traits of the reserves

Mineral reserves (probable and proved), as mentioned in previous chapters, represent exploitable parts of the corresponding mineral resources (indicated and measured ones) in deposits obtained by conversion of the resources into the reserves. The reserves are delineated, estimated and classified on the basis of appropriate technical-economic studies (preliminary feasibility study and feasibility study) that include consideration of the modтурују, процењују и класификују на основу одговарајућих техничко-економских студија (претходне студије изводљивости и студије изводљивости) које укључују разматрање модификујућих фактора од стране компетентног лица рударске струке Минералне резерве се, по растућој детаљности и поузданости техничко-економских студија, разврставају у поткласе вероватних и доказаних резерви и приказују у одговарајућем документу: елаборату.

Ваља, међутим, напоменути да се код процене резерви узимају у обзир разблажења и губици минералне сировине који се јављају у експлоатацији.

Вероватне резерве имају задовољавајући ниво детаљности и поузданости, демонстриран у одговарајућој техничко-економској студији (претходној студији изводљивости укључујићи у њој примењене модификујуће факторе), а доказане резерве пак имају највиши ниво детаљности и поузданости, демонстриран у одговарајућој техничко-економској студији (студији изводљивости укључујући у њој примењене модификујуће факторе).

Утврђивање минералних резерви, на горе описан начин, врши компетентно лице рударске струке. Само они делови индицираних и измерених ресурса, за које поменуте техничко-економске студије дају позитивне резултате, преводе се у одговарајуће резерве: вероватне и доказане.

Модифкујући фактори представљају разматрања (анализе) која, при изради техничко-економских студија, врши горе поменуто компетентно лице, у циљу конверзије неексплоатабилних минералних ресурса (индицираних и измерених) у одговарајуће експлоатабилне минералне резерве (вероватне и доказане).

Најважнији модификујући фактори су: рударски (рударско-технички), технолошки (укључујући металуршке), еколошки, регионални (комуникације – путеви, железничке пруге, енергетски извори, насељеност, водоснабдевање, клима), економски (укључијући финансијску анализу и процену ризика), тржишни, законско-правни, социјални и државно-стратешки.

ifying factors by a competent person of mining profession (or a team of competent persons of other relevant professions, in the first place an expert in geology, led by the mining expert). The reserves are classified into subclasses of probable and proved ones according to increasing detailedness and confidence of technical-economic studies and presented in a proper document (report).

It is noteworthy that on the occasion of estimation of mineral reserves are taken into account dilutions and losses of mineral raw material which occur during its extraction.

Probable reserves have a satisfactory level of detailedness and confidence demonstrated in the corresponding technical-economic study (the preliminary one including the modifying factors applied). Proved reserves, however, have the highest level of detailedness and confidence demonstrated in the corresponding technical-economic study (the feasibility one, including the modifying factors applied).

Establishing of mineral reserves, in the way mentioned above, is performed by a competent person of mining profession. Only these parts of indicated and measured resources which for the abovementioned technical-economic studies offer positive results, are converted into the corresponding reserves (the probable and proved ones)-

The modifying factors are considered (analyzed), during completion of technical-economis studies), by competent persons mentioned above, in order to convert economically non-exploitable nineral resources (the indicated and measured ones) into the corresponding exploitable reserves (the probable and proved ones).

Most important modifying factors are: mining (mining-technical), technological (including metallurgical), ecological, regional (communications – roads, railroad tracks, energy sources, water sources population, climate), economic (including financial analysis and risk assessment), market, legal, social and governmental-strategic ones.

Овде ваља истаћи да се минералне резерве утврђују разматрањем актуелних модификујућих фактора. Уколико у току времена дође до значајне промене неког (или неких) од поменутих фактора, онда се приказане резерве морају преиспитати. Тако, у неким случајевима, раније утврђене резерве се морају превести назад – у одговарајуће ресурсе, што је приказано двостраним стрелицама у т*абелама 1* и *3*.

Минералне резерве (доказане и вероватне) служе инвеститорима као основ за инвестициона улагања у активности, објекте и производно активирање рудника у следећој – рударској фази минералних пројеката: у стадијумима пројектовања (дизајнирања), изградње и производње рудника.

Треба имати у виду да многе компаније, поред геолошким истраживањима и одоварајућим техничко-економским студијама утврђених експлоатабилних делова лежишта (*in situ*), у минералне резерве увршћују откопану, утоварену (за транспорт) и депоновану (лагеровану) минералну сировину намењену постројењима за њену припрему и прераду или пак продаји и третирају их као робу (енглески: *commodity*).

Међусобни однос ресурса и резерви

Разматрање међусобног односа минералних ресурса и минералних резерви показује да се они, иако геолошки тесно повезани, економски битно разликују. Ресурси, који се први утврђују (процењују) – на основу података добијених геолошким истраживањима лежишта (најважнији су подаци о количини и квалитету припадајуће минералне сировине), али није утврђена њихова експлоатабилност. Резерве се пак изводе из одговарајућих ресурса применом адекватних техничко-економских студија (*претходне студије изводљвости и студије изводљивости*) које *укључују разматрање модификујућих фактора*, на бази којих се установљава њихова експлоатабилост. *Због тога се они разврставају у посебне класе*: *ресурси у неекплоатабилну геолошку класу*, а *резерве у експлоатабилну економску кла-*

It should be mentioned that mineral reserves are established by consideration of actual modifying factors. If significant changes of one (or several) factors happen the reserves estimated should be reconsidered accordingly. Hence, in some cases, previously established reserves must be brought back – into the corresponding resources, what is shown by bilateral arrows in *Tables 1 and 3.*

Mineral reserves (proved and probable) serve to investors as a base for investing into activities, structures and mine activation of the next – mining (investment) phase of a mineral project: in the stages of mine design, mine construction and activation of mine production.

It is noteworthy that many companies, besides exploitable parts of mineral deposits, established *in situ* by geological exploration and the appropriate technical-economic studies, include in mineral reserves excavated, loaded (for transportation) and deposited (in stocks) mineral raw material aimed to plants for its beneficiation and processing or to sale, treat the raw material as *commodity*.

Mutual relation of the resources and the reserves

Consideration of mutual relation of mineral resources and mineral reserves demonstrates that they, although closely related geologically, essentially differ economically. The resources which are estimated first – on the basis of data obtained by geological exploration of the deposits (most important are data about quantity ans quality of the belonging mineral raw material) but their exploitability has not been established. The reserves, however, are derved from the corresponding resources by application of adequate technical-economic studies (the preliminary technical-economic study and the technical-economic study which include consideration of the modifying factors) on the basis of which their exploitability is established. Therefore they are classified into separate classes: the resources into the nonexploitable geological class and the reserves into the exloitable economic class. The resources are, according to the increasing *су. Ресурси се, по растућм нивоу (степену) геолошке проучености и поузданости, деле на поткласе претпостављених, индицираних и измерених, а резерве се, по растућем нивоу детаљности ипоуздaности одговарајућих техничко-економских студија, деле на поткласе вероватних и доказаних.*

Минерални ресурси (и то индицирани и измерени), утврђени геолошким истраживањима лежишта, дакле, чине неексплоатабилну геолошку (минерално-сировинску) базу из које се, применом поменутих техничко-економских студија, издвајају експлоатабилни делови - резерве (вероватне и доказане).

Минералне резерве (доказане и вероватне) служе као основ за инвестициона улагања у следећој, рударској фази извођења минералних пројеката: у стадијимима пројектовања, изградње и производње рудника.

РЕЗИМЕ

Резултати разматрања проблематике третиране у овом раду резимирани су у следећим закључцима и препорукама.

Закључци

- *Истраживања лежишта чврстих минералних сировина, намењена утврђивању минералних ресурса и из њих изведених минералних резерви, у геолошкој фази минералних пројеката, реализују се поступно: по сукцесивним стадијумима и то изводјењем растућег броја истражних радова (из којих се узима растући број проба за одговарајућа испитивања припадајуће минералне сировине), те се добија све већи број релевантних података.*
- *Минерални ресурси се утврђују, од компетентних лица геолошке струке, на основу података добијених геолошким истраживањима лежишта и рашчлањују се, по растућем нивоу геолошке проучености и поузданости, у претпостављене, индициране и измерене ресурсе.*

level (degree) of gelogical knowledge and confidence, divided into subclasses of inferred, indicated and measured ones while the reserves are, according to the increasing level of detailedness and confidence of appropriate technical-economic studies, divided into subclasses of probable and prooved ones.

So, indicated and measured mineral resources, established by geological exploration of mineral deposits, make up a nonexploitable geological (raw materials) base which from, by use of the technical-economic studies mentioned above, are singled out exploitable parts - mineral reserves (probable and prooved ones).

Mineral reserves (both prooved and probable) serve as a basis for investing in the next, mining phase of performing of mneral projects in stages of mine design, mine construction and mine production.

SUMMARY

The results of consideration of the problems treated in this paper are summarized in the following conclusions and recommendations.

Conclusions

- Exploration of deposits of solid mineral raw materials intended for establishing of mineral resources and mineral reserves derived from the resources, in the geological phase of mineral projects, are carried out gradually: in successive stages by performing of an increasing number of exploratory workings (from which are taken samples for the appropriate testing of the belonging mineral raw material) so that an increasing number of relevant data is obtained.
- The resources are established by competent persons of geological profession, on the basis of the data obtained by geological exploration of mineral deposits and, according to an increasing level of geological knowledge and confidence, are classified into inferred, indicated and measured ones.

- *Минералне резерве се изводе, од компетентних лица рударске струке, из индицираних и измерених ресурса* на основу *адекватних техничко-економских студија* (*претходне студије изводљивости и студије изводљивости*) *које укључују разматрање модификујућих фактора, и рашчлањују се, по растућем нивоу детаљности и поузданости тих студија, у вероватне и доказане резерве.*
- *Иако су минерални ресурси и минералне резерве геолошки тесно повезани, они се економски битно разликују: ресурси нису експлоатабилни, а резерве су експлоатабилне. Због тога се они разврставају у различите класе: ресурси у неексполатабилну геолошку класу, а резерве у експлоатабилну економску класу.*

Препоруке

- Регулативу Републике Србије у области рударства и геолошких истраживања треба у потпуности усагласити са одговарајућом регулативом Европске Уније: законима, прописима, стандардима и директивама, који су ефикасни и признати у свету. То се, пре свега, односи на будући српски *Закон о рударству и геолошким истраживањима* и пратећи *Правилник о извештавању о резултатима геолошких истраживања, ресурсима и резервама чврстих минералних сировина ии њиховој класификацији,* који треба да буду базирани на и усклађени са PERC Стандардом [1].
- Пошто PERC Стандард [1] дозвољава да се, уз придржавање његових темељних одредаба, у националне правилнике укључе и додатна упутства за поједине земље специфичне и/или значајне минералне сировине, типове њихових лежишта и методе њиховог истраживања, таква додатна упутства треба унети у будући српски Правилник.

- The reserves are derived from the corresponding resources (indicated and measured ones) by competent persons of mining profession on the basis of technical-economic studies (preliminary feasibility study and feasibility study) which include consideration of the modifying factors, and, according to an increasing level of detailedness and confidence of the studies, are classified into probable and proved reserves.
- Although mineral resources and mineral reserves are closely related geologically they essentially differ economically: the resources are not exploitable while the reserves are exploitable. Therefore they are classified into different classes: the resources into the non-exploitable geological class and the reserves into the exploitable economic class.

Recommendations

- Serbian legislation in the field of mining and geological exploration should be based on and fully harmonized with the corresponding legislation of the European Union: its laws, regulations, standards and directives which are efficient and recognized worldwide. First of all it refers to a future Serbian *Law of Mining and Geological Exploration* and the accompanying *Book of Regulations of Reporting Exploration Results, Resources and Reserves of Solid Mineral Raw Materials and Their Classification* which should be based on and harmonized with the PERC Standard [1].
- As the PERC Standard [1] permits that, if its principal rules are obeyed, in national books of regulations could be added special instructions for specific or important mineral raw materials, types of their deposits and methods of their exploration. Such additional instructions should be included in the future Serbian *Book of Regulations*.

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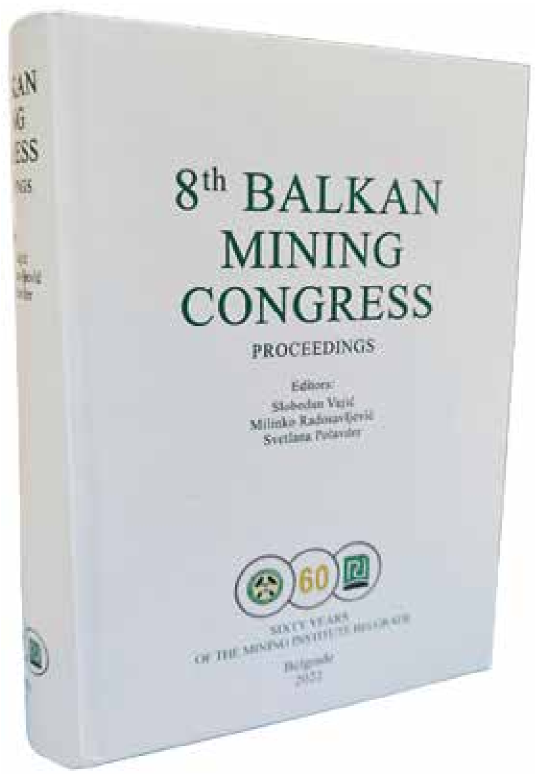
КЊИГЕ / BOOKS



8. БАЛКАНСКИ РУДАРСКИ КОНГРЕС - Зборник радова, издавач Рударски институт Београд, ISBN 978-86-82673-21-7 (РИ) CIP 622(082), 553(497)(082), COBISS.SR-ID 72313353, DOI: 10.25075/BMC.2022.00, Београд, 808 страна. Уредници: Академик проф. др Слободан Вујић, др Милинко Радосављевић, др Светлана Полавдер.

Публиковано је 90 радова, 206 аутора из 20 земаља са свих континената осим Африке, на теме из: Технологије експлоатације и припреме минералних сировина, рудничке логистике; рудничке геологије; хидрогеологије; механике стена и геомехнаике; заштите рудника од вода; техничких, технолошких, еколошких, социјалних и економских

8TH BALKAN MINING CONGRESS PROCEEDINGS, published by the Mining Institute Belgrade, ISBN 978-86-82673-21-7 (RI) CIP 622(082), 553(497)(082), COBISS.SR-ID 72313353, DOI: 10.25075 /BMC.2022.00, Belgrade, 808 pages. Editors: Academician Prof. Slobodan Vujić, PhD, Milinko Radosavljević, PhD, Svetlana Polavder, PhD

A total of 90 papers by 206 authors from 20 countries from all continents except Africa were published on topics in Technology of exploitation and processing of mineral resources, mining logistics; mining geology; hydrogeology; rock mechanics and geomechanics; mines protection from water; technical, technological, ecological, social and economic aspects аспекат експлоатације и припреме минералних сировина; планирања, пројектовања и оптимизација производње; математичко-моделских приступа; рачунарски интегрисаних технологија; ризика и управљања ризицима у рударству; примењених истраживања и иновација; развојних трендова у рударства; модернизације, ревитализација и реинжењеринг рудничких система; заштите животне и радне средине, рекултивацијр, ревитализације и уређења деградираних површина; аутоматизације и управљања процесима у рударству; праћења рада и одржавања опреме и машина у рудницима; стандарда, законске и нормативне регулативе; инжењерског образовања и образовних трендова; историје рударства и културног наслеђа.

Штампање књиге омогућили су Рударски институт Београд и Министарство просвете, науке и технолошког развоја Републике Србије.

Приредили
Ј. Нешковић
Р. Шарац

of exploitation and processing of mineral resources; production planning, design and optimization; mathematical model approaches; computer-integrated technologies; mining risks and risk management; applied research and innovation; development trends in mining; mining system modernization, revitalization and reengineering; working and living environmental protection, reclamation, revitalization and managing of degraded areas; mining automation and process management; mining equipment and machinery monitoring and maintenance; standards, legal and normative regulations; engineering education and educational trends; history of mining and cultural heritage.

Book printing was supported by the Mining Institute Belgrade and the Ministry of Education, Science, and Technological Development of the Republic of Serbia.

Prepared by
J. Nešković
R. Šarac

8. БАЛКАНСКИ РУДАРСКИ КОНГРЕС
8th BALKAN MINING CONGRESS

8. БАЛКАНСКИ РУДАРСКИ КОНГРЕС, 28-30. септембар 2022, Београд, хотел Фалкенштајнер, организатор Рударски институт Београд, суорганизатори Балканска академија рударских наука и Одељење рударских, геолошких и системских наука Академије инжењерских наука Србије.

У раду Конгреса учествовало је 150 стручњака из Србије, Румуније, Бугарске, Републике Српске БиХ, Турске, Црне Горе, Северне Македоније, Словеније, Албаније, Грчке, Хрватске, Русије, Кине, Немачке, Белгије, Аустралије, Канаде, Индонезије, Грузије и Сингапура.

На свечаности отварања Конгреса уручене су дипломе новим редовним и почасним члановима Балканске академије рударских наука.

Материјалну подршку организацији Когреса пружили су: Министарство просвете, науке и технолошког развоја Републике Србије; Рударски институт Београд; Dundee precious metals Бугарска; Tevel Словенија; Wood Аустралија; WBM Београд; Serbia Zijin copper doo Bor и Serbia Zijin mining doo Bor.

Према оцени учесника, Конгрес је веом успешно организован. У наставку је колаж фотографија са Конгреса.

Приредили:
Ј. Нешковић
Р. Шарац

8TH BALKAN MINING CONGRESS, September 28-30, 2022, Belgrade, Hotel Falkensteiner, organized by Mining Institute Belgrade, co-organized by Balkan Academy of Mining Sciences and Department for Mining and Geological Engineering Sciences of the Academy of Engineering Sciences of Serbia.

The Congress was participated by 150 experts from Serbia, Romania, Bulgaria, Republika Srpska, Bosnia and Herzegovina, Turkey, Montenegro, North Macedonia, Slovenia, Albania, Greece, Croatia, Russia, China, Germany, Belgium, Australia, Canada, Indonesia, Georgia, and Singapore.

At the Congress opening ceremony, diplomas were awarded to new full and honorary Balkan Academy of Mining Sciences members.

Material support for the Congress organization was provided by the Ministry of Education, Science, and Technological Development of the Republic of Serbia; Mining Institute Belgrade; Dundee Precious Metals Bulgaria; Tevel Slovenia; Wood Australia; WBM Belgrade; Serbia Zijin Copper doo Bor and Serbia Zijin Mining doo Bor.

According to the general participant evaluation, the Congress was organized very successfully. The collage of photos from Congress is below.

Prepared
J. Nesković
R. Šarac


VIII БАЛКАНСКИ РУДАРСКИ КОНГРЕС
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У СЕЋАЊУ
IN MEMORIAM

Петар Милановић, (Београд, 22. 06. 1931 – Београд, 07. 09. 2020), дипл. инж. рударства, др техничких наука, професор универзитета, истакнути стручњак за механику стена. Школовао се у Београду. На Рударском одсеку Рударско-геолошког факултета у Београду дипломирао 1962.

Специјализирао механику стена 1963/64. године на Missouri School of Mines and Metallurgy, Рола, САД, где је одбранио и магистарску тезу. Докторску дисертацију на тему *Прилог одређивања напона стенског масива при решавању специфичних проблема у рударству*, одбранио је 1965. на Рударско-геолошком факултету у Београду.

Усавршавао се и студијски боравио у ВНИМИ Лењинград, Институт Скочински Москва, Рударско-металуршка Академија Краков, и Главни рударски институт Катовице.

После завршене средње школе 1949. радио је као машински техничар у Жељезари Зеница, затим у Телеоптику Земун и Генералној дирекцији тешке индустрије у Београду. Као дипломирани рударски инжењер запослио се 1962. у Рударски институту у Земуну, где је радио као истраживач, начелник Одељења за механику стена и помоћник директора за науч-

Petar Milanović (Belgrade, June 22, 1931 – Belgrade, September 7, 2020), Mining Engineering, Doctor of Technical Sciences, University Professor, prominent rock mechanics expert. He was educated in Belgrade and graduated from the Mining Section of the Faculty of Mining and Geology in Belgrade in 1962.

Petar majored in rock mechanics in 1963/64 at the Missouri School of Mines and Metallurgy, Rolla, USA, where he also defended his master's thesis. In 1965, he defended his doctoral dissertation on the *Contribution to determining rock mass stress in solving specific mining problems* at the Faculty of Mining and Geology in Belgrade.

He studied at VNIMI Leningrad, Skochinsky Institute of Mining in Moscow, Krakow Mining and Metallurgical Academy, and the Central Mining Institute in Katowice.

After finishing secondary school in 1949, he worked as a mechanical technician at the Zenica Still Mill, then at Teleoptik Zemun, and the General Directorate of Heavy Industry in Belgrade. As a mining engineer, he got a job in 1962 at the Mining Institute in Zemun, where he worked as a researcher, Head of the Rock Mechanics Department, and Assistant Director of Scientific Development. He ни развој. Каријеру наставља 1971. на Рударско-геолошком факултету, на Катедри за опште рударске радове као доцента за предмет Механика стена. Један је од оснивача 1973. Катедре за механику стена на Рударском одсеку и први њен шеф. За редовног професора изабран је 1986.

На матичном факултету, Технички факултет у Бору, Рударско-металуршком факултету у Титовој (Косовској) Митровици и Рударско-геолошко-нафтном факултету у Загребу предавоа је на редовним или последипломским студијама Механику стена.

Руководио је израдом и био члан више комисија за одбрану дипломских радова, магистарских теза и докторских дисертација.

У Рударском институту увео је у процедуру фотоеластична испитивања напонско-деформационих стања стенских масива. Аутор или коаутор је 25 стручних и научних радова, 45 студија, научних и привредних пројеката, два помоћна уџбеника.

Био је продекана Рударско-геолошког факултета у Београду и шефа Катедре за механику стена, члан Савеза инжењера и техничара Југославије, Југословенског друштва за механику стена и подземне радове, Међународног друштва за механику стена (ISRM - International Society for Rock Mechanics) и Интернационалног бироа за механику стена (IBRM - International Bureau for Rock Mechanics, САД), Друштва за експериментал-

continued his career in 1971 at the Faculty of Mining and Geology, Department of General Mining, as an Assistant Professor of Rock Mechanics. In 1973, he was one of the founders and first head of the Department of Rock Mechanics within the Mining Section. He was elected Full Professor in 1986.

At his home faculty, the Technical Faculty in Bor, the Faculty of Mining and Metallurgy in Titova (Kosovska) Mitrovica, and the Faculty of Mining, Geology, and Petroleum Engineering in Zagreb, Petar taught Rock Mechanics in undergraduate or postgraduate studies.

He mentored the preparation and was a member of several graduate theses, master's theses, and doctoral thesis defense committees.

At the Mining Institute, he introduced the procedure of photoelastic tests of stress-strain states of rock masses. He is the author or co-author of 25 professional and scientific papers, 45 studies, scientific and economic projects, and two auxiliary textbooks.

He was Vice-Dean of the Faculty of Mining and Geology in Belgrade and Head of the Department of Rock Mechanics, a member of the Union of Engineers and Technicians of Yugoslavia, the Yugoslav Society for Rock Mechanics and Underground Works, the International Society for Rock Mechanics (ISRM), the International Bureau for Rock Mechanics (IBRM, USA), and the Sociну анализу напона (SESA – Society for Experimental Stress Analysis, САД).

За научне и стручне доприносе одликован је Ордена рада са сребрним венцем и носилац је више других признања.

Приредио
В. Чебашек

ety for Experimental Stress Analysis (SESA, USA).

Prof. Milanović was awarded the Order of Labor with Silver Wreath and several other recognitions for his scientific and professional contributions.

Prepared by
V. Čebašek

Јуриј Николајевич Малишев (Вороњеж, 1. 9. 1939 – Москва, 5. 9. 2022), дипл. инж. рударства, др техничких наука, професор, редовни члан Руске академије наука, оснивач и председник Руске академије рударских наука.

Дипломирао на Кемеровском рударском институту 1963. Професионалну каријеру започео је 1956. као радник на утовару у руднику угља Прокопиевск, 1963. прелази у Кемеровски рударски институт, 1985. постао је генерални директор удружења за угаљ Кузбаса, 1989. директор Института за рударство „А. А. Скочински", 1992. председник Комитета за индустрију угља Министарства горива и енергетике Руске Федерације. По налогу Владе 1993. именован је за генералног директора Државног предузећа „Руска компанија за угаљ" („Росугол"), после трансформације у акционарско друштво 1997. био је њен председник. Од 1997. водио је Савез индустријалаца и предузетника индустрије угља, а 1999–2013. био је председник Непрофитног партнерства „Рудари Русије".

Yuri Nikolaevich Malishev (Voronezh, September 1, 1939 – Moscow, September 5, 2022), **Mining Engineer**, Doctor of Technical Sciences, Professor, full member of the Russian Academy of Sciences, founder and President of the Russian Academy of Mining Sciences.

He graduated from the Kemerovo Mining Institute in 1963. Yuri started his professional career in 1956 as a loading worker in the Prokopyevsk coal mine. In 1963, he moved to the Kemerovo Mining Institute, in 1985 he became Director General of the Kuzbass coal cluster, in 1989 the Director of the A.A. Skochinsky Institute of Mining, and in 1992 he took office as Chairman of the Coal Industry Commission of the Ministry of Fuel and Energy of the Russian Federation. By order of the Government, in 1993 he was appointed Director General of Public Enterprise «Russian Coal Company» («Rosugol»). After it was transformed into a joint-stock company in 1997, he became its Chairman. From 1997, he led the Union of Industrialists and Entrepreneurs of the Coal Industry, and from 1999 to 2013, he chaired Non-Profit Partnership «Miners of Russia».

Малишев је дао значајан допринос унапређењу рударског законодавства, нарочито унапређењу пореског система заснованог на рационалном коришћењу рударске ренте, као и Закона о удружењу послодаваца, Закона о раду и других регулаторних правних аката. Велику подршку и помоћ пружао је побољшању ефикасности развоја минерално- сировинског комплекса, владиних агенција и рударског пословања у земљи. Посебно је значајна његова концепција горивног и енергетског биланса земље уз повећање удела угља, који је коришћен у изради Генералног локацијског плана електроенергетских објеката Русије до 2030. Малишев је припремио научне основе развоја еколошки прихватљиве енергије угља, предложио нова горива из угља (суспензија угаљ–вода и супер чисто угљенично гориво) и технологије сагоревања угља.

Као председник Државног геолошког музеја Руске академије наука „В. И. Вернадски”, био је покретач активног развоја најстаријег академског музеја у Москви, као модерног научног, информативног, образовног и културног центра. У сарадњи са Московским институтом за челик и легуре, Руским државним универзитетом за нафту и гас „И. М. Губкин”, Руским државним геолошким истраживачким универзитетом „Серго Орџоникидзе”, Московским државним универзитетом за геодезију и картографију, оформио је Међууниверзи-

Malishev contributed significantly to the improvement of mining legislation, especially the rationalized resource rent taxation, as well as the «Law on Association of Employers», «Labor Law» and other legal regulation. He provided great support and assistance in improving the efficiency of the development of the mineral resource complex, government agencies and mining operations in the country. His idea of the fuel and energy balance of the country with coal share increase is particularly significant and was used to develop the Russian General Scheme for the Location of Electricity Generating Facilities to 2030. In addition, Malishev prepared the scientific grounds for developing environmentally friendly coal energy, proposed new coal fuels (coal-water suspension and super-clean carbon fuel) and coal combustion technologies.

As the President of the Vernadsky State Geological Museum of the Russian Academy of Sciences, Malishev was the initiator of the active development of the oldest academic museum in Moscow as a modern scientific, informative, educational, and cultural center. In cooperation with Moscow Institute of Steel and Alloys, Gubkin Russian State University of Oil and Gas, Sergo Ordzhonikidze Russian State University for Geological Prospecting, Moscow State University of Geodesy and Cartography, he established the Interuniversity Academic Center for Navigation in the specialties of mining and geological profile, to provide school-faculty-business career guidance for young people.

тетски академски навигациони центар за рударске и геолошке специјалности, с циљем каријерног вођења младих на релацији школа–факултет–привреда.

Аутор је више од 160 научних радова, 50 патената и проналазака. Био је члан уређивачких одбора часописа *Угаљ* и *БЕРГ*, Савета Федералне службе за еколошки, технолошки и нуклеарни надзор, заменик председника Међународног организационог комитета Светског рударског конгреса и члан Међународног комитета за научна истраживања у индустрији угља.

Инострани је члан Академије инжењерских наука Србије, дописни члан Међународне инжењерске академије и редовни члан Евроазијске академије рударских наука.

За заслуге и доприносе одликован је Орденом заслуга за отаџбину, Орденом части и Орденом пријатељства. Заслужни је радник науке и технологије Руске Федерације. Лауреат је Награде Савета министара СССР-а, Државне награде Руске Федерације, Награде Владе Руске Федерације, Награде Лењинског комсомола, Дипломе за заслуге председника Руске Федерације, Значке кавалира „Рударска слава", Златне значке „Рудар Русије", Златне медаље „Дизел" Немачког института за проналаске, Командантског крста ордена заслуга за Републику Пољску итд.

Приредио:
С. Вујић

Malishev is the author of more than 160 scientific papers, 50 patents and inventions. He was a member of the editorial boards of «Ugalj» and «BERG» journals, the Council of the Federal Service for the Supervision of Environment, Technology and Nuclear Management, the Deputy Chairman of the International Organizing Committee of World Mining Congresses, and a member of the International Committee for Coal Industry Scientific Research.

He is a foreign member of the Academy of Engineering Sciences of Serbia, a corresponding member of the International Academy of Engineering, and a full member of the Eurasian Academy of Mining Sciences.

For his outstanding contributions, he was awarded the medal of the Order «For Merit to the Fatherland,» the Order of Honor and the Order of Friendship. He is an Honored Worker of Science and Technology of the Russian Federation, a laureate of the Council of Ministers of the Soviet Union Prize, State Prize of the Russian Federation, Government Prize of the Russian Federation, Lenin Komsomol Prize, Russian Federation Presidential Certificate of Honour, cavalier of the Honorary Badge «Mining Glory», Golden Badge «Miner of Russia», «Diesel» Gold Medal of the German Institute of Inventions, Commander's Cross of the Order of Merit for the Republic of Poland, etc.

Prepared by:
S. Vujić

Анте Глушчевић (Стари Трг, 23. 8. 1938 – Београд, 6. 5. 2022), дипл. инж. рударства, др техничких наука, истакнути српски рударски стручњак за подземну експлоатацију металичних минералних сировина. Школовао се у Београду и Косовској Митровици, где је матурирао 1955. Дипломирао је 1961. на Рударско-геолошком факултету Универзитета у Београду.

Магистарску тезу Студија одређивања димензија сигурносних стубова и стабилног распона у отвореним откопима Рудника Сасе одбранио је 1972. на Рударско-геолошком факултету у Београду, а докторску дисертацију Допринос изучавања техничких параметара откопавања сигурносних стубова методом подетажног зарушавања у циљу максималног искоришћења и минималног осиромашења 1976. такође на матичном факултету.

Стручну каријеру започиње у Руднику Трепча где је радио на месту управника производног погона, касније шефа техничке припреме. У Руднику Трепча радио је до 1969. кад прелази у Рударски институт у Београду, где ради као пројектант у звању вишег стручног сарадника. На Рударско-геолошки факултет Универзитета у Београду прелази 1973. Биран је за асистента на предметима Технологија подземне експлоатације неслојевитих лежишта и Истражни радови. Прошао је сва изборна звања, за редовног професора изабран је 1988.

Ante Gluščević (Stari Trg, August 23, 1938 – Belgrade, May 06, 2022), **Mining Engineer**, Doctor of Technical Sciences, prominent Serbian mining expert for underground exploitation of metallic resources. He was educated in Belgrade and Kosovska Mitrovica, where he finished school in 1955. In 1961, he graduated from the Faculty of Mining and Geology, University of Belgrade.

In 1972, he defended his master's thesis *Study of determining safety size of pillars and stable span in the open pits of the Sasa Mine* at the Faculty of Mining and Geology in Belgrade, and in 1976 his doctoral dissertation *Contribution of studying technical parameters of safety pillars excavation using sublevel caving method for maximum utilization and minimal depletion* also at the home university.

He began his professional career in the Trepča Mine, where he worked as a production manager, later as head of technical preparation. He worked in the Trepča Mine until 1969 when he moved to the Mining Institute Belgrade, where he worked as a senior associate designer. He moved to the Faculty of Mining and Geology of the University of Belgrade in 1973, where he was elected an assistant professor in *Non-stratified deposit underground exploitation* and *Exploration works* courses. He had been elected to all positions, and was appointed Full Professor in 1988.

He paid study visits to Sweden in 1974, Germany in 1976, Ради стручног усавршавања студијски је боравио у: Шведској 1974, Немачкој 1976, САД 1977, Канади 1977. и Финској 1978. Научноистраживачки рад др Глушчевића усмерен је ка области подземне експлоатације неслојевитих лежишта. Објавио је монографију, скрипта и више десетина научних и стручних радова. Као руководилац или члан тима учествовао је у изради више научних студија, бројних индустријских пројеката, стручних оцена и контрола. Руководио је израдом више дипломских радова, шест магистарских теза и једне докторске дисертације.

Био је на функцији продекана 1987–1989. и декана 1987–1991. Рударско-геолошког факултета у Београду, те шеф Катедре за подземну експлоатацију 1992–2003. За експерта Савезне владе за област рударства именован је 1993. Један је од оснивача и првих чланова Српског рударског друштва. Добитник је Медаље заслуге за народ 1963. Пензионисан је 2003.

Приредили:
Б. Глушчевић
Р. Шарац

the USA in 1977, Canada in 1977, and Finland in 1978. Dr. Glušćević's scientific research focused on underground exploitation of non-stratified deposits. He published a monograph, a script and dozens of scientific and professional papers. As the head or team member, he participated in the preparation of several scientific studies, numerous industrial projects, professional evaluations and controls. He mentored several diploma theses, six master's theses, and one doctoral dissertation.

Glušćević held the office of a vice dean and dean of the Faculty of Mining and Geology in Belgrade in 1987-1989 and 1987-1991, respectively. He was the Head of the Department of Underground Mining in 1992-2003. He was appointed a mining expert of the Federal Government in 1993, and is one of the founders and first members of the Mining Association of Serbia. He was awarded the Medal of Merit to the People in 1963. He retired in 2003.

Prepared by:
B. Glušćević
R. Šarac

Драган Ђорђевић (Бајчина, 23. 5. 1949 – Београд, 7. 4. 2022), дипл. инж. рударства, др техничких наука, универзитетски професор. Школовао се у Трепчи, Новом Брду, Лецу, Алексинцу и Косовској Митровици. Радио је годину дана у Алексиначким рудницима угља као техничар. На Смеру за рударска мерења Рударско-геолошког факултета Универзитета у Београду дипломирао је 1974.

Магистарску тезу Провера стохастичких законитости улегања поткопаног терена моделским испитивањима одбранио је 1986, а докторску дисертацију *Одређивање параметара померања поткопаног терена у рудницима угља са подземном експлоатацијом*, са посебним освртом на рударске законе и техничке нормативе у Југославији 1989. на матичном факултету.

По дипломирању радио је у Служби рударских мерења Рудника Трепча, а затим у Служби рударских мерења ИЕК Костолац. За асистента приправника изабран је 1980. на Катедри за рударска мерења Рударско-геолошког факултета у Београду, а након одбране магистарске тезе изабран је у звање асистента за предмет Рударска мерења. Прошао је сва изборна звања, за редовног професора изабран је 2007. Као хонорарни наставник држао је наставу на Техничком факултету у Бору и на Факултету техничких наука у Косовској Митровици.

Стручни и научни рад Д. Ђорђевића оријентисан је ка

Dragan Đorđević (Bajčina, May 23, 1949 – Belgrade, April 07, 2022), **Mining Engineer**, Doctor of Technical Sciences, University Professor. Dragan was educated in Trepča, Novo Brdo, Lece, Aleksinac and Kosovska Mitrovica. He worked for a year as a technician in the Aleksinac coal mines. In 1974, he graduated from the Department of Mine Surveying of the Faculty of Mining and Geology at the University of Belgrade.

In 1986, he defended his master's thesis *Verification of stochastic regularities of mine subsidence using model tests*, and in 1989 his doctoral dissertation *Determining parameters of underground exploitation coal mine ground movement with special reference to mining laws and technical standards in Yugoslavia*, also at his home faculty.

After graduating, he worked in the Mine Surveying Service of the Trepča Mine, and then in the Mine Surveying Service of IEK Kostolac. In 1980, he was appointed assistant trainee at the Department of Mine Surveying of the Faculty of Mining and Geology in Belgrade, and after defending his master's thesis, he took the office of Assistant Professor in *Mine Surveying* course. He had been elected to all positions, and was appointed Full Professor in 2007. He taught as a part-time teacher at the Technical Faculty in Bor and the Faculty of Technical Sciences in Kosovska Mitrovica.

D. Đorđević's professional and scientific work was focused рударским мерењима, посебно ка проблемима померања поткопаног терена и заштити објеката од утицаја рударских радова. Аутор или коаутор је више од 60 научних и стручних радова. Учествовао је у реализацији више научних и привредних пројеката. Коаутор је две монографске публикације, практикума и скрипата за предмет Померање поткопаног терена и заштита објеката од рударских радова.

Био је ментор или члан комисија за израду и одбрану више дипломских радова на Смеру за рударска мерења, члан комисија за одбрану магистарских теза и одбрану докторских дисертација.

У више мандата био је шеф Катедре и Смера за рударска мерења. Био је члан Међународног друштва за рударска мерења, члан његовог Председништва и Комисије за померање поткопаног терена. Био је члан Управног одбора РБ Колубара 2001–2004. и члан Републичке комисије за полагање стручног испита из Рударских мерења. Пензионисао се 2014.

Приредили:
А. Ганић
А. Милутиновић
Р. Шарац

on mine surveying, especially the issues of mine ground movement and protection of buildings from the influence of mining operations. He is the author or co-author of more than 60 scientific and professional papers. He participated in the implementation of several scientific and economic projects. He is the co-author of two monographs, a practicum, and a script for *Mine ground movement and protection of buildings in mining areas* course.

He was a mentor or a member of several graduation theses commissions at the Department of Mine Surveying, a member of master's theses and doctoral dissertation commissions.

Đorđević was the head of the Department for Mine Surveying for several terms. He was a member of the International Society for Mine Surveying, a member of its Presidency and of the Mine Ground Movement Commission. He was a member of the Board of Directors of RB Kolubara in 2001-2004 and a member of the Republic Commission for Mine Surveyor Licensure Examination. He retired in 2014.

Prepared by:
A. Ganić
A. Milutinović
R. Šarac

Слободан Димитријевић (Лесковац, 5. 11. 1942 – Београд, 9. 5. 2022), дипл. инж. рударства и дипл. инж. геодезије, др техничких наука, универзитетски професор. Школовао се у родном граду. На Рударско-геолошком факултету у Београду, на Смеру за рударска мерења, дипломирао је 1966. На Геодетском одсеку Грађевинског факултета Универзитета у Београду дипломирао је из области примењене геодезије. Архитектонски факултет уписао је 1963, а Саобраћајни факултет 1972. и апсолвирао 1980. Ради усавршавања студијски је боравио у Дрездену 1972. и више пута на Рударско-геолошком универзитету у Софији.

Магистарску тезу *Могућности одређивања гранулометријског састава одминиране стенске масе на површинским коповима фотограметријском методом мерења на основу лабораторијских истраживања одбранио је 1980, а докторску дисертацију Испитивање ефикасности и тачности класичног, терестричког и аерофотограметријског снимања површинских копова у зависности од технологије откопавања* одбранио је 1986. на матичном факултету.

У звање асистента за предмет Рударска мерења на Рударско-геолошком факултету изабран је 1969. Прошао је сва изборна звања, за редовног професора изабран је 1999. Предавао је и на Вишој геодетској школи у Београду.

Научна и стручна оријентација С. Димитријевића

Slobodan Dimitrijević (Leskovac, November 05, 1942 – Belgrade, May 09, 2022), **Mining Engineer** and Engineer of Geodesy, Doctor of Technical Sciences, University Professor. He was educated in his hometown and graduated in 1966 from the Faculty of Mining and Geology in Belgrade in the Department of Mine Surveying. At the Faculty of Civil Engineering of the University of Belgrade, he graduated from the Department of Geodesy, majoring in Applied Geodesy. He enrolled in the Faculty of Architecture in 1963 and the Faculty of Transport and Traffic Engineering in 1972, where he became senior undergraduate in 1980. He paid study visits to Dresden in 1972 and several times at the University of Mining and Geology in Sofia.

He defended his master's thesis *Possibilities of determining the granulometric composition of demined rock mass in open pit mines using laboratory research-based photogrammetry* in 1980, and his doctoral dissertation *Testing the efficiency and accuracy of classical, terrestrial and aerial photogrammetry imaging of open pit mines depending on excavation technology* in 1986 at his home university.

He was elected Assistant Professor in *Mine Surveying* course at the Faculty of Mining and Geology in 1969. He had been elected to all positions, and was appointed Full Professor in 1999. He also taught at the College of Geodesy in Belgrade.

S. Dimitrijević's Scientific and professional work focused on усмерена је ка примени геодезије у рударству. Аутор или коаутор је 80 научних и стручних радова, аутор уџбеника и коаутор четири монографије. Учествовао је у реализацији више научних и индустријских пројеката и студија.

Руководио је израдом или био члан комисија за одбрану више дипломских радова, магистарских теза и докторских дисертација на Рударско-геолошком и Грађевинском факултету у Београду.

Био је шеф Смера и Катедре за рударска мерења на Рударско-геолошком факултету, члан комисија Министарства за грађевинарство, Министарства за привреду и члан Комисије за полагање стручног испита за стицање лиценце за инжењерску геодезију. Пензионисан је 2008.

Приредили:
А. Ганић
А. Милутиновић
Р. Шарац

the application of geodesy in mining. He is the author or co-author of 80 scientific and professional papers, the author of textbooks and the co-author of four monographs. He participated in the implementation of several scientific and industrial projects and studies.

He mentored or was a member of the defense commissions for several graduate theses, master's theses and doctoral dissertations at the Faculty of Mining and Geology and Faculty of Civil Engineering in Belgrade.

He was the head of the Department of Mine Surveying at the Faculty of Mining and Geology, a member of the commissions of the Ministry of Construction, Ministry of Economy and a member of the Commission for Geodetic Engineer Licensure Examination. He retired in 2008.

Prepared by:
A. Ganić
A. Milutinović
R. Šarac

Тања Хафнер Љубеновић (Зајечар, 25. 12. 1964 – Београд, 10. 12. 2022), дипл. инж. геологије, одговорни сарадник за квалитет у Лабораторији за геомеханику Рударског института Београд.

Школовала се у родном граду. Наставила је породичну традицију и завршила студије геологије на Рударско-геолошком факултету у Београду, смер Геотехника 1989. године. Говорила је руски и енглески језик. Након завршених сту-

Tanja Hafner Ljubenović (Zaječar, December 25, 1964 – Belgrade, December 10, 2022), Engineer of Geology, responsible quality associate in the Laboratory for Geomechanics of the Mining Institute Belgrade.

She was educated in her hometown. She continued her family's tradition by completing geology studies at the Faculty of Mining and Geology in Belgrade, majoring in Geotechnics, in 1989. She spoke Russian and English. After completing her дија посветила се породици до 1998. године када је почела да ради у Рударском институту у Лабораторији за геомеханику, где је стасала у врсног стручњака за примењена геотехничка испитивања.

Аутор или коаутор је више стручних радова, бројних елабората и студија за рударство и грађевинарство и око хиљаду лабораторијских извештаја.

Под њеним руководством Лабораторија за геомеханику је за шест месеци акредитована, што је био велики подухват с обзиром на обим активности и потребних докумената. Радила је на увођењу нових стандарда, као и на осавремењавању лабораторије и увођењу нових метода. Систем квалитета у Лабораторији за геомеханику довела је до највишег нивоа. И поред тешке дуготрајне болести, до последњег дана радила је на унапређењу Лабораторије. Таква борбеност, снага и енергија духа ретко се срећу.

Била је члан Савеза инжењера и техничара Србије, Друштва за механику стена Србије, Инжењерске коморе Србије и Института за стандардизацију Србије.

Када нам је тешко, њена храброст и речи „није још време за плакање” мотивишу да наставимо стваралаштвом, поносни што смо је имали.

Приредила:
С. Јанковић

studies, Tanja devoted herself to her family until 1998, when she started working at the Mining Institute in the Laboratory for Geomechanics, where she became an exceptional expert in applied geotechnical testing.

She is the author or co-author of several professional papers and studies in mining and construction, and about a thousand laboratory reports.

Under her leadership, the Laboratory for Geomechanics was accredited in 6 months, which was a huge undertaking considering the scope of required activities and documents. She worked on introducing new standards, as well as modernizing the Laboratory and introducing new methods in its operations. She brought the quality system in the Laboratory for Geomechanics to the highest level. Despite a severe long-term illness, she worked on improving the Laboratory until her last days. One can rarely encounter such persistence, strength and energy.

She was a member of the Union of Engineers and Technicians of Serbia, the Serbian Society for Rock Mechanics, the Serbian Chamber of Engineers and the Institute for Standardization of Serbia.

When we face difficult times, her courage and the words «It's not time to cry yet» motivate us to continue creating, proud to have had her.

Prepared by:
S. Janković

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