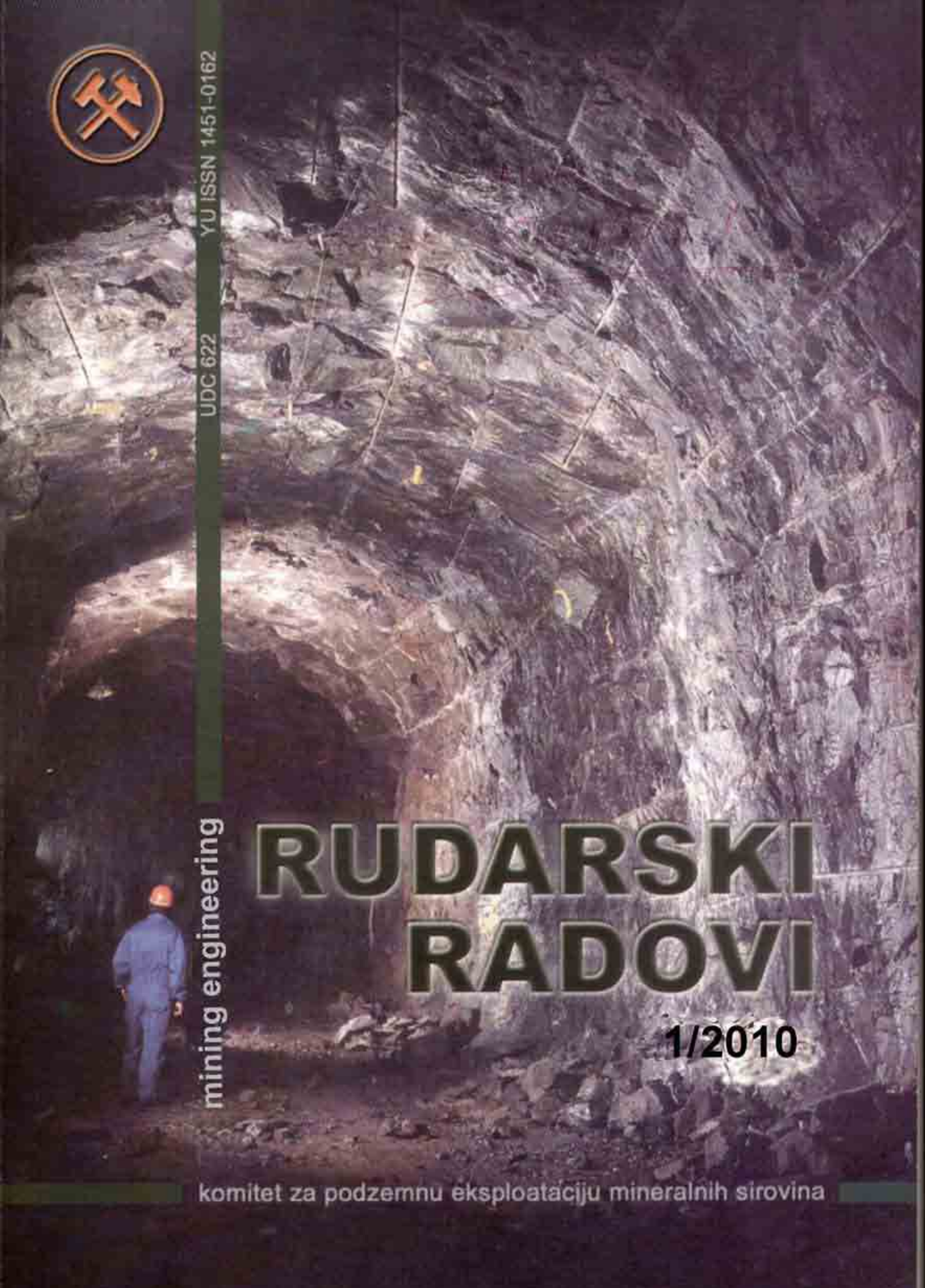

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Dejan Sokolović, Dragana Erdeljan*, Petar Popović**

USLOVI I NAČIN UZIMANJA UZORAKA ZA TEHNOLOŠKU PROBU U TOKU DETALJNIH GEOLOŠKIH ISTRAŽNIH RADOVA

Izvod

Ministarstvo rudarstva i energetike (MRE), kao resorno ministarstvo, u skladu sa Zakonom o rudarstvu (''Službeni glasnik RS'' broj 44/95 i 34/08), izdaje saglasnost za uzimanje uzoraka za tehnološku probu na odobrenom istražnom prostoru. U ovom radu prikazani su uslovi za izdavanje saglasnosti za uzimanje mineralne sirovine radi ispitivanja tehničko-tehnoloških karakteristika u toku istražnih radova, količine koje se mogu uzeti kao tehnološka proba, kao i analiza izdatih saglasnosti po godinama. Period u kome su izvršene analize je 2003-2009. godina.
Ključne reči: *Ministarstvo rudarstva i energetike, uprošćeni rudarski projekat, tehnološka proba*

UVOD

Rešavajući po zahtevima preduzeća zainteresovanih za detaljna geološka istraživanja, Ministarstvo rudarstva i energetike izdaje odobrenja za izvođenje rudarskih radova u cilju uzimanja tehnološke probe. U toku izvođenja detaljnih geoloških istraživanja projektom se u velikom broju slučajeva predviđaju i radovi na uzimanju tehnološkog uzorka za industrijska i poluindustrijska ispitivanja. Za izvođenje radova na uzimanju tehnološkog uzorka neophodno je uraditi Uprošćeni rudarski projekat (URP). Ovim projektom precizira se količina i tehnologija dobijanja sirovine.

Period koji je uzet za sagledavanje dosadašnjih odobrenja je od 2003. godine zaključno sa 2009. godinom. Za period pre 2003. godine podaci kojima raspolaže MRE nisu pouzdani. Naime, od 2002. godine sva dokumentacija se beleži u digitalnoj formi, a podaci uredno čuvaju u arhivi, dok se za period pre 2002. godine dokumentaciji teže ulazi u trag ili je, iz različitih razloga, nedostupna.

Odobrene količine materijala koje se uzimaju kao tehnološka proba su različite i zavise od vrste mineralne sirovine koja se ispituje, kao i njene industrijske primene. Količine takođe zavise od načina i

* *Ministarstvo rudarstva i energetike*

tehnologije ispitivanja sirovine, te je bilo neophodno precizno odrediti potrebnu količinu mineralne sirovine za sprovođenje tehnoloških ispitivanja. MRE je definisalo tačne količine koje se obrađuju uprošćenim rudarskim projektom i prikazane su u tabeli 1.

Tabela 1. *Količine mineralne sirovine za sprovođenje tehnološlih ispitivanja*

Mineralna sirovina	**Količina za tehnološku probu (m^3)**
Pesak (kao građevinski materijal)	300
Kvarcni pesak (staklarska industrija itd)	300
Šljunak (kao građevinski materijal)	300
Glina (kao opekarski materijal)	1000
Glina (kao keramički materijal)	1000
Bentonitska glina	1000
Tehničko-građevinski kamen	500
Arhitektonsko-građevinski kamen	250
Metalične mineralne sirovine	1000
Fosfati	
Borati	
Ugalj	

AKTUELNA ZAKONSKA REGULATIVA

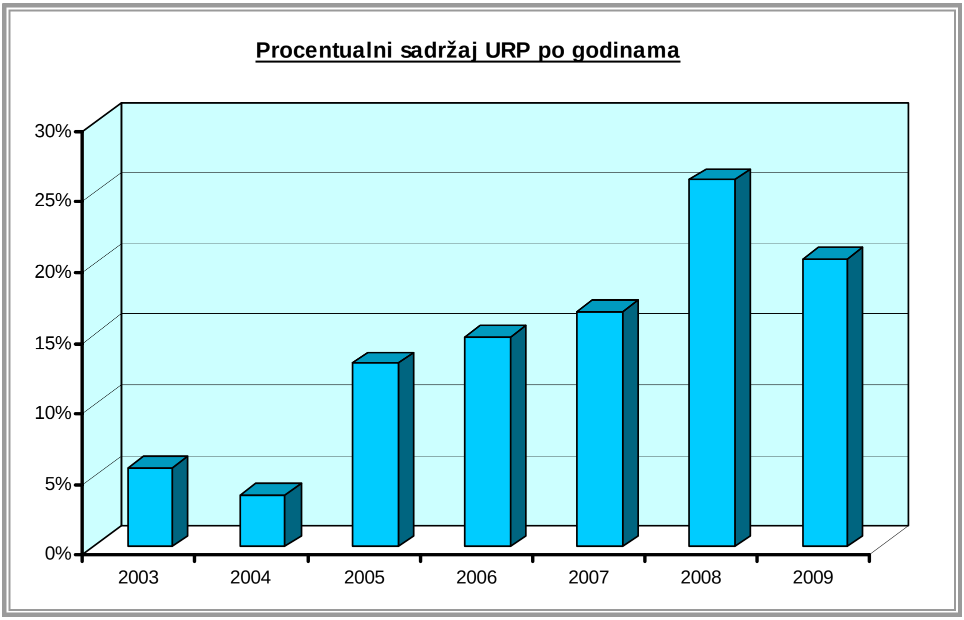
MRE kao resorno ministarstvo, u skladu sa Zakonom o rudarstvu (''Službeni glasnik RS'' broj 44/95 i 34/08) [4], izdaje saglasnosti za uzimanje uzoraka za tehnološku probu na odobrenom istražnom prostoru. U skladu sa članom 28. stav 4. koji kaže, da se ''uprošćeni rudarski projekat izrađuje za rudarske radova na istraživanju mineralnih sirovina'', MRE po zahtevu zainteresovaih lica koja u skladu sa Zakonom o geološkim istraživanjima (''Službeni glasnik RS'' broj 44/95) [3] poseduju odobrenje za geološka istraživanje, izdaje rešenja kojim se preduzeću ili kompaniji daje saglasnost za uzimanje uzoraka u cilju ispitivanja kvaliteta mineralne sirovine.

Izvođenju ovih rudarskim radovima, u skladu sa članom 37. Zakona o rudarstvu (''Službeni glasnik RS'' broj 44/95 i 34/08), može se pristupiti, kao što se kaže u stavu 1. ''po pribavljenoj saglasnosti Ministarstva, a ukoliko se tim radovima utiče na režim voda i narušava životna sredina i Ministarstva nadležnog za poslove vodoprivrede, odnosno zaštite životne sredine''.

URP ZA UZIMANJE UZORAKA U OKVIRU GEOLOŠKIH ISTRAŽIVANJA

Tehnološka ispitivanja imaju za cilj dobijanje podataka o stepenu iskorišćenja sirovine u finalne proizvode. Pored toga, utvrđuje se obradivost, cepljivost, frezovanje, brušenje, poliranje itd.

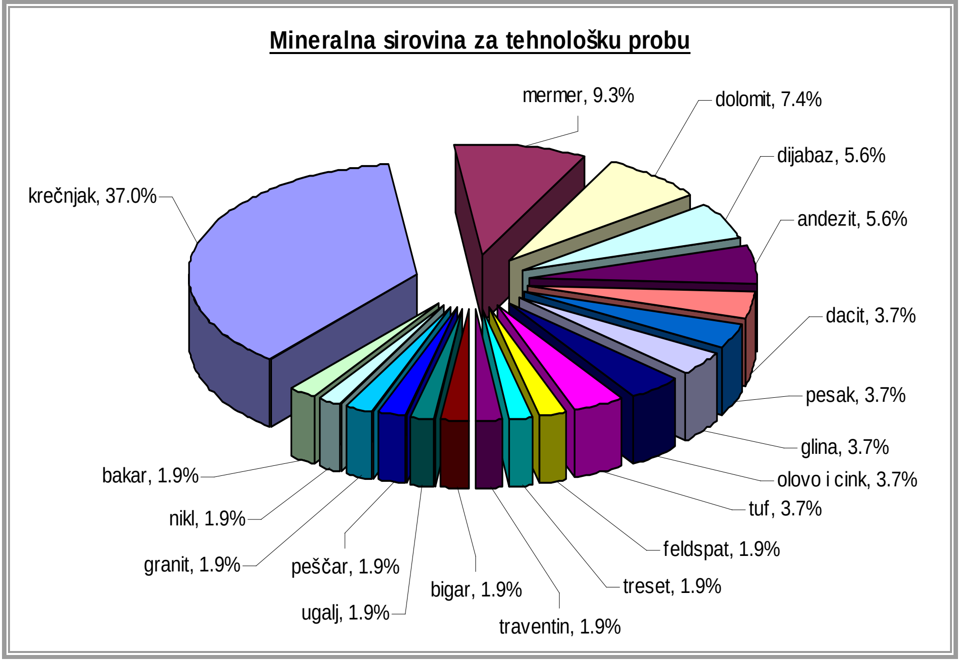
Analizirajući ovaj način uzorkovanja na istražnim poljima, vidimo da je od 2003. do 2009. godine zainteresovanost za uzimanje uzoraka mineralne sirovine sa istražnog prostora konstantno rasla. Na slici 1. se može videti procentualna zastupljenost URP-a za tehnološke probe u okviru istražnih radova u odnosu na ukupan broj saglasnosti za URP za određenu godinu.



Sl. 1. *Procentualni sadržaj URP-a po godinama*

Sa dijagrama se može videti konstantan rast broja saglasnosti, sa izuzetkom 2004. godine, gde je došlo do malog pada. Najveći obim investicija u ovoj vrsti istraga bio je u 2008. godini, dok se njihov pad 2009. godine može objasniti tkz ’’ekonomskom krizom’’, te smanjenim obimom istražnih radova u zemlji.

Na slici 2. prikazan je dijagram zastupljenosti mineralnih sirovine za koje su date saglasnosti za URP, za uzimanje tehnoloških proba, u toku istražnih radova za od period 2003 do 2009. godine.



Sl. 2. *Mineralna sirovina za tehnološku probu*

Sa dijagrama se može videti da je krečnjak kao mineralna sirovina najviše zastupljen u odobrenim URP za uzimanje tehnoloških proba, iza njega sledi mermer, zatim dolomit, dijabaz i druge sirovine. Udeo ruda metala u procentulanoj zastupljenosti, sirovina, je ako što se vid, neznatan u odnosu na nemetale.

Određivanje kvaliteta mineralne sirovine u ležištu, odnosno rudnom telu određuje se oprobavanjem i propisano je Pravilnikom o klasifikaciji i kategorizaciji rezervi čvrstih mineralnih sirovina i vođenju evidencije o njima (''Službeni list SFRJ'' broj 53/79) [2].

Količine mineralne sirovine, nisu jasno definisane pomenutim pravilnikom, osim za arhitektonsko-građevinski kamen. Iz tog razloga MRE donosi akt kojim se jasno propisuju i usklađuju količine mineralne sirovine koje se mogu eksploatisati u cilju uzimanja uzoraka za tehnološka ispitivanja (tabela 1).

Prema tome, količinu materijala koja se može uzeti kao tehnološka proba, treba odrediti u skladu sa navedenim iznosima. Na navedeni način, nakon izvršenih rudarskih radova, ne postoji potreba za vršenjem rekultivacije zemljišta na površini sa koje je uzeta proba, kao ni vraćanja zemljišta prvobitnoj nameni, što su bili glavni razlozi donošenja ovog akta od strane Ministarstva.

SADRŽINA UPROŠĆENOG RUDARSKOG PROJEKTA

Uzimanje tehnološke probe mora biti predviđeno projektom istraživanja, gde se daju i osnovni elementi - prostorni položaj probne etaže, količine koje se otkopavaju kao i laboratorijske i druge analize koje će biti urađene. Uprošćeni rudarski projekat u skladu sa članom 43. Pravilnika o sadržini rudarskih projekata ('Službeni glasnik RS'' broj 27/97) [1] sadrži sledeće delove:

1. Projektni zadatak sa saglasnošću investitora i odgovarajućim podlogama za projektovanje,
2. tehničko rešenje sa podacima o lokaciji,
3. tehnički opis načina izrade probne etaže,
4. energetsko rešenje,
5. predmer i predračun,
6. crteže i planove u odgovarajućoj razmeri,
7. posebne mere zaštite.

Projektni zadatak treba da pruži osnovne smernice i sadržaj projekta, a investitor potvrđuje saglasnost potpisom odgovornog lica i pečatom preduzeća. Tehničkim rešenjem daje se opis tehnologije uzimanja uzorka, količina predviđena za uzimanje i tačan prostorni položaj probne etaže. Tehnički opis treba da prikaže tehnološki proces sa svim parametrima tehnološkog procesa uzi-manja mineralne sirovine, neophodnim da se predviđene količine bezbedno izdvoje iz masiva. U nedostatku osnovnih parametara za projektovanje (na prvom mestu inženjersko-geoloških uslova sredine) potrebno je ograničiti samu probnu etažu na manje visine (3 do 5 m) da bi se izbegli eventualni nekontrolisani odroni i klizanja masa.

Ministarstvo rudarstva i energetike izdaje saglasnost kojim se definiše količina mineralne sirovine prema projektu koja se može eksploatisati i koja mora biti u granicama propisanim aktom ministarstva. Rok važenja ovog rešenja se poklapa sa rokom važenja koji je definisan osnovnim rešenjem o istražnim geološkim radovima na tom lokalitetu.

Rezultati dobijeni analizama tehnološke probe prikazuju se u elaboratu o rezervama mineralne sirovine.

ZAKLJUČAK

Uzimanje tehnološkog uzorka i ispitivanje tehnološkog iskorišćenja je veoma bitan kriterijum, pored ostalih, za bilansiranje rezervi mineralne sirovine.

Kao što smo videli, poslednjih godina došlo je do intenziviranja rudarskih radova, u smislu tehnoloških proba na istraživanom lokalitetu. Izložena kretanja, pokazuju da je postepeno dolazilo do oporavka, u smislu veće potražnje za građevinskim materijalom.

Kretanje traženih saglasnosti takođe predstavljaju ne samo jedan dobar pokazatelj zainteresovanosti investitora za ovu vrstu istraživanja i za određena ulaganja u ovoj industrijskoj grani, već i njenu veoma veliku osetljivost na ekonomske tokove.

Za dalje analize ovakve vrste možemo koristiti u budućem radu uporedne analize dobijenih geoloških istraga i analize URP-a kao i njihovo upoređenje sa određenom lokacijom tj. opštinom. Isto tako upoređenje sa overenim mineralnim sirovinama na istim lokalitetima i njihovo iskorišćenje mogu nam dati veoma interesantne podatke.

LITERATURA

[1] Pravilnik o sadržini rudarskih projekata (’’Službeni glasnik RS’’ broj 27/97).

[2] Pravilnik o klasifikaciji i kategorizaciji rezervi čvrstih mineralnih sirovina i vođenju evidencije o njima (’’Službeni list SFRJ’’ broj 53/79).

[3] Zakon o geološkim istraživanjima (’’Službeni glasnik RS’’ broj 44/95).

[4] Zakon o rudarstvu (’’Službeni glasnik RS’’ broj 44/95 i 34/08).

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Dejan Soković[*], *Dragana Erdeljan*[*], *Petar Popović*[*]

TERMS AND METHOD OF SAMPLING FOR TECHNOLOGICAL SAMPLE IN DETAILED GEOLOGICAL PROSPECTING WORKS

Abstract

The Ministry of Mining and Energy (MME), as the competent ministry, in accordance with the Law on mining ("Official Gazette RS" No. 44/95 and 34/08), issued the consent for taking samples for technology probe on the approved area of geological exploration. This paper presents the conditions for issuing permits for sampling the mineral raw materials for analyzing the technical and technological characteristics during the exploration works, the amount that can be taken as a technological sample, and analyses of compliances issued per years. The period of realized analyses is from 2003-2009.
Key words: *Ministry of Mining and Energy, simplified mining project, technological testing*

INTRODUCTION

Addressing the requirements of companies interested in detailed geological investigations, the Ministry of Mining and Energy issued the approvals for execution the mining works for the aim of technological sampling. During realization the detailed geological investigations, the works of technological sampling for industrial and semi- industrial testing are also provided. It is necessary to develop the Simplified Mining Project (SMP) for the works on technological sampling. This project specifies the quantity and technology of obtaining the raw materials.

The taken period for review the previous approvals is from 2003 ending with 2009. For the period before 2003, the data available to the MME are not reliable. In fact, since 2002 the all the documentation has been recorded in a digital form and the data properly stored in the archive, while for the period before 2002, the track of documentation is harder or, for various reasons, it is unavailable.

The approved quantities of material that should be taken as a technological sample are various and depend on the type of tested mineral raw material and its industrial use. Quantities also depend on the way of investigation the technological raw material; therefore it was necessary to determine accurately the required quantity of mineral raw material for implementation the technological investigations. MME has defined the exact quantities that are processed by the Simplified Mining Project and they are presented in Table 1.

[*] *Ministry of Mining and Energy*

Table 1. *Quantity of the meneral deposits for technological testing*

Mineral raw material	Quantity for technological sample (m^3)
Sand (as construction material)	300
Quartz sand (glass industry)	300
Gravel (as construction material)	300
Clay (as bricking material)	1000
Clay (as ceramic material)	1000
Bentonite clay	1000
Technical-construction stone	500
Architectural stone	250
Metallic mineral raw materials	1000
Phosphates	
Borates	
Coal	

CURRENT LEGISLATION

MME as the competent ministry, in accordance with the Law on Mining ("Official Gazette" Nos. 44/95 and 34/08), issued the approvals for sampling the technological sample on the approved prospecting area. In accordance with the Article 28, Paragraph 4, which says that the "Simplified Mining Project is developed for mining works on prospecting the mineral resources", MME on request of interested persons in accordance with the Law on Geological Investigations ("Official Gazette" No. 44/95) have the approval for geological prospecting, issue the decisions to the enterprise or company for giving the consent for sampling to the aim of testing the quality of mineral raw materials.

Realization of mining works, in accordance with the Article 37 of the Law on Mining ("Official Gazette" Nos. 44/95 and 34/08), can be accessed, as referred to in the Paragraph 1 "upon obtained the approval of Ministry, and if these works affect the water regime and environment and the Ministry in charge for water management, and environment protection".

SIMPLIFIED MINING PROJECT FOR SAMPLING WITHIN THE GEOLOGICAL PROSPECTING WORKS

Technological investigations are aimed to the data obtaining on recovery degree of raw materials into final products. In addition, the workability, cleavage, milling, grinding, polishing, etc., are also determined.

By analyzing this way of sampling on the prospecting fields, it is seen that since 2003 until 2009, the interest in sampling of mineral raw material from the prospecting area is constantly increased. Figure 1 gives the percentage representation of the SMP for technological samples within the prospecting works regarding the total number of approvals for the SMP for the certain year.

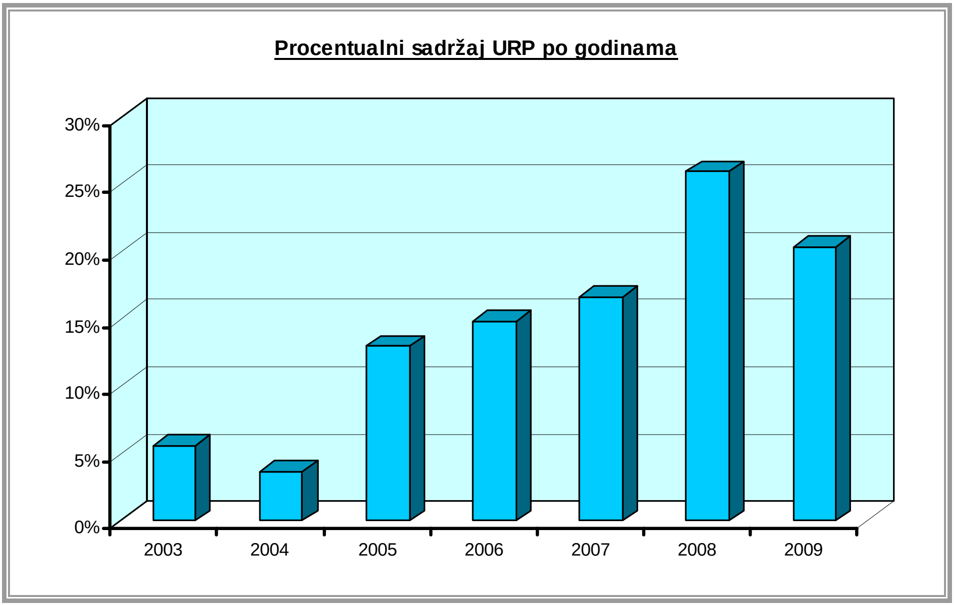

Figure 1. *The percentage content of the SMP per year*

A constant increase in the number of approvals can be seen on a diagram can be seen on a diagram with the exception of 2004, where there was a small decline. The largest volume of investments in this type of investigations was in 2008, while their fall in 2009 can be explained by the socalled "economic crisis" and reduced volume of prospecting works in the country.

Figure 2 presents a diagram of distribution the mineral raw materials for which the approvals for SMP were given for taking the technological samples during prospecting works for the period 2003 – 2009.

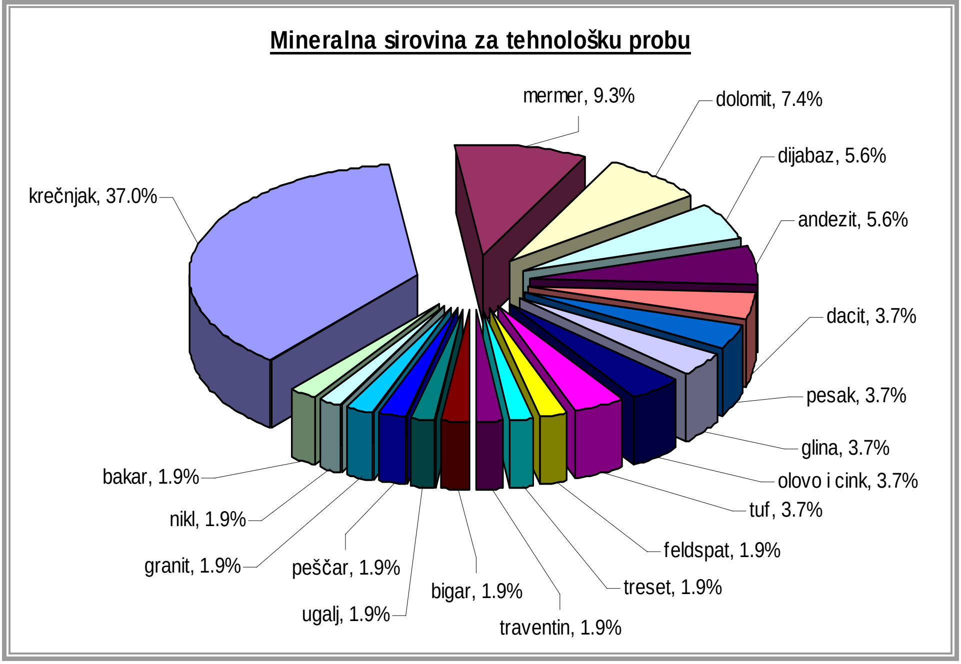

Figure 2. *Mineral raw material for technological sample*

It could be seen from diagram that the lime as mineral raw material is the most present in the approved SMP for taking the technological samples, then marble, dolomite, diabase and other raw materials. The share of metal ores in percentage distribution of raw materials is, as it could be seen, insignificant in comparison to the non-metals.

Determining the quality of mineral raw materials in deposit, that is the ore body, is determined by sampling and prescribed by the Regulation on classification and categorization of reserves the solid mineral raw materials and keeping records of them ("Official Gazette of SFRY" No. 53/79).

Quantity of mineral raw materials, are not clearly defined in this Regulation rules, except for architectural-construction stone. Due to this reason, MME have brought an act that clearly prescribed and adjusted amounts of mineral raw materials that can be exploited for the purpose of taking samples for technological investigations (Table 1).

Therefore, quantity of material that can be taken as a technological sample should be determined in accordance with these terms. For the following method, after realized mining works, there is no need for land reclamation on surface where the sample was taken, as well as land restoring to the original purpose, what were the main reasons for enactment of this Act by the Ministry.

CONTENT OF THE SIMPLIFIED MINING PROJECT

Taking a technological sample have to be provided by the project of investigation, where their basic elements are also given – spatial position of testing bench, amounts that are mined as well as laboratory and other analyses to be done. Simplified Mining Project in accordance with the Article 43 of the Regulation on contents of mining projects ("Official Gazette of RS No. 27/97) contains the following parts:

1. Project task with the consent of investors and appropriate bases for design,
2. Technical solution with location data,
3. Technical description on method of test bench development,
4. Energy solution,
5. Bill of quantities and calculation,
6. Drawings and plans at the appropriate scale,
7. Special protective measures.

Project task should provide the basic guidelines and content of the project and the investor confirms the agreement signed by the responsible person and stamp of the company. Technical solution provides a description of sampling technology, prescribed quantity for sampling and the exact spatial position of test bench. Technical description has to show the technological process with all parameters of technological process of taking minerals, necessary to secure anticipated amount set aside from the massif. In the absence of basic parameters for design (in the first place of engineering- geological environmental conditions), it is required to limit the test bench itself to the lower heights (3 to 5m) in order to avoid possible uncontrolled landslides and sliding mass.

Ministry of Mines and Energy issued the consent on defining the quantity of mineral raw material to the project that could be exploited and have to be within the prescribed limits by the act of Ministry. Validity of this solution coincides with the period of validity that is defined by the basic solution of geological prospecting works at this locality.

The results obtained by the analyses of technological samples are shown in the project report on reserves of mineral raw materials.

CONCLUSION

Technological sampling and analyzing of technological efficiency is an important criterion, among others, for balancing the reserves of mineral raw materials.

As we have seen, in recent years there has been intensification of mining in terms of technological tests in the locality. The exposed movements show that recovery came gradually in terms of higher demand for construction material.

The movement of required approvals also presents not only a good indicator of interested investor in this type of investigation and for certain investments in this field of industry, but its very high sensitivity to the economic trends.

For further analyses of this type, the comparative analyses of the obtained geological prospecting and analyses of SMP could be sued in future work as well as their comparison with a specific location, i.e. municipality. Also a comparison with the certified mineral raw materials in the same localities and their usage could give very interesting data.

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[1] Regulations on the Content of Mining Projects ("Official Gazette RS" No. 27/97).

[2] Regulations on Classifications and Categorization the Reserves of Solid Mineral Raw Materials and Keeping Records ("Official Gazette SFRY No. 53/79).

[3] Law on Geological Explorations ("Official Gazette RS" No. 44/95).

[4] Law on Mining ("Official Gazette RS" Nos. 44/95 and 34/08).

UDK: 624.13(282.2)(045)=861

Neđo Đurić, Anđa Đujić*, Snežana Tadić*, Jovo Miljanović***

GEOTEHNIČKA ISTRAŽIVANJA TERENA ZA UREĐENJE OBALE RIJEKE SAVE U BRČKOM

Izvod

U centralnom gradskom dijelu u Brčkom neophodno je urediti obalu rijeke Save, kako bi se postojeća površina privela određenoj namjeni. Djelimično zapušteni prostor, novim regulacionim planom predviđen je za izgradnju dvosmjerne saobraćajnice, šetališta pored rijeke, kao i izgradnju carinskog terminala.

Obala rijeke Save tokom godine je promjenljiva, obzirom na visinu vodostaja koji se nekoliko puta mijenja. Zapuštenost obale i nedostatak prostora za navedene svrhe, zahtijevalo je njeno uređenje, a time i provođenje određenih istraživanja za potrebe izrade neophodne dokumentacije.

Provedena istraživanja omogućila su sagledavanje geološke građe terena, njegovih morfoloških, inženjerskogeoloških i hidrogeoloških karakteristika, što je predstavljalo podlogu za izradu projektne dokumentacije.

Ključne riječi: *obala, inženjerskogeološka i geotehnička istraživanja, istražni radovi, saobraćajnica*

UVOD

Za potrebe uređenja desne obale rijeke Save u dijelu od postojećeg carinskog termi-nala do luke Brčko, urađena su geotehnička istraživanja i ispitivanja terena. Dobiveni podaci pokazali su karakteristike terena duž obale rijeke, kao i južno prema stambenom naselju Srpska Varoš i dijelu terena koji predstavlja istorijsko gradsko jezgro.

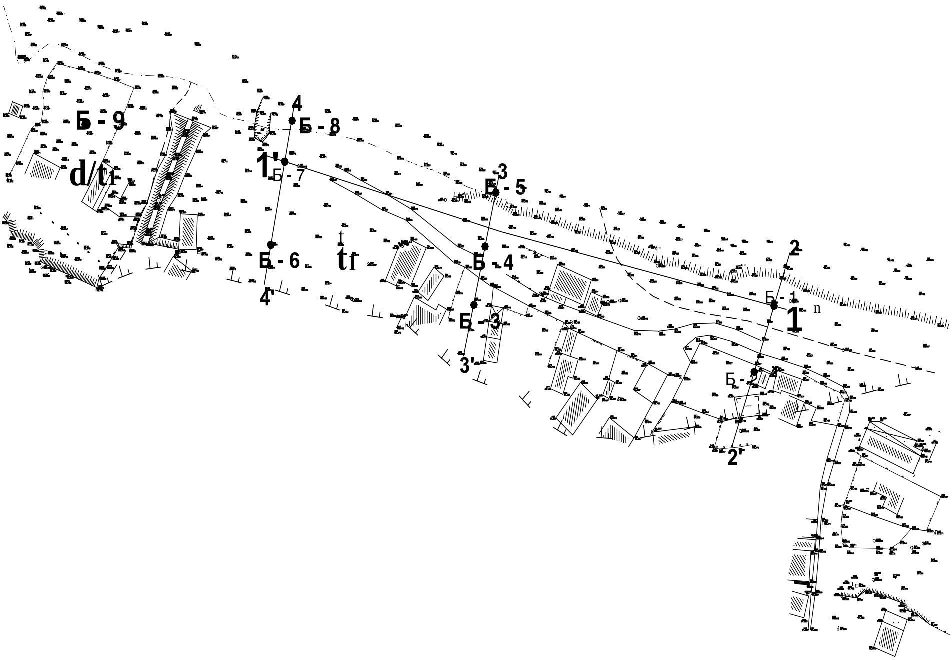
U cilju kvalitetnijeg iskorištenja prostora u navedenom dijelu terena, predviđena je i zgradnja dvosmjerne saobraćajnice, šetališta, carinskog terminala i pratećih objekata. Pored istraživanje geološke građe terena i fizičko-mehaničkih karaktersitika sedimenata, važnu ulogu ima stanje nivoa voda u rijeci Savi tokom godine.

* *Tehnički instutut Bjeljina*
** *JPPEU - Resavica*

OSNOVNE KARAKTERISTIKE TERENA

U okviru sagledavanja karaktersitika terena izvršeno je prikupljanje postojeće dokumentacije, koja je stvarana u različitom periodu XX vijeka, a čiji je nivo kvaliteta i pouzdanosti različit. Nakon njenog proučavanja urađena su potrebna terenska istraživanja i laboratorijska ispitivanja.

Izvedeno je devet (9) istražnih bušotina, dubine 8,0 – 12,0 m, na kojima su provedeni opiti SPT-a, uzeti poremećeni i neporemećeni uzorci tla, registrovani nivoi podzemnih voda i ugrađeni piezometri za praćenje oscilacija tokom vremena. Prostorni položaj istražnih bušotina je po profilima upravnim na riječni tok, slika 1.



Sl. 1. *Inženjerskogeološka karta terena sa rasporedom istražnih bušotina d/t_1) deluvijalno terasni sedimenti, t_1) sedimenti prve terase*

U morfološkom smislu, teren predstavlja plato mlađe riječne terase (t_1) rijeke Save sa visinama 79,0–84,5 mnm. U zaleđu platoa prema gradu prostire se terasni odsjek visine oko 4,0–5,0 m, koji je ujedno i granica istražnog prostora. Na krajnjem jugoistočnom dijelu odsjeka prirodni nagib je zamaskiran tehnogenim radom, te su veličine nagiba i preko 20^0. Veličina nagiba u središnjem dijelu padine je od $15–20^0$, a na krajnjem jugozapadnom dijelu terena nagibi terasnog odsjeka su do 10^0.

Drugi morfološki oblik koji dominira prostorom i koji ima najveći značaj za buduće objekte je desna obala rijeke Save. U području krajnjeg istočnog dijela prostora obala je visine oko 3,0–3,5 m sa procijenjenim nagibom kosine od 1:1,5–1:2. Visina obale smanjuje se idući prema mostu preko Save, tako da je u području mosta teren zaravnjen sa nagibom oko 7^0.

Prirodna morfologija terena izmijenjena je nasipom koji se pruža od pravca vodozahvatnog objekta na obali rijeke Save prema zgradi opštine. Nasip je izgrađen za ugradnju cjevovoda za koji je nepoznato da li je nekada bio u funkciji. Visina nasipa je oko 1,0 – 2,0 m, tako da je istražni prostor podijeljen na dvije cjeline.

U geološkoj građi terena, do dubine istraživanja oko 12,0 m učestvuju tehnogene tvorevine, sedimenti aluvijalnog nanosa i sedimenti riječne terase.

Tehnogene tvorevine su nasipi (n), registrovani skoro na čitavoj lokaciji, različite moćnosti od 0,5–3,3 m Izgrađen je od gline prašinasto pjeskovite, šljunkovito pjesko-vitog materijala i građevinskog otpada. Površinski dio nasipa do 0,2 m prektiven je humusnim slojem.

Sedimenti aluvijalnog nanosa (a), registrovani su na površini terena neposredno uz korito rijeke Save, a njihova moćnost na pojedinim dijelovima terena kreće se i do 12,0 m, odnosno do dubine istraživanja. Predstavljeni su prašinastim sedimentima i zaglinjenim pijeskovima, a manjim dijelom i šljunkovito-glinovitim sedimentima. Niži dijelovi prašinasto-pjeskoviti sedimenata, karakterišu proslojke gline muljevite.

U pojedinim dijelovima, lokalnog karaktera, sedimenti aluvijalnog nanosa prekriveni su tankim slojem deluvijalne ilovačaste gline, moćnost do 1,4 m. Ovi sedimenti kao i ostali do dubine 2,0 m, nemaju uticaje na temeljenje budućih objekata, tako da nisu detaljnije ni proučavani.

Za temeljenje planiranih objekata, interesovanje predstavljaju dubine veće od 2,0 m. Tako su navedeni sedimenti detaljnije proučavani sa aspekta mogućnosti prihvatanja opterećenja od objekata, kao i uticaja sredine na temeljenje potpornih konstrukcija za stabilnost puta.

Terasni sedimenti (t_1), čine podinu sedimentima aluvijalnog nanosa, pjeskovito-šljunkovitog sastava, čija podina nije definisana u toku istraživanja. Sa dubinom pokazuju bolje otporno-deformabilne karakteristike.

Savremeni inženjerskogeološki procesi, prisutni su na kosini obale, a manifestuju se kao otkidanja i manja kliženja. Uzroci nestabilnosti su različiti, a prvenstveno su vezani za poplavne talase rijeke Save koji vrše eroziju obale. Dalje, nestabilnost obale vezana je za ispiranje najsitnijih čestica iz tla koje je izgrađeno od prašinastih sedimenata. Ispitranja su uglavnom vezana za uslove oscilacija nivoa podzemne vode, što su veoma česte pojave, obzirom da proučavana lokacija predstavlja inudaciono područje rijeke Save.

Nepovoljni hidrološki i hidrogeološki uslovi terena u odnosu na stabilnost obale, pogoršani su i naknadno stvorenim uslovima, koji se odnose na ispuštanje kanalizacionih voda iz okolnih stambenih objekata. Poseban značaj imaju u nožičnom dijelu kosine obale, gdje se teren stalno razblaćuje i pogoršava njegove geome haničke karaklteristike.

Kosina u zaleđu istraživanog terena koja predstavlja prirodni odsjek u terenu je stabilna, iako je lokalno, nagib kosine poremećen radovima vezanim tokom izgradnje manjih stambenih objekata. Stabilnost je zadržana obzirom da je održavana ravnoteža terena u pogledu zasijecanja i nasipanja.

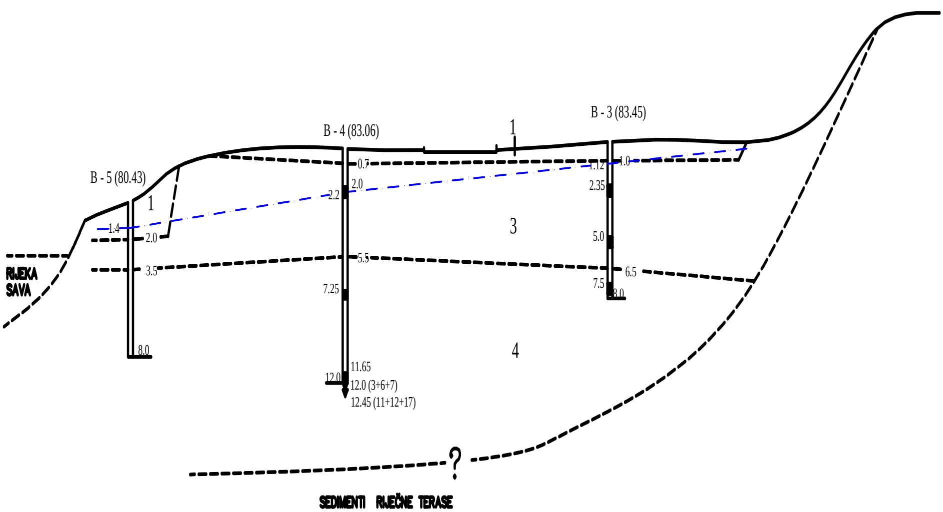
Teren podložan plavljenju predstavlja zaravan poljoprivrednog zemljišta, čija je kota 83,0 mnm. Kota velikih voda je 83,30 mnm, što znači da su česte poplave, a kota stogodišnjih voda je 85,0 mnm. Tada se poplavi čitav istraživani prostor, sve do luke Brčko.

Hidrogeološke karakteristike terena, pokazuju da se hidrogeološka svojstva sedimenata mijenjaju zavisno od kolebanja nivoa rijeke Save, posebno u dijelu koji je podložan stalnom plavljenju prilikom oscilacija nivoa vodostaja. Kada je nivo voda rijeke veći, sedimenti su potpuno natopljeni i raskvašeni, a sa povlaćanjem nivoa rijeke usljed povećanih dnevnih temperatura dolazi do isušivanja i stvaranja pukotina nepravilnog oblika, različite dubine. Sa ponovnim porastom nivoa sedimenti se zasićuju vodom i pri tome stalno mijenjaju strukturu, ispirajući najsitnije čestice. Pri tome se pogoršavaju njihove geomehaničke karakteristike i nisu povoljni za tehničke zahvate.

GEOMEHANIČKE KARAKTERISTIKE TERENA

Terensakim istraživanjima do dubine 12,0 m izdvojeni su slojevi nasipa, ilovačastih glina, glina prašinasto pjeskovitih i prašina glinovita-muljevita, slika 2.

Posljednja dva sloja mogu se svrstati u jedan sloj glinovito prašinasti sedimenti sa proslojcima muljevitog materijala. Ispod navedenog sloja su pjeskovito šljunkoviti sedimenti koji istraživanjem nisu konstatovani.



Sl. 2. *Popreči geološki profil 3 – 3’*
1. nasip, 3. glina prašinasto pjeskovita, 4. prašina glinovita muljevita

Rezultati terenski istraživanja i laboratorijski ispitivanja dali su određeni podatke neophodne za dalje geomehaničke prora-čune. Dobiveni podaci u laboratoriji nešto su bolji u odnosu na karakteristike terena definisane tokom bušenja i snimanja jezgra iz bušotina. Ovo se prvenstveno odnosi na sloj glinovito prašinastih sedimenata sa proslojcima muljevitog materijala.

U cilju izgradnje navedenih objekata provedene su određene analize stabilnosti obale za prirodne uslove i uslove koje će nastati izgradnjom predviđenih objekata. Za glinovito prašinaste sedimente usvojeni su nešto niži parametri obzirom na prisustvo muljevite komponente: γ_{pot}=9,6 kN/m^2, φ=10^0 i c=8 kN/m^2, pri čemu su dobivene vrijednosti:

- za prirodno stanje bez opterećenja, nivo voda 83,0 m, Fs = 1,226
- za prirodno stanje sa predviđenim opterećenjem, nivo vode 83,0 m Fs = 1,112

Imajući u vidu navedene analize za date karakteristike terena, prašinasti sedimenti ni-su povoljni za za temeljenje potpornih konstrukcija koje se planiraju za osiguranje trupa puta. Za poboljšanje sigurnosti potpornih konstrukcija, neophodno je izvršiti zamjenu materijala sa kvalitetnim savskim šljunkom, koji u uslovima dobre zbijenosti može biti stabilan oslobnac. Zamjenom materijala spriječiti će se iznošenje najsitnijih čestica, što će usloviti stabilizaciju terena ispod nasipa.

ZAKLJUČAK

Istraživanja provedena za potrebe uređenja desne obale rijeke Save u Brčkom dala su neophodne podatke o geološkoj građi i geomehaničkim karakteristikama terena. Rezultati laboratorijskih ispitivanja djelimično se razlikuju od terenskih podataka dobivenih tokom istražnog bušenja i kartiranja jezgra bušotina. Razlike su vezane za prisustvo muljevitih materijala u glonovito prašinastom sloju, koji pogoršava njegove karakteristike.

Provedene analize stabilnosti obale za prirodne uslove i uslove koje će nastati izgradnjom predviđenih objekata pokazuju da se teren nalazi negdje na granici prirodne ravnoteže, tako da svaki novi zahvati na terenu zahtijevaju detaljnije analize i proračune kako stabilnosti terena, tako i nosivosti pojedinih slojeva u kojima će se temeljini određeni objekti.

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GEOTECHNICAL INVESTIGATIONS OF THE TERRAIN FOR PLANNING THE RIVER SAVA IN BRCKO

Abstract

In the central part of town Brcko, it is necessary to regulate the river Sava for particular purpose of the existing surface. Partially abandoned area is predicted for construction of two-way road and custom terminal by the new regulatory plan.

Riverside of the river Sava is variable during a year regarding to the height of water level that changes several times. Disrepair of the river side and the lack of space required its regulation and therefore the conduct of specific researches for the needs of development the specific documentation

Conducted researches have allowed a consideration of geological field formation, materials field, its morphological, engineering geological and hydrogeological characteristics, what was the base for project documentation development.

Key words: *riverside, engineering geological and geotechnical investigations, investigation work, roads*

INTRODUCTION

Geotechnical and terrain investigations were carried out for the needs of planning the right bank of the river Sava in a part from the existing custom terminal to the port Brcko. The obtained data have showed the terrain characteristics along the river banks as well as on the south towards the residential area Srpska Varos and a part of terrain that presents the historical town centre.

For the aim of better utilization the space in the given terrain part, the construction of two-way road, walkways, customs terminal and associated facilities was predicted. In addition to the investigation of geological formation of terrain and physic-mechanical characteristics of sediments, the state level of water in the river Sava during a year has an important role.

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BASIC CHARACTERISTICS OF THE TERRAIN

Within the insight into terrain characteristics, the existing documentation was collected, that was created in various periods of the 20th century, and with various levels of quality and reliability. After study of this documentation, the required terrain investigations and laboratory testing were carried out. Nine (9) prospecting drill holes, depth from 8.0 to 12.0 m were done, with realized SPT tests, taken disturbed and undisturbed samples of soil, registered ground water levels and installed piezometers for monitoring the oscillations over time. The spatial position of prospecting drillholes is per vertical profiles on the river flow, Figure 1.

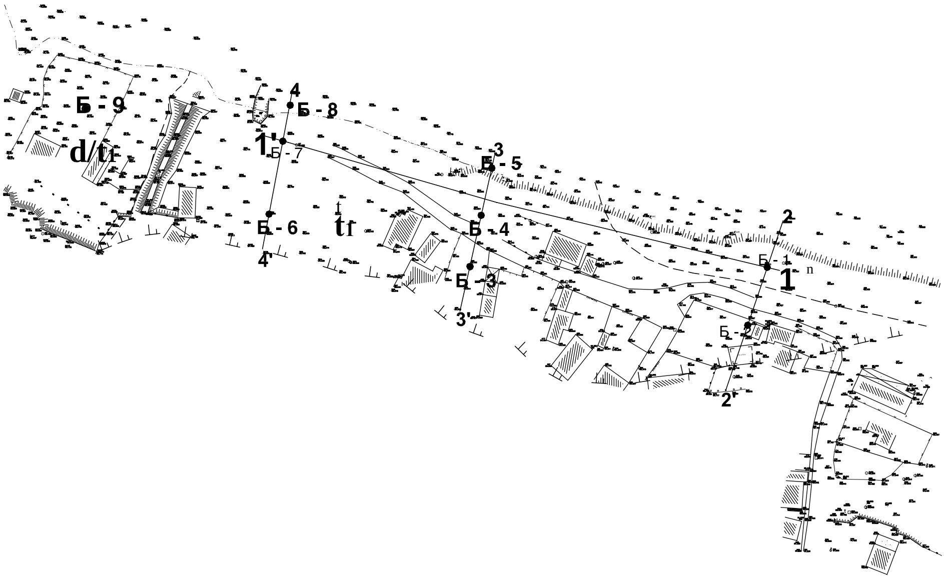

Figure 1. *Engineering geological map of the terrain with the layout of prospecting drillholes d/t1) terrace talus sediments, t1) first terrace sediments,*

In morphological terms, the terrain is a plateau of younger river terrace (t_1) from the river Sava River with heights of 79.0 to 84.5 m above sea level. The terrace cur, height about 4.0–5.0 m, is extended on the plateau background that is also the boundary of prospecting area. In the southeastern part of the cut is a natural slope, disguised with technogenic work, and the sizes of the slope are over 20^0. The slope size in the central part is $15–20^0$, and in the southwestern part up to 10^0

Other morphological form that dominates in this area and has the greatest importance for future facilities is the right riverside of the river Sava. The final area of eastern part of the space around the coast has height from 3.0 to 3.5 m with estimated slope of 1:1,5-1:2. Elevation of the coast decreases towards the bridge over the river Sava, so the terrain within the bridge in the area is flat with slope of about 7^0.

The terrain natural morphology embankment that extends from direction of water intake facility on the coast of the river Sava towards the municipality building. Dike was built for the installation of pipelines for which it is unknown that was in operation. Height of embankment is about 1.0 to 2.0 m, so prospecting area is divided into two units.

In the geological structure of terrain, to the prospecting depth of about 12.0 m, the technogenetic formations, sediments of alluvial deposits and river terrace sediments are included.

Technogenetic formations are the embankments (n), registered almost the entire site of various thickness from 0.5 to 3.3 m. They are built of dusty and sandy clay, gravel and sandy material of construction waste. Surface part of dike, up to 0.2 m, is covered by layer of humus.

Sediments of alluvial deposits (a), registered on the surface of terrain close to the river Sava, and their thickness in some parts of terrain ranges up to 12.0 m, i.e. up to the prospecting depth. They are presented by powdered dusty sediments and clayed sands, and partly pebble-clay sediments. Lower parts of the dusty and sandy sediments are characterized by interlayers of muddy clay.

In some parts of local character, sediments of alluvial deposits are covered by a thin layer of talus clay loam, thickness up to 1.4 m. These sediments and the other to the depth of 2.0 m, have no influence on the foundations of future buildings, so they neither were study in detail.

For foundation for the planned facilities, the depth of interest is greater than 2.0 m. The listed sediments are studied from the viewpoint of possibility of accepting the load of buildings as well as the influence of environment on the foundations of supporting structures for the stability of roads.

Terrace sediments (t_1), form the substratum of alluvial deposit sediments, sandy gravel composition, with defined substratum during prospecting. With depth, they show better resistant deformable characteristics.

Modern engineering geological processes are present on the slopes of the coast and manifested as tear and less slipping. The causes of instability are different, and primarily related to the river Sava flood waves that carry out shore erosion. Furthermore, the coast instability is related to the flushing of small soil particles that is built of dust sediments. Mainly, the leaching conditions related to groundwater level fluctuations, which are very common, considering that they study the flooded sites of the river Sava.

Unfavorable hydrological and hydrogeological conditions of the terrain in relation to the coast stability, aggravated and subsequently created the conditions relating to discharge of sewage water from the surrounding residential buildings, have special significance in the lower slope of the coast, where the terrain constantly deteriorates its geomechanical characteristics.

Slope in the background of prospected terrain, that presents the natural section in terrain, is stable, although local, the gradient of slope disturbed during construction works related to the small residential buildings. Stability is retained as the terrain balance is adjusted in terms of cutting and filling.

Terrain, subjected to flooding of agricultural land is a plateau that is 83.0 m above sea level. The peak elevation of water is 83.30 m above sea level, that means the frequent flooding, and the peak elevation of century water is 85.0 m above sea level. Then, the entire prospected area is flooded, all of the Brcko port.

Hydrogeological characteristics of the terrain, according to the hydrogeological properties of sediments are changed depending on fluctuations in the level of the river Sava, especially in the area that is subjected to the constant flooding at the level of water level fluctuations. When the water level is higher, sediments are completely soaked and soft, and dragging of the river, due to the increased levels of daily temperature, leads to dryness and formation of cracks of irregular shape, varying in depth. With the re-growth of levels, sediments are saturated with water and constantly change the structure by washing the smallest particles. Therefore, their geomechanical characteristics become worse and unfavorable for technical operations.

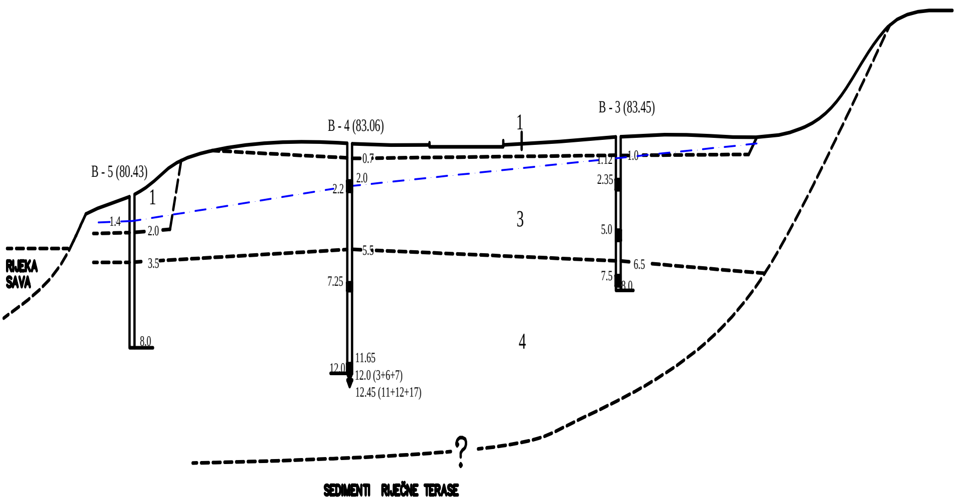

Figure 2. *Geological cross-profile 3-3 '*
1. dike, 3. dusty sandy clay,
4. dust clayey muddy

GEO-MECHANICAL FEATURES OF THE TERRAIN

The site prospecting up to 12.0 m depth separates the layers of dikes, loamy clays, dusty sandy clays and sandy clays and clayey muddy dusts, Figure 2. The last two layers can be divided into a dust layer of clay sediments from lower layers of silt materials. Below the layer above the sandy gravel sediments , this prospecting is not registered.

The results of site prospecting and laboratory tests have given the information necessary for further geomechanical calculations. Data obtained in the laboratory are somewhat better in relation to the terrain characteristics defined during drilling and core from the recording drillholes. This primarily refers to the layer of clayey dusty sediments with interlayers of muddy material.

In order to build these facilities, the certain stability analysis for the coast natural conditions and conditions that will occur provided the construction of buildings was implemented. For clayey dusty sediments, the adopted parameters are somewhat lower due to the presence of muddy components: $\gamma_{pot.} = 9.6$ kN/m^2, $\varphi = 10^0$ and c = 8 kN/m^2, where the following values were obtained:

- the natural state with no load, the water level of 83.0 m, Fs = 1.226
- the natural state of the specified load, water level 83.0 m, Fs = 1.112

Given the above analysis to date features of the terrain, dust sediments are favorable for the foundation support structures which are planned to ensure the road trunk. For improvement the security of support structures, it is necessary to replace materials with good quality gravel from the river Sava, which in the good conditions of compactness could be a stable support. The replacement of material will prevent the export of finest particles, which would result into the terrain stabilization of embankment.

CONCLUSION

The investigations, conducted for the purpose of planning the right riverside of the river Sava in Brcko, gave the necessary information about the geological structure and geomechanical characteristics of the terrain. The laboratory testing results are partly differ from the site data obtained during the investigation and mapping the drillholes. The differences are related to the presence of sludge materials in clayey dusty layer that deteriorates its properties.

The analysis of stability for the riverside natural conditions and conditions that will occur in construction of buildings, shows that the terrain is located somewhere on the border between the natural balance, so that each new intervention on the ground require more detailed analysis and calculations of terrain stability as well as load of individual layers for foundations of facilities.

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UDK: 622.1:550.8(045)=861

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OPAŽANJE PROMENA I MERENJE SLEGANJA NA KOLEKTORU ISPOD VZO P.K. „BOGUTOVO SELO“ U UGLJEVIKU

Izvod

Kolektor predstavlja veoma važan objekat za prihvatanje voda iz vodotokova koji se nalaze u blizini rudnika. Zato je važno ispitati sve faktore koji bitno utiču na njegovu stabilnost i dugotrajnost. Takođe je potrebno vršiti periodična merenja i opažanje stanja kolektora i na vreme pristupiti sanaciji novonastalih oštećenja. U ovom radu su prikazani rezultati merenja i posmatranja stanja kolektora ispod VZO P.K. „Bogutovo selo“ u Ugljeviku, koji su primenljivi i na kolektor Kriveljske reke u Boru.

Ključne reči: *kolektor, faktori stabilnosti, periodična merenja*

UVOD

Izgradnja podzemnih prostorija, kao što su tuneli i kolektori, zahteva složeni pristup rešavanju tog problema. Idealno bi bilo izraditi takvu prostoriju u izotropnoj sredini, što je u praksi gotovo nemoguće. Takođe se vrlo često susrećemo sa sledećom situacijom: da prostorije (tuneli) koji su izgrađeni pod projektovanim uslovima, se vremenom nađu u sasvim drugačijim, bitno izmenjenim uslovima. Te promene se, u glavnom, odnose na promenu vertikalne komponente opterećenja (npr. izgradnja nasipa iznad tunela). Promene opterećenja iznad podzemnog objekta izazvaće izmenu naponsko-deformacijskog stanja u masivu, što za posledicu može imati slabljenje samog objekta ili njegovih delova (pojava pukotina, prslina ili urušavanja). Pri tome su, kao prve, izložene zone koje su u inženjersko-geološkom pogledu svrstane u zone rizika. Zato se uticaj promene vrednosti vertikalne komponente mora definisati.

MERENJE SLEGANJA KOLEKTORA

Merenje sleganja kolektora izvršeno je preciznim nivelmanskim instrumentom sa tačnošću registrovanja pomaka od 0,1 mm. U stropu kolektora, njegovom celom dužinom počevši od ose brane do izlaza, postavljeni su fiksni metalni reperi na međusobnom rastojanju od 23,0 do 50,0 m, zavisno od ranije utvrđenog sleganja kolektora.

Vrlo sličan intenzitet spuštanja stropa kolektora uočen je i u svim dosadašnjim merenjima. Karakteristično je da se izlaz

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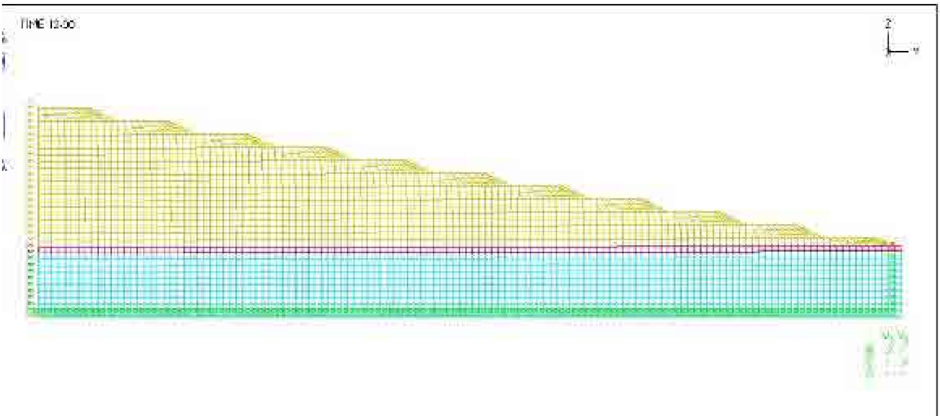
kolektora (strop) izdiže što pokazuju rezultati merenja na jednom od repera, i oni iznose od +14 mm do +65 mm.

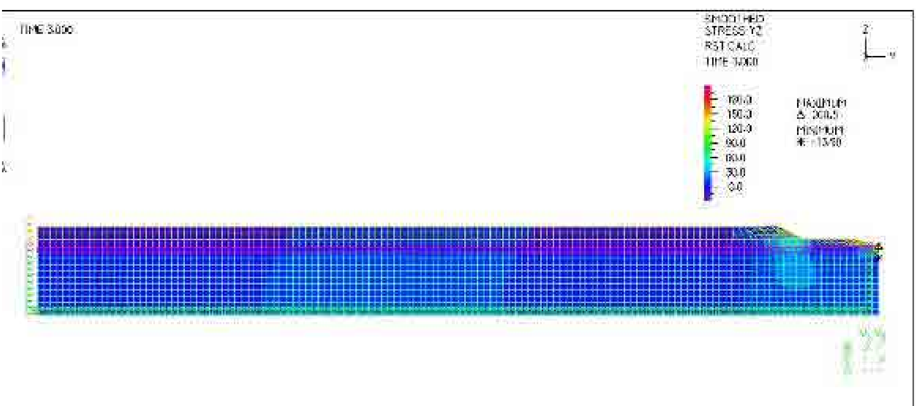
I pored visoke tačnosti merenja na ovaj način dobijeni rezultati su nepouzdani. Neophodno je postaviti stabilne repere u blizini ulaza i izlaza u kolektor, koji bi bili povezani sa državnom trigonometrijskom mrežom i imali apsolutne kote. Ovim načinom bi se moglo vršiti izravnanje nivelmanskog vlaka, računati dozvoljena odstupanja, obzirom da se radi o nivelmanskom vlaku velike dužine od preko 4.000 m. Pri tom je neophodno nivelisati osim stropa i podinu kolektora i pratiti kako se ta dva elementa uzajamno ponašaju.

NUMERIČKA ANALIZA STANJA KONSTRUKCIJE KOLEKTORA NA NJEGOVOM NAJUGROŽENIJEM DELU

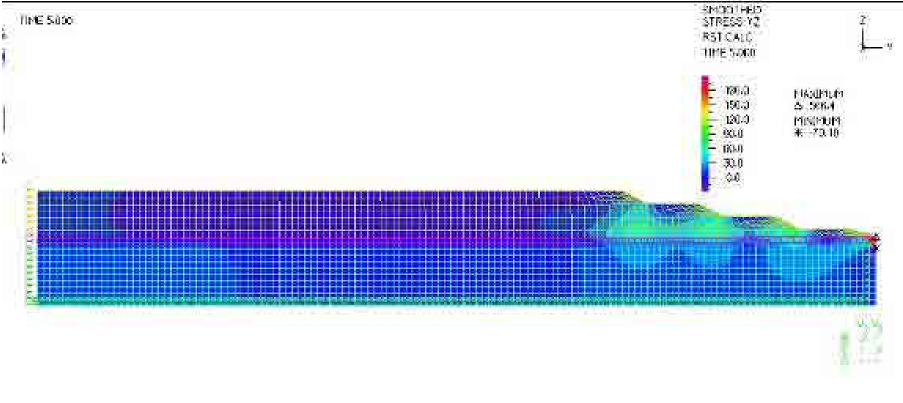
Numerički model kolektora po dužini od 332 m je prikazan na sl. 1. Bojom su odvojeni elementi podloge, konstrukcija kolektora i odloženi materijal. Naponi pritiska su označeni sa negativnim predznakom.



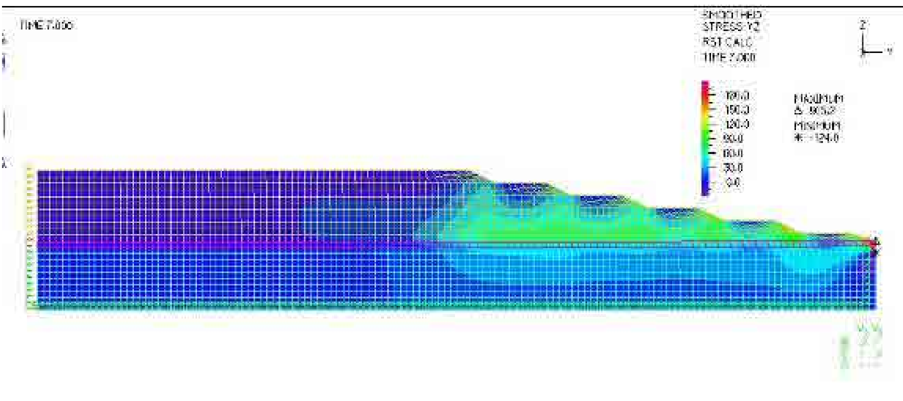
Sl. 1. *Numerički model podužnog preseka dela kolektora sa završnom konturom odložene mase*



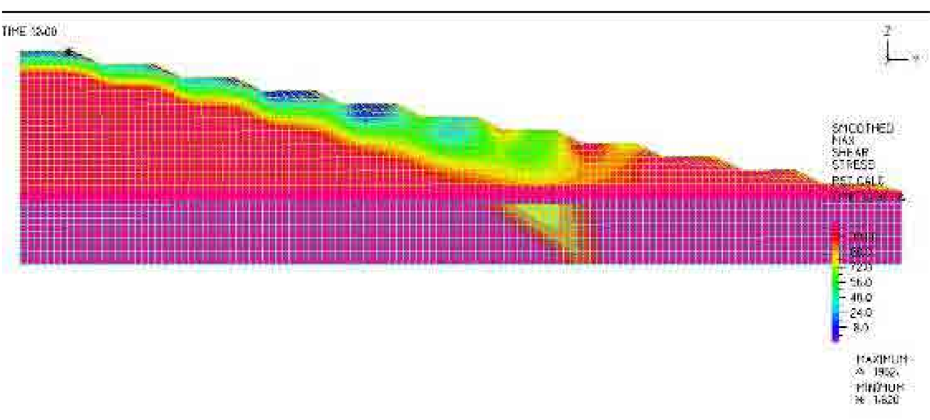
Sl. 2. *Smičući naponi u konstrukciji kolektora u funkciji opterećenja odloženih masa*



Sl. 3. *Smičući naponi u konstrukciji kolektora u funkciji opterećenja odloženih masa*

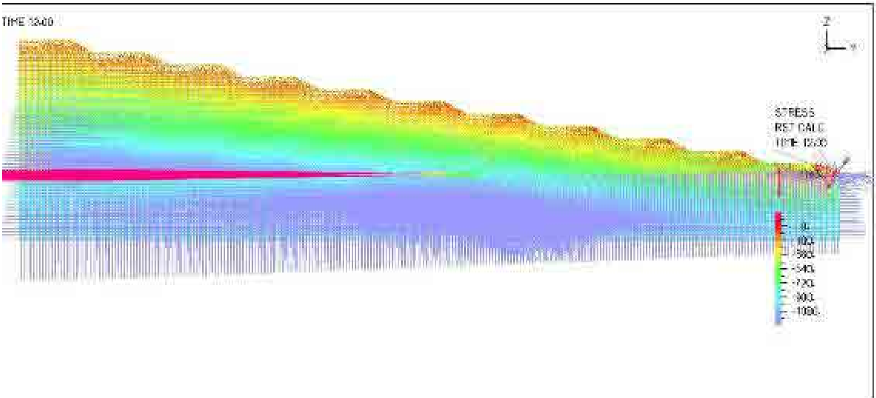


Sl. 4. *Smičući naponi u konstrukciji kolektora u funkciji opterećenja odloženih masa*

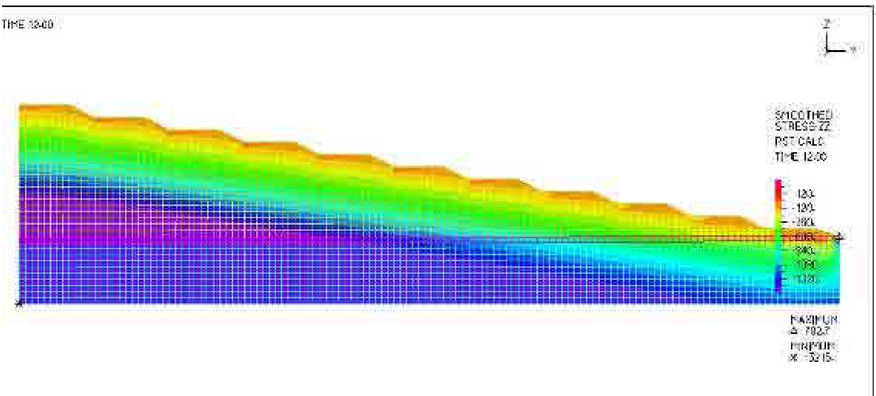


Sl. 5. Smičući naponi u konstrukciji kolektora u funkciji opterećenja odloženih masa

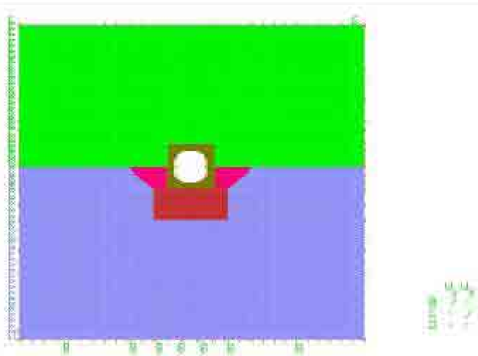
Navedene slike od 2 do 5 prikazuju raspodelu smičućih napona u masivu I preseku duž kolektora. Sa slika se vidi das u smičući naponi prouzrokovali pojavu loma u oblozi kolektora. Na slici 6 i 7 su prikazani vertikalni naponi koji rastu sa porastom visine odložene mase.



Sl. 6. *Vertikalni naponi u funkciji priraštaja opterećenja*



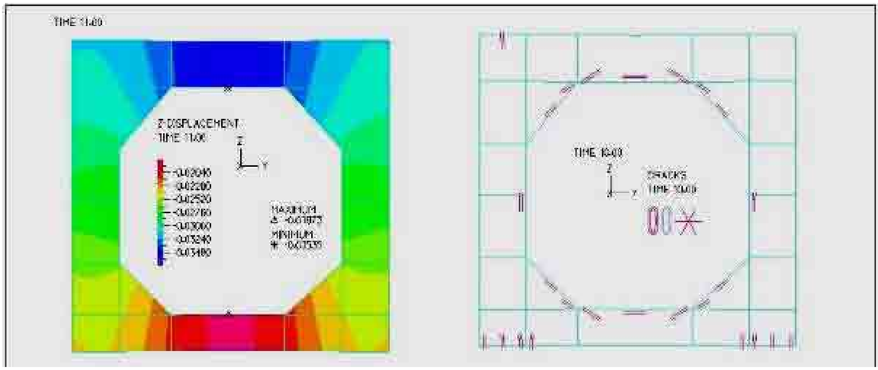
Sl. 7. *Vertikalni naponi u funkciji priraštaja opterećenja*



Sl. 8. Numerički model poprečnog preseka konstrukcije kolektora

Na modelu bojom su razgraničeni odloženi materijal, elementi kolektora sa označenim rubnim uslovima na granicama modela.

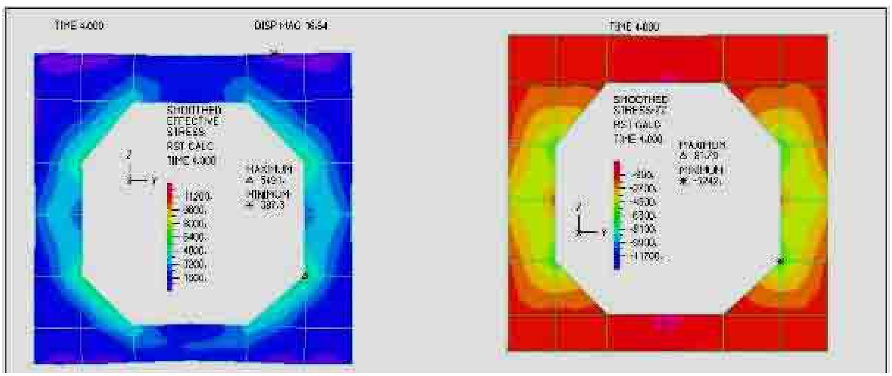
Na slici 9 prikazana je raspodela vertikalnih pomeranja i pojave pukotina u oblozi za pretpostavljenu visinu nasipa od 100 m.



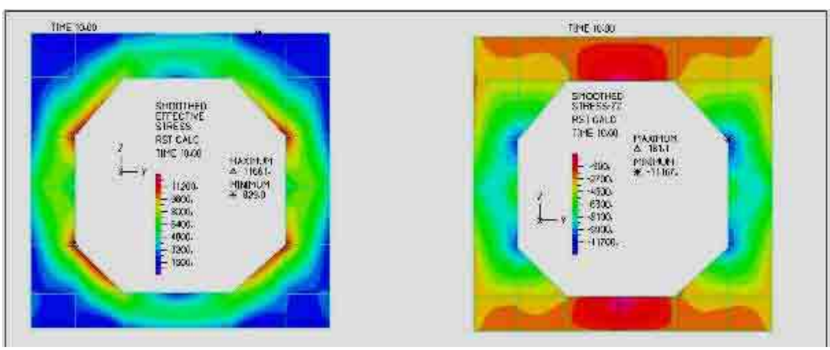
Sl. 9. *Raspodela vertikalnih pomeranja i pojave pukotina u oblozi kolektora za visinu nasipa od 100 m*

Sa slike 9 se vidi da je pomeranje unutar kolektora oko 1,0 cm.

Na slici 10 i 11 prikazane su veličine efektivnih i vertikalnih napona u elementima kolektora.



Sl. 10. *Efektivni i vertikalni naponi u elementima kolektora*



Sl. 11. *Efektivni i vertikalni naponi u elementima kolektora*

Model materijala nasipa i osnovnog tla analiziran je sa Mohr-Coulombovim uslovom loma, a model materijala kolektora kao beton sa sledećim karakteristikama: MB40, $E = 24 \cdot 10^5$ kN/m^2 i koeficijent Poissona $\nu = 0,15$.

Veličina relativnog sleganja kolektora je 18 cm, dok je maksimalno ulegnuće kolektora do 35 cm.

ZAKLJUČAK

Obzirom da kolektor predstavlja kapitalni objekat za jedan rudnik, treba naročito obratiti pažnju kako na njegovu izradu tako i na sredinu u kojoj je kolektor lociran (zbog naponsko-deformacionog stanja). Pre bilo kakvih sanacionih mera neophodno je postaviti stabilne repere u blizini ulaza i izlaza kolektora, koji bi bili povezani na državnu trigonometrijsku mrežu i imali apsolutne kote. Sa tim apsolutnim kotama izvršiti preciznim nivelmanom nulto merenje stropa i poda kolektora, kako bi se mogle pratiti stanje te dve tačke duž kolektora.

Sva merenja i opažanja koja su izvršena na kolektoru ispod VZO P.K. "Bogutovo selo" u Ugljeviku mogu biti primenjena na tunel Kriveljske reke.

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UDK: 622.1:550.8(045)=20

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OBSERVATION OF CHANGES AND MEASUREMENT OF SUBSIDENCE ON THE COLLECTOR UNDER THE OPEN PIT "BOGUTOVO SELO" IN UGLJEVIK

Abstract

Collector presents one of the most important facility for water collecting from water currents located nearby mine. Due to this it is important to investigate all factors that have influence on its stability and continuance. It is also necessary to carry out the periodical measurements and observations of collector condition and take measures for repairing the new damages. This paper presents the results of measurements and observation the collector condition under the open pit "Bogutovo selo" in Ugljevik, that would be also applied to the Kriveljska river tunnel in Bor.

Key words: *collector, stability factor, periodical measurements*

INTRODUCTION

Construction of underground facilities, such as tunnels and collectors, requires a complex approach to the problem solution. The ideal environment for tunnel construction is isotropic environment that is almost impossible in practice. Also, we faced with next situation: rooms (tunnels), constructed under projected conditions, are over time in completely different, changed conditions. These changes are, mainly, related to a change of vertical component of loads (exp. dike construction over the tunnel). Load changes above the underground facility will cause a stress – deformation change of the massif, what can result in a weakness of object or its parts (appearance of cracks, cleavages or collapse). The first exposed parts are areas, which are in engineering and geological terms classified in the zones of risk. Therefore, the impact of changes in a value of vertical component has to be defined.

MEASURING SUBSIDENCE OF COLLECTOR

Measuring subsidence of collector was carried out by the precise levelling instrument with the accuracy of registration shift of 0.1 mm. Metal bench marks are fixed on the roof of collector in a mutual distance of 23.0 to 50.0 m, along the entire length, starting from the axis of dam to the exit, according to previously established subsidence of collectors.

Very similar intensity of lowering ceiling panels was observed in the previous measurements. It is characteristic that collector exit (ceiling) rises as it is shown by the results of measurement at one of the

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bench marks, and they amount from +14 mm to +65 mm. Despite the high accuracy of measurement, results get this way are unreliable. It is necessary to set the bench marks near entrance and exit of the collector, which would be related with the State trigonometric network and had absolute elevation. This method could make an adjustment of levelling vane, counting tolerance, since it is a big levelling vane with length of more than 4 000 m. Levelling of floor and roof of the collector is necessary as well as observation of their mutual behaviour.

NUMERICAL ANALYSIS OF COLLECTOR CONSTRUCTION CONDITION ON ITS MOST ENDANGERED PART

Numerical collector model, in length of 332 m, is presented in Figure 1. Elements of base, collector construction and dumped material are separated by colour. Pressure stresses are indicated with a negative sign.

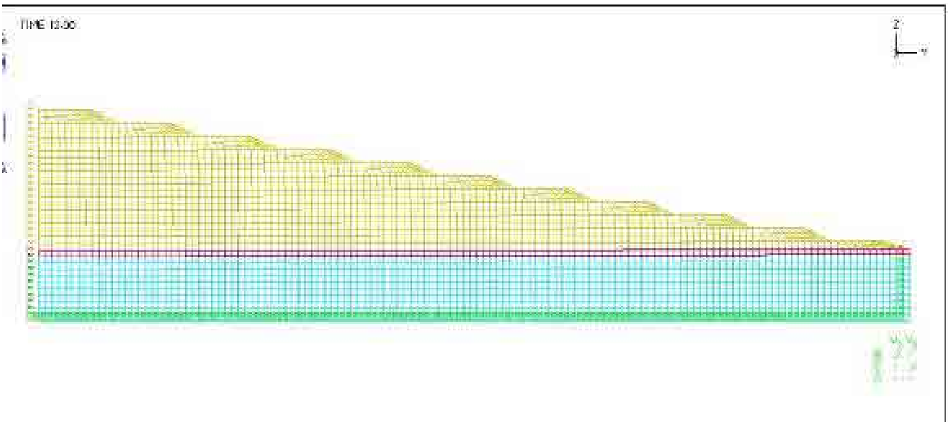

Figure 1. *Numerical model of collector longitudinal section with final contour of dumped material*

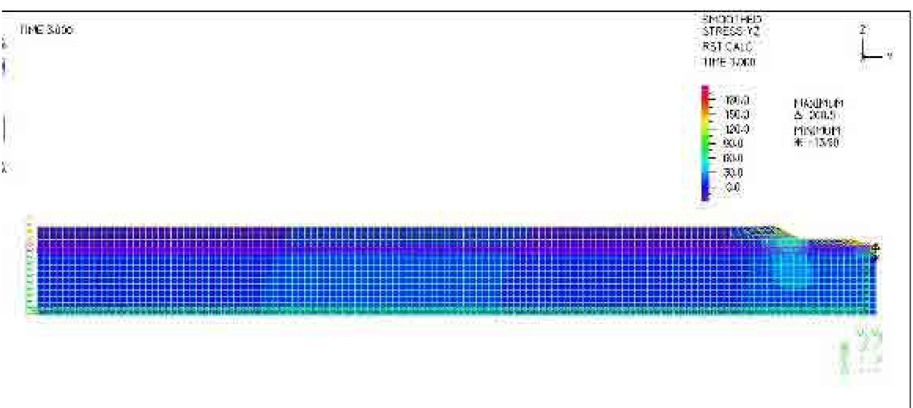

Figure 2. *Shear stresses in collector construction in the function of dumped material*

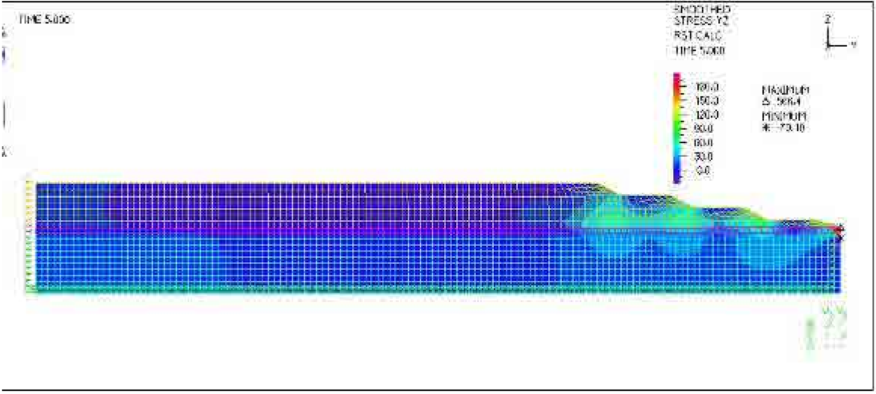

Figure 3. *Shear stresses in collector construction in the function of dumped material*

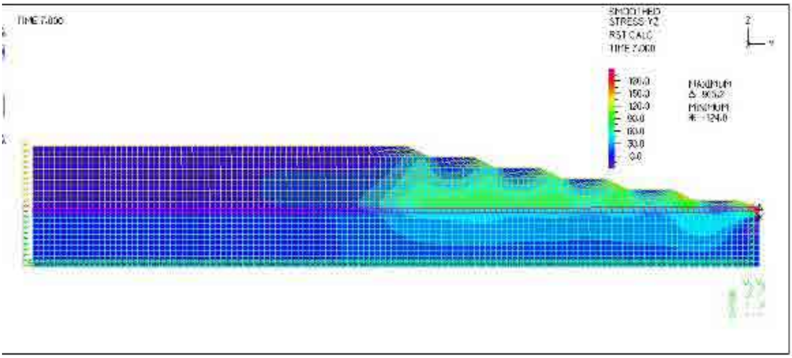

Figure 4. *Shear stresses in collector construction in the function of dumped material*

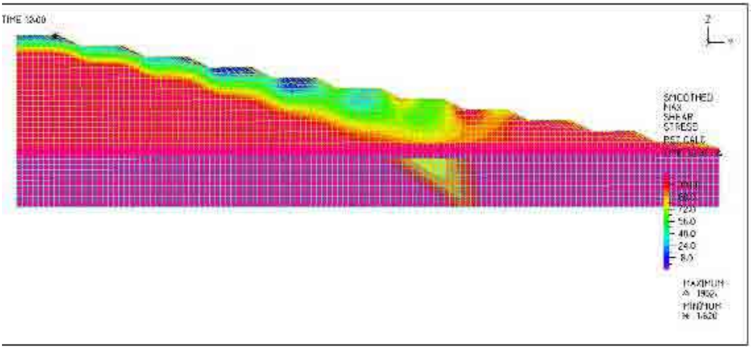

Figure 5. Shear stresses in collector construction in the function of dumped material

Figures 2 to 5, show shear stresses distribution in the massif and in the section along collector. It can be seen from these Figures that the shear stresses caused fracture in the collector cover. Figures 6 and 7 show vertical stresses increased with the increase of dumped material.

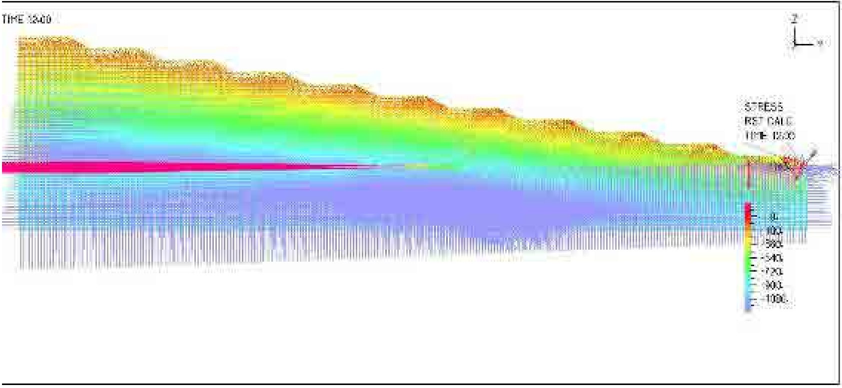

Figure 6. *Vertical stresses in the function of load increment*

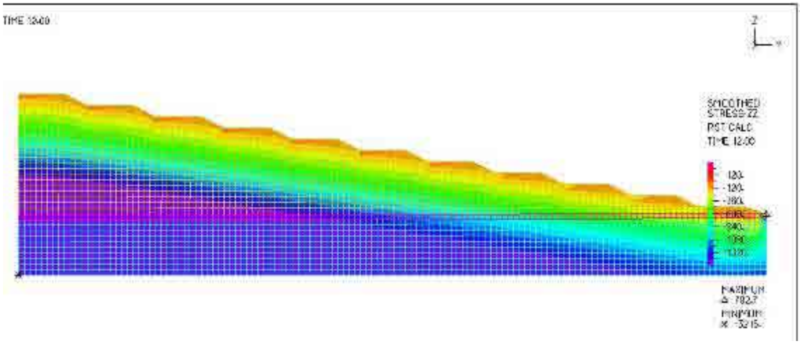

Figure 7. *Vertical stresses in function of load increment*

Calculation of collector cross-section was made for construction type I (coating thickness 45 cm). Model of finite elements for collector cross-section is shown in Fig. 8.

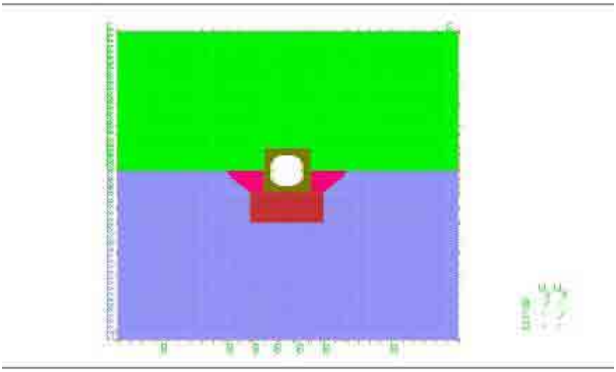

Figure 8. Numerical model for the collector cross-section

Dumped material and collector elements, with defined edge conditions on the model borders, are separated by colour

Figure 9 shows a distribution of vertical displacements and cracks appearance in coating, for the presumed embankment height of 100 m.

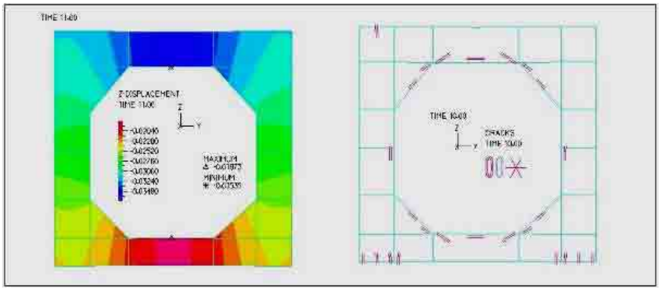

Figure 9. *Distribution of vertical displacements and cracks appearance in coating, for presumed embankment height of 100 m*

Fig. 9 shows displacement inside the collector of approximately 1.0 cm.

Fig. 10 and 11 show size of effective and vertical stresses in the collector elements.

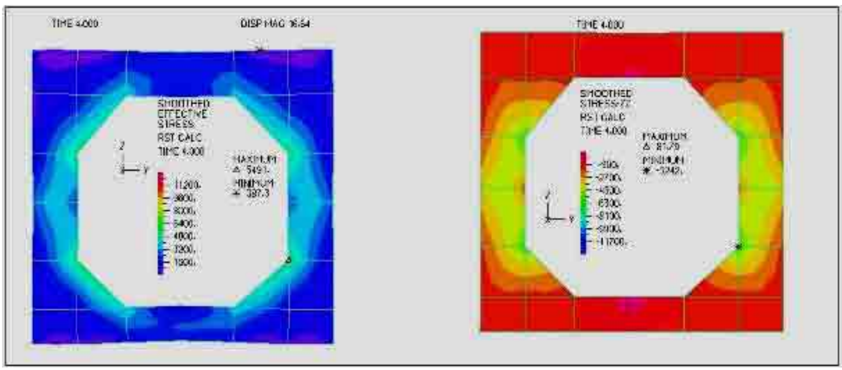

Figure 10. *Effective and vertical stresses in the collector elements*

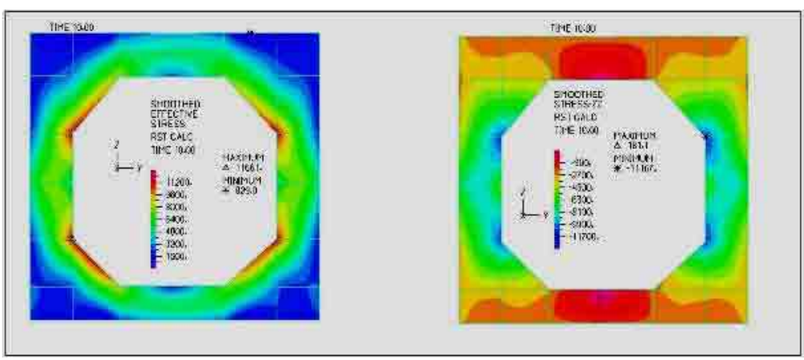

Figure 11. *Effective and vertical stresses in the collector elements*

Model of embankment material and basic soil were analyzed by the Mohr – Coulomb fracture condition, and model of collector material as the concrete material with the following characteristics: MB40, $E = 24 \cdot 10^5$ kN/m^2 and the Poisson coefficient $\nu = 0.15$

Size of collector relative subsidence is 18 [cm], while maximum collector depression is 35 cm.

CONCLUSION

Since the collector is the capital facility for a mine, particular attention should be paid to its development and environment of collector location (due to the stress-deformation condition). It is necessary to set up the stable benchmarks near inlet and outlet of the collector before taking any rehabilitation measures, and those benchmarks would be connected to the State trigonometric network and had the absolute elevations. With this absolute elevation, zero measurement of roof and floor should be made with precision levelling as the condition of these two points could be observed.

All measurements and observations made on the collector under the open pit "Bogutovo selo" in Ugljevik can be applied to the Kriveljska river tunnel.

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ISPITIVANJE MOGUĆNOSTI ISTOVREMENE EKSPLOATACIJE UGLJA I ULJNIH ŠKRILJACA U ALEKSINAČKOM BASENU

Izvod

Prateći nastojanja i aktivnosti u drugim zemljama, koje poseduju uljne škriljce, vidimo da se na ovaj energetski potencijal računa i intenzivno radi na osvajanju ekonomskih tehnologija njihove eksploatacije i prerade, u cilju dobijanja tečnih i gasovitih ugljovodonika i drugih vrednih proizvoda.

Obim i struktura energetskih resursa i energenata u Srbiji je u nezavidnoj situaciji i ovim istraživanjem je pokušano da se inicira drugačiji pristup iskorišćenja energetskog potencijala u Srbiji. Sa privrednog i strateškog aspekta potrebno je naučno-istraživačke snage usmeriti u pravcu razvoja iskorišćenja uljnih škriljaca i time smanjiti zavisnost zemlje od uvoza energenata.

Prema neki procenama, Aleksinačko ležište uljnih škriljaca spada u naše najperspektivnije ležište, a rezerve uljnih škriljaca se procenjuju na oko 2 milijarde tona, sa srednjim sadržajem od 9,78% ulja, te sadrže ukupno oko 190.000.000 t ulja. U ovom radu razmatramo mogućnosti istovremene eksploatacije uljnih škriljaca i preostalog mrkog uglja primenom metoda eksploatacije širokim čelom i metodom podzemne gasifikacije (PGU).

Ključne reči: *uljni škriljci, Aleksinački basen, mrki ugalj, široko čelo, gasifikacija, PGU*

UVOD

Obim i struktura energetskih rezervi i resursa Srbije je veoma nepovoljna. Rezerve kvalitetnih energenata, kao što su nafta i gas su simbolične i čine manje od 1% u ukupnim bilansnim rezervama Srbije, dok preostalih 99% energetskih rezervi čine razne vrste ugljeva, u kome dominira niskokvalitetni lignit, sa učešćem od preko 92% u ukupnim bilansnim rezervama. Ovo se posebno odnosi na lignit koji se eksploatiše u rudnicima sa površinskom eksploatacijom, koji sa ukupnim eksploatacionim rezervama od oko 13.350 miliona tona, predstavlja najznačajniji energetski resurs Republike Srbije. Geografski posmatrano, u Kolubarskom basenu nalazi se 14%, u Kostolačkom

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** *Rudarsko-geološki fakultet Beograd*

3,3%, dok Sjenički i Kovinski basen sadrže samo 2,7% ovih rezervi.[9]

Struktura tekuće potrošnje energije u svakoj zemlji, uslovljena je stanjem ekonomije u svim sektorima, uključujući i sektor energetike, a posebno strukturom i intenzitetom proizvodnih i uslužnih aktivnosti, standardom i navikama građana, kao i raspoloživošću energetskim izvorima i ekonomsko - energetskim okolnostima u okruženju.

Zbog poznatih okolnosti u proteklom periodu, Srbija je primer zemlje, koja radi dostizanja višeg nivoa socio-ekonomskog razvoja, mora u kratkoročnom periodu da uskladi, ne samo razvoj energetike sa privredno ekonomskim razvojem, već i razvoj energetskih proizvodnih sektora sa sektorima potrošnje energije. Uljni škriljci su do pre par godina spadala u „nekonvencionalna" fosilna goriva, pa su u svetskim razmerama veoma malo istraženi.

Interesovanje za uljne škriljce i ispitivanje mogućnosti njihovog korišćenja u našoj zemlji datira još od pre prvog svetskog rata. Posle rata istraživanje je vršeno u više navrata, ali nesistemski, tako da ni do danas nije sprovedeno do kraja.

ULJNI ŠKRILJCI U SRBIJI

Istraženost Srbije u pogledu na uljne škriljce je veoma mala. Na teritoriji Srbije otkrivene su pojave i nalazišta uljnih škriljaca u sledećim regionima: Niškom (Aleksinački basen, reoni sela Bovna i Prugovca, Bubušinački i Kosanički basen, i Svrljički deo senonskog tektonskog rova), Zaječarskom (Timočka zona senonskog tektonskog rova, između Knjaževca i Boljevca), Južnomoravskom (Vranjski basen), Kraljevačkom (Kruševački i Čačansko-Kraljevački basen) i Podrinjsko-Kolubarskom (Valjevsko-Mionički basen). Danas se samo za ležište uljnih škriljaca u okolini Aleksinca može reći da je bolje istraženo nego druga, zahvaljujući istražnim radovima koji su obavljani za potrebe proizvodnje mrkog uglja, te su pri tome prikupljani podaci i o uljnim škriljcima, na osnovu istražnih bušotina. Međutim, čak i ti podaci nisu dovoljni za konačnu procenu geoloških i eksploatacionih rezervi, odnosno njihovu kategorizaciju.

Rezerve uljnih škriljaca u Srbiji, su prema procenama, oko 8–10 milijardi tona, pri čemu je najviše istraženo upravo Aleksinačko ležište. Veliki deo rezervi uglja kod nas nije dostupan zbog ekonomskih ili tehničkih razloga. Dokazane rezerve uglja koje nisu pogodne za površinsku eksploataciju iznose preko 500 miliona tona, a uljnih škriljaca, samo u Aleksinačkom ležištu, ima preko 2 milijarde tona. [1]

CILJ ISTRAŽIVANJA

Već do sada poznate rezerve uljnih škriljaca u našoj zemlji, stavljaju nas pred zadatak da utvrdimo koliki je to energetski i sirovinski potencijal, sa kojim možemo računati, na određenom nivou sadašnjih tehnoloških rezervi, a posebno onih koje treba očekivati u perspektivi.

Sa ciljem, da se razradi mogućnost industrijskog korišćenja uljnih škriljaca, a imajući u vidu da naša zemlja raspolaže značajnijim rezervama uljnih škriljaca i da su rezerve uglja u našim rudarsko - energetskim kombinatima „Kolubara" i „Kostolac" ograničene, urađena je analiza mogućnosti istovremene eksploatacije uglja i uljnih škriljaca iz Aleksinačkog basena.

PODRUČJE ISTRAŽIVANJA

Aleksinačko ležište mrkih ugljeva i uljnih škriljaca zahvata područje između reke Južne Morave i Moravice, pruža se neposredno od grada Aleksinca, u pravcu SSZ–a, u dužini od 10 km i zahvata površinu od oko 20 km^2.

Karakterističko je i jedno od retkih u svetu, gde se slojevi uljnih škriljaca nalaze zajedno sa mrkim ugljem i to u krovini i podini glavnog ugljenog sloja..

Godine 1883, dolazi do eksploatacije mrkih ugljeva, dominirala je primena kombinovane, stubno-komorne metode otkopavanja. U zavisnosti od rudarsko-geoloških uslova eksploatacije, razvijene su bile dve varijante ove metode otkopavanja i to :

- klasična aleksinačka metoda otkopavanja i
- izmenjena ili modifikovana aleksinačka metoda

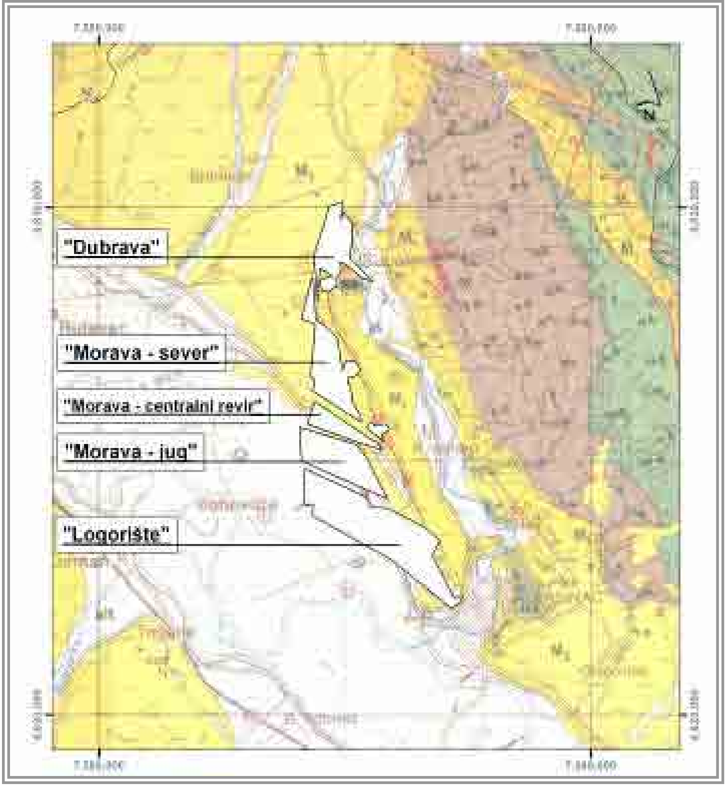
Do zatvaranja rudnika došlo je nakon velike kolektivne nesreće koja se dogodila 1989. godine. Eksploatacija uglja se vršila u Severnom reviru polja Morava kada su primenjivane stubno-komorne metode tzv. Aleksinačke metode.

Aleksinačko ležište podeljeno je rudarskim radovima na tri ugljonosna polja: „Logorište”, „Morava” i „Dubrava”, (sl. 1) pa su i rezerve posebno utvrđene za svako polje.

Do sada je na području Aleksinačkih rudnika i u široj okolini izbušeno preko 120 bušotina. Većina ovih bušotina bušena je u cilju ispitivanja ugljonosnosti.

Pri određivanju mogućnosti eksploatacije uljnih škriljaca moraju se imati u vidu njihove specifičnosti. Tako se prema veličini i geološkoj složenosti ležišta škriljaca razvrstavaju u tri grupe, pri čemu se svaka grupa deli u tri podgrupe u zavisnosti od debljine sloja i sadržaja kerogena. Kod određivanja kvaliteta rezervi škriljaca mora se izvršiti oprobavanje slojeva, kompleksan karotaž na svim istražnim bušotinama, utvrđivanje genetskog tipa škriljaca i naročito, utvrđivanje kvalitativnih i tehnoloških osobina. Zahtevi koji se postavljaju pri definisanju uljnih škriljaca doprineli su da postoje veoma malo utvrđenih rezervi i resursa, dok je daleko veći udeo potencijalnih rezervi.

Prema strukturnoj građi, Aleksinačko ležište ima sinklinalnu formu, u većem delu ležišta i složenu građu u „Dubravi” i podeljeno je rasedima u više, većih, samostalnih blokova. Slojevi su horizontalni, blago nagnuti pod uglom do 20^o i strmi do 90^o, pa je ležište svrstano u drugu grupu. Prema postojanosti debljine i kvaliteta krovinskih uljni škriljaci svrstani su u I podgrupu. Podinski uljni škriljci zbog povećane izmenljivosti debljine i kvaliteta svrstani su u II podgrupu. [10]



Sl. 1. *Položaj ugljonosnih polja u Alesinačkom basenu*

MOGUĆNOSTI ISTOVREMENE EKSPLOATACIJE UGLJA I ULJNIH ŠKRILJACA

Činjenica, da se uljni škriljci pojavljuju na površini, u vidu izdanaka, na većem prostranstvu po pružanju ležišta, od lokaliteta „Dubrava", do lokaliteta „Logorište", predstavlja povoljnost za površinsku eksploataciju.

Nepovoljnost za veće učešće površinske eksploatacije u ukupnim rezervama ležišta predstavlja veoma strmo zaleganje škriljaca u jednom delu ležišta i do 90^o. Strmo zaleganje ležišta uslovljava veliku dubinu i preko 700m, tako da se veći deo rezervi škriljaca mora otkopavati podzemnom eksploatacijom.[5]

Visoki troškovi u podzemnoj eksploataciji i kompleksnost proizvodnih procesa zahtevaju primenu savremenih sistema eksploatacije odnosno pravilan izbor i dimenzionisanje otkopne mehanizacije. Osnovna karakteristika savremenih sistema je visok stepen mehanizovanosti i automatizovanosti svih rudarskih operacija (otkopavanje, utovar, transport, izrada podzemnih prostorija, podgrađivanje i dr.), uz poštovanje strogih zahteva u pogledu sigurnosti rada, bezbednosti radnika i zaštite životne sredine.

Da bi se izbor otkopne mehanizacije izvršio pravilno, potrebno je sagledati sve relevantne faktore uticaja, koji mogu delovati isključujuće ili ograničavajuće. Izbor otkopne mehanizacije je posebno složen kada produktivni slojevi nisu regularni, odnosno, kada nisu horizontalni ili blago nagnuti i kada njihova debljina ne omogućava formiranje takvih otkopnih frontova, kojima se u jednom zahvatu, na dužinama od više kilometara može otkopavati.[2]

Analiza mogućnosti širokočelne metode eksploatacije

Komforne radne uslove i navedene proizvodno-ekonomske parametre, u jamskim uslovima su mogle da obezbede široko čelne metode otkopavanja sa kompleksnom mehanizacijom. Međutim, ove metode i savremena kompleksna mehanizacija, zahtevaju veoma povoljne rudarsko-geološke uslove i u ležištu uglja koje se otkopava.

Rezerve ispod dubine od 50 m se mogu otkopavati podzemnim (jamskim) postupkom. Sigurno je da je za podzemnu eksploataciju potrebno duže vreme i više sredstava za izradu rudarskih objekata za otvaranje ležišta, transport i izvoz, za šta je neophodno izvršiti dodatna ispitivanja za izbor najpovoljnije varijante za otkopavanje i eksploataciju uglja i uljnih škriljaca podzemnim postupkom.

Dostignuta savremena nauka i praksa podzemne eksploatacije, definitivno je u tom procesu dala industrijski karakter. Istina, po mnogo čemu on je specifičan, ali u osnovi ima sva obeležja industrijskog procesa. Eksploatacioni zahvati u ležištu međusobno su tehnološki povezani u jednu skladnu integralnu celinu sa kontinuitativnim odvijanjem. Savremena tehnološka dostignuća inkorporirana su u tehnološke faze rada i to tako da komplementarno izgrađuju proizvodnu celinu koja sve više gubi ekstenzivni karakter, što je jedno od osnovnih obeležja industrijskog procesa. Koncepcija otvaranja i pripreme ležišta-uvažavajući sva predhodno data ograničenja i principe, kao i poznate uslove eksploatacije ležišta, nameću se sledeća okvirna tehnička rešenja:

- racionalno je projektovati rudnik sa min. 1,5 mil. t/g i perspektivnim povećanjem kapaciteta na 4 mil t/g i više;
- za kapacitet od 1,5 mil t/g i više od 4 mil. t/g neophodno je izgraditi minimum 3 prostorije otvaranja. Naime, neophodno je razdvojiti izvoz uglja i škriljca od prevoza ljudi i snadbevanja jame repromaterijalom i imati posebnu prostoriju za ventilaciju;
- prostorni položaj ležišta i elementi zaleganja upućuju na centralno lociranje glavnog izvoznog i ventilacionog sistema; izbor mikro lokacije objekata je u funkciji morfologije terena, komunikacija, uslova gradnje površinskog kompleksa i drugo, pa je teško preciznije dati tehničke elemente koji definišu tehnologiju i troškove izgradnje, već će se isti dati procenom na osnovu cene sličnih objekata u drugim rudnicima.

Svim poznatim i pretpostavljenim uticajnim faktorima odgovara sistem otvaranja koji obuhvata:

- Glavni izvozni niskop, sa površinom poprečnog preseka od oko 14 m^2, padom oko 15°, ukupne dužine do 1000 m;
- Ventilacioni niskop, sa površinom poprečnog preseka od oko 10 m^2 i padnim uglom od oko 30° (paralelan sloju) i dužine do 800 m;
- Servisno vertikalno okno za prevoz radnika, opreme, repromaterijala i delova dubine oko 400 m;

Iz područja otvaranja, neophodno je ostvariti poprečne veze sa produktivnim slojevima, na međusobnom rastojanju od 40 do 60 m. Spajanje horizonata ostvaruje se izradom kosih prostorija, najmanje tri, lociranih u produktivnim slojevima, u cilju uspostavljanja protočnog provetravanja. Dalji sistem pripreme, ostvaruje se izradom paralelnih hodnika do granica ležišta, u krovinskom i podinskom bloku. Uspostavljanjem poprečnih veza među pripremnim hodnicima stvaraju se uslovi za formiranje širokočelnih mehanizovanih otkopa. U datim uslovima, uvažavajući zahteve proizvodne funkcionalnosti i sigurnosti rada, smatra se svrsishodnim dvokrilno otkopavanje.

Nameće se logična dilema, može li ovo tehničko rešenje biti primenjeno u uslovima uljnih škriljaca u Aleksincu. Poznavajući fizičko-mehanička svojstva škriljaca i na bazi iskustva pri eksploataciji uglja u jami „Morava”, može se dati siguran pozitivan odgovor. [4]

Analiza mogućnosti primene podzemne gasifikacije

Višedecenijska svetska iskustava, kada se govori o podzemnoj gasifikaciji uglja (sl. 2), ukazuju, da se radi o ekološki čistoj tehnologiji kompleksnog iskorišćenja uglja i to u potpuno neiskorišćenim ili u nekorišćenim ugljenim slojevima ili delovima ležišta.

Imajući u vidu kvantitet i kvalitet energetskih resursa kojima raspolažemo, a posebno izraženije potrebe za što racionalnijim korišćenjem primarnih energetskih resursa (dakle, ne samo sekundarnih), našli smo se u situaciji da osvajamo tehnologiju eksploatacije vanbilansnih rezervi, kao i otkopnih ostataka bilansnih rezervi. Metoda bez alternative za takve rezerve uglja je podzemna gasifikacija uglja.

Sam proces gasifikacije mrkih ugljeva je proces prerade organske materije uglja u gasovite produkte. Gasifikacija mrkih ugljeva se može odvijati i kod ugljeva sa niskim stepenom hemijske zrelosti, te se na taj način ugalj potpuno oslobađa od mineralnih primesa i vode. Gasifikacija se može odvijati dvojako: podzemnom gasifikacijom uglja-PGU ili u gas generatorima.

Pri opredeljenju za aktivnosti na tom planu, najvažniji je pristup što savesnijem izboru optimalne lokacije za PGU. Pri tome je neophodno sagledati količine uglja koje će se moći izgasifikovati, a time i odrediti količinu ukupno proizvedenog gasa iz PGU.

Dosadašnja iskustva su pokazala de se podzemnom eksploatacijom uglja iskoristi oko 30-35%, a da praktično ostaje napušteno oko 65-70%, što bi se sa aspekta eventualnog postojanja viška energetskih resursa i razumelo, ali nije tako, pogotovo zbog brige za buduća vremena. Takvo stanje bi se moglo i prihvatiti, ali pojavljivanjem novih ili alternativnih tehnologija, kao što je i ova – PGU, odavno poznata (licencu PGU je još 1974. godine SSSR prodao SAD), sa komparativnim prednostima u odnosu na konvencionalne metode eksploatacije (koje u osnovi karakteriše težak rudarski rad, izražen određeni društveni interes, nedovoljna rentabilnost, zaštita okoline, emisija gasova, itd), ozbiljno nas opredeljuje za ove nove tehnologije.

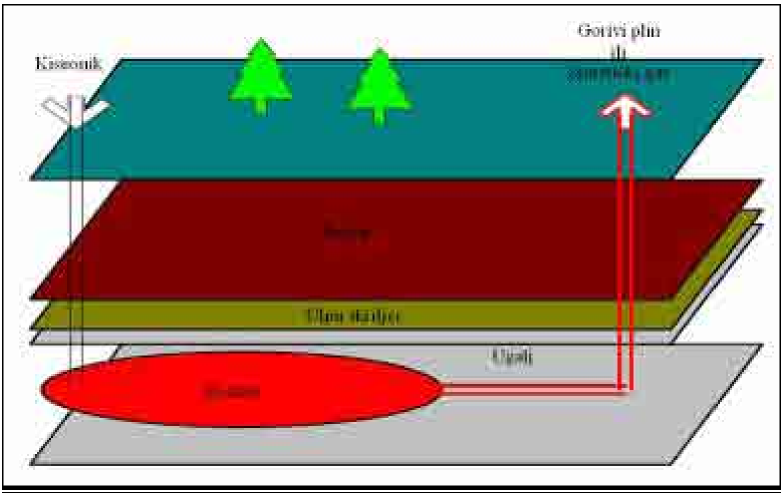
Podzemna gasifikacija uglja, autotermički proces, obuhvata proces degasacije, odnosno pirolize i samu gasifikaciju. Ti procesi nastaju kao rezultat uticaja visoke temperature i upravljanja sagorevanja uglja pri dovođenju sredstava za gasifikaciju, koja je najčešće vazduh, vodena para sa vazduhom u određenom odnosu, te vazduh ili vodena para obogaćeni kiseonikom, ili pak sam kiseonik. Danas uglavnom egzistiraju dve poznate metode PGU.

- Metoda bez podzemnih prostorija, koja se zasniva na bušenju bušotine sa površine kroz slojeve i provođenjem gasifikacije dovođenjem gasifikujućeg agensa kroz bušotinu, odnosno kanala, a odvođenjem produkta gasifikacije kroz produkcionu bušotinu;
- Metode iz podzemnih prostorija u kojoj se sloj, preostao nakon izrade sigurnosnih stubova, gasificira korišćenjem izrađenih prostorija.

Prva grupa metoda (bušotinska PGU) je uglavnom aktuelna za korišćenje vanbilansnih rezervi uglja, a druga za gasifikaciju zaostalih sigurnosnih stubova, odnosno otkopnih ostataka bilansnih rezervi, posle završene jamske eksploatacije. Od bušotinskih metoda obično su u primeni: filtraciona, kanalna i protočna metoda.

Uglavnom je rasprostranjena filtraciona metoda, nakon prethodnog zapaljenja reakcione zone. U američkim eksperimentima primenjuje se kanalna metoda, s tim, da se kanali zapaljuju filtracionom metodom.

Podzemna gasifikacija uglja, karakteriše se stepenom iskorišćenja uglja, koji predstavlja odnos gasifikovanog uglja prema ukupno raspoloživoj količini uglja za PGU. Termička efikasnost procesa je definisana odnosom toplotne moći dobijene gasne smeše prema toplotnoj moći uglja, iz koga je nastala smeša, svedeno na ekvivalentne dimenzije, što zavisi od vrste gasifikujućeg agensa, njegovog pritiska i temperature, te osobine uglja za gasifikaciju, dubine zaleganja sloja, vlažnosti uglja, kao i tektonskih uslova u ležištu.



Sl. 2. *Pojednostavljena šema PGU procesa*

Cilj PGU je izdvajanje toplotne energije iz uglja, u vidu gorivog gasa, ili za proizvodnju gasa za sintezu. Proces transformacije energije se odvija putem potpunog i nepotpunog sagorevanja uglja i vodeno-gasnog procesuiranja zažarenog koksa na samom mestu zaleganja uglja putem vazduha, kiseonika, pare ili njihovom mešavinom. Tehnološki proces PGU sastoji se iz pripreme ugljenog sloja za gasifikaciju i samog proces gasifikacije.

Priprema ugljenog sloja za gasifikaciju sastoji se u izradi kosih i vertikalnih bušotina sa površine terena. Do povlate ugljenog sloja bušotine se zacevljuju, a kontakt cevi sa sredinom kroz koju se buši i cementira. Bušotina kroz ugljeni sloj se ne zacevljuje. Dno bušotine je na oko 0,5 m od podine ugljenog sloja. Konstrukcija bušotinskog sistema, raspored bušotina i njihov prečnik određuju se konkretno za svako ležište na osnovu geoloških karakteristika ležišta. Za formiranje kanala između bušotina primenjuje se dirigovano bušenje sa kojim se kroz sloj izbuši horizontalna bušotina, pri podini ugljenog sloja, koja povezuje vertikalne bušotine. Frakturisanje ugljenog sloja vrši se pomoću vazduha visokog pritiska, hidraulično ili plameno, da bi se obezbedio prolaz vazduha kroz pore u uglju. Ugljeni sloj se potpaljuje ubacivanjem zažarenog koksa kroz bušotinu i uduvavanjem vazduha niskog pritiska ili brenerom.

Tokom pirolize, ugalj se žari i oslobađa smole, ulja, niže ugljovodonike i volatile. Gasifikacija se javlja kad vodena para, kiseonik, ugljen-dioksid i vodonik reaguju sa užarenim ugljem.

Metan je proizvod pirolize i njegovu produkciju pospešuju niže temperature i viši pritisci. Rezultati ukazuju da povišeni pritisak uzrokuje prodiranje pirolize kroz ugljeni sloj i tako podspešuje gasifikacioni proces. Reakcije oksidacije ugljenika dominiraju na nižim temperaturama i nižim pritiscima, sto vodi većem sadržaju ugljendioksida u proizvedenom gasu i manjoj toplotnoj vrednosti. Ovakvi uslovi su tipični za ranije, relativno plitke probe PGU.

Osnovni princip koji se koji bi se mogao primeniti za Aleksinačko ležište uglja i uljnih škriljaca je u tome da se vrši gasifikacija uglja sa čistim kiseonikom pod pritiskom do 20 bara, a da se toplota dobijena ovim postupkom koristi za švelovanje uljnih škriljaca delimično u podini ugljenog sloja, a najvećim delom krovinskih uljnih škriljaca.

Uobičajeni postupak za švelovanje škriljaca je da se vrši gasifikacija uglja ili čvrstog ostatka pri preradi produkata švelovanja uljnih škriljaca i da produkti gasifikacije svojom toplotom vrše švelovanje škriljaca u višem delu šahte.

Priroda je učinila da Aleksinačko ležište ima baš takav raspored (jedino što bi povoljnije bilo da podinski škriljci ne prelaze debljinu ugljenog sloja).

Postupak bi bio sledeći:

Gasifikacijom ugljenog sloja oslobađaju se produkti gasifikacije CO, H_2, CH_4 sa temperaturom od oko 700°C i ugljeni sloj se sa svoje debljine od 6 m svodi na debljinu od cca 0,8 m (zavisno od sadržaja pepela). Usled toga, dolazi do prirodnog zarušavanja krovinskih škriljaca, njihove dezintegracije i pripreme za švelovanje. Vreli produkti gasifikacije vrše švelovanje povlatnih uljnih škriljaca prolaženjem kroz dezintegrisanu masu škriljaca. Podinski škriljci se zagrevaju prolaženjem toplote.

Kod Aleksinačkih ležišta predlaže se gasifikacija sa čistim kiseonikom (dobijanje modifikovanim postupkom Linde-Frenkl). Predlaže se modifikacija sa prethodnim hlađenjem vazduha korišćenjem toplote dobijene hlađenjem gasova iz bušotine. Gasifikacija čistim kiseonikom umesto vazduhom predlaže se s obzirom na daleko brže odvijanje procesa, većeg koeficijenta iskorišćenja toplote, i dobijanja gasovitih produkata daleko veće toplotne vrednosti.

Gas dobijen gasifikacijom uglja kiseonikom i uz pritisak koji normalno ima oko 16,7 MJ/m^3 obogaćuje se gasovitim produktima švelovanja uljnih škriljaca te dostiže vrednost od oko 20,9 MJ/m^3. Kao takav spada u red srednjekaloričnih gasova i može se direktno koristiti za pogon termoelektrane-toplane kao i u industrijske svrhe. Takođe, moguće su razne konverzije, kao i dobijanje tečnih ugljovodonika.

U procesu prečišćavanja gasa, dobijaju se: fenoli, amonijak, benzoli i mnogi drugi produkti, dok se iz sumporvodonika lako dobija čist sumpor.[11]

ZAKLJUČAK

Aleksinačko ležište uglja i uljnih škriljaca spada u ležišta vrlo složene geološke strukture, sa ograničavajućim elementima za primenu metoda otkopavanja širokim čelom i tehnologije mehanizovanog otkopavanja.

Prema broju istraženih tehničkih parametara, neophodnih za projektovanje podzemnih proizvodnih sistema i konstrukcije otkopa, ovo ležište spada u grupu nedovoljno istraženih ležišta.

Ova činjenica je utvrđena kroz analizu raspoložive tehničke dokumentacije i prouzrokuje mnoge teškoće i upućuje na nepouzdane ocene i prognoze tehničkih veličina i takođe zahteva neophodna istraživanja radne sredine, u početnom periodu rekonstrukcije rudnika.

Nakon zatvaranja Aleksinačkog rudnika, preostalo je kroz bilansne i vanbilansne rezerve 27,5 mil.t. kvalitetnog mrkog uglja. Iz svetskih industrijskih iskustava sa PGU poznato je da je stepen iskorišćenja „napadnutih" slojeva uglja 72-96%. Ako računamo sa svega 80% takve iskoristivosti, ostaje otvoreno mišljenje da bi se pomoću PGU u Aleksincu iskoristilo 22 mil. t uglja.

Postojanje uljnih škriljaca, direktno naleglih na ugalj, omogućavali bi povećanje efikasnosti procesa PGU. Naime, gubitak toplote iz procesa PGU na krovinu će proizvesti dodatne ugljovodonične gasove i tečnosti. Veći deo tih tečnosti će krekovanjem proizvesti dopunski deo ugljovodoničnih gasova. Takvo kombinovano dobijanje ugljovodoničnih gasova iz uljnih škriljaca povećava toplotnu moć gasa dobijenog iz PGU, a omogućava i dobijanje određene količine nafte, kao nusproizvoda u ovom procesu.

Da bi se ostvarila proizvodnja na bazi već dokazanih geoloških rezervi, potrebno je nastaviti sa istraživanjem načina dobijanja sintetičke nafte iz uljnih škriljaca, uz konsultaciju inostranih firmi, čija su iskustva i osvojene tehnologije u ovoj oblasti još uvek neprevaziđene. Pri tome se mora imati u vidu, da je realizacija eksploatacije ovih potencijala limitirana, kako sadržajem uljne frakcije koja diktira tehnologiju, prostornim zahtevima i uslovima vezanim za životnu sredinu, a posebno u postizanju rentabiliteta za pojedina ležišta i nalazišta, pri čemu u osnovi rentabilitet zavisi od cene nafte na svetskom tržištu, koja bi za uslove naših ležišta morala biti znatno veća u dužem vremenskom periodu. To ipak znači da ovaj resurs zaslužuje pažnju i proučavanje kao alternativni energetski potencijal.

U slučaju Aleksinačkog ležišta, pored pravilne raspodeljenosti korisnih i štetnih komponenti, presudan uticaj na ekonomske uslove eksploatacije imaće nagib i dubina zaleganja slojeva, tj. morfološke karakteristike rudnog tela. Naravno, posebne analize je potrebno napraviti za iskrorišćenje korisne materije i velikih količina uljnih škriljaca koje se nalaze ispod samim naseljenih mesta (Aleksinac, Subotinac, Vakupac, itd) U ovim delovima ležišta, tkz. zaštitnim stubovima, proces PGU može predstavljati najoptimalnije rešenje.

Količine od oko 3,8 milijardi bituminoznih laporaca, koji se nalaze u povlati uljnih škriljaca sa oko 4-5% organske materije, takođe mogu biti predmet posebnih istraživanja, a buduće vreme će već pokazati da li se oni mogu tretirati zajedno za škriljcima ili odvojeno.

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INVESTIGATION OF POSIBILITES FOR SIMULTANEOUS EXPLOITATION OF COAL AND OIL SHALE IN THE ALEKSINAC BASIN

Abstract

Following the efforts and activities in other countries that have oil shale, we can see, that this energy potential is intensive and accounts for winning the technology of their economic exploitation and processing, in order to obtain liquid and gaseous hydrocarbons and other valuable products.

The scope and structure of energy resources and energy in Serbia is in unenviable situation and this research attempts to initiate a different approach for utilization the energy resources in Serbia. With the economic and strategic aspects is need to scientific research forces directed towards development of utilization the oil shale and reduce dependence on energy imports from the country.

According to some estimates, the Aleksinac deposit of oil shale is one of our most promising deposits, and oil shale reserves are estimated at about 2 billion tons, with high content of 9.78% oil, and contains total of about 190.000.000 t oil. In this paper, we are considering the possibility of simultaneous exploitation of oil shale and remaining brown coal using the mining method of longwall and the method of underground gasification.

Key words: *Oil shale, Aleksinac deposit, brown coal, longwall mining, gasification, UCG*

INTRODUCTION

The scope and structure of energy reserves and resources of Serbia is very unfavorable. Reserves of high-quality energy such as oil and gas are symbolic and are less than 1% of total balance reserves of Serbia, while the remaining 99% of energy reserves are various types of coal, which dominates low quality lignite, with the participation of over 92% of total balance reserves. This is especially true of lignite that is exploited in the mines with surface mining, the exploitation by total reserves of about 13,350 million tons, the most important energy resources of the Republic of Serbia. Geographically speaking, in the Kolubara basin is 14%, in the Kostolac basin 3.3%, while the Sjenica and Kovinski basin contain only 2.7% of these reserves. [6]

The structure of current energy consumption in every country, caused by the state of economy in all sectors, including energy sector, especially the structure and intensity of production and service

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activities, standards and habits of citizens, as well as the availability of energy resources and economic - energy conditions in the environment.

Because of known circumstances in the past, Serbia is an example of the country, which is forced in the short term to harmonize not only energy development with the business economic development, but development of energy production sector with the sectors of energy consumption in order to achieve higher levels of socio-economic development. Oil shales, a few years ago, fell in the "unconventional" fossil fuels, and are of worldwide very little explored.

Interest in oil shale and testing capabilities their use in our country dates back to before the I World War. After the War, research was done on several occasions, but not systematically, so it has not been carried out to the end.

OIL SHALE IN SERBIA

Site researches of oil shale in Serbia are very small. On the territory of Serbia oil shale sites were discovered in the following regions: Niš (the Aleksinac Basin, regions village Bovan and Prugovac, Bubušnica and Kosanica Basin), Zaječar (Timok zone between Knjaževac and Boljevac), South Moravic (the Vranje basin), Kraljevo (the Kruševac and Čačak-Kraljevo basin) and Podrinje - Kolubara (the Valjevo-Mionica basin).

Today, only for the oil shale deposit around Aleksinac we can say it is better researched than others, thanks to investigative work that are undertaken for the production of coal, and thereby collected data on oil shale, on the basis of prospecting the drillholes. However, even these data are not sufficient for final evaluation and exploitation of geological reserves and their categorization.

Reserves of oil shale in Serbia, according to estimates, are approximately 8-10 billion tons, where the Aleksinac deposit is the most researched. Large reserves of coal in our country are not available due to the economic or technical reasons. Proven coal reserves that are not suitable for surface exploitation amounts exceeding 500 million tons, and oil shale are only in the Aleksinac deposit, over 2 billion tons. [1]

AIM OF RESEARCH

For the currently known oil shale reserves in our country, put us to the task to determine what is the energy and raw potential, with which we can count on a certain level of current technological reserves, especially those to be expected in the future.

In order to elaborate the possibility for industrial use of oil shales while bearing in mind the fact that our country has a considerable oil shale reserves, and that the coal reserves in our mining – the energy plant "Kolubara" and "Kostolac" limited, made the possibility of simultaneous analysis of coal and oil shale from the Aleksinac basin.

RESEARCH AREA

The Aleksinac deposit of brown coal and oil shale overtakes the area between the River Morava and the South Moravica offers directly from the town of Aleksinac, in the direction of NNW, the length of 10 km and covers the area of about 20 km^2.

It is one of the few in the world, where the layers of oil shale stored together with brown coal, in floor and overlie main coal layer. In 1883, the exploitation of brown coal was dominated by the combined, room-pillar mining methods. Depending on the mining-geological conditions of exploitation, two variants of this method of mining were developed as well as:

- the classic Aleksinac mining method, and
- the changed or modified Aleksinac method

The closure of the mine, occurred after the large collective accident in 1989, the coal exploitation was done in the north area of "Morava" field, where the room-pillar mining methods were applied, so called the Aleksinac methods.

The Aleksinac deposit is divided by mining works into three coal fields: the "Logorište", "Morava" and "Dubrava" (Fig. 1) and the reserves are specially determined for each field.

Until now, the area of Aleksinac mines in its surroundings drilled over 120 drillholes. Most of these drillholes were drilled in order to investigate the coal.

In determining the possibility of oil shale exploitation, their characteristics have to be taken into account. Thus, according to the size and complexity of the geological oil shale deposits divided into three groups, with each group divided into three subgroups depending on the thickness of the layer and the content of kerogen. In determining the quality of oil shale reserves, exploring layers, must be done, complex mapping of all exploratory drillholes, determine the genetic type of oil shale and in particular, to determine the qualitative and technological characteristics. Requirements are set in definition of oil shale contributed, to exist very few established reserves and resources, while the far greater share of potential reserves. According to the structural material, the Aleksinac deposit has a syncline form, in most of the deposits and complex structure in the "Dubrava", and is divided into several thrust faults, major, independent blocks. Layers are horizontal, slightly sloping angle to 20^o and sink to 90^o, and the deposit belong to second group. The thick consistency and quality, of overlie oil shale, there are classified into the subgroup I. The floor oil shale, due to the increased thickness variability and quality were classified in the subgroup II. [11]

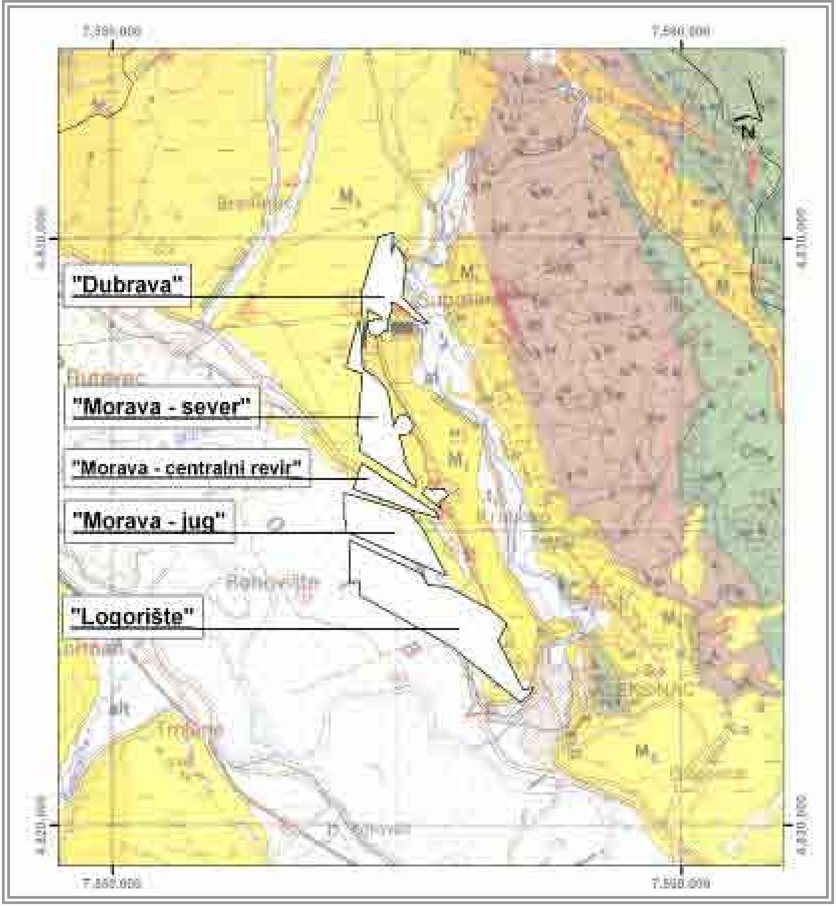

Figure 1. *Shows the geographical location - view from the geographic information system (GIS software package ArcView 9.2) and contours of coal fields on the geological map in the Aleksinac basin.*

POSIBILITES FOR SIMULTANEOUS EXPLOITATION OF COAL AND OIL SHALE

The fact that oil shale appears on the surface, in a form of offspirngs, the more space by providing the deposit of the field "Dubrava", to the field "Logorište", presents the benefits for surface exploitation.

Skid for greater participation of surface exploitation of reserves in total deposits, is very steep sink of oil shale in one part of the deposit, up to 90^o. Steeply sink of deposits causes a great depth, over 700m, so that most of the oil shale reserves must be exploited using the underground methods. [7]

High costs in the underground operations and complexity of production processes, require the use of modern systems of exploitation and proper selection and sizing exploitation machinery. The main characteristic of modern systems is a high degree of mechanization and automation of mining operations (mining, loading, transport, construction of underground facilities, supporting, etc.), with respect the strict requirements in terms of work safety, worker safety, and environmental protection.

For suitable selection of excavation mechanization, it is necessary to observe the all relevant factors of influence that can affect exclusive or limiting. Features of excavation machinery is particularly complex when the productive strata are not regular, i.e., when they are not horizontal or slightly sloping when their thickness does not allow the formation of such excavation fronts, which in one grip, the length of several kilometers can excavate [2].

Analysis of longwall mining exploitation opportunities

Comfortable working conditions and set of production-economic parameters, in mine conditions could provide the longwall mining methods with complex machinery. However, these methods and modern machinery complex, requiring a very favorable mining-geological conditions in the coal deposit that is mined.

Reserves below a depth of 50m can be excavated using the underground method. It is certain that the underground exploitation is longer and more resources for development of mining facilities for the opening of the deposit, transport and export, for what the additional tests are necessary to be carried out to select the best variant for mining and exploitation of coal and oil shale using the underground method.

Reached by modern science and practice of underground exploitation, certainly in the process gave the industrial character. True, in many ways it is specific, but basically has all the characteristics of industrial processes. Operational procedures in each deposit are technologically related to a single integral whole with harmonious development of continuity. Modern technological developments are incorporated into the technological phases of work and to build complementary production unit, which lost more extensive character, that is one of the basic characteristics of industrial process. Opening concept and preparing the deposit-taking into account all previous data limitations and principles, as well as known conditions of exploitation of deposits, impose the following approximate technical solutions:

- rational design is mine with min. 1.5 mil. t/year with prospective increase in the capacity of 4 mil. t/year or more;
- capacity of 1.5 mil. t/year and more than 4 mil. t/year are necessary to build minimum of 3 open rooms, namely, it is necessary to separate the export of coal and oil shale from the transportation of people and supply of raw materials and the pits have a special room for ventilation;
- geographical location of deposit and slop elements pointing to the central location of the main export and ventilation systems; selection of micro-site facilities in the function of the morphology of the terrain, communications, construction conditions of surface complex and more, and it is difficult to give precise technical elements that define the technology and costs of construction, but will give the same assessment of the cost of similar facilities in other mines.

All known and presumed influential factors corresponding to the opening a system that includes:

- Main export decline slope, with cross-sectional area of about 14 m^2, falling about 15^o, the total length up to 1000 m;
- Ventilation decline slope, with cross-sectional area of about $10m^2$ and fall

angle of 30° (parallel to layer) and up to 800 m;
- Service vertical shaft for transport of the employed, equipment, materials and parts of the depth of about 400 m;

From the opening area, it is necessary to achieve transversal connection with productive layers, the mutual distance of 40 to 60 m. Merging horizons achieved with making slope rooms for at least three, located in the productive layers, in order to establish flow ventilation. Further preparation of the system, achieved production of parallel corridors to the limits of the deposit, in overlie, and floor block. The establishment of cross-links between preparatory corridors creates the conditions for the formation of longwall mechanized pits. In the given conditions, taking into account the production requirements of functionality and security work, considered to be purposeful doors mining.

A logical dilemma is imposed, whether this technical solution could be implemented in terms of oil shale in Aleksinac. Knowing the physical-mechanical properties of oil shale and based on experience in the exploitation of coal in the field, "Morava", can be given to secure a positive response. [5]

Analysis of underground gasification opportunities

Many decades of world experiences, when speaking about the underground gasification of coal (Fig. 2), indicate that it is environmentally clean technology and complex utilization of coal in a completely unexploited or unused coal layers or parts of the deposit.

Given the quantity and quality of energy resources at our disposal, and especially prominent as the need for rational use of primary energy resources (i.e., not just secondary), we found the situation to conquer the technology exploitation off-balance reserves and remains excavating balance reserves. For such underground coal reserves, the coal gasification is the method without any alternative.

The process of gasification of brown coal is processing of organic matter into the coal gas products. Gasification of brown coal could be also carried out with the coals of low degree of chemical maturity, and thus the coal is completely free of mineral inclusions and water. Gasification could be carried out by two ways: the underground coal gasification – UCG, or in the gasgenerators.

Determination the activities in this area, the most important approach is the most conscientious choice for optimal location of PGU. When it is necessary to observe the quantity of coal that would be gasified, and thus determine the total amount of produced gas by the UCG.

Previous experiences have shown that the underground mining of coal use around 30-35%, and virtually abandoned remains about 65-70%, which would point to possible existence of surplus energy resources and understanding, but it is not so, especially because of concerns for the future time. This situation could be, and accept, but the appearance of new or alternative technologies, such as is this - UCG, long known (UCG license was sold by the Soviet Union to the USA in 1974), with a comparative advantage over the conventional methods of exploitation (which in basically characterized by difficult mining operation, expressed the social interest, insufficient profitability, environmental protection, emissions, etc.), seriously we choose for these new technologies.

Underground gasification of coal, autotermic process, includes the process of degasification, or pyrolysis and gasification itself. These processes occur as the result of impact the high temperature and management of coal combustion at bringing the funds for gasification that is usually air, water vapor with air in a certain respect, and air or oxygen-enriched water vapor, or oxygen. Today, the two known UCG methods exist.

- method without underground rooms, based on drilling the drilholes from surface through layers and bringing gasification, enforcement gasification agent through wells, or channel, and removing product gasification through production well;
- methods of underground rooms where the layer, remaining after the completion of the security pillars, gasification made using the premises.

The first group of methods (wells UCG) is mainly for current use the off-balance reserves of coal gasification and other outstanding security pillars and remnants exploited balance reserves, after finishing underground exploitation. Since wells methods are usually applied in: filtering, channel and flow method.

The mostly widespread is the filtering method, after the previous inflammatory reaction zone. The American experiment is the applied channel method, but, to channel inflame with filtering method.

Underground gasification of coal, characterized by the efficiency of exploited coal, which represents the ratio of gasified coal to the total amount of coal input of the UCG. Thermal efficiency of the process is defined by the relation of thermal power obtained by heating a mixture gas of coal power, which made a mixture, reduced to the equivalent size, depending on the type of gasified agent, its pressure, and temperature, and properties of coal gasification, layer depth, humidity of coal, and tectonic conditions in the reservoir.

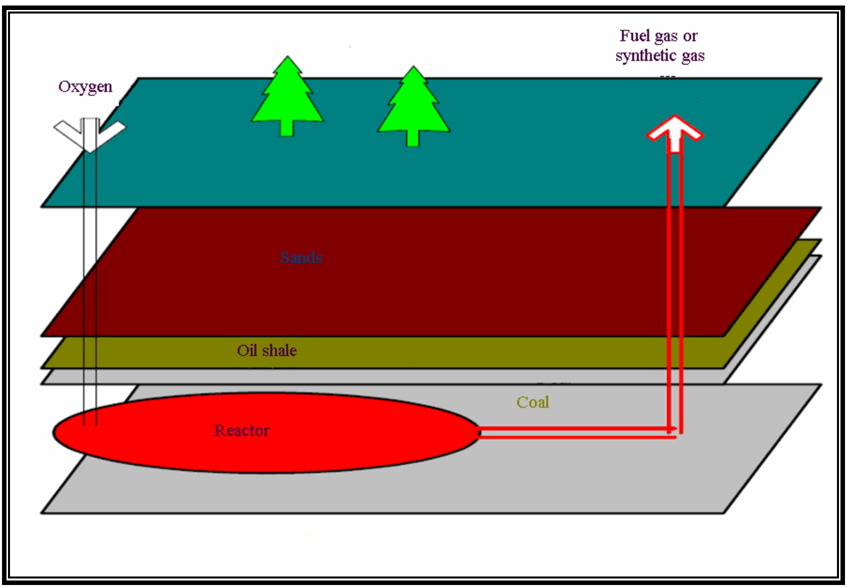

Figure 2. *Simplified UCG process scheme*

The aim of the UCG is to extract thermal energy from coal, as fuel gas or synthesis gas production. The process of transformation of energy takes place through the complete and incomplete combustion of coal and water-gas processing burning fiery coke at the site of coal slope, by air, oxygen, steam, or their mixture. UCG technological process consists of preparing for the gasification of coal layer and the process of gasification.

Preparing a coal layer for the gasification are consists in making slope and vertical wells to the surface terrain. To floor of the coal layer through wells are pipes set, and contact with middle tube through which the drill and cementing. Well through the coal layer is not pipes set. The bottom of the well is about 0.5 m from the floor of coal layer. Construction of well system, wells schedule and their diameter are determined specifically for each deposit based on geological characteristics of the deposit. The formation of the channel between wells is applied with controlled drilling with which through layer well a horizontal well, to the floor of coal layer, which connects the vertical wells. Fractures of coal layer are performed using high pressure air, hydraulic, or fire, to ensure the passage of air through the pores in coal. Coal layer is ignite inserting glowing coke through a well and insufflation of air, at low pressure or with brener.

During pyrolysis, coal is glowing and frees resins, oils, lower hydrocarbons and volatile. Gasification occurs when water vapor, oxygen, carbon dioxide and hydrogen react with hot coal.

Methane is a product of pyrolysis and boost production of its lower temperatures and higher pressures. The results indicate that the increased pressure causes the penetration the pyrolysis through coal layer and so stimulates gasification process. Carbon oxidation reactions dominate at lower temperatures and lower pressures, which leads to higher carbon dioxide content in the produced gas and lower heating value. Such conditions are typical of earlier, relatively shallow UCG probe.

Basic principles that could be applied to Aleksinac deposit of oil shale and coal is that the coal gasification is carried out with pure oxygen under pressure to 20 bar, and that the heat obtained by this procedure is used for reduced of oil shale partially in floor of coal layer and for the most part in overlie of oil shale.

The usual procedure for reduce oil shale is to done gasification of coal or the solid rest of the processing of reduced of oil shale products and that gasification products with its heat made reduced oil shale in the higher part of the manhole himself.

Nature is made to Aleksinac deposit has just such an arrangement (the only thing that would be favorable is that the floor oil shale does not exceed the thickness of coal layer).

The procedure would be as follows:

Gasification of coal layers are released gasification products CO, H_2, CH_4 with a temperature of 700° C and coal layer with its thickness from 6 m down to thickness of approximately 0.8 m (depending on the ash content). As the result, there is a natural crashing of overlie of oil shale, their disintegration and prepare for reduce. Hot products of gasification perform reduce of overlie oil shale passing through the mass of disintegrated oil shale. Floor oil shale is heated with passage of heat.

In the Aleksinac deposits are proposed gasification with pure oxygen (to obtain the modified procedure of Linde-Frenkl). It is proposed modifications to the previous air cooling using heat obtained by cooling gas from wells. Gasification with pure oxygen rather than air, it is suggested due to the much faster conducting the process, greater utilization coefficient of heat and gaseous products to obtain far greater heat value.

Gasification of coal derived gas and oxygen with the pressure that normally has about 16.7 MJ/m^3 enriches the gaseous products oil shale reduce and reaches a value of about 20.9 MJ/m^3. As such, it belongs to medium caloric gas and can be directly used to drive power plants as well as industrial heating purposes. Also, there are various conversion and obtaining liquid hydrocarbons.

In the process of purification of gas, the followings are obtained: phenols, ammonia, benzenes, and many other products, while pure sulfur is easily produced from sulfur hydrogen. [4]

CONCLUSION

The Aleksinac deposit of coal and oil shale is one with very complex geological structure, the limiting elements for the implementation of mining methods and technology, like long wall mining metod and mechanized mining technologies.

The number of investigated technical parameters necessary for designing production systems and underground mining construction, this deposit belongs to a group of under-explored deposits.

This fact was established through analysis of available technical documentation and cause many difficulties and leads to unreliable assessments and forecasts of technical size and also requires the necessary research work environment, in the initial period of reconstruction of the mine.

After closing the Aleksinac mine, through the remaining balance and off-balance reserves of 27.5 million ton of quality lignite coal. From the world of industrial experience with the UCG is known that the efficiency "attacked" the layers of coal 72-96%. If the count with only 80% of such usage, it remains an open view to using the UCG in Aleksinac, will benefit around 22 million tons of coal.

The existence of oil shale, directly adjacent to coal, permitted to increase the efficiency of the process of UCG. Namely, the heat loss from the process of UCG on overlie of layers will produce additional hydrocarbon gases and liquids. Most of these liquids will produce additional cracking of hydrocarbon gases. Such combined of hydrocarbon gases getting from oil shale, increases the thermal power of the gas obtained from UCG, and allows obtaining a certain quantity of oil, as well as by-products in this process.

In order to achieve the production based on already proven geological reserves, it is necessary to continue to research ways of obtaining synthetic oil from oil shale, with the consultation of foreign companies, whose experience and gained technology in this area is still unsurpassed. It must be borne in mind that the realization of the exploitation of these resources is limited, as content of oil fractions, which dictates the technology, space requirements and conditions related to the environment, particularly in achieving the profitability of individual deposits, while essentially breakeven depends of oil prices on the world market, which would be the conditions of our deposit had to be significantly higher over a longer period of time. That still means that this resource deserves attention and study as an alternative energy potential.

In the case of the Aleksinac deposit, in addition to regular distribution useful and harmful components, a decisive influence on economic exploitation will slope and depth of layers, i.e. morphological characteristics of ore bodies. Of course, specific analysis is needed to make the exploiting useful materials and large amounts of oil shale that are under very populated places (Aleksinac, Subotinac, Vakupac, etc.) In these parts of deposits, so called the protective pillars, the process of UCG may represent the most optimal solution.

Quantities of about 3.8 billion bituminized marlon, that overlies the oil shale, with about 4-5% organic matter, may also be subject to special investigations, and future time will show whether they can be treated together or separately for the oil shale.

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FIZIČKA KARAKTERIZACIJA PEPELA I ŠLJAKE SA DEPONIJE U MEDOŠEVCU

Izvod

U radu su prikazani rezultati fizičke karakterizacije na izuzetim reprezentativnim uzorcima pepela i šljake sa deponije u Medoševcu, koja se nalazi u okviru DP "Kolubara-Prerada" Vreoci. Cilj je iznalaženje najboljeg plana upravljanja ovom vrstom sirovine. Poseban akcenat je dat smanjenju negativnog uticaja pepela i šljake na životnu sredinu, kao i njihova reciklaža i ponovna upotreba u drugim granama industrije, što za krajnji cilj ima deponovanje manjih kolicina na deponijama.

Izvršena je fizička karakterizacija dvanaest uzoraka, koja obuhvata: određivanje vlage u uzorcima, nasipne mase, specifične gustine, pH vrednosti pepela i šljake i granulometrijski sastav pepela i šljake.

Ključne reči: *fizička karakterizacija, lebdeći pepeo i šljaka, deponija, životna sredina*

UVOD

Elektofilterski pepeo i šljaka kao sekundarni materijali, tj. nus proizvodi sagorevanja uglja iz toplane u dp kolubara-prerada, koja je sastavni deo rb kolubara, odlažu se na deponiji u medoševcu, lociranoj takođe u okviru preduzeća kolubara.

Sagorevanjem oko 220.000 tona uglja godišnje u toplani, produkuje se prosečno oko 28.820 tona pepela, za koji je na godišnjem nivou potrebno oko 40.000 m^3 akumulacionog prostora.

Ukupna količina pepela i šljake, transportuje se hidrauličnim sistemom do deponije – taložnika – kaseta u Medoševcu.

S obzirom na gore navedenu količinu pepela i šljake koja se generiše na godišnjem nivou, jasno je da ova vrsta otpada ima značajan negativan uticaj na životnu okolinu. Prema sistemu klasifikacije otpada u RS, pepeo i šljaka iz termoelektrana već su kategorisani kao opasan otpad, indeksnog broja iz kataloga otpada 100101/190205/190299.

S tim u vezi neophodno je izvršiti fizičko-hemijsku karakterizaciju u cilju definisanja mogućnosti za manipulaciju ovim otpadom ili za njegovo moguće ponovno korišćenje.

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FIZIČKA KARAKTERIZACIJA PEPELA I ŠLJAKE

U okviru fizičke karakterizacije pepela i šljake iz kasete-deponije u Medoševcu izvršena su sledeća ispitivanja:

- određivanje vlage u uzorcima,
- određivanje nasipne mase,
- određivanje specifične gustine,
- određivanje pH vrednosti pepela i šljake,
- određivanje granulometrijskog sastava pepela i šljake.

Određivanje vlage u uzorcima pepela i šljake

Za određivanje vlažnosti uzoraka pepela korišćena je **ВМК** (*Validna metoda kuće*)*-Određivanje vlažnosti uzorka (E.б.5:2007).*

Metoda podrazumeva određivanje grube vlage, neposredno po izuzimanju uzoraka, sušenjem u sušnici do postizanja konstantne mase.

Proračun:

Sadržaj vlage se izračunava po obrascu:

$$V = \frac{m_1 - m_2}{m_1} \cdot 100 \quad (\%)$$

gde je:

V- Sadržaj vlage (%)

m_1- masa uzorka pre sušenja (gr)

m_2- masa uzorka posle sušenja (gr)

Procentualni sadržaj vlage u uzorcima pepela dati su u tabeli 1.

Tabela 1. *Sadržaji vlage u uzorcima pepela*

Naziv uzorka	Vlažnost %
P1	50,41
P2	45,40
P3	46,86
P4	47,37
P5	48,93
P6	48,96
P7	48,05
P8	48,20
P9	49,83
P10	46,82
P11	51,02
P12	49,82
Psr	**48,47**

Određivanje nasipne mase

Za određivanje nasipne mase uzoraka pepela i šljake korišćena je ВМК (*Validna metoda kuće*)*-Određivanje vlažnosti uzorka*) *(E.б.11:2007).*

Metoda podrazumeva određivanje mase slobodno nasutog uzorka, bez sabijanja, u sud poznate zapremine V i mase m.

Proračun:

Nasipna masa se izračunava po sledećem obrascu:

$$\Delta = \frac{m_1 - m}{V} \quad , (kg/m^3)$$

gde je:

Δ - nasipna masa uzorka;

m_1 - masa uzorka i suda;

m - masa suda;

V - zapremina suda.

Nasipne mase uzoraka pepela date su u tabeli 2.

Tabela 2. *Sadržaji vlage u uzorcima pepela*

Naziv uzorka	**Nasipna masa** kg/m^3
P1	0,6277
P2	0,6594
P3	0,6595
P4	0,6615
P5	0,660
P6	0,5769
P7	0,5988
P8	0,5849
P9	0,5810
P10	0,5952
P11	0,5823
P12	0,5950
Psr	**0,6150**

Određivanje specifične težine

Određivanje specifične težine pepela i šljake vršeno je u staklenom sudu - piknometru.

Proračun

Specifična težina uzoraka se izračunava po sledećem obrascu:

gde je:

m_1 - masa praznog piknometra, (kg)
m_2 - masa piknometra sa uzorkom, (kg)
m_3 - masa piknometra sa uzorkom i vodom, (kg)
m_4 - masa piknometra sa vodom, (kg)

ρ_F^t - gustina fluida (vode) pri temperature merenja, (kg/m^3)

Specifične težine uzoraka pepela date su u tabeli 3.

$$\rho = \frac{m_2 - m_1}{(m_4 - m_1) - (m_2 - m_2)} \rho_{F'}^t \quad \left(\frac{kg}{m^3}\right)$$

Tabela 3. *Specifične težine uzoraka pepela i šljake*

Naziv uzorka	**Specifična težina kg/m^3**
P1	2220
P2	2270
P3	2220
P4	2250
P5	2270
P6	2380
P7	2380
P8	2370
P9	2390
P10	2380
P11	2370
P12	2370
Psr	**2322,5**

Određivanje pH vrednosti pepela i šljake

Za određivanje pH vrednosti uzoraka pepela i šljake korišćenja je Standardna metoda *(SRPS EN 12176 2005).*

Imajući u vidu da se radi o čvrstoj sirovini - pepelu i šljaci, princip merenja pH vrednosti po ovoj metodi se sastoji u formiranju odgovarajućih vodenih suspenzija i potenciometriskom određivanju.

Rezultati izmerenih pH vrednosti su prikazani u tabeli 4.

Tabela 4. *Izmerene pH vrednosti uzoraka pepela*

Naziv uzorka	pH vrednost na 25^0C
P1	8,85
P2	9,14
P3	9,15
P4	8,98
P5	9,29
P6	10,09
P7	10,38
P8	10,33
P9	10,16
P10	10,18
P11	10,02
P12	9,52
Psr	**9,70**

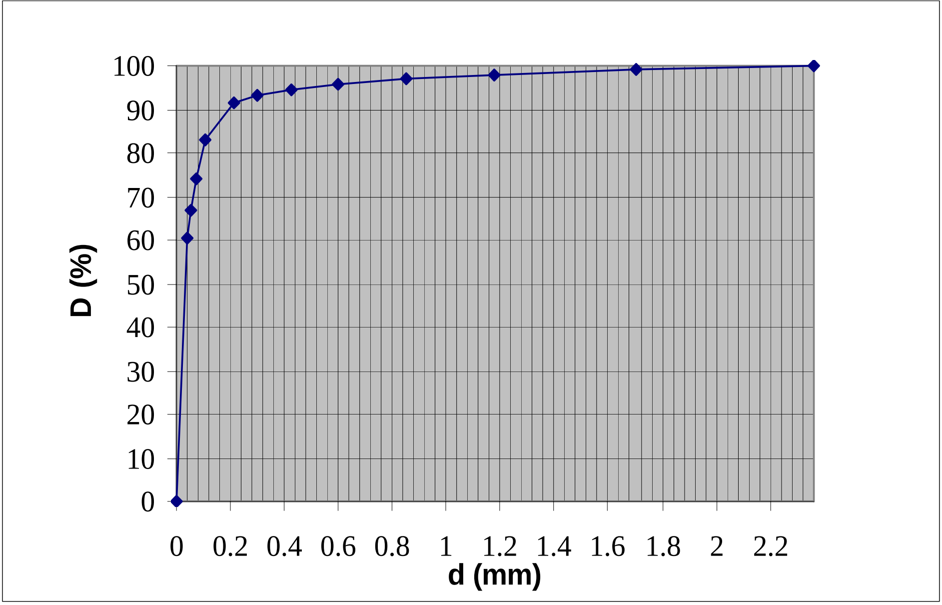
Određivanje granulometrijskog sastava pepela i šljake

Standardnom metodom prosejavanja, na seriji sita tipa Tyler, prečnika prosevne površine 200 mm, određivanje granulometrijski sastav, mokrim prosejavanjem.

U tabeli 5 i na slici 1, prikazan je srednji granulometrijski sastav uzoraka pepela i šljake.

Tabela 5. *Srednji granulometrijski sastav uzoraka pepela i šljake*

Klasa krupnoće d(mm)	Maseno učešće m(%)	Kumulativno učešće po plusu R(%)	Kumulativno učešće po minusu D(%)
-2,362+1,700	1,06	1,06	100,00
-1,700+1,180	0,99	2,05	98,94
-1,180+0,850	1,04	3,09	97,95
-0,850+0,600	1,19	4,28	96,91
-0,600+0,425	1,18	5,46	95,72
-0,425+0,300	1,15	6,61	94,54
-0,300+0,212	1,74	8,35	93,39
-0,212+0,106	8,61	16,96	91,65
-0,106+0,075	8,90	25,86	83,04
-0,075+0,053	7,25	33,11	74,14
-0,053+0,038	6,56	39,67	66,89
-0,038+0,000	60,33	100,00	60,33



Sl. 1. *Srednji granulometrijski sastav uzoraka pepela i šljake*

ZAKLJUČAK

Iz tabele 5 i slike 1 izvodi se zaključak da je prisustvo finih frakcija ispod 0,038 mm (prašine) u masi 60,33%.

Fine frakcije pepela mogu imati jak degradirajući uticaj na životnu sredinu i okolinu, posebno u periodu jakih vetrova, kada se raznose po okolini, što može dovesti do velikih ekoloških problema, a pre svega narušavanja zdravlja stanovništva, imajući u vidu da je ova sirovina kategorisana kao opasan otpad.

Ovo naročito treba imati u vidu pri mehanizovanom čišćenju i transportu pepela i šljake iz kasete u Medoševcu do deponije za trajno odlaganje pepela, s obzirom da se u neposrednoj blizini objekta nalaze okolna naselja.

Obzirom na svoje fizičko-hemijske karakteristike, negativni uticaji pepela na životnu sredinu se ogledaju kroz zagađenje vazduha, površinskih i podzemnih voda, zemljišta, pa sve do poljoprivrednih proizvoda, čime se direktno ugrožava zdravlje ljudi, u oblastima gde se TE nalaze. S tim u vezi treba raditi na minimiziranju nastanka pepela i šljake, ukoliko je to moguće.

Što se tiče mogućnosti primene pepela i šljake u drugim granama industrije, ova vrsta sirovine može imati značajnu primenu u građevinarstvu, kao podloga za puteve, čime bi se smanjila količina otpada koja se odlaže na deponiji.

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PHYSICAL CHARACTERIZATION OF FLY ASH AND SLAG FROM THE MEDOSEVAC DUMP

Abstract

This paper presents the results of physical characterization the excluded representative samples of ash and slag from the dump in Medoševac, which is located within the "Kolubara - Prerada", located in Vreoci. The of this work is finding the best plan for managing this type of materials. Special emphasis is given to thereduction of negative impact of ash and slag on the environment, as well as their recycling and reuse in other industries, as the ultimate aim of smaller amount of deposit in landfills. The physical characterization was carried out on twelve samples and it contains: determination of moisture content, volumetric density, specific density, pH of solid and sieve analysis of fly ash and slag.

Key words: *physical characterization, fly ash and slag, dump, environment*

INTRODUCTION

Electofilter ash and slag as a secondary material, the by-products of coal combustion from the power plants in the DP Kolubara-Processing, which is an integral part of Kolubara, goes to the landfill in Medoševac, also located within the company Kolubara. Combustion of approximately 220 000 tons of coal per year in heating plant, produced an average about 28 820 tons of ash, which required about 40 000 m^3 of accumulation space per year. The total amount of ash and slagis transported to landfills by the hydraulic systems- cassettes in Medoševac.

Given the above amount of ash and slag that is generated annually, it is clear that this type of waste has a significant negative impact on the environment. According to the classification system of waste in the RS, ash and slag from the power plants have already been categorized as hazardous waste, index number from the catalog of waste 100101/190205/190299. Regarding to this, it is necessary to carry out the physical-chemical characterization of defining the possibilities for waste handling or possible reuse.

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PHYSICAL CHARACTERIZATION OF ASH AND SLAG

In the physical characterization of ash and slag dumps of the cassette-in Medoševac the following tests were carried out:

- ✓ Determination of moisture in the samples;
- ✓ Determination of volumetric density;
- ✓ Determination of specific density;
- ✓ Determination of pH value in the solution of ash sample;
- ✓ Determination of particle size composition of the ash and slag.

Determination of moisture content in the samples of ash and slag

For the determination of moisture content in ash samples the VMK (valid method of home) was used.

Determination of the sample moisture (E.b.5: 2007).

The method involves the determination of moisture content, immediately after the exclusion of samples, drying in the Dryer to achieve constant mass.

Calculation

Moisture content is calculated by the following formula:

$$V = \frac{m_1 - m_2}{m_1} \cdot 100 \quad (\%)$$

Where is:

V-moisture content (%)
m_1-mass of the sample before drying (g)
m_2- mass of the sample after drying (g)

The percentage moisture content in the ash samples are given in Table 1.

Table 1 *Moisture content in the ash samples*

Identification of sample	**Moisture content %**
P1	50.41
P2	45.40
P3	46.86
P4	47.37
P5	48.93
P6	48.96
P7	48.05
P8	48.20
P9	49.83
P10	46.82
P11	51.02
P12	49.82
Psr	48.47

Determination of volumetric density

VMK (valid method of home) was used to determine the volumetric density of ash and slag samples.

Determination the volumetric density of samples (E.b.11: 2007).

The method includes determination the mass of sample without compress in the court known volume V and the mass m.

Calculation:

Volumetric density is calculated by the following formula:

$$\Delta = \frac{m_1 - m}{V} \quad , (\text{kg/m}^3)$$

Where is:

Δ - volumetric density of sample;
m_1- weight of sample and the court;
m - mass of the court;
V - volume of the court.

Volumetric density of ash samples are given in table Table 2

Table 2 – *Bulk mass of ash samples*

Identification of sample	Volumetric density kg/m^3
P1	0.6277
P2	0.6594
P3	0.6595
P4	0.6615
P5	0.660
P6	0.5769
P7	0.5988
P8	0.5849
P9	0.5810
P10	0.5952
P11	0.5823
P12	0.5950
Psr	**0.6150**

Determination of specific density

Determination the specific density of ash and slag was done in the glass Pycnometer.

Calculation

Specific density of samples is calculated by the following formula:

$$\rho = \frac{m_2 - m_1}{(m_4 - m_1) - (m_2 - m_2)} \rho_{F'}^{t} \quad \left(\frac{kg}{m^3}\right)$$

Where is:

m_1 - mass of empty Pycnometer, (kg)
m_2 - mass of Pycnometer with sample, (kg)
m_3 - weight of Pycnometer with sample and water, (kg)
m_4 – mass of Pycnometer with water, (kg)
ρ_F^t - density of fluid (water) at the temperature of measurement, (kg/m^3)

Specific density of ash samples are given in Table 3

Table 3 *Specific density of ash and slag samples*

Identification of sample	Specific density of samples (kg/m^3)
P1	2220
P2	2270
P3	2220
P4	2250
P5	2270
P6	2380
P7	2380
P8	2370
P9	2390
P10	2380
P11	2370
P12	2370
Psr	**2322.5**

Determination of pH value in the solution of ash and slag

Determination the pH of the solution of ash and slag samples was carried out using the *Standard methods (SRPS EN 12176 2005).*

Because they are the solid raw materials - ash and clay, the principle of this method is formation of the corresponding aqueous suspensions and potentiometric method for determination the pH value.

Results of measured pH values are shown in Table 4.

Table 4 *Measured pH values of the solution of ash samples*

Identification of sample	pH values at 25^0C
P1	8.85
P2	9.14
P3	9.15
P4	8.98
P5	9.29
P6	10.09
P7	10.38
P8	10.33
P9	10.16
P10	10.18
P11	10.02
P12	9.52
Psr	**9.70**

Determination of particle size composition of the ash and slag

Sieve analysis standard methods, on a series of Tyler sieves type, 200 mm diameter sieve surface, have determined the particle size composition, wet sieving.

Table 5 and Figure 1 show the middle particle size composition of ash and slag samples.

Tabela 5. *The middle particle size composition of ash and slag samples.*

Particle size d(mm)	Mass m (%)	R (%)	D (%)
-2.362+1.700	1.06	1.06	100.00
-1.700+1.180	0.99	2.05	98.94
-1.180+0.850	1.04	3.09	97.95
-0.850+0.600	1.19	4.28	96.91
-0.600+0.425	1.18	5.46	95.72
-0.425+0.300	1.15	6.61	94.54
-0.300+0.212	1.74	8.35	93.39
-0.212+0.106	8.61	16.96	91.65
-0.106+0.075	8.90	25.86	83.04
-0.075+0.053	7.25	33.11	74.14
-0.053+0.038	6.56	39.67	66.89
-0.038+0.000	60.33	100.00	60.33

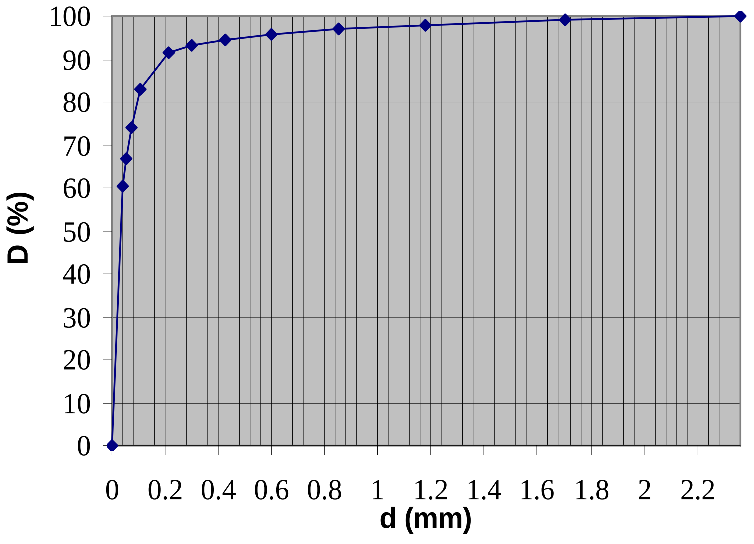

Figure 1 *Average granulometric composition of the ash and slag samples*

CONCLUSION

From Table 5 and figure 1, a conclusion could be made about the presence of fine fraction below 0.038 mm (dust) in weight of 60.33%.

Fine ash fractions can have a strong degradation effect on the environment, especially in the period of strong winds, which can lead to the major environmental problems, especially violations of public health, bearing in mind that this raw material categorized as the hazardous waste.

This especially should be kept in mind when mechanized cleaning and transport of ash and slag from the cassettes in Medoševac to the landfill for permanent disposal of ash in the vicinity of nearby villages.

In a view of its physical and chemical characteristics, the negative effects of ash on the environment are reflected through the pollution of air, surface and ground water, land, to the agricultural products, which directly threatens human health, in areas where those are. If it is possible to work on reducing the emergence due to minimize the occurrence of ash and slag.

Regarding to the use of ash and slag in other industries, this type of materials can have significant use in the field of civil construction as a foundation for roads. The use of ash and slag like secondary materials could greatly reduce the amount of waste that is disposed in a landfill.

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ANALIZA STABILNOSTI UNUTRAŠNJEG ODLAGALIŠTA JALOVINE „KUTLOVAČA“ POVRŠINSKOG KOPA UGLJA „POTRLICA“ – PLJEVLJA SOFTVEROM GEOSTUDIO 2007

Izvod

U radu su prikazani rezultati proračuna stabilnosti unutrašnjeg odlagališta jalovine „Kutlovača“ površinskog kopa uglja „Potrlica“ koji je u sastavu pljevaljkog ugljenog basena. Proračun stablinosti je izvršen softverom GeoStudio 2007, odnosno njegovim alatom SLOPE/W koji je specijalizovan za uslov granične ravnoteže. Proračun je izvršen metodama Morgenstern – Price, Bishop i Janbu. Uticaj podzemnih voda na stabilnost modeliran je preko koeficijenta porne vode.
Ključne reči: *odlagalište jalovine, stabilnost, softver GeoStudio 2007, koeficijent porne vode*

UVOD

Površinski kop uglja „Potrlica“ je u sastavu pljevaljskog ugljenog basena. Dinamikom razvoja radova na kopu u periodu 2010 – 2014. god, predviđeno je da se na postojećem unutrašnjem odlagalištu „Kutlovača“, koje je locirano na istočnom delu kopa, odloži 10.920.000 m^3 čvrste stenske mase sa kopa [1]. Odloženi materijal je najvećim delom laporac, uz znatno manji procenat međuslojne gline.

U podlozi na kojoj je formirano odlagalište, prema litološkom modelu ležišta, uočava se raznorodnost litoloških struktura. Prisutni su laporac, dva sloja uglja, međuslojna i podinska glina.

Proračun stabilnosti unutršanjeg odlagališta „Kutlovača“ izvršen je po kritičnom profilu softverom GeoStudio 2007, odnosno njegovim alatom SLOPE/W koji je specijalizovan za uslov granične ravnoteže.

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ULAZNI PODACI ZA PRORAČUN STABILNOSTI

Litološka građa basena Potrlica je složena. Na svakom profilu zapaža se više litoloških članova. Svaki od litoloških članova određen je svojim fizičko–mehaničkim karakteristikama. Glavni ugljeni sloj generalno ocrtava oblike paleoreljefa. Slojevi i proslojci međuslojne i podinske gline posebno negativno utiču na stabilnost radova.

Područje površinskog kopa „Potrlica“ odlikuje se izuzetnom heterogenošću anizotropnosti, a u skladu sa tim velika su i odstupanja u pogledu fizičko–mehaničkih pokazatelja zastupljenih stenskih masa.

Statistička analiza fizičko–mehaničkih pokazatelja zastupljenih stenskih masa urađena je na osnovu postojećih geomehaničkih podataka. Analiza je izvršena na malom i nedovoljnom broju uzoraka tako da su i velika odstupanja. U tabeli 1 dat je prikaz rezultata statističke analize laboratorijskih geomehaničkih ispitivanja [2].

Tabela 1. *Fizičko – mehaničke karakteristike radne sredine*

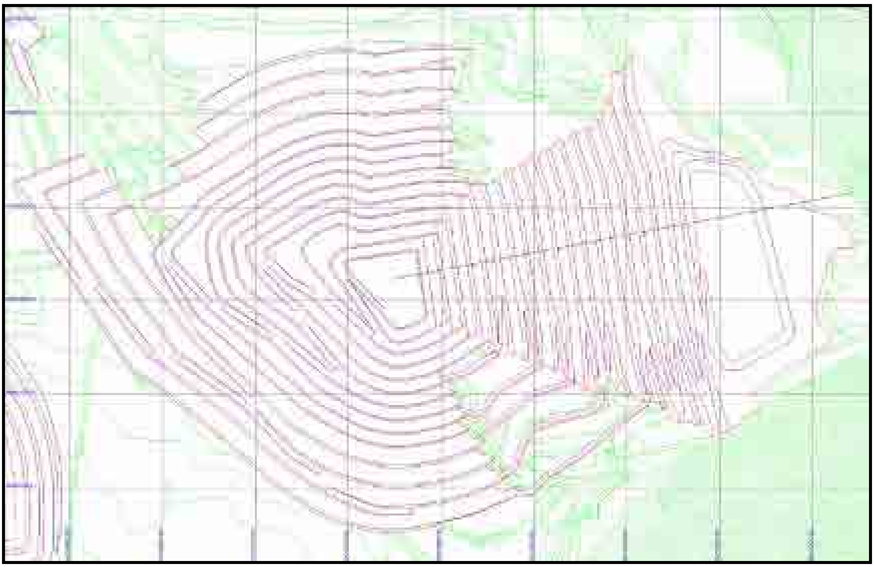
Sredina	Zapreminska težina kN/m^3	Ugao unutrašnjeg trenja φ °	Kohezija kN/m^2
Kvartar	17,74	18,5	18,40
Laporac	17,37	28,8	1 382,50
Međuslojna glina	19,81	19,5	16,22
Ugalj	13,62	18,5	18,40
Ugljevita glina	18,31	16,6	20,98
Podinska glina	20,95	16,6	23,52
Krečnjak	25,83	39,2	657,97
Odloženi materijal	19,90	18,4	19,76

Tačan nivo podzemnih voda u ležištu “Potrlica” nije poznat.

Sa hidrogeološkog aspekta, kvartar, laporac, ugljeni slojevi, krečnjak i odloženi materijal su vodopropusni, dok je glina vodonepropusni materijal.

Uticaj podzemne vode na stabilnost modeliran je koeficijentom porne vode R_u. Analiza stabilnosti urađena je za koeficijent porne vode R_u sa varijacijom vrednosti od 0 do 0,5 uz korak 0,1.

Zapremina odlagališta iznosi 14.200.000 m^3. Nožica odlagališta je na koti K+610 m, a završni plato odlaganja K+800 m. Visina etaža na odlagalištu je 10 m. Položaj kritičnog profila za analizu stabilnosti prikazan je na slici 1 [1].



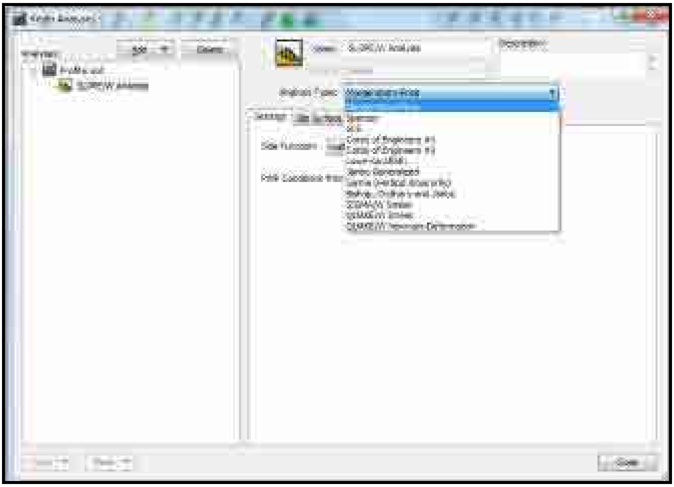
Sl. 1. Položaj kritičnog profila za analizu stabilnosti unutrašnjeg odlagališta „Kutlovača“

PRORAČUN STABILNOSTI SOFTVEROM GEOSTUDIO 2007 – SLOPE/W

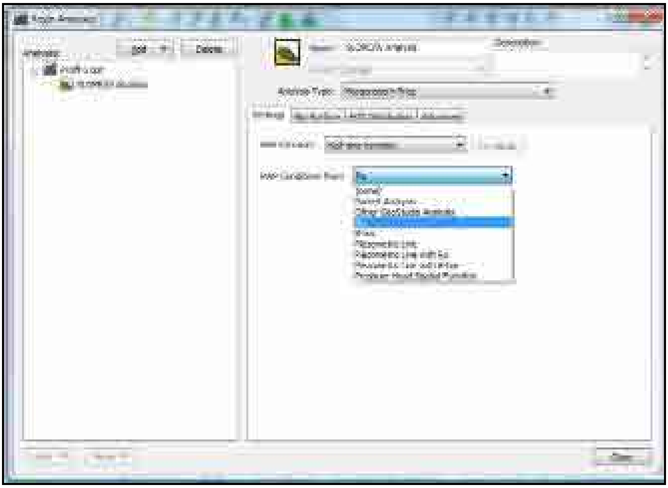
Softver GeoStudio 2007, odnosno njegov alat SLOPE/W namenjen je za proračun stabilnosti uslovom granične ravnoteže [3].

Softver sadrži sve metode proračuna stabilnosti uslovom granične ravnoteže koje se danas koriste u svetu: Bishop, Janbu, Spenser, Morgenstern – Price, Sarma–slika 2.

Uticaj podzemnih voda na stabilnost u softveru GeoStudio 2007 SLOPE/W može da se modelira na više načina: piezometrijskim nivoom vode, koeficijentom porne vode R_u, pritiskom porne vode B-bar – slika 3.



Sl. 2. *Metode uslova granične ravnoteže u softveru GeoStudio 2007 SLOPE/W*



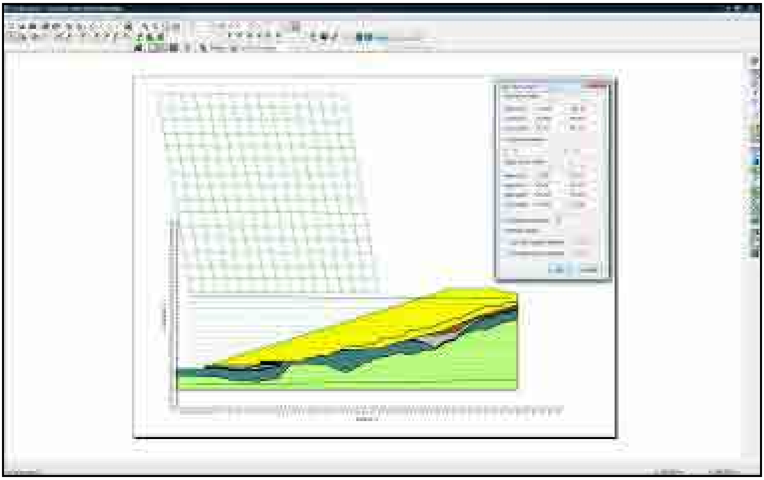
Sl. 3. *Modeliranje uticaja podzemne vode na stabilnost u softveru GeoStudio 2007 SLOPE/W*

Proračun stabilnosti unutrašnjeg odlagališta "Kutlovača" urađen je metodama: Morgenstern – Price, Bishop i Janbu.

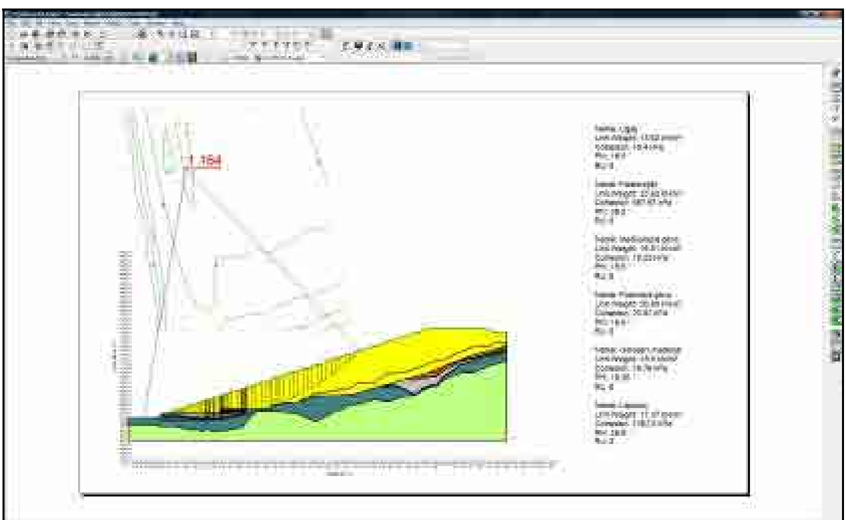
Položaj kliznih ravni je biran alatom-*Grid and Radius*, kojim se definišu potencijalne klizne ravni njihovim centrom i poluprečnikom klizanja – slika 4.

Na slikama 5 – 7 prikazani su klizne ravni i rezultati proračuna stabilnosti kritičnog profila unutrašnjeg odlagališta "Kutlovača" metodama Morgenstern – Price, Bishop i Janbu za koeficijent porne vode vodonepropusnog materijala $R_u = 0$.

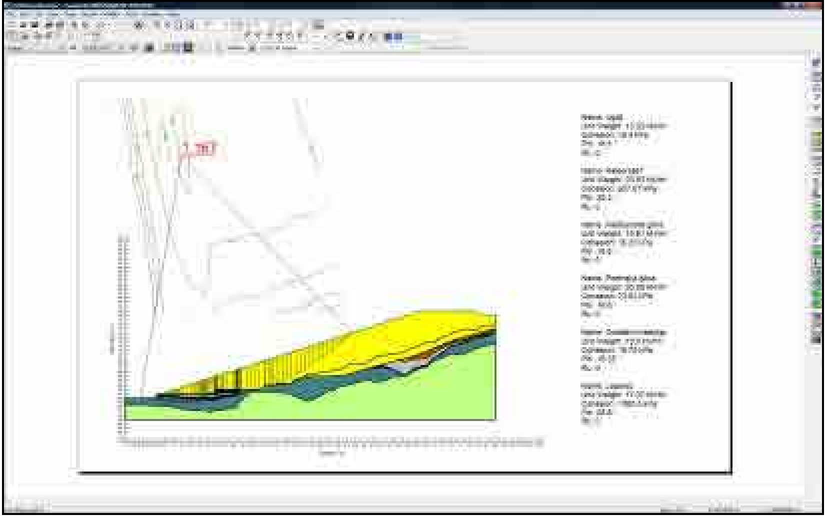
U tabeli 2 i na slici 8 prikazani su rezultati proračuna stabilnosti unutrašnjeg odlagališta "Kutlovača" po kritičnom profilu za vrednosti koeficijenta porne vode R_u od 0,0 do 0,5.



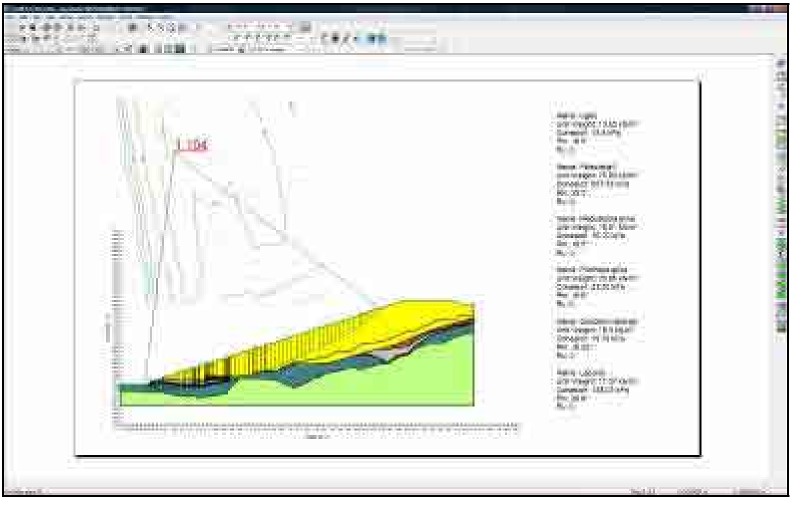
Sl. 4. *Proračun stabilnosti u softveru GeoStudio 2007 SLOPE/W alatom Grid and Radius*



Sl. 5. *Izgled klizne ravni i koeficijent stabilnosti po metodi Morgenstern – Price u softveru GeoStudio 2007 SLOPE/W alatom Grid and Radius*



Sl. 6. *Izgled klizne ravni i koeficijent stabilnosti po metodi Bishop u softveru GeoStudio 2007 SLOPE/W alatom Grid and Radius*



Sl. 7. *Izgled klizne ravni i koeficijent stabilnosti po metodi Janbu u softveru GeoStudio 2007 SLOPE/W alatom Grid and Radius*

Tabela 2. *Koeficijent stabilnosti zavisno od koeficijenta porne vode R_u*

R_u	0,0	0,1	0,2	0,3	0,4	0,5
Metoda	F_s					
Morgenstern - Price	1,164	1,100	1,037	0,972	0,900	0,796
Bishop	1,167	1,104	1,039	0,975	0,899	0,793
Janbu	1,104	1,060	1,001	0,923	0,829	0,735

Sl. 8. *Grafik koeficijenta stabilnosti Fs zavisno od koeficijenta porne vode Ru*

Na osnovu rezultata dobijenih iz navedenih ulaznih parametara može se zaključiti da je za usvojene geometrijske elemente zahvata koeficijent stabilnosti po svim korišćenim metodama proračuna veći od 1 za koeficijent porne vode $R_u < 0,2$.

Takođe treba ponoviti da nisu poznate tačne vrednosti koeficijenta porne vode.

Za dobijanje tačnih rezultata potrebno je postavljanje piezometara po analiznom profilu u cilju dobijanja tačnih podataka o nivou podzemnih voda u ležištu, pre početka odlaganja jalovine. Takođe je potrebno stalno praćenje eventualnih promena u radnoj sredini (pukotine, klizišta, sleganje).

ZAKLJUČAK

Softver GeoStudio 2007 – SLOPE/W je program kojim veoma precizno mogu da se determinišu svi relevantni uslovi za proračun stabilnosti kosina površinskih kopova, odlagališta jalovine i zemljanih brana.

Svaki litološki član na profilu može biti realno modeliran prostornim položajem i fizičko – mehaničkim karakteristikama.

Takođe je moguće na više načina modelirati uticaj podzemnih voda na stabilnost, kao i površinska opterećenja na podlogu.

Korišćenjem ovog softvera značajno se skraćuje vreme proračuna u odnosu na klasično projektovanje.

Za projektovanje, uz pravilan izbor početnih parametara, i dalje je najvažniji projektant. Međutim upotrebom računarskih programa posao projektanta je znatno olakšan sa aspekta vremena i kvaliteta usled mogućnosti brze analize u cilju odabira najboljih rešenja.

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UDK: 622.271:681.33(045)=20

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STABILITY ANALYSIS OF INNNER WASTE DUMP "KUTLOVACA" OF THE COAL OPEN PIT MINE "POTRLICA"– PLJEVLJA USING THE GEOSTUDIO 2007 SOFTWARE

Abstract

This work presents the results of stability calculation the inner waste dump "Kutlovaca" of the coal open pit mine "Potrlica" within the "Pljevlja" Coal Basin. Stability calculation was made using the GeoStudio 2007 software with its tools SLOPE/W, specialized for the limit equilibrium conditions. Calculation was made using Morgenstern – Price, Bishop and Janbu. The impact of ground water on stability was modeled by the pore water coefficient.
Key words: *dumping, stability, GeoStudio 2007 software, pore water coefficient*

INTRODUCTION

Coal open pit "Potrlica" is within the Pljevlja coal basin. By dynamics of work development at the open pit in the period 2010 – 2014, it was predicted that 10 920 000 $m^3$of solid rock mass from the open pit will be dumped at the existing internal waste dump "Kutlovaca", which is located on the eastern part of open pit [1]. Dumped material is mostly marl, with much lower percentage of interlayer clay.

A diversity of lithological structures is noticed in the ground of formed waste dump, according to the lithological model of deposit. Marl, two layers of coal and interlayer floor clay are present.

Stability calculation of the internal waste dump "Kutlovaca" was carried out by a critical profile of GeoStudio 2007 software, that is its tool COPE/W, which is specialized in the limit equilibrium condition.

INPUT DATA FOR STABILITY CALCULATION

Lithological structure of the Potrlica basin is complex. Many lithological members are observed on each profile. Each lithological member is determined by its physical - mechanical characteristics. The main coal layer generally outlines the forms of paleorelief. Layers and interlayers of floor clay particularly have negative effect on the stability of works.

The area of open pit "Potrlica" is characterized by extreme heterogeneity of anisotropy and according to this the variations are great in terms of physical - mechanical indicators of represented rock masses.

Statistical analysis of physical - mechanical indicators of represented rock masses was made on the basis of existing geomechanical data. The analysis was carried out on a small and insufficient

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number of samples so that the deviations are large. Table 1 gives an overview of the results of statistical analysis of laboratory geomechanical tests [2].

Table 1. *Physical - mechanical characteristics of working samples*

Sample	Volumetric weight kN/m^3	Angle of internal friction φ °	Cohesion kN/m^2
Quaternary	17.74	18.5	18.40
Clay marl	17.37	28.8	1 382.50
Interlayer clay	19.81	19.5	16.22
Coal	13.62	18.5	18.40
Coal clay	18.31	16.6	20.98
Floor clay	20.95	16.6	23.52
Lime stone	25.83	39.2	657.97
Dumped material	19.90	18.4	19.76

The exact level of ground water in the “Potrlica” deposit is not known.

In hydrogeological terms, quaternary, clay marl, coal strata, and limestone and dumped material are water permeable, while the clay is waterproof material.

The effect of ground water on the stability was modeled by the coefficient of pore water R_u. Stability analysis was done for the coefficient of pore water R_u with the value variation from 0 to 0.5 with step 0.1.

Volume of waste dump is 14 200 000 m^3. The bottom of waste dump is at elevation K+610 m, and the final plateau of dumping at K+800 m. Bench height at waste dump is 10 m. Position of critical profile for stability analysis is shown in Figure 1 [1].

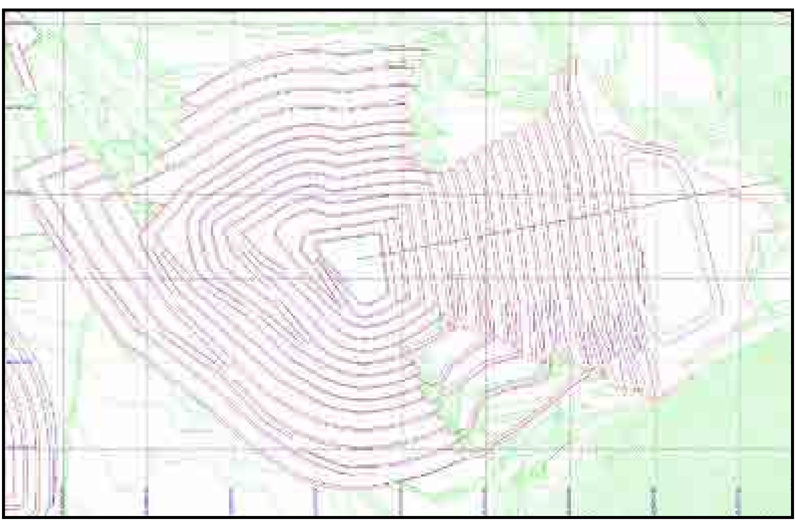

Figure 1. *Position of critical profile for stability analysis of internal dump”Kutlovaca”*

CALCULATION OF STABILITY BY THE SOFTWARE GEOSTUDIO 2007 - SLOPE / W

Software GeoStudio 2007, i. e. its tools SLOPE / W is intended for stability calculation by the condition of limit equilibrium [3].

The software contains all the methods of stability calculation by the condition of limit equilibrium, used in the world at present: Bishop, Janbu, Spencer, Morgenstern - Price, Sarma - Figure 2.

Influence of groundwater on the stability in the software GeoStudio 2007 SLOPE / W could be modeled in several ways: piezometric water level, coefficient of pore water R_u, pore water pressure B-bar- Figure 3.

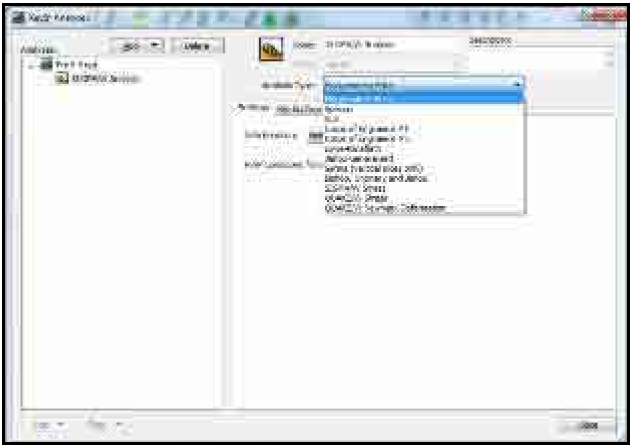

Figure 2. *Methods of limit equilibrium conditions in the software GeoStudio 2007 SLOPE / W*

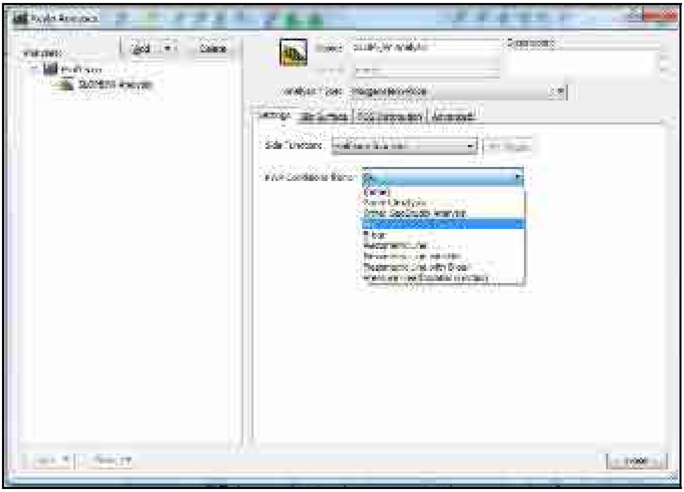

Figure 3. *Modeling of ground water impact on stability in the software GeoStudio 2007 SLOPE / W*

Stability calculation of the internal dump "Kutlovaca" was made by the methods: Morgenstern - Price, Bishop and Janbu.

The position of sliding planes was selected by the *Grid and Radius* tools, which defines the potential sliding planes by their center and skating radius - Figure 4.

Figures 5-7 show the sliding planes and calculation results of critical profile stability the internal dump "Kutlovaca" by the methods Morgenstern - Price, Bishop and Janbu for pore water coefficient of waterproof material $R_u = 0$.

Table 2 and Figure 8 show the results of stability calculation the internal dump "Kutlovaca" per critical profile for the coefficient value of pore water R_u from 0.0 to 0.5.

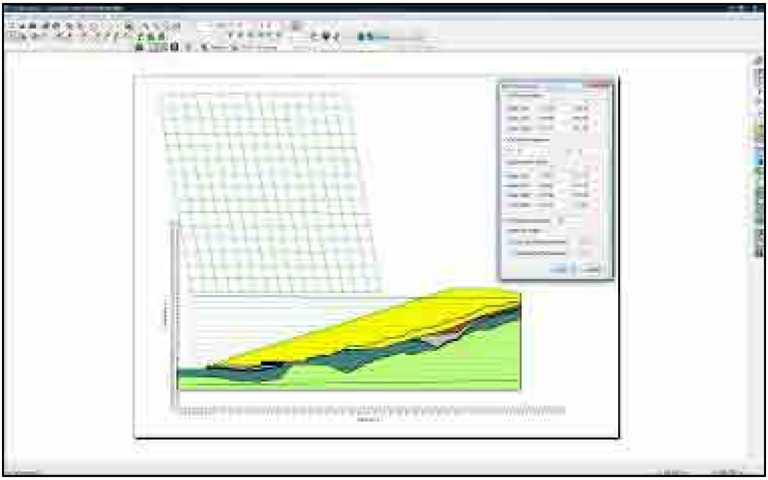

Figure 4. *Calculation of stability in the software GeoStudio 2007 SLOPE / W by the Grid and Radius tools*

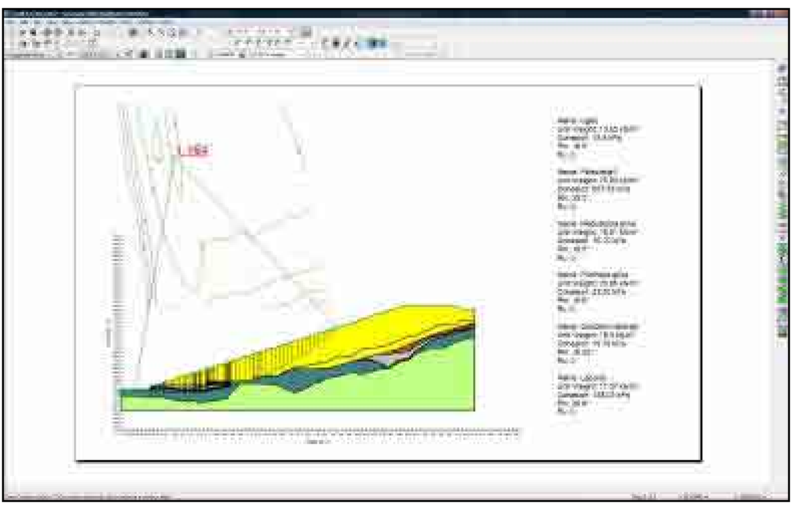

Figure 5. *View of sliding plane and stability coefficient by the method of Morgenstern - Price in the software GeoStudio 2007 SLOPE / W by the Grid and Radius tools*

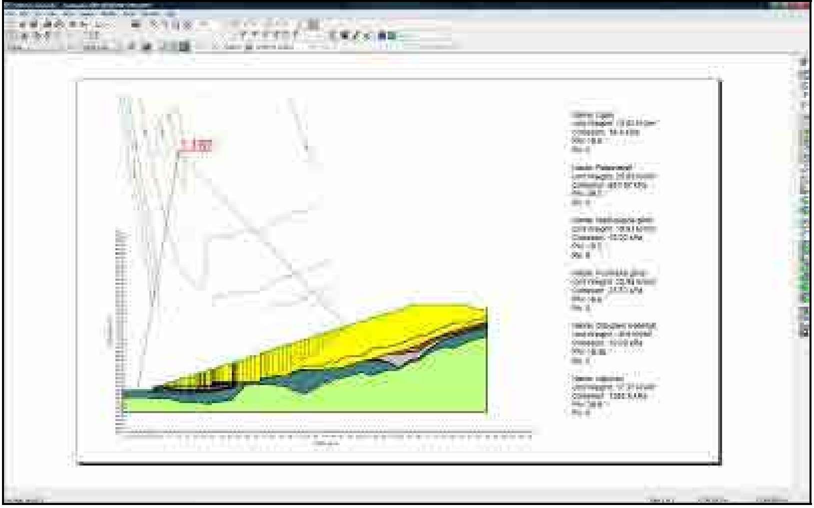

Figure 6. *View of sliding plane and stability coefficient by the method of Bishop in the software GeoStudio 2007 SLOPE / W by the Grid and Radius tools*

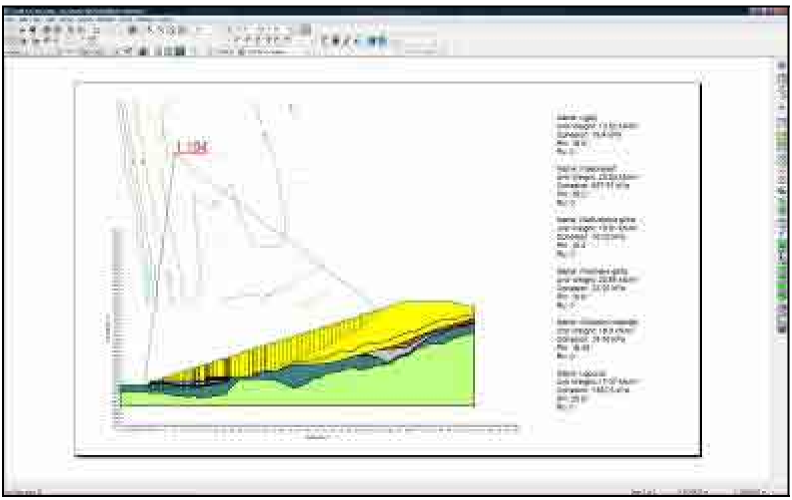

Figure 7. *View of sliding plane and stability coefficient by the method of Janbu in the software GeoStudio 2007 SLOPE / W by the Grid and Radius tools*

Table 2 Stability coefficient depending on the pore water coefficient R_u

R_u	0.0	0.1	0.2	0.3	0.4	0.5
Method	F_s					
Morgenstern - Price	1.164	1.100	1.037	0.972	0.900	0.796
Bishop	1.167	1.104	1.039	0.975	0.899	0.793
Janbu	1.104	1.060	1.001	0.923	0.829	0.735

Figure 8. *Graph of the stability coefficient Fs depending on the pore water Ru*

Based on the obtained results from these input parameters it could be concluded that the adopted geometrical elements, affected by the stability coefficient using the all methods of calculation, is greater than 1 for the pore water coefficient $R_u < 0.2$.

Also, it has to be repeated that there are no known the exact values of the pore water coefficient. To obtain the accurate results, it is necessary to set the piezometer per analyzed profile in order to obtain the accurate data at the level of ground water in deposit, before the waste disposal. It is also necessary to constantly monitor any changes in the work environment (cracks, landslides, subsidence).

CONCLUSION

Software GeoStudio 2007 - SLOPE / W is a program that can accurately determine all relevant conditions for calculation of slope stability in open pits, waste dumps and earth dams.

Each member of the lithological profile could be realistically modeled by spatial location and physical - mechanical characteristics.

It is also possible, in many ways, to model the impact of groundwater on the stability as well as the surface loads on the substrate surface.

Using this software significantly reduces the calculation time compared to the classic design.

For design, with proper initial selection parameters, the designer is still the most important designer. However, by the use of computer software, the job of designer is much easier in terms of time and quality due to rapid analysis capabilities in order to select the best solution.

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UDK: 66.061:546.57(045)=861

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LUŽENJE SREBRA IZ SULFIDNOG KONCENTRATA IZ RUDNIKA „RUDNIK”[**]

Izvod

Ovaj rad sadrži rezultate laboratorijskih istraživanja hidrometalurškog postupka izdvajanja obojenih metala i srebra iz sulfidnih koncentrata sa lokaliteta rudnika „Rudnik“. Pri preradi koncentrata primenjen je nekonvencionalan postupak razrađen u Institutu za rudarstvo i metalurgiju u Boru - niskotemperaturna sulfatizacija za degradaciju sulfidnih formi obojenih metala i prevođenje u oksidne forme lako rastvorne u vodi. Luženjem produkta sulfatizacije vodom, postignut je stepen izluženja bakra i cinka i gvožđa viši od 95 %. Postupak je pokazao zadovoljavajuće rezultate i u pogledu osnovnog zahteva - oslobađanja čestica srebra uklopljenih u pirit čime su stvoreni uslovi za dalji proces luženja. Niskotemperaturnom sulfatizacijom postižu se pozitivni energetski efeki u odnosu na široko primenjivano oksidaciono prženje sulfidnih koncentrata. Sledeća tehnološka faza je cijanidni proces luženja srebra sa postignutim stepenom izluženja od 71,8% Ag. Ispitan je i proces direktnog luženja srebra iz sulfidnog koncentrata primenom tiouree kao lužnog reagensa, pri čemu je 47,4 % Ag prevedeno u rastvor.

Ključne reči: *sulfidni koncentrat, cijanidno luženje, srebro , tiourea*

UVOD

Kod prerade sulfidnih koncentrata karakteristično je da su čestice plemenitih metala uklopljene u sufidima, najčešće u piritu. Prva faza u kompleksnoj preradi sulfidnih koncentrata je razaranje sulfida u cilju oslobađanja uklopljenih čestica zlata i srebra i na taj način priprema za hidrometalurško izdvajanje plemenitih metala i drugih obojenih metala.

Sledeći procesi se primenjuju kao prva tehnološka faza:

- Oksidaciono prženje,
- autoklavno luženje,
- oksidaciono-hloridni postupak,
- visokotemperaturno hloriranje,
- bakteriološko luženje.

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[**] *Ovaj rad je proistekao iz Projekta broj 19002 koji je finansiran sredstvima Ministarstva za nauku i tehnološki razvoj Republike Srbije*

Druga tehnološka faza je izdvajanje plemenitih metala luženjem. Izbor rastvarača zavisi od sadržaja plemenitih metala u koncentratu kao i od drugih ekonomskih i ekoloških zahteva. Više od 100 godina, cijanidi su nezamenljivi kao lužni reagensi zbog svojih prednosti u pogledu visokog stepena izluženja zlata i srebra i relativno niske cene procesa [1].

I danas, 100 godina kasnije [2], cijanidni postupak izdvajanje zlata i srebra odvija se po reakcijama 1 i 2:

$$4Au+8NaCN+O_2+2H_2O= =4Na[Au(CN)_2]+4NaOH \quad (1)$$

$$4Ag+8NaCN+O_2+2H_2O= =4Na[Ag(CN)_2]+4NaOH \quad (2)$$

Proces cijanidnog luženja se odvija u alkalnoj sredini pri pH vrednosti između 10 i 11, u zavisnosti od individualnih karakteristika koncentrata i optimalne brzine procesa [3].

Koncentracija cijanidnog rastvora je takođe važna u procesu luženja i obično se kreće u rasponu od 0.02% - 0.15% NaCN. Koncentracija NaCN zavisi od sadržaja prisutnih plemenitih metala i drugih primesa, u prvom redu bakra, u sulfidnom koncentratu.

Prisustvo oksidansa, u prvom redu kiseonika, ima takođe značajnu ulogu u procesu cijanidnog luženja plemenitih metala. Dokazano je da je brzina rastvaranja plemenitih metala u cijanidnom rastvoru direktno proporcionalna količini prisutnog oksidansa [4].

Na osnovu mineraloškog sastava koncentrata definiše se tehnološka šema prerade koncentrata [5].

Pored cijanida postoje i alternativni lužni reagensi, prvenstveno tiourea koja dobija na značaju iz ekoloških razloga [6].

EKSPERIMENTALNA ISTRAŽIVANJA

Karakterizacija sirovine i postupci prerade

Ispitivanja su vršena na uzorcima sulfidnog koncentrata rudnika „Rudnik". Hemijska analiza koncentrata data je u tabeli 1.

Tabela 1. *Hemijska analiza koncentrata*

Elemenat	Sadržaj, %
Cu	18.04
Fe	24.51
Pb	7.45
Zn	12.04
Bi	0.47
Ag (g/t)	895

Prema rendgenodifrakcionoj analizi fazni sastav koncentrata je sledeći: ZnS, FeS_2, FeS, SiO_2, PbS, $CuFeS_2$.

Za izdvajanje obojenih i plemenitih metala iz koncentrata primenjeni su sledeći tehnološki postupci:

- Niskotemperaturna sulfatizacija koncentrata u cilju prevođenja sulfidnih formi metala u oksidne forme.
- Luženje produkata sulfatizacije vodom u cilju prevođenja bakra, gvožđa i cinka u rastvor.
- Cijanidno luženje srebra iz produkta sulfatizacije nakon izdvajanja obojenih metala.
- Luženje srebra tioureom direktno iz koncentrata.

Ispitivanja su vršena sa 100 g koncentrata po opitu. Za ispitivanja je korišćena cevasta peć za process sulfatizacije. Za process luženja korišćen je stakleni laboratorijski balon sa grejnom oblogom snabdeven mešačem, automatskom regulacijom temperature i otvorima za šaržiranje i dovod kiseonika.

RESULTATI I DISKUSIJA

Niskotemperaturna sulfatizacija koncentrata

Niskotemperaturna sulfatizacija koncentrata je vršena koncentravanom sumpornom kiselinom. Luženjem vodom, nakon sulfatizacije, postignut je sledeći stepen izluženja (tabela 2):

Tabela 2. *Stepen izluženja metala vodom iz koncentrata nakon sulfatizacije*

Elemenat	Stepen izluženja, %
Cu	95.7
Fe	98.3
Ag	0.2
Zn	98.1

U prvoj fazi luženja iz koncentrata se odstranjuju cink, bakar i gvožđe.

Drugu fazu predstavlja cijanidno luženje u cilju prevođenja srebra u rastvor.

Cijanidno luženje srebra

Laboratorijska istraživanja procesa cijanidnog luženja rađena su na produktima sulfatizacije nakon izdvajanja obojenih metala.

Parametri luženja :

- Temperatura: 25oC
- Odnos č:t 1:2
- Koncentracija NaCN: 0.15%
- Brzina mešanja: 800^{o}/min
- Oksidans: kiseonik
- Vreme luženja: 8 h
- Koncentracija NaOH: 0.03%
- pH: 10-11

Pri ovim parametrima procesa luženja postignuti stepen izluženja srebra iznosio je 71,8 %.

Luženje srebra tioureom direktno iz koncentrata

Urađen je opit direktnog luženja srebra iz koncentrata tioureom čija je glavna prednost to što se na ovaj način eliminišu predtretmanski procesi prženja i luženja koncentrata. Postiže se i ekonomski efekat obzirom da se luženje odvija uz mali utrošak energije (na temperaturi od 40^{o} C).

Uzorak od 100 g sulfidnog koncentrata tretiran je rastvorom tioruee uz dodatak oksidansa na temperaturi od 40^{0} C. Postignuti stepen izluženja prikazan je u tabeli 3:

Tabela 3. *Stepen izluženja metala sa tioureom*

Elemenat	Stepen izluženja, %
Ag	47.40
Zn	2.76
Fe	14.01
Pb	0.008
Cu	1.16

Ovaj preliminarni test luženja tioureom pokazao je da je moguće direktno luženje srebra iz koncentrata. Nastavak istraživanja biće usmeren na utvrđivanje optimalnih tehnoloških parametara luženja.

ZAKLJUČAK

Na osnovu rezultata dobijenih eksperimentalnim istraživanjama prerade sulfidnog koncentrata sa lokaliteta rudnik "Rudnik" može se zaključiti sledeće:

1. niskotemperaturna sulfatizacija dovodi do razaranja sulfida prisutnih metala
2. luženjem produkta sulfatizacije vodom se postiže izluženje preko 95 % obojenih metala (bakar, cink i gvožđe)
3. Postupkom cijanidnog luženja srebra u prisustvu oksidansa izluženo je 71,8 % Ag
4. Direktnim luženjem srebra iz sulfidnog koncentrata postignut je stepen izluženja srebra od 47,4 %.

Zahvalnost

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SILVER LEACHING FROM SULPHIDE CONCENTRATE FROM THE „RUDNIK" MINE[**]

Abstract

This work presents the results of laboratory investigations of hydrometallurgical method for non-ferrous and silver recovery from sulphide concentrate from mine "Rudnik". The unconventional method, developed in the Mining and Metallurgy Institute Bor – the low temperature sulphidation for degradation of sulphide forms of metals and transfer ion to oxide forms easy disoluble in water, was used for treatment the sulphide concentrate. Tne results of copper, zink and iron, leached with water after the sulphidation process, showed that the percentage of leaching for all elements was above 95 %. This method has shown the good results regarding to the basic requirement – total degradation of present sulphides, and also the important savings regarding to widely used oxidation roasting of sulphide concentrates. Next stage was cyanide leaching of silver with leaching percentage of 71.8 % Ag. Method of direct Ag leaching from sulphide concentrate with tiouree as the leaching reagent was also investigated. The leaching degree of Ag was 47.4 % Ag.

Key words: *sulphide concentrate, cyanide leaching, silver, tiourea*

INTRODUCTION

The treatment of sulphide concentrate is characteristic that the precious metals particles were inserted into sulphides, more often in pyrite. First stage in complex treatment of sulphide concentrates is sulphide destruction for the aim of release the inserted gold and silver particles and, by this way, preparation for hydrometallurgical separation of precious metals and other non-ferrous metals.

The following processes are used as the first technological stage:

- Oxidation roasting
- Autoclave leaching
- Oxidation – chlorination method
- High temperature chlorination
- Nitro method
- Bacterial leaching

Second technological stage is precious metals recovery by leaching. Selection of dissolvent depends on precious metals content in concentrate as well as the other economical and ecological requirements. For over 100 years, cyanide has been the

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leaching reagents in the gold mining because of its high gold and silver recoveries and relatively low costs of process [1].

And today, over 100 years later [2], gold and silver are recovered using the cyanide simple reactions 1 and 2:

$4Au+8NaCN+O_2+2H_2O=$

$=4Na[Au(CN)_2] +4NaOH$..............(1)

4Ag+8NaCN+O2+2H2O=

=4Na[Ag(CN)2] +4NaOH.............(2)

Most cyanide leaching is carried out at an alkaline pH between 10 and 11, depending on individual concentrate characteristics [3].

Concentration of cyanide solution is also important in the leaching process with concentration of NaCN ranging from 0.02% to 0.15%. Concentration of sodium cyanide depends on precious metals content and other ingredients, first of all copper in sulphide concentrate.

Oxidant [4], first of all oxygen, has also an important role in the leaching process of precious metals in cyanide solution. It has been proven that the dissolution rate of precious metals in cyanide solution is directly proportional to the amount of present oxygen.

Mineralogical identification of concentrate is used for defining the technological flow sheet for concentrate [5]. Some alternative leaching agents, namely thiourea, have been tried due to the environmental concerns, generally without economic success [6].

EXPERIMENTS

Characterization of Raw Materials and Treatment Methods

Investigations were carried out on sulphide concentrate samples from the mine "RUDNIK". Chemical analysis of concentrate is given in Table 1.

Table 1. *Chemical analysis of concentrate*

Element	Content, %
Cu	18.04
Fe	24.51
Pb	7.45
Zn	12.04
Bi	0.47
Ag (g/t)	895

According to the carried out X-ray – structural analysis, the stage content of concentrate is the following: ZnS, FeS_2, SiO_2, PbS, $CuFeS_2$.

For separation of non-ferrous and precious metals from concentrate, the following technological methods were used:

- Low temperature sulphatization for the aim of transfer the sulphide forms of metal into oxide forms
- Leaching of sulphatization products with water for the aim of copper, iron and zinc transfer into solution
- Cyanide leaching of Ag from sulphatization product after the recovery of non-ferrous metals.
- Thiourea leaching of Ag from untreated concentrate.

Investigations were carried out with 100 g of concentrate per experiment. Tube furnace for annealing was used in investigation as well as the glass laboratory reactor with heating lining and stirrer and heater with automatic temperature regulation, holes for charging and oxygen supply, and the other necessary laboratory equipment.

RESULTS AND DISCUSSION

Low Temperature Sulphatization Process

Low temperature sulphatization process was carried out with the concentrated sulphuric acid. By leaching with water, after sulphatization, the following leaching degree was realized (Table 2):

Table 2. *Degrees of metal leaching with water from concentrate after sulphatization*

Element	Leaching degree, %
Cu	96.7
Fe	98.3
Ag	0.2

In the first phase of leaching, the zinc, copper and iron are removed from concentrate.

The second phase is presented by the cyanide leaching for the aim of silver transfer into solution.

Cyanide Leaching of Silver

Laboratory investigations for cyanide leaching experiments on samples were carried out on the sulphatization process products after the recovery of copper, zinc and iron.

Leaching parameters are:

- Temperature: $25^{o}C$
- S:L ratio: 1:2
- NaCN concentration: 0.15%
- Stiring rate: 800 min^{-1}
- Oxidant: oxygen
- Leaching time: 8 h
- NaOH concentration: 0.03%
- pH: 10 - 11

The result of cyanide leaching test, obtained after 8 h of leaching, was 71.8 % Ag.

Silver Leaching with Thiourea Directly from Concentrate

The test of untreated concentrate leaching was carried out with thiourea as the reagent. The main advantage of this reagent is that it eliminates the pre-treatment concentrate processes of roasting and leaching. The economic effect is also achieved since leaching is the process with small power consumption (at temperature of 40^{o} C).

A sample of 100 g of sulphide concentrate was treated with thioruea solution and addition of oxidizer at temperature of $40^{o}C$. The results are shown in Table 3.

Table 3. *Metals leaching degree*

Element	Leaching degree, %
Ag	47.40
Zn	2.76
Fe	14.01
Pb	0.008
Cu	1.16

This preliminary test has shown that the silver leaching from untreated concentrate is possible. The following investigation will be aimed to the defining of optimal technological leaching parameters.

CONCLUSION

Based on the obtained experimental results of investigation the silver leaching from sulphide concentrate from the »Rudnik« mine, it could be concluded the following:

1. Low temperature sulphatization of concentrate leads to the destruction of present metal sulphides
2. Leaching degree of non-ferrous metals (copper, iron and zinc) over 95 % was obtained by leaching of sulphatization products with water
3. Silver leaching degree of 71.8 % was obtained by cyanide leaching of silver in the presence of oxidant
4. Silver leaching degree of 47.4 % was obtained by direct leaching of silver with thiourea from concentrate.

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OVODNJENOST I PUMPNI SISTEM ZA ODVODNJAVANJE POVRŠINSKOG KOPA UGLJA „POTRLICA“ – PLJEVLJA

Izvod

U radu su prikazani uticajni parametri i količina vode na površinskom kopu uglja „Potrlica“ koji je u sastavu pljevaljkog ugljenog basena. Prikazan je sistem ispumpavanja vode na kopu i urađena je njegova verifikacija.

Ključne reči: *pumpni sistem, količina vode, verifikacija*

UVOD

Površinski kop uglja „Potrlica“ je u sastavu pljevaljskog ugljenog basena.

Na veličinu ovodnjenosti najveći uticaj imaju površinske vode nastale usled atmosferskih padavina koje padnu direktno na područje kopa, površinske vode nastale usled atmosferskih padavina sa slivnih površina sa kojih gravitiraju ka kopu i podzemne vode.

Najveći priliv u područje kopa je od podzemnih voda i iznosi od 40 pa čak do 500 l/s.

Za područje Pljevalja, početni intenzitet maksimalniih pedesetogodišnjih padavina iznosi 4,12 mm/min. Maksimalna količina podzemnih i površinskih voda koja za osam sati može da dospe u kop iznosi 57.000 m^3.

Prosečna ispumpana količina vode od 1991. do 2008. god. je bila 10.680.000 m^3/god.

Za ispumpavanje vode predviđen je sistem bunarskih i centrifugalnih pumpi, postavljenih na tri lokacije. Ukupna snaga sistema iznosi 2 692 kW. Ukupna geodetska visina dizanja je 114 m, a maksimalni protok vode kroz sistem iznosi 720 l/s.

PRIKAZ I ANALIZA UTICAJNIH PARAMETARA

Padavine imaju kontinentalni tip raspodele, maksimum u kasno proleće, sekundarni maksimum u kasnu jesen i minimum u toku zime. Godišnja količina taloga je 800 – 1.100 mm i spada u najmanje u Crnoj Gori. Godišnja raspodela padavina po mesecima je ravnomerna. Prosečan broj dana sa padavinama je 144 godišnje. Broj dana u godini sa snežnim pokrivačem većim od 1 cm je 67, a visine većim od 10 cm je 32. Snežne padavine obično počinju sredinom novembra, a završavaju sredinom aprila [1].

U prostoru ležišta uglja Potrlica postoje tri tipa izdani: zbijeni tip, pukotinski tip i karstni tip [1].

Zbijeni tip izdani je formiran u aluvijalnom nanosu reke Ćehotine i u odloženim jalovinskim masama u prostoru unutrašnjeg

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i spoljašnjih odlagališta PK "Potrlica”. Aluvijalni peskovito-šljunkoviti sedimenti imaju površinu od 4 km^2, a širina aluvijona Ćehotine varira 25 – 600 m. Nivo izdani je u direktnoj zavisnosti od promena nivoa vode u reci. U periodu niskog vodostaja dreniranje izdani se vrši ili isticanjem u rečni tok, ili proceđivanjem u delu gde su aluvijalne naslage nataložene preko krečnjaka gde prihranjuje pukotinsko – karstnu izdan. Debljina šljunka i peska varira 0,30 – 2,55 m, a prosečna iz 10 bušotina je 1,60 m. U severnom i severozapadnom delu P.K "Potrlica” u otkopanom prostoru formirano je unutrašnje odlagalište. Deponovani su krovinski laporci i prateće naslage debljina preko 25 m. Pre nasipavanja, u prostoru unutrašnjeg odlagališta registrovana su dva izvora na koti 708 i 704 m. Preko njih odložene su iskopane mase bez prethodne drenaže, pa oni utiču na hranjenje izdani u odloženim masama, koja se drenira preko izvora u njenom podnožju. Procenjena zbirna izdašnost izvora je približno 10 l/s. U delu gde odložene mase leže preko nagnute podloge krečnjaka, dreniranje izdani se vrši i u krečnjački masiv.

Pukotinski tip izdani je u krovinskim laporcima ali i u samom ugljenom sloju. Srednja debljina laporca je 41 m, a maksimalna 131 m. Laporci su uslojeni i različitog pada od 15 – 48°. Ispucalost stena u površinskom delu je veća od dubljih delova. Laporci se prostiru na površini od 7 km^2 što se poklapa sa površinom rasprostranjenja ugljenog sloja. Prihranjivanje izdani vrši se infiltracijom atmosferske vode, infiltracijom iz aluviona reke Ćehotine i infiltracijom vode iz trijaskih krečnjaka u obodnom delu ležišta (akumulacija Durutovići). Dreniranje izdani vrši se frontalnim procurivanjem sa isticanjem podzemnih voda duž etaža ili preko koncentrisanih izvora duž kontakta svetlosivih ispucalih i tamnosivih kompaktnih laporaca kao i na kontaktu glavnog ugljenog sloja i njegove krovine. Izdašnost izvorišnih zona varira. Kartiranjem je registrovano više zona procurivanja i isticanja od najviših do najdubljih radnih etaža u južnom delu kopa, izdašnosti od 1 l/s do preko 10 l/s. Izdan u laporcima je sa slobodnim nivoom. Dubina do izdani je 5 – 50 m. U ugljenoj seriji debljine 20 m, gde pored glavnog sloja postoje još dva ili tri ugljena sloja debljine do 15 m, formirana je pukotinska izdan. Izdan je formirana u delu gde su tektonski stvarani sistemi pukotina i raseda. Glavno napajanje vodom izdani dolazi iz istočnog i centralnog dela basena, južno od otkopnog fronta P.K "Potrlica", gde sloj uglja leži direktno na krečnjacima. Hranjenje izdani u uglju moguće je i iz krovinskih laporaca, ali su to slabiji izvori prihranjivanja u odnosu na karstnu izdan.

Karstni tip izdani je u trijaskim krečnjacima, a prostor kopa "Potrlica" je samo deo velike i prostrane akumulacije koja se prostire na površini od oko 500 km^2. Krečnjaci su podina neogenim naslagama u celom basenu, a takođe izgrađuju severni i istočni obod basena. Istražnim bušenjem krečnjaci sa samo nabušeni, a u gro slučajeva bušotine su završavane u neogenu, pa se procenjuje da debljina krečnjaka iznosi više stotina metara, dok baza karstifikacije nije jasno definisana. U delu gde su krečnjaci otkriveni izdan je sa slobodnim nivoom. U izvorištima “Tvrdaš” i „”Kutlovača” potvrđena je osobina karsta da se NPV spušta sledeći kotu isticanja. Usled eksploatacije kote isticanja vrela “Tvrdaš” i povremenog vrela “Kutlovača”, spuštene su sa 775,3 m na 660 m, što je dovelo i do generalnog spuštanja NPV u karstnoj izdani. U delu gde su krečnjaci pokriveni neogenom NPV je subarteski. Prisustvo karstne izdani je konstatovano u svakoj bušotini završenoj u podini basena. Oscilacije nivoa izdani su blage i ujednačene sa jasnim uticajem padavina. Za ovo područje prosečne padavine iznose 795,2 mm/god. i od te količine veći deo ponire i vrši veoma obilno hranjenje izdani. Prema literaturnim podacima za krečnjake efektivna infiltracija padavina može da iznosi

70%. Dreniranje izdani vrši se po obodu basena preko vrela “Bezdan”, “Prkos”, “Debela česma”, a u zoni P.K. preko izvorišta “Tvrdaš”, povremenog vrela “Kutlovača” gde je rudarskim radovima otvoren krečnjak. Nakon formiranja klizišta u zoni vrela “Tvrdaš”, izvor je sada iznad bivšeg mesta isticanja, a u nižem delu istekla voda se spaja u jedno slapište. Kontinuirana merenja izdašnosti nisu vršena, ali maksimalna za vrelo “Tvrdaš” je 490 l/s i “Kutlovaču” 750 l/s (20.11.1985. posle ekstremnih padavina 18.11.1985. od 123,5 mm/m^2). Minimalna izdašnost vrela Tvrdaš se procenjuje na 30 – 40 l/s i na osnovu srednje izdašnosti, vrelo Tvrdaš pripada trećoj grupi sa izdašnošću od 0,1 do 1,0 m^3/s.

Stenske mase basena imaju pukotinsko – kavernoznu poroznost, sa spletom različito orijentisanih pukotina i raseda, kao i međuzrnsku poroznost, gde preovlađuje superkapilarna poroznost. Na osnovu ispitanih filtracionih karakteristika izvršena je podela na hidrogeološke kolektore, hidrogeološki kompleks i hidrogeološke izolatore. Hidrogeološke kolektor čine krečnjaci i aluvijalne naslage, HG kompleksu pripadaju laporci i ugljena serija, a hidrogeološke izolatore čine podinske laporovite i ugljevite gline [1].

Filtracione karakteristike krečnjaka su izrazito nehomogene i zavise od stepena raspucanosti i stepena karstifikovanosti. Filtracione karakteristike su najbolje upoznate u severoistočnom delu PK "Potrlica". Hidrogeološkim bušotinama u krečnjaku je i na dubini od 104 m konstatovana dobra vodoprovodnost. Ispitivanjem VDP-a tokom izgradnje lučne brane “Durutovići” i izrade injekcione zavese na repernim bušotinama je utvrđena srednja i velika vodoprovodnost K = 1,75 x 10^{-5} ÷ 4,30 x 10^{-6} m/s. Vodopropusnost krečnjaka u desnom boku brane je preko 60 l/s. U bušotinama dubine 45 – 100 m, koje služe za osmatranje efekata injekcione zavese u pojedinim intervalima na različitim dubinama opit VDP, nije urađen zbog postojanja sistema pukotina i kaverni u kojima se gubila voda. Dobijeni K_f varira od 1,61 x 10^{-7} ÷ 9,68 x 10^{-5} m/s, a niže vrednosti važe za dublje intervale. Generalno, za krečnjake se može usvojiti vrednost K_f = 3,5 x 10^{-6} m/s.

U laporovitim naslagama i ugljenoj seriji filtracione karakteristike po dubini se često menjaju, u zavisnosti od lokalne ispucalosti i rasednih zona, pa variraju od dobropropusnih do vodonepropusnih, što ih svrstava u hidrogeološki kompleks. Generalno se krovinski laporci mogu zonirati na dobrovodopropusne, slabovodopropusne i vodonepropusne. U istočnom delu basena kod Durutovića, do dubine od 30 m laporci se odlikuju dobrovodopropusnim svojstvima, mada je najveći deo krovinskih laporaca slabovodopropusnih karakteristika, a u centralnom delu basena, na dubinama preko 30 m, laporci su vodonepropusni, sa koefcijentom filtracije manjim od 1 x 10^{-7} m/s.

Za ugljenu seriju su karakteristične promenljive filtracione karakteristike, prema stepenu ispucalosti i izlomljenosti. U zonama razvijenih pukotina i u zoni fleksura (obodni deo basena) izražene su dobrovodopropusne karakteristike, dok je u većini ispitivanih bušotina ugalj slabo do srednjevodopropustan. Lokalno ugalj pokazuje i dobropropusne karakteristike, K_f = 1,46 – 7,77 x 10^{-6} m/s.

Neposredno uz reku Ćehotinu preovlađuju šljunkovi, mestimično peskoviti i glinoviti. Filtracione karakteristike aluvijalnih naslaga su emprijski proračunate i odlikuju se dobro vodopropusnim svojstvima K_f = 2,87 ÷ 6,57 x 10^{-2} m/s.

KOLIĆINA VODE NA KOPU

Na formiranje priliva rudničkih voda i ovodnjenost ležišta Potrlica sem geološko-tektonskih i hidrogeoloških faktora bitno utiču i fizičko geografski. Pored njih ne smeju se zanemariti ni antropogeni usled približavanja i spuštanja rudarskih radova i pojave blokovskog klizišta u krečnjačkom zaleđu. Količina ispumpane vode na kopu u period 1991 – 2009. god. prikazana je u tabeli 1 [2].

Tabela 1. *Ispumpana voda na P.K. "Potrlica" za period 1991 – 2008. god.*

Godina	Iskopani materijal		Ispumpana voda	
	Ugalj, t	Laporac, t	m^3	l/s
1991	241 578	2 684 770	9 434 805	299
1992	346 033	3 196 592	8 202 140	260
1993	412 982	2 619 592	6 949 980	260
1994	357 244	2 837 444	9 737 280	309
1995	420 237	2 263 595	10 528 170	334
1996	502 999	1 581 865	11 856 660	376
1997	433 940	1 634 858	8 634 760	274
1998	500 297	1 145 471	9 170 370	291
1999	500 235	1 461 465	8 781 324	278
2000	594 211	2 102 340	8 961 246	284
2001	434 913	2 914 609	9 958 824	316
2002	519 587	3 381 798	10 987 488	348
2003	643 554	4 024 590	11 043 066	350
2004	650 741	3 138 254	13 521 740	428
2005	774 997	2 684 042	13 476 779	427
2006	826 126	3 334 549	13 053 359	414
2007	778 541	2 850 184	13 283 709	421
2008	1 084 231	2 863 917	14 714 221	465
2009	662 036	3 979 077	16 451 424	648
Prosek	527 497	2 458 944	10 120 838	357

Početni minutni intenzitet maksimalnih dnevnih padavina za period od 50 godina u trajanju od 30 minuta iznosi 4,12 mm/min, a srednji intenzitet padavina u trajanju od 8 časova, merodavan za proračun normalnih priliva nastalih usled atmosferskih padavina iznosi 0,08 mm/min.

Maksimalna dnevna količina površinskih voda nastalih usled atmosferskih padavina koja dospeva u kop iznosi 14.000 m^3. Količina vode nastala usled atmosferskih padavina koja dospeva u kop za normalne prilive iznosi 735 m^3.

Maksimalni priliv podzemnih voda procenjen je na 500 l/s. Normalni priliv podzemnih voda iznosi 40 l/s.

Maksimalni dnevni priliv od podzemnih voda je prilikom ekstremnih padavina i iznosi 43.200 m^3. Normalni dnevni priliv od podzemnih voda iznosi 3 450 m^3.

Ukupni maksimalni priliv u kop od površinskih i podzemnih voda, merodavan za dimenzionisanje pumpnih postrojenja na kopu, iznosi 57.200 m^3.

SISTEM ZA ISPUMPAVANJE VODE

Na površinskom kopu „Potrlica“ u funkciji su dva tipa pumpi proizvođača „Jastrebac“ iz Niša:

- Cevne pumpe BP 300 – 1 snage motora 132 kW, i centrifugalne pumpe VPN 251 – 3 snage motora 475 kW.

Sistem za ispumpavanje vode je sledeći [2]:

- Na najnižoj etaži kopa nalazi se privremeni vodosabirnik u kome su 2 pumpe tipa BP 300 – 1. Kota sa koje se ispumpava voda je K+632 m, dužina cevovoda iznosi 50 m.
- Voda iz pomoćnog vodosabirnika se ispumpava u glavni vodosabirnik na nivou K+643 m, gde se nalaze 4 pumpe tipa BP 300 – 1.
- Iz glavnog vodosabirnika voda se ispumpava kroz cevovod dužine 160 m

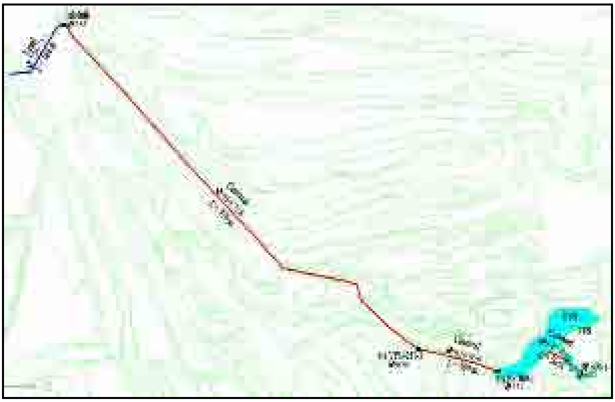
do kote K+656 m gde su postavljene 4 pumpe tipa VPN 251 – 3. Pumpe BP – 300 – 1 i VPN

- 251–3 su direktno povezane cevovodom.
- Sa nivoa K+656 m voda se ispumpava do taložnika na nivou K+758 m, cevovodom dužine 970 m.

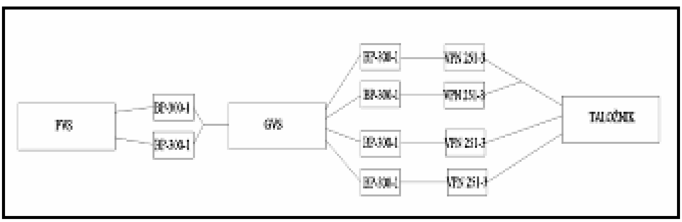
Jednu sekciju pumpi za ispumpavanje vode od glavnog vodosabirnika do taložnika čine po jedna redno vezana pumpa BP 300 – 1 i pumpa VPN 251 – 3. Na kopu su u funkciji četiri ovakve sekcije.

Na slikama 1 i 2 prikazani su linijska šema sistema za odvodnjavanje i prostorni položaj pumpnih postrojenja, a na slici 3 dijagram rada jedne sekcije.

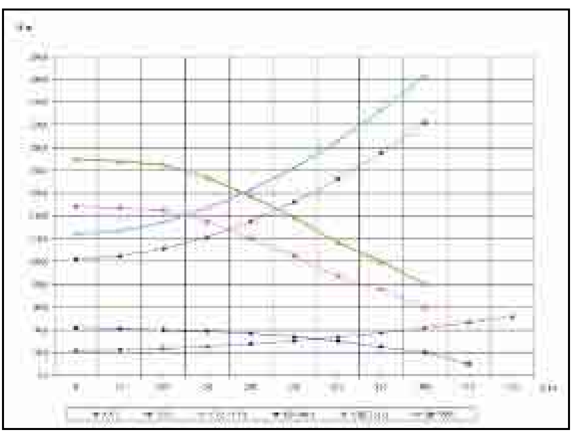
Radne tačke pumpi na pomoćnom i sekcija na glavnom vodosabirniku date su u tabeli 2.



Sl. 1. *Položaj pumpnih postrojenja na P.K. „Potrlica“*



Sl. 2. *Linijska šema pumpnih postrojenja na P.K. „Potrlica“*



Sl. 3. *Dijagram rada pumpi na P.K. „Potrlica“*

Tabela 2. Radne tačke pumpi na P.K. „Potrlica“

Pumpa	Vodosabirnik	H, m	Q_{jed}, l/s	Kom	Q_{max}, l/s
BP-300-1	PVS	15	420	2	840
(BP-300-1 + VPN 251-3)/r	GVS	160	180	4	720

Ukupni maksimalni priliv u kop od površinskih i podzemnih voda iznosi: Q_v = 57.200 m^3. Ukupni kapaciteti pumpnih postrojenja prikazani su u tabeli 2. Za ispumpavanje maksimalnih priliva potreban je istovremeni rad obe pumpe na pomoćnom vodosabirniku i obe sekcije pumpi na glavnom vodosabirniku.

Potrebna vremena ispumpavanja vode od maksimalnih priliva iz pomoćnog vodosabirnika na nivou K+634 m u glavni vodosabirnik na nivou K+649 m, i iz glavnog vodosabirnika u taložnik na nivou K+754 m, iznose 19 odnosno 22 časa sukcesivno.

Pumpna postrojenja se dimenzionišu za maksimalne prilive vode. Potrošnja električne energije na godišnjem nivou se određuje prema prosečnoj godišnjoj količini vode koja se ispumpava – 10.680.000 m^3.

Broj moto – sati rada pumpi BP-300-1 na pomoćnom vodosabirniku iznosi 7.063 h/god. Broj moto – sati rada sekcije na glavnom vodosabirniku iznosi 16.481 h/god.

Ukupna prosečna potrošnja električne energije za ispumpavanje vode iz kopa “Potrlica” iznosi na godišnjem nivou 10.936.283 kWh/god.

Prosečni normativ električne energije za ispumpavanje vode na kopu “Potrlica” iznosi 1,02 kW/m^3 ispumpane vode.

ZAKLJUČAK

Prilivi vode u površinski kop “Potrlica” su izuzetno veliki. Najveći priliv je od podzemnih voda čiji dotok u kop ne može da se spreči, pa se vrši njeno ispumpavanje. Postojećim sistemom za ispumpavanje vode na površinskom kopu “Potrlica” je do sada uspešno ispumpavana voda koja je dospevala u područje kopa.

Sa napredovanjem razvoja rudarskih radova po planu i dubini, mogu se očekivati i veći prilivi od sadašnjih. Prema dinamici razvoja radova za narednih pet godina, glavni vodosabirnik bi ostao na sadašnjoj koti, dok bi se pomoćni vodosabirnik spustio do kote K+600 m.

S toga je u narednom periodu potrebna nabavka još jedne pumpe BP 300 – 1 i jedne pumpe VPN 251 – 3 za glavni vodosabirnik, kao i još dve pumpe tipa BP 300 – 1 za pomoćni vodosabirnik.

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UDK: 622.271(045)=20

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QUANTITY OF WATER AND PUMP SYSTEM FOR DRAINAGE AT THE OPEN PIT OF THE COAL MINE "POTRLICA" – PLJEVLJA

Abstract

This work shows the effect parameters and quantity of water at the coal open pit mine „Potrlica" within the Pljevlja Coal Basin. The system of water pumping at the open pit was shown and its verification was made.

Key words: *pump system, water quantity, verification*

INTRODUCTION

The coal open pit "Potrlica" is within the Pljevlja Coal Basin.

The size of water quantity is under the largest impact of surface water caused by the atmospheric precipitation that falls directly on the area of open pit, the surface water due to the atmospheric precipitation from the catchment area from which gravitate towards the pit and underground water.

The biggest influx in the area of the open pit is by the groundwater and ranges from 40 and up to 500 l / s. For the area of Pljevlja, the initial intensity of maximum fifty-year rainfall is 4.12 mm/min. Maximum quantity of groundwater and surface water for eight hours can reach the open pti is 57 000 m^3.

The average amount of pumped water from 1991 to 2008. was 10 680 000 m^3/year.

The system of well and centrifugal pumps is predicted for water pumping, set at three locations. Total power system is 2 692 kW. Total geodetic lifting height is 114 m, and maximum water flow through system is 720 l / s.

REVIEW AND ANALYSIS OF INFLUENTIAL PARAMETERS

The rainfalls have a continental type of distribution, maximum in late spring, the secondary maximum in late autumn and minimum during the winter. The annual amount of sediment is 800-1 100 mm and is one of the lowest in Montenegro. The annual distribution of monthly rainfalls is uniform. The average number of days with rainfalls is 144 per year. Number of days per year with snow cover >1 cm is 67, and height >10 cm is 32. Snowfalls usually start in mid-November and ends in mid-April [1].

In the area of coal deposits Potrlica there are three types of aquifers: compact type, fracture type and karst type of aquifers [1].

Compact type of groundwater is formed in the alluvial coat of the river Ćehotina and dumped waste masses in the space of inner and outer waste dumps of the open pit "Potrlica". Aluvial sandy-pebbly sediments have area of 4 km^2 and the width of Ćehotina alluvion varies 25-600 m. The groundwater level is in

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directly connection to the water level change in the river. In the period of low water, the drainage of aquifers is done by highlighting the river, or stream, or trickling through the part where alluvial sediments deposited over the limestone where they supply the fracture - karst aquifer. Thickness of gravel and sand range from 0.30 – 2.55 m and the average of 10 drillhoeles was 1.60 m. In the northern and north-western part of the open pit “Potrlica”, the inner waste dump was formed. The roof marls and accompanying deposits of thickness over 25 m are dumped. Before dumping, in the space of the internal dumps, two sources at bench levels of 708 and 704 m were registered. Over them, the mined masses were dumped without drainage, and they affect the aquifer feeding in the dumped masses, which is drained over resources in its foot.The estimated aggregate yield of the source is approximately 10 l/s. The area where the dumped masses lay over sloping surface of limestone, the aquifer drainage is also done in the limestone massif.

Fracture type of aquifer is in the roof marls but also in the coal layer. Average thickness of marl is 41 m and maximum 131 m. The marls are bedded and various fall of 15-48º.The fracture of rocks in the surface area is larger than the deeper areas. Marls cover an area of 7 km^2, which coincides with the distribution of surface carbon layer. Aquifer feeding is done by the infiltration of atmospheric water, infiltration from alluvion of the river Ćehotina and infiltration of water from the Triassic limestone deposits in the rim area (the accumulation of “Durutovici”). Drainage of aquifers is leakage from the frontal prominence of groundwater along the floor or a concentrated source of contacts along light gray fractured and dark gray compact marls as well as on a contact of the main coal layer and its roof. The yield zone of sources varies. Mapping registered multi areas of leakage and expiration of the highest to the deepest levels of work in the southern part of the mine yield of 1 l / s to over 10 l / s. The aquifer in the marls was released in the free level. The depth to aquifer is 50-50 m. In the coal series its thickness is 20 m, where in addition to the main layers two or three carbon layers, thickness up to 15 m, the fractured aquifer was formed. Aquifer was formed in the part where the actual tectonic fissures and fault systems are. The main water supply comes from aquifers from the eastern and central part of the basin, on the south of mining front of the open pit “Potrlica”, where the coal layer lies directly on limestone. Feeding the aquifers in the coal is also possible from the roof marls, but they are weaker sources in the feeding compared to the karst aquifer. Karst type of aquifers is in Triassic limestone, and the space of open pit “Potrlica” is just a part of large and spatial accumulation which covers an area of 500 km^2. Limestones are substratum of Neogene deposits throughout the basin, and also built the northern and eastern edge of the basin. By prospecting drilling, the limestones are only bored, and in the majority of cases the drill holes were ended in the Neogene, so it is estimated that the thickness of limestone is several hundred meters, while the base of karstification is not clearly defined. The area where the limestone was discovered, the aquifer is with a free level. The sources “Tvrdaš” and “Kutlovača “, the characteristic of karst was confirmed that the open pit drops to the next level of outflow. Due to the exploitation of source “Tvrdaš” and periodical source “Kutlovača“, the elevation levels of outflow were dropped from 775.3 m to 660 m, resulting in an overall lowering the open pit in the karst aquifer. The area where the limestone is covered by Neogene, the open pit is subarteritic. The presence of karst groundwater is found in every drill completed in the basin substratum. Groundwater level oscillations were mild and consistent with clear influence rainfall. For this area the average amount of precipitation 795.2 mm/year, and the quantity of most dives and is very abundant feeding aquifers. According to literature data for the limestones effective infiltration of rainfall may amount to 70%. Drainage of aquifer is done by the edge of basin over the aquifers the “Bezdan”, “Prkos”, “Debela česma”, and in the zone of open pit over the aquifer “Tvrdaš”, periodical aquifer “Kutlovača” where the limestone is oped by the mining works. After the formation of landslides in the zone of aquifer “Tvrdaš“, the source is now over the former place of posting, and lower part of expired water is connected to a ware fall. Continuous measurements of yield were not performed, but the maximum for the aquifer “Tvrdaš“ is 490 l/ “Kutlovaču” 750 l/s (in 20.11.1985. after extreme rainfalls 18.11.1985. of 123.5 mm/m^2). Minimum yield of aquifer “Tvrdaš” is estimated to 30-40 l/s and on the basis of high yield, the aquifer “Tvrdaš” belongs to the third group with capacity of 0.1 to 1.0 m^3/s.

Rock mass of the basin have the fracture-cavernous porosity, with a combination of differently oriented cracks and faults, and integranular porosity, where super capillary porosity prevails. Based on the filtration characteristics of the respondents completed the division of hydrogeological collectors, hydro-geological and hydrogeological complex insulators. Hydrogeological collector consists of limestones and alluvial deposits, and marls and coal series belong to the HG complex, and hydrogeological insulators are substratum marly and coal clays[1].

Filtration characteristics of limestone are very inhomogeneous and depend on the degree of fracture and degree of carstification. Filtration characteristics are most familiar in the northeastern part of the open pit “Potrlica”. Hydrogeological drilling in limestone is at depth of 104 m where good permeability is noted. By the VDP examination during the construction of arch dam “Durutovici” and making in injection curtain on drill holes, the medium and large vodoprovodnost water permeability was determined $K = 1.75 \times 10^{-5} \div 4.30 \times 10^{-6}$ m/s. Waterpermeability of limestone in the right side of the dam is over 60 l / s. The drilling depth of 45-100 m, which is used to observe the effects of the injection curtain in different intervals at different depths VDP experiment is not done because of the existence of fissures and caverns in which they lost water. The obtained Kf ranges from $1.61 \times 10^{-7} \div 9.68 \times 10^{-5}$ m/s, and lower values are for deeper intervals. In general, the value of $K_f = 3.5 \times 10^{-6}$ m/s could be adopted for limestones.

In marl deposits and coal series, the filtration characteristics per depth often change, depending on the local fracture and fault zone, and range from good water permeable to waterproof, which puts them in hydrogeological complex. Generally, the roof marls may zone from good water permeable, poor waterproof and waterproof. In the eastern part of the basin at Durutovići, to a depth of 30 m, the marls are characterized with good water permeable characteristics, although most of the roof marls have poor water permeable characteristics, and in the central part of the basin at depths over 30 m, the marls are waterproof, with coefficient of filtration less than 1×10^{-7} m / s.

For the coal series are characteristic variables filtration characteristics according to the degree of fracture and breaking. In the areas of developed cracks and in the flexure zone (edge of the basin) the good water permeable characteristics are expressed, while the majority of tested drill holes, the coal is poor to medium water permeable. Locally, the coal shows good permeable characteristics, $K_f = 1.46 – 7.77 \times 10^{-6}$ m/s.

Immediately near the river Ćehotina , the gravel, partly sandy and clayey, are prevalent.Filtration characteristics of the alluvial deposits are empirically calculated and characterized with good water permeability $K_f = 2.87 \div 6.57 \times 10^{-2}$ m/s.

QUANTITY OF WATER AT THE OPEN PIT

Except geological tectonic and hydrogeological factors, the physico-geographic factors have an important effect on formation the influx of mine water and deposit water quality. Besides them, the anthropogenic factors should not be neglected due to the closer access and lowering of mining works and occurrence of landslides in the karst hinterland. The amount of pumped water at the open pit in the period 1991 – 2009. is shown in Table 1 [2].

Table 1. *Pumped water at the open pit "Potrlica" in the period 1991 – 2008.*

Year	Mined material		Pumped water	
	Coal, t	Marl, t	m^3	l/s
1991	241 578	2 684 770	9 434 805	299
1992	346 033	3 196 592	8 202 140	260
1993	412 982	2 619 592	6 949 980	260
1994	357 244	2 837 444	9 737 280	309
1995	420 237	2 263 595	10 528 170	334
1996	502 999	1 581 865	11 856 660	376
1997	433 940	1 634 858	8 634 760	274
1998	500 297	1 145 471	9 170 370	291
1999	500 235	1 461 465	8 781 324	278
2000	594 211	2 102 340	8 961 246	284
2001	434 913	2 914 609	9 958 824	316
2002	519 587	3 381 798	10 987 488	348
2003	643 554	4 024 590	11 043 066	350
2004	650 741	3 138 254	13 521 740	428
2005	774 997	2 684 042	13 476 779	427
2006	826 126	3 334 549	13 053 359	414
2007	778 541	2 850 184	13 283 709	421
2008	1 084 231	2 863 917	14 714 221	465
2009	662 036	3 979 077	16 451 424	648
Average	527 497	2 458 944	10 120 838	357

Start-minute maximum intensity of daily rainfall for the period of 50 years in the period of 30 minutes is 4.12 mm / min, and medium intensity rainfall in the period of 8 hours, authoritative for the calculation of normal flow caused by atmospheric precipitation is 0.08 mm / min.

Maximum daily amount of surface water caused by atmospheric precipitation, which is released into the open pit is 14 000 m^3. The amount of atmospheric water caused by rainfall that reaches the prospect of normal inflows is 735 m^3.

Maximum inflow of ground water is estimated at 500 l/s. Normal influx of ground water is 40 l/s.

Maximum daily inflow of underground water is during the extreme rainfalls and is 43 200 m^3. Normal daily inflow of underground water is 3 450 m^3.

Total maximum inflow into the pit of surface and ground water is considered as the relevant for dimensioning the pumping plant at the open pit, amounts to 57 200 m^3.

SYSTEM FOR WATER PUMPING

At the open pit “Potrlica“ , two types of pump, manufactured by “Jastrebac” from Niš are in operation:

- Pipe pumps BP 300 – 1 engine power 132 kW, and
- Centrifugal pumps VPN 251 – 3 engine power 475 kW.

System for water pumping is the following [2]:

- The temporary water sump is located at the lowest bench of open pit with 2 pumps, type
- BP 300 – 1. Water is pumped from bench level K+632 m, pipeline length is 50 m.
- The water from auxiliary water sump is pumped into the main water sump at level K+643 m, where 4 pumps, type BP 300 – 1, are located.
- From the main water sump, the water is pumped through pipeline, length 160 m to the level K+656 m where 4 pumps, type VPN 251 – 3, are installed. The pumps BP – 300 – 1 and VPN 251 – 3 are directly connected with pipeline.
- From the level of K +656 m, the water is pumped to the water sump at level +758 K m, by pipeline of 970 m length.

One section of pumps for water pumping from the main water sump to the settling tank are connected by a serial BP 300-1 pump and VPN 251 – 3 pump. Such four section are in operation at the open pit.

Figures 1 and show the line diagram of drainage system and spatial position of pump facilities, and Figure 3 shows the operation diagram of one section.

Operation points of pumps at auxiliary and section on the main water sump are given in Table 2.

Figure 1. *Location of pumping facilities at the open pit "Potrlica"*

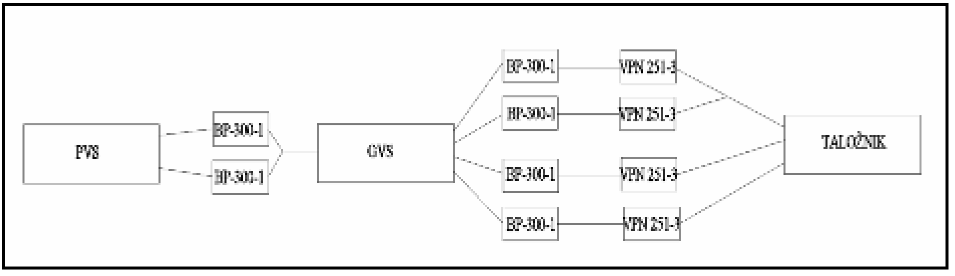

Figure 2. *Line diagram of pumping facilities at the open pit "Potrlica"*

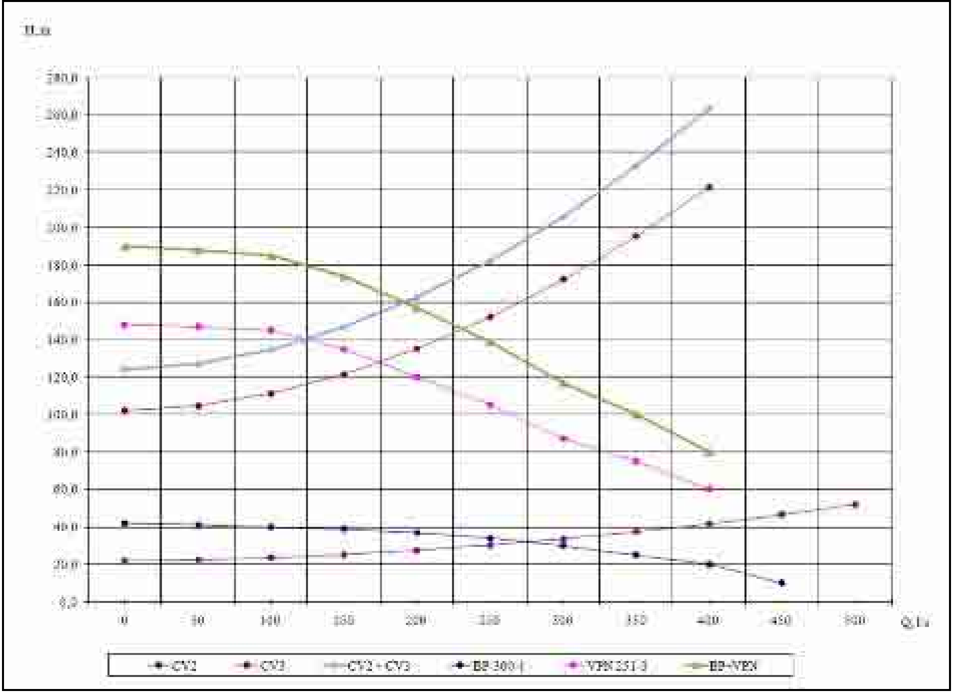

Figure 3. *Operation diagram of pumps at the open pit "Potrlica"*

Table 2. *Operation point of pumps at the open pit "Potrlica*

Pump	Water sump	H, m	Q_{unit}, l/s	Pcs.	Q_{max}, l/s
BP-300-1	PVS	15	420	2	840
(BP-300-1 + VPN 251-3)/r	GVS	160	180	4	720

Total maximum inflow into the open pit of surface and ground water is: Q_v = 57 200 m^3. Total capacity of pumping plants is shown in Table 2. For pumping the maximum inflows, the simultaneous operation of both pumps is needed at auxiliary water sump and both pump sections on the main water sump.

The required pumping time of water from maximum inflow from the auxiliary water sump at level +634 K into the main water sump at level K-level +649 m, and from the main water sump into the settling tank at level +754 K m, is 19 and 22 hours successively.

Pumping plants are sized for maximum water inflows. Electricity consumption per year is determined by the average annual amount of water that is pumped - 10 680 000 m^3.

Number of moto – operation hours of pump BP-300-1 at the auxiliary water sump is 7063 h/year. Number of moto - hours of section operation at the main water sump is vodosabirniku 16 481 h / year.

Total average consumption of electricity for water pumping from the open pit "Potrlica" 10 936 283 kWh / year.

The average rate of electricity yield for water pumping water at the open pit "Potrlica" is 1.02 kW/m^3 of pumped water.

CONCLUSION

Water inflows into the open pit "Potrlica" are extremely high. The highest influx of groundwater flow into the open pit can not be stopped, so it has to be pumped. The existing system for water pumping at the open pit "Potrlica" has successfully pumped water that got into the mine area.

With development of mining works per plan and depth, higher inflows could be expected than the existing ones. According to the dynamics of development work for the next five years, the water sump would remain at the current level, while the auxiliary water sump would be lowered to the level K+600 m.

Therefore, it is necessary in the future to purchase another BP 300-1 pump and a pump VPN 251-3 for the main water sump as well as two pumps type BP 300-1 for auxiliary water sump.

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UDK: 622.73:546.56(045)=861

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UTICAJ FINOĆE MLEVENJA NA ISKORIŠĆENJE BAKRA U OSNOVNOM KONCENTRATU[***]

Izvod

Rezerve bakra u RTB su sve manje, a sadržaj bakra u raspoloživoj rudi sve niži. Istovremeno, posledica dugogodišnjeg rudarenja je deponovanje u neposrednoj blizini grada Bora topioničke šljake koja sadrži značajne količine metala. Kao takva predstavlja izuzetan ekološki problem, ali i značajnu rezervu bakra, zlata i srebra. Godinama se istražuje mogućnost valorizacije korisnih metala iz šljake. Rezultat istraživanja je pokretanje industrijske probe flotacijske koncentracije korisnih metala iz čega je proizašla i industrijska proizvodnja. U periodu od 2002-2006. godine prerađeno je 1.284.346 t šljake iz koje je dobijeno 3.870,451 t bakra, 69,4093 kg zlata i 457,804 kg srebra. Još uvek nisu u potpunosti postignuti zadovoljavajući tehnološki rezultati, pa se u tom cilju nastavljaju istraživanja. U ovom radu je prikazana zavisnost iskorišćenja bakra u osnovnom koncentratu procesa flotiranja topioničke šljake od finoće mlevenja, a time i jedna od mogućnosti poboljšanja tehnoloških rezultata. Naime, povećanje iskorišćenja bakra je moguće povećanjem finoće mlevenja šljake.

Ključne reči*: šljaka, flotacija, finoća mlevenja, iskorišćenje bakra*

UVOD

Tehnogeno ležišta bakra, Depo šljake 1, nalazi se u industrijskom krugu Topionice i rafinacije (TIR), odnosno u neposrednoj blizini grada Bora. Graniči se sa deponijama stenske jalovine nastalim pri površinskom otkopavanju geogenog ležišta bakra Bor (odnosno pojedinih rudnih tela ovog ležišta). Delom se graniči i sa flotacijskim jalovištem borske flotacije, smeštenim u otkopanom prostoru nastalom posle površinskog otkopavanja rudnog tela H.[1]

Šljaku tehnogenog ležišta bakra, Depo šljake 1, karakteriše heterogenost u pogledu fizičkih, mineraloških i hemijskih osobina. To je posledica raznovrsnosti ruda, koncentrata i topitelja koji su korišćeni u procesu topljenja, kao i tehnologija koje su primenjivane u relativno dugom periodu

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(do 1943. i do 1997. godine).

Šljaka ili troska je rastop oksida koji se stvaraju pri topljenju metalurške šarže. Osnovne komponente ovog rastopa prilikom topljenja bakarnih ruda, odnosno, sada, skoro isključivo koncentrata bakra (uz prethodnu aglomeraciju) su: SiO_2, FeO, Fe_2O_3 i MgO. Pored navedenih komponenti, šljaka često sadrži: Fe_3O_4, BaO, ZnO, Cu_2S i skoro redovno sitne kapljice mehanički zahvaćenog kamenca (bakrovog kamena, bakrenca). Sastav šljake ne mora odgovarati hemijskom jedinjenju: na primer FeO u šljaci se može nalaziti u obliku fajalita $(FeO)_2SiO_2$, ali u fajalitu može biti rastvoren i višak slobodnog FeO u baznim šljakama.

U tabeli 1 prikazane su rezerve u ležištu bakra Depo šljake – 1 Bor. [1]

Tabela1. *Ukupne rezerve u tehnogenom ležištu bakra Depo šljake – 1 Bor*

Korisna komponenta	Sadržaj	Rezerve rude (šljake), t			Rezerve korisnih komponenti		
		Ukupne	Bilansne	Eksplo-atacione	Ukupne	Bilansne	Eksplo-atacione
Cu, ukupni	0,715%				86.567 t	80.062 t	65.715 t
Cu, oksidni	0,202%				24.457 t	22.619 t	18.566 t
Cu, sulfid.	0,513%				62.110 t	57.443 t	47.150 t
Zlato	0,282 g/t	12.107.354	11.197.587	9.190.940	3.414 kg	3.158 kg	2.592 kg
Srebro	4,50 g/t				54.483 kg	50.389 kg	41.359 kg
Magnetit	8,60%				1.041.232t	962.992 t	790.421 t
Molibden	0,0413%				5.000 t	4.625 t	3.796 t
Sumpor	0,611%				73.976 t	68.417 t	56.157 t

Ogromna količina odložene otpadne šljake, i takođe velika količina otpadne šljake iz redovne i buduće proizvodnje bakra, predstavljaju čitav niz ekoloških problema, a sa druge strane ova značajna količina korisnih metala zaostalih u šljaci kao nužnost nameće istraživanja u pravcu njihove valorizacije i samim tim rešavanje kako ekoloških tako i tehno-ekonomskih problema. Rezultat istraživanja je pokretanje industrijske probe flotacijske koncentracije korisnih metala iz čega je proizašla i industrijska proizvodnja. U periodu od 2002-2006. godine prerađeno je 1.293.509 t šljake iz koje je dobijeno 3.870,451 t bakra, 69,4093 kg zlata i 457,804 kg srebra.

U tabeli 2 dati su rezultati eksperimentalne proizvodnje koncentrata bakra u Flotaciji Bor, u periodu jul, 2002. – decembar, 2006. godine. [2]

Tabela 2. *Tehnološki rezultati prerade šljake u periodu od 2002-2006. godine*

Elementi prerade	J. mere	Godine					
		2002.	2003.	2004.	2005.	2006.	02-06.
Šljaka vlažna	t	159.117	334.831	271.624	138.963	388.874	1.293.509
Sadržaj vlage	%	0,53	0,622	0,763	0,85	0,742	0,708
Šljaka suva	t	158.275	332.749	269.551	137.783	385.988	1.284.346
Bakar u šljaci	%	0,664	0,565	0,529	0,792	0,716	0,639
Bakar u šljaci	t	1.051	1.881	1.426	1.091	2.765	8.214
Zlato u šljaci	g/t	-	-	0,134	0,193	0,260	0,205
Zlato u šljaci	kg	-	-	36,21	26,568	100,21	163
Srebro u šljaci	g/t	-	-	3,789	2,934	3,369	3,435
Srebro u šljaci	kg	-	-	1.021	404	1.300	2.725
Koncentrat vlažni	t	5.950	12.164	6.834	3.670	8.951	37.569
Sadržaj vlage	%	12,17	13,16	14,84	14,77	12,16	13,23
Koncentrat suvi	t	5.226	10.563	5.820	3.128	7.863	32.600
Bakar u koncentratu	%	12,76	10,16	12,56	12,76	12,71	11,87
Bakar u koncentratu	t	667	1.073	731	399	1.001	3.871
Zlato u koncentratu	g/t	-	2,6498	2,197	2,396	2,688	2,464

Zlato u koncentratu	kg	-	27,988	12,788	7,493	21,14	69,409
Srebro u koncentratu	g/t	-	13,100	19,973	15,389	19,719	19,001
Srebro u koncentratu	kg	-	138,373	116,246	48,13	155,055	457,804
Iskorišćenje bakra	%	63,47	57,05	51,28	36,57	36,20	47,13
Iskorišćenje zlata	%	-	-	35,32	28,20	21,09	25,41
Iskorišćenje srebra	%	-	-	11,38	11,90	11,93	11,72
Vreme rada mlinova	h	1.926	4.580	3.458	1.776	5.240	16.980
Vremensko iskorišćenje	%	21,99	52,28	38,15	20,27	59,82	32,30
Časovni kapacitet-vlažni	t/h	82,90	73,10	78,50	78,30	74,20	76,18

Na šljaci još uvek nisu postignuti zadovoljavajući tehnološki rezultati što se i vidi iz tabele 2. Šljaka ovakva kakva jeste je izuzetno otporna na usitnjavanje što govori i vrednost Bondovog radnog indeksa, za mlin sa šipkama iznosi 25 kWh/t a za mlin sa kuglama 30 kWh/t. Primer za to je potrošnja električne energije i metala u tabeli 3 u kojoj je prikazana ostvarena potrošnja normativnog materijala na preradi topioničke šljake. [2]

Tabela 3. *Potrošnja normativnog materijala na preradi topioničke šljake*

Normativni materijal	**j. mere**	**Godine**						**j. mere**	**po toni**
		2002.	2003.	2004.	2005.	2006.	02-06.		
Komadasti kreč	t	570	2.046	2.163	1.081	3.329	9.189	kg/t	7,15
Penušač	kg	1.567	4.988	3.341	1.685	4.627	16.208	g/t	12,62
Kolektor	kg	8.439	23.185	15.430	9.620	26.930	83.604	g/t	65,09
Čelične obloge	kg	40.431	36.938	40.700	41.791	67.177	267.468	kg/t	0,208
Gumene obloge	kg	-	8.115	-	6.891	1.115	16.121	kg/t	0,012
Čelične šipke	t	149.4	417,6	389,1	228,3	573,2	1.757,4	kg/t	1,368
Čelične kugle	t	121,5	288,82	301,0	153,0	390,5	1.254,82	kg/t	0,977
Ulja i maziva	kg	2.828	6.211	8.227	6.615	8.565	32.446	kg/t	0,025
Elektr. energija	MWh	-	19.159	14.094	7.619	20.034	60.906	kWh/t	54,09
Filter platno	m^2	59	117	79	62	199	516	m^2/t	0.0004
Industrijska voda	m^3x10^3	240,2	706	697,7	401,9	644,02	2.689,82	m^3/t	2,094

Problemi kod prerade topioničke šljake postoje, a takođe postoje i očekivani pozitivni ekonomski efekti. Neophodna su dodatna istraživanja karakteristika topioničke šljake kao i mogućnosti unapređenja tehnoloških pokazatelja a time i ekonomskih efekata prerade. Iz tog razloga su izvedeni eksperimenti flotiranja radi sagledavanja uticaja finoće mlevenja šljake na iskorišćenje bakra u osnovnom koncentratu.

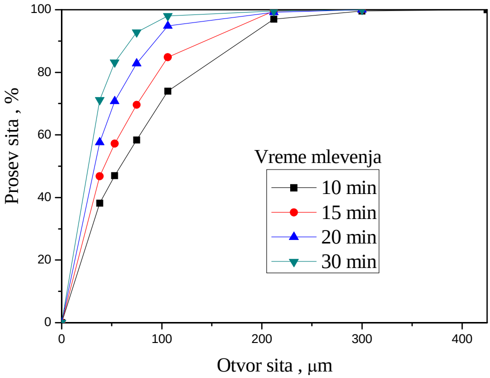
EKSPERIMENTALNI DEO

Eksperimenti mlevenja su izvedeni u elipsoidnom mlinu sa kuglama zapremine 15,2 dm^3. Masa šarže kugli na početku ispitivanja bila je 12 kg. Za jedan eksperiment mleveno je 870 g šljake, pri sadržaju čvrstog od 75 %. Za određivanje zavisnosti sadržaja klase - 75 μm od vremena mlevenja samlevena su četiri uzorka. U tabeli 4 prikazan je granulometrijski sastav samlevenih uzoraka.

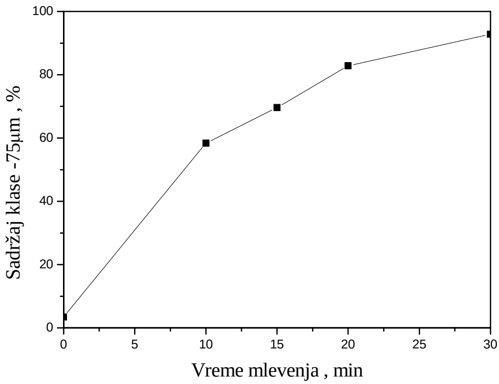
Tabela 4. *Granulometrijski sastav proizvoda mlevenja za različita vremena mlevenja*

Klasa krupnoće, µm	Vreme mlevenja, min							
	10		15		20		30	
	m%	D%	m%	D%	m%	D%	m%	D%
-425+300	0,4	100,0						
-300+212	2,6	99,6	0,4	100,0	0,8	100,0	0,4	100,0
-212+106	23,0	97,0	14,8	99,6	4,4	99,2	1,6	99,6
-106+75	15,6	74,0	15,2	84,8	12,0	94,8	5,2	98,0
-75+53	11,4	**58,4**	12,4	**69,6**	12,0	**82,8**	9,6	**92,8**
-53+38	8,8	47,0	10,4	57,20	13,2	70,8	12,0	83,2
-38+0	38,2	38,2	46,8	46,8	57,6	57,6	71,2	71,2

Na slici 1 prikazan je granulosastav proizvoda mlevenja za različita vremena mlevenja a na slici 2 zavisnost sadržaja klase -75 µm od vremena mlevenja.



Sl. 1. *Granulosastav proizvoda mlevenja za različita vremena mlevenja*



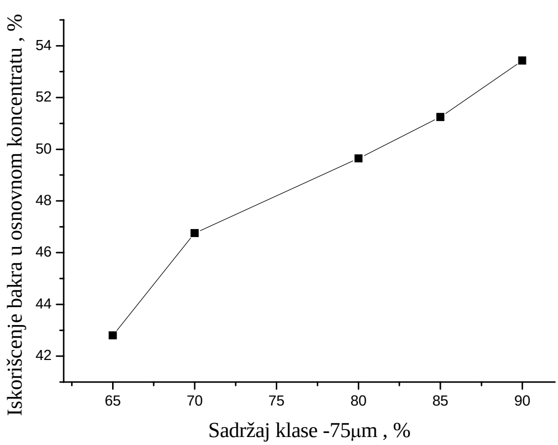
Sl. 2. *Zavisnost sadržaja klase -75 µm od vremena mlevenja*

Na samlevenim uzorcima topioničke šljake izvedeni su eksperimenti osnovnog flotiranja pod istim uslovima ali sa različitom finoćom mlevenja u cilju utvrđivanja uticaja na iskorišćenje bakra. Svi eksperimenti osnovnog flotiranja izvedeni su u Denver flotacijskoj mašini zapremine komore 2,4 dm^3 i brzinom obrtanja rotora od 1500 min^{-1}. U tabeli 5 prikazani su rezultati eksperimenata.

Tabela 5. *Rezultati eksperimenata osnovnog flotiranja*

Sadržaj klase -75 µm, %	**Proizvod**	**m, %**	**Cu, %**	**Raspodela Cu, %**
65%	U	100,00	0,6864	100,00
	K	10,57	2,78	42,80
	J	89,43	0,439	57,20
70%	U	100,00	0,7072	100,00
	K	12,62	2,62	46,75
	J	87,38	0,431	53,25
80%	U	100,00	0,7086	100,00
	K	16,44	2,14	49,65
	J	83,56	0,427	50,35
85%	U	100,00	0,7272	100,00
	K	16,56	2,25	51,24
	J	83,44	0,425	48,76
90%	U	100,00	0,7146	100,00
	K	20,20	1,89	53,43
	J	79,80	0,417	46,57

Na slici 3 prikazana je zavisnost iskorišćenja bakra od finoće mlevenja.



Sl. 3. *Zavisnost iskorišćenja bakra u osnovnom koncentratu od finoće mlevenja*

DISKUSIJA REZULTATA

Dobijeni rezultati ukazuju na to, da, ako se finoća mlevenja poveća sa 65 na 90% učešća klase -75 μm, povećava se iskorišćenje bakra u osnovnom koncentratu sa 42,80 na 53,43%. Povećanje finoće mlevenja uslovljava i značajno povećanje utroška električne energije i metala. Međutim, svaki procenat povećanja iskorišćenja bakra je veoma značajan sa aspekta ekonomičnosti proizvodnje, tim pre što se radi o strateškoj sirovini čija je cena danas na svetskom tržištu preko 7000 US$[3].

ZAKLJUČAK

Tehnogeno ležišta bakra, Depo šljake 1, pored toga što predstavlja ekološki problem, istovremeno je i značajan sirovinski resurs sa značajnim sadržajem bakra, zlata i srebra. Više godina u nazad korisni metali se valorizuju iz topioničke šljake postupkom flotacijske koncentracije. Za sada nisu postignuti zadovoljavajući rezultati, pa se istraživanja nastavljaju u pravcu poboljšanja tehno-ekonomskih pokazatelja. U ovom radu je prikazana mogućnost povećanja iskorišćenja bakra u osnovnom koncentratu, putem povećanja finoće mlevenja. Do koje granice finoću mlevenja treba povećavati, a da troškovi energije i metala ne premaše pozitivne efekte ostvarene povećanjem iskorišćenja bakra pokazaće buduća istraživanja.

Zahvalnost

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UDK: 622.73:546.56(045)=20

Srđana Magdalinović, Daniela Urošević*, Sonja Petković ***

THE EFFECT OF GRINDING FINENESS ON COPPER RECOVERY IN BASIC CONCENTRATE***

Abstract

Copper reserves in RTB are less and less and copper content in the available ore is lower and lower. At the same time, a consequence of many year mining is dumping of smelter slag with content of significant amounts of metal near the town of Bor. As such, it presents an exceptional environment problem, but also a significant reserve of copper, gold and silver. The possibility of recovery the useful metals from slag has been researched for many years.

The result of research is launching the industrial testing of flotation concentration the useful metals from which the industrial production was also resulted. In the period from 2002-2006, 1 284 346 tons of slag was treated, from which 3 870.451 tons of copper, 69.4093 kg of gold and 457.804 kg of silver were obtained. It is still not fully achieved The satisfactory technological results have not been completely realized yet, therefore the researches are continued to this aim. This paper presents the dependence of copper concentrate recovery in the basic concentrate from the flotation process of smelter slag from grinding fineness, and thus one of the possibilities of improving the technological results. Namely, the increased utilization of copper is possible by increasing the grinding fineness of slag.

***Key words**: slag, flotation, grinding fineness, copper recovery*

INTRODUCTION

Techno-genetic copper deposit, Slag Depot 1, is located within the industrial site of the Smelter and Refinery (TIR), i.e. near the town of Bor. It is bordered by rock waste dumps formed at open pit mining of geogenetic Bor copper deposit (i.e. some ore bodies of this deposit). It is partly bordered by the flotation tailing dump of the Bor Flotation Plant, situated in the excavation area, formed after open pit mining of the ore body H. [1]

The slag of techno genetic copper deposit, Slag Depot 1, is characterized by-heterogeneity in terms of physical, mineralogical and chemical properties. This is the result of ore diversities and flux, used in the smelting process, as well as used technologies in a relatively long period (from 1943 to 1997).

Slag is the melt of oxides, formed in smelting of metallurgical charge. Basic components of this melt during smelting of

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copper ores, that is, now, almost exclusively copper concentrates (with the previous agglomerations) are: SiO_2, FeO, Fe_2O_3 and MgO. In addition to thesecomponents, slag often contains: Fe_3O_4, BaO, ZnO, Cu_2S, and almost always fine droplets of mechanically affected matte (copper matte). The composition of slag may not correspond to the chemical compounds: for example, FeO in slag may be present in a form of fayalite $(FeO)_2SiO_2$, but the excess of free FeO in basic slags may be also dissolved in fayalite.

Table 1 presents the reserves in the copper deposit Slag Depot – 1 Bor. [1]

Table 1. *Total reserves in techno genetic copper deposit Slag Depot – 1 Bor*

Useful component	Content	Reserves of ore (slag), t			Reserves of useful components		
		Total	Balanced	Minable	Total	Balanced	Minable
Cu, total	0.715%				86.567 t	80.062 t	65.715 t
Cu, oxide	0.202%				24.457 t	22.619 t	18.566 t
Cu, sulfide	0.513%				62.110 t	57.443 t	47.150 t
Gold	0.282 g/t	12,107.354	11,197.587	9,190.940	3.414 kg	3.158 kg	2.592 kg
Silver	4.50 g/t				54.483 kg	50.389 kg	41.359 kg
Magnetite	8.60%				1,041.232t	962.992 t	790.421 t
Molybdenum	0.0413%				5.000 t	4.625 t	3.796 t
Sulfur	0.611%				73.976 t	68.417 t	56.157 t

An enormous amount of dumped waste slag, and also a large amount of waste slag from regular and future production of copper, present a range of environmental problems, on the other hand, this significant quantity of useful metals in the residual slag, as a necessity, impose the researches in a direction of their valuation and thus solution both for ecological and techno-economic problems. The result of research is launching the industrial testing of flotation concentration the useful metals from which the industrial production was also resulted. In the period from 2002-2006, 1 284 346 tons of slag was treated, from which 3 870.451 tons of copper, 69.4093 kg of gold and 457.804 kg of silver were obtained.

Table 2 gives the results of experimental production of copper concentrate in the Flotation Plant Bor, in the period July 2002 – December 2006. [2]

Table 2. *Technological results of slag processing in the period from 2002 – 2006.*

Elements of treatment	Unit measure	Year					
		2002	2003	2004	2005	2006	02-06
Wet slag	t	159,117	334.831	271.624	138.963	388.874	1.293.509
Content of humidity	%	0.53	0.622	0.763	0.85	0.742	0.708
Dry slag	t	158,275	332.749	269.551	137.783	385.988	1.284.346
Copper in slag	%	0.664	0.565	0.529	0.792	0.716	0.639
Copper in slag	t	1,051	1.881	1.426	1.091	2.765	8.214
Gold in slag	g/t	-	-	0,134	0.193	0.260	0.205
Gold in slag	kg	-	-	36,21	26,568	100,21	163
Silver in slag	g/t	-	-	3,789	2,934	3,369	3,435
Silver in slag	kg	-	-	1.021	404	1.300	2.725
Wet concentrate	t	5,950	12.164	6.834	3.670	8.951	37.569
Content of humidity	%	12.17	13.16	14.84	14.77	12.16	13.23

Dry concentrate	t	5,226	10.563	5.820	3.128	7.863	32.600
Copper in concentrate	%	12.76	10.16	12,56	12,76	12,71	11,87
Copper in concentrate	t	667	1.073	731	399	1.001	3.871
Gold in concentrate	g/t	-	2,6498	2,197	2,396	2,688	2,464
Gold in concentrate	kg	-	27,988	12,788	7,493	21,14	69,409
Silver in concentrate	g/t	-	13,100	19,973	15,389	19,719	19,001
Silver in concentrate	kg	-	138,373	116,246	48,13	155,055	457,804
Copper recovery	%	63.47	57.05	51,28	36,57	36,20	47,13
Gold recovery	%	-	-	35,32	28,20	21,09	25,41
Silver recovery	%	-	-	11,38	11,90	11,93	11,72
Operation times of mills	h	1,926	4,580	3.458	1.776	5.240	16.980
Time recovery	%	21.99	52.28	38,15	20,27	59,82	32,30
Horly capacity-wet	t/h	82.90	73.10	78,50	78,30	74,20	76,18

The satisfactory technological results have not been realized yet, what could be seen from Table 2. This slag is extremely resistant to fragmentation, what could be seen from the Bond work index value, 25kWh/t for the rod mill and 30 kWh/t for the ball mill. An example of this is the consumption of electricity and metals in Table 3, which is shown in the achieved consumption of normative material[2] in processing of smelter slag. [2]

Table 3. *Consumption of normative material in processing of smelter slag*

Normative material	Unit measure	Year						Unit measure	Per ton
		2002	2003	2004	2005	2006	02-06		
Lumpy lime	t	570	2.046	2.163	1.081	3.329	9.189	kg/t	7.15
Frother	kg	1.567	4.988	3.341	1.685	4.627	16.208	g/t	12.62
Collector	kg	8.439	23.185	15.430	9.620	26.930	83.604	g/t	65.09
Steel linings	kg	40.431	36.938	40.700	41.791	67.177	267.468	kg/t	0.208
Rubber linings	kg	-	8.115	-	6.891	1.115	16.121	kg/t	0.012
Steel rods	t	149.4	417,6	389,1	228,3	573,2	1.757,4	kg/t	1,368
Steel balls	t	121,5	288,82	301,0	153,0	390,5	1.254,82	kg/t	0.977
Oil and grease	kg	2.828	6.211	8.227	6.615	8.565	32.446	kg/t	0.025
Ekec.energy	MWh	-	19.159	14.094	7.619	20.034	60.906	kWh/t	54.09
Filter cloth	m^2	59	117	79	62	199	516	m^2/t	0.0004
Industrial water	m^3x10^3	240,2	706	697,7	401,9	644,02	2.689,82	m^3/t	2.094

Problems in processing the smelter slag are present, and the expected positive economic effects are also present. The additional reserches of smelter slag characteristics are required as well as the possibilities for improvement the technological indicators, and thus the economic effects of processing. For this reason, the experiments of the flotation process were carried out for considering the effect of grinding fineness on copper recovery in basic concentrate.

EXPERIMENTAL PART

Milling experiments were carried out in the elliptical ball mill, volume 15.2 dm^3. Mass of ball charge at the beginning of testing was 12 kg. For one experiment, 870 g of slag was ground with solid content of 75%. For determination the dependence of class content - 75µm on grinding time, four samples were ground. Table 4 presents the grain-size distribution of ground samples.

Table 4. *Grain-size distribution of grinding products for various grinding times.*

Size class, µm	Grinding time, min							
	10		15		20		30	
	m%	D%	m%	D%	m%	D%	m%	D%
-425+300	0,4	100,0						
-300+212	2,6	99,6	0,4	100,0	0,8	100,0	0,4	100,0
-212+106	23,0	97,0	14,8	99,6	4,4	99,2	1,6	99,6
-106+75	15,6	74,0	15,2	84,8	12,0	94,8	5,2	98,0
-75+53	11,4	58,4	12,4	69,6	12,0	82,8	9,6	92,8
-53+38	8,8	47,0	10,4	57,20	13,2	70,8	12,0	83,2
-38+0	38,2	38,2	46,8	46,8	57,6	57,6	71,2	71,2

Figure 1 presents the grain-size distribution of grinding products in various grinding times, and Figure 2 presents the dependence of size-class content -75µm on grinding time.

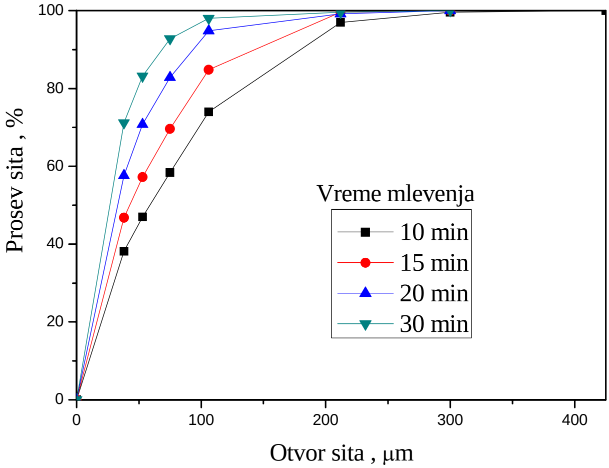

Figure 1. *Grain-size distribution of grinding products in various grinding times*

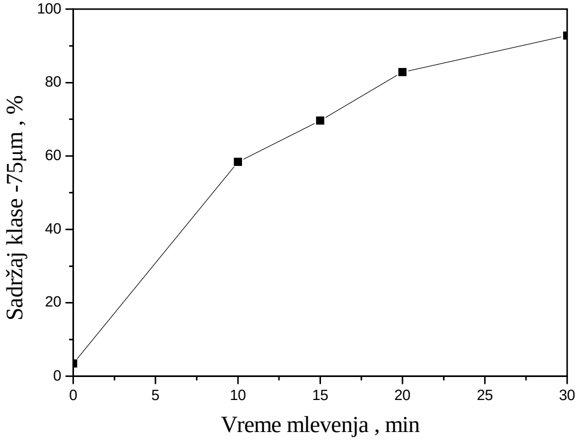

Figure 2. *Dependence of size-class content -75µm on grinding time*

The experiments of basic flotation were carried on the samples of ground smelter slag under the same conditions but with various grinding fineness, in order to determine the effect on copper recovery. All experiments of basic flotation were carried out in the Denver flotation machine, chamber volume of 2.4 dm^3 rotor speed of 1500 min^{-1}. Table 5 presents the results of experiments.

Table 5. *Experimental results of basic flotation*

Size-class content-75µm, %	Product	m, %	Cu, %	Distribution Cu, %
65%	U	100,00	0,6864	100,00
	K	10,57	2,78	42,80
	J	89,43	0,439	57,20
70%	U	100,00	0,7072	100,00
	K	12,62	2,62	46,75
	J	87,38	0,431	53,25
80%	U	100,00	0,7086	100,00
	K	16,44	2,14	49,65
	J	83,56	0,427	50,35
85%	U	100,00	0,7272	100,00
	K	16,56	2,25	51,24
	J	83,44	0,425	48,76
90%	U	100,00	0,7146	100,00
	K	20,20	1,89	53,43
	J	79,80	0,417	46,57

Figure 3 presents dependence of copper recovery on grinding fineness.

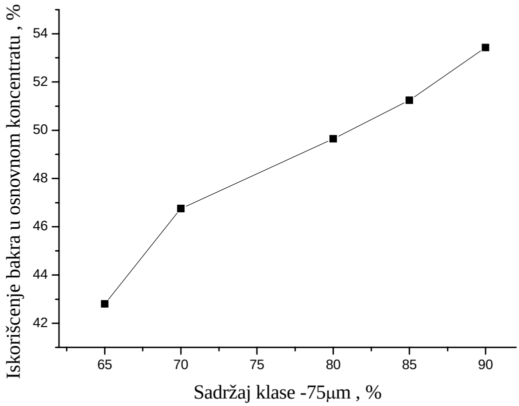

Figure 3. *Dependence of copper recovery in basic concentrate on grinding fineness.*

DISCUSSION OF THE RESULTS

The obtained results indicate that, if the grinding fineness is increased from 65 to 90% of participation of size-class -75 μm , copper recovery in basic concentrate is increased from 42.80 to 53.43%. Increase of grinding fineness also causes the important increase of electric energy and metal consumption. However, each percentage of increase the copper recovery is very important from an aspect of production efficiency, since it is rather a strategic ram material with price on the world market of over 7000 US$.[3]

CONCLUSION

Techno-genetic copper deposit, Slag Depot 1, in addition to the environmental problem, is at the same time an important raw material resource with significant content of copper, gold and silver. Many years back, the useful metals are recovered from the smelter slag using the flotation concentration method. Until now, there are no successful results, and research continues to improve the techno-economic indicators. This paper presents the possibility for increasing the copper recovery in basic concentrate by increasing the grinding fineness. The future researches would show to what limits the grinding fineness should be increased, and that the costs of energy and metal do not exceed the positive effects, realized by copper recovery.

Acknowledegements

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Ruzica Lekovski, Zoran Vaduvesković*, Ljubiša Obradović**

ODREĐIVANJE TRAJEKTORIJE ZONE UTICAJA POVRŠINSKIH KOPOVA NA NIVO PODZEMNIH VODA U ŽIVOTNOJ SREDINI CEROVA**

Izvod

Rudarski radovi u Cerovu nose potencijalnu opasnost promene režima voda u životnoj sredini i njihovog zagađivanja vodama iz površinskih kopova (slika 1 i 2) koje sadrže razne hemijske materije u obliku rastvora. Domet uticaja otkopanih delova ležišta rude bakra u Cerovu na podzemne i površinske vode u okviru eksploatacionog područja površinskih kopova je značajan za organizovanje zaštite zemljišta u životnoj sredini od isušivanja, a površinske kopove od priliva voda (slika 1). U ovom radu posebno se analizira mogućnost prognoze dometa promene nivoa podzemnih voda u okolnom zemljištu izazvane otkopavanjem ležišta ruda bakra u Cerovu.

Ključne reči: *površinski kop, životna sredina, podzemna voda*

UVOD

Na području Cerova 20 km severno od Bora u hidrotermalno izmenjenoj zoni locirano je rudno polje Mali Krivelj – Cerovo sa ležištima bakra: Cerovo Primarno, Cerovo 2, Drenovo i Kraku Bugaresku – Cerovo - Cementacija 1. Na ovom području predviđa se otvaranje tri površinska kopa (slika 3.) čija dinamika kontinualne proizvodnje je usklađena i iznosi 7,5 miliona tona rude bakra godišnje. Prema biznis planu, otvaranje kopova je po sledećem redosledu:

1) Najpre se postojeći površinski kop Cerovo –Cementacija 1 proširuje (slika 1), otvoren 1993 na lokalitetu Kraku Bugaresku. Površinska eksploatacija trajala je do 2002. godine. Doistražene rezerve bakra na istom ležištu omogućavaju proširenje ovog kopa prema istoku, jugu i jugozapadu i sada se ovaj kop naziva: Kraku Bugaresku – Cerovo 1. ili skraćeno C 1.

2) Drugi površinski kop na prostoru Cerova otvara se na oko 600 m od površinskog kopa Kraku Bugaresku – Cerovo 1 (C1). Ovaj površinski kop se naziva: Kraku Bugaresku - Cerovo 2. ili skraćeno C2. Eksploatacija rude bakra na površinskom kopu C1 i površinskom kopu C2 usklađuje se tako da dok se otkopava

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ruda na površinskom kopu C1, na ležištu C2 se vrši raskrivanje rude.

3) Treći površinski kop na području Cerova otvara se u neposrednoj blizini površinskog kopa C2. Ovaj površinski kop se naziva Cerovo – Primarno - Drenovo ili skraćeno CPD. Za potrebe otvaranja ovog površinskog kopa potrebno je izmeštanje dela pruge Bor – Majdanpek u dužini od 12.00,0 m sa železničkom stanicom, izmeštanje dalekovoda i korita Cerove Reke izradom odgovarajućeg tunela kojim će se Cerova reka sprovesti u korito reke Valja Mare. na sl. 1 prikazan je površinski kop *Kraku* Bugaresku – Cementacija 1 koji se proširuje i produbljuje, jer je dopunskim istraživanjima utvrđena značajna količina rude koja je eksplotabilna.

Na sl. 2 je prikazana reka nakon uliva lužnih rastvora sa kopa C1.

Na sl. 3 je prikazan međusobni položaj površinskih kopova u eksploatacionom polju Cerovo – Kraku Bugaresku.

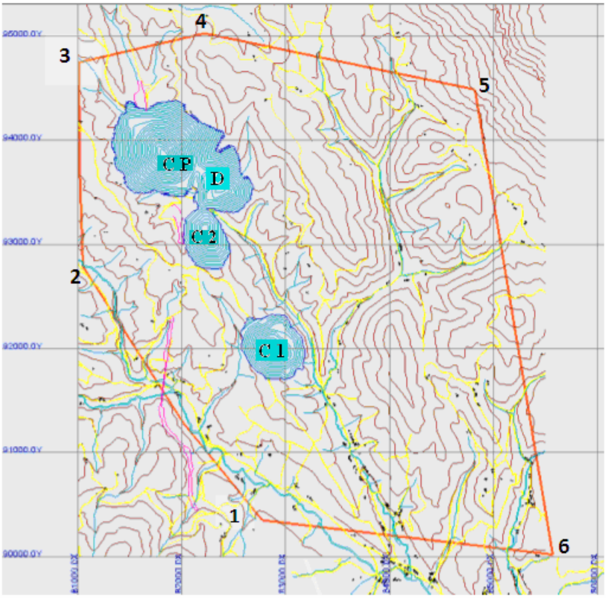
U tabeli 1 prikazane su prelomne tačke eksploatacionog polja Cerovo–Kraku Bugaresku u pravouglom koordinatnom sistemu.

Sl. 1. *Površinski kop Kraku Bugaresku –Cementacija 1 koji se proširuje*

Sl. 2. Lužne vode sa površinskog kopa C1

Tab. 1. *Koordinate temena eksploatacionog polja Cerovo – Kraku Bugaresku*

r.b.	TAČKA N^O	X	Y
1	1	7 582 775.0	4 890 350.0
2	2	7 581 050.0	4 892 750.0
3	3	7 581 010.0	4 892 790.0
4	4	7 582 220.0	4 895 030.0
5	5	7 584 820.0	4 894 490.0
6	6	7 585 570.0	4 890 020.0



Sl. 3. *Međusobni položaj površinskih kopova u eksploatacionom polju Cerovo – Kraku Bugaresku*

Morfološko - hidrološke karakteristike ležišta Cerovo – Kraku Bugaresku

Morfologija terena, ispucalost stena, hidrološke i meteorološke prilike utiču na nivo podzemnih voda na području Cerova. Teren iznad ležišta Cerovo - Kraku Bugaresku – Cementacija je brdovit, ispresecan uskim dolinama reka i potoka. Na području Cerova najveću zastupljenost imaju vulkanske i hidrotermalno izmenjene stene za koje su vezana ležišta bakra. Glavno obeležje reljefa je postojanje kupastih i blago zaobljenih uzvišenja sa padinama koje su ispresecane jarugama. Krečnjaci izgrađuju istočne delove područja i ujedno čine istočni obod Timočkog magmatskog kompleksa (TMK) i pripadaju krečnjačkom masivu Velikog Krša. Krečnjački teren je hipsometrijski izdignut sa kotama koje dostižu 1.148 m. Intenzivno je karstifikovan, pri čemu proces karstifikacije doseže do vodonepropusne podloge koju čine peščari i konglomerati mezozojske starosti i starije paleozojske i proterozojske tvorevine. Prema granitoidu

Gornjana za krečnjački teren karakteristični su strmi odseci i brojne pojave sipara. U centralnim delovima ovog terena registrovano je nekoliko manjih speleoloških objekata.

Područje rudnog polja Mali Krivelj – Cerovo, pripada slivu Kriveljske reke, a generalno slivu Timoka i Dunava. U hidrološkom smislu značajne su Crvena reka, Valja Mare i Cerova reka koje kod sela Mali Krivelj čine Kriveljsku reku. U Kriveljsku reku nizvodno se ulivaju potok Urs i Ujova reka. Svi ovi vodeni tokovi u toku leta imaju vodu, a za vrema kišnog perioda poprimaju bujični karakter.

Ovodnjenost ležišta Cerovo-Kraku Bugaresku određena je na osnovu hidrogeoloških istraživanja, gde je konstantovano da pojedini delovi ležišta se nalaze iznad lokalnog erozionog bazisa i da su izgrađeni od slabo vodopropusnih, hidrotermalno izmenjenih i orudnjenih stena sa prslinama. U ovim stenama postoje pukotinski izdani koji se prihranjuju isključivo na račun voda od atmosferskih padavina.

Prema ispitivanjima nivoi podzemnih voda u ležištima na području Cerova vezani su za pukotinske izdani, hidrometeorološke prilike, morfologiju terena i stepena ispucalosti stenskih masa. Istraživanjima je utvrđeno da se nivoi podzemnih voda nalaze na 3-10 m ispod površine terena. Delove ležišta iznad lokalnog erozionog bazisa karakterišu relativno male količine pod-zemnih voda. Veći priliv podzemnih voda očekuje se na površinskim kopovima ispod kote lokalnih erozivnih bazisa kada dolazi do infiltracija površinskih voda.

UTICAJ SNIŽAVANJA PODZEMNIH VODA POVRŠINSKIM KOPOVIMA NA FLORU U OKOLINI

Prema strukturi, izdani na Cerovu su razbijenog tipa jer se javljaju u pukotinama i prslinama čvrstih nepropusnih stena. Vodopropusnost ovih stena zavisi pre svega od karaktera i razmera pukotina, kroz koje se kretanje podzemnih voda potčinjava zakonu linearne filtracije gravitacionim putem. Kretanje podzemnih voda može biti usmereno i ka površini Zemlje, ukoliko se one u izdanima nalaze pod hidrostatičkim pritiskom, naročito izraženim na presecima različitih pukotina. Ovi pritisci mogu biti vezani i za emanaciju gasova i za temperature veće od 100° C, što je karakteristično za aktivne ili relativno ugašene vulkanske oblasti.

Razbijeni tip izdani karakteriše se diskontinualnošću izdanske zone, odnosno zone zasićenja slobodnim podzemnim vodama. Hrane se infiltracijom padavina u površinskim izdancima, površinskim i podzemnim doticajem sa površine sliva koji je kao lokani erozioni bazis. Količina vode u izdani pre svega zavisi od: oblasti prostiranja, zone hranjenja i zone isticanja, sabirne površine i debljine izdani.

Izdani sa slobodnim nivoom formiraju se na vodonepropusnim stenama u rastresitim, najčešće kvartarnim i neogenim sedimentima, ali i u ispucalim i krasifikovanim geološkim sredinama. Imaju široko rasprostranjenje u prirodi. U zonama aeracije mogu da se jave manje akumulacije podzemnih voda na sočivima ili proslojcima nepropusnih stena, kada se formira lebdeća, ili lažna, izdan.

Zona iznad slobodnog nivoa izdani pa sve do površine uključujući i rudinski pojas, naziva se nadizdanskom ili eracionom zonom. Debljina ove zone je u zavisnosti od reljefa i klimatskih prilika. Drveće se preko korenja snabdeva vodom i hranljivim materijama iz ove zone. U zoni aeracije mogu se javiti vidovi voda i kretanja vode i to:

- u vidu pare od stena veće vlažnosti u pravcu stena manje vlažnosti,
- higroskopske (u vidu pare na t>100^0C) i opnene vode (asorpcionih sila od čestica sa debljom opnom u pravcu čestica sa tanjom opnom),
- gravitacione slobodne vode u zoni aeracije (infiltracija površinskih voda i atmosferskih taloga pod uticajem kapilarnih i gravitacionih sila),
- gravitacionih voda u zoni zasićenja-infiltracija (kroz pore, pukotine i kaverne).

Eksploatacija ležišta rude bakra na području Cerova dovodi do stvaranja depresija (levkova), čime se spušta nivo podzemnih voda u okolini kopova. Podzemna voda ispod depresione krive na kopu je statička voda i ona se ne kreće, dok se voda na granici depresionog levka i aeracione zone kreće. Horizontalno rastojanje između preseka kosine kopai tačke gde se depresiona kriva spaja sa statičkim nivoom podzemne vode naziva se poluprečnik dejstva levka na nivo podzemnih voda u prvom vodonosnom horizontu na površini. Ako se nivo izdani pod uticajem otkopnih prostora površinskih kopova spusti, presušiće nesavršeni bunari (ulaze samo jednim delom u vodonosni sloj) izdubljeni do izdanske vode, a zona aeracije će postati deblja. U njoj će se kretanje higroskopske i opnene vode vršiti odozgo na dole i na taj način isušivati tlo i rudinske vode. Nedostatak vode u površinskom sloju izaziva promenu ekoloških faktora za opstatak pojedinih vrsta flore u životnoj okolini površinskih kopova na području Cerova. Dodatna nepogodnost je i ta da površine levka površinskog kopa i odlagališta jalovine zbog izloženosti jugu i povećane insolacije – degradiranih i ogoljenih površina (prevelike količine svetlostii toplote), a nedovoljno atmosferskih padavina u toku vegetacionog perioda (karakteristično za Borski region) za snabdevanje rudinske zone podzemnih voda i nedostatka vode u zemljištu i pregrevanja prizemnog sloja vazduha, biljke zaostaju u rastu, a osetljivije vrstei potpuno nestaju. Prizemna flora zbog nedostatka vlage se suši, a lišće drveća (bukove šume) umesto tamno zelene boje zbog nedostatka vode poprima žućkastu boju.

Da bi se procenio pojas oko površin-skih kopova koji će biti ugrožen, određuje se domet uticaja otkopnih prostora na životnu sredinu pomoću poznatih formula iz literature koje se oslanjaju na poznavanje zone dejstva bunara, odnosno poluprečnika dejstva.

Određivanje trajektorije zone uticaja površinskih kopova na nivo podzemnih voda na području Cerova

Trajektorija krive slobodnog nivoa izdani koja se uspostavlja nakon formiranja depresionih levkova (otkopnih prostora površinskih kopova), na terenu se određuje merenjima. Međutim, površinski kopovi su u fazi projektovanja (osim površinskog kopa C1 koji treba da se proširuje) pa trajektorija uticaja snižavanja nivoa podzemnih voda površinskim kopovima na Cerovu je procenjena i to primenom formule koja je za ovu potrebu izvedena prema prof. M. Miljkoviću

Za proveru dometa uticaja depresionog levka na isušivanje podzemnih voda u okolini površinskih kopova i mogući uticaj na floru, pošlo se od činjenice da:

- završne kosine površinskih kopova u Cerovu presecaju jedan ili više vodonosnih horizonata, međusobno razdvojenih nepropusnim slojevima stena,
- na preseku vodonosnih stena i kosine kopova, voda slobodno ističe u stvorenu depresiju pri čemu dolazi do spuštanja slobodnog nivoa izdani od presečne tačke do vodonepropusnog sloja,
- slobodni nivo izdani u okviru vodonepropusnih stena, sa udaljavanjem od presečne tačke zauzima položaj u obliku depresionog levka dreniranja vodonosnih stena,
- pravougli koordinatni sistem je postavljen sa nulom u tačci preseka nepropusnih stena i ravni kosine kopova preko sledeće formule:

$$X = 2\frac{K}{P} \times ln\, S \quad \text{(m)},$$

gde je:

K - koeficijent filtracije (prema proceni 15 m/dan);

X - domet uticaja depresije (m);

P - poroznost stena (prema proceni = 0,40);

H - visina vodenog stuba za kotu 245 m (dubina vodonosnog horizonta do presečne tačke kosine kopa sa vodonepropusnim stenama H= S za PK CPD; H = 435 m); za PK C1, H=270 m,

S - visina sniženja nivoa vode (S=H - h),

h – visina etaža koja mogu biti potopljena je 15 m (dno kopa), slika 1.

Prosečno vertikalno rastojanje od dna kopa do procenjenog nivoa vode u površinskom kopu CPD je S=420 m, a za PK C1 S=255m

Prema proceni, domet uticaja depresije (otkopnih prostora površinskih kopova) na životnu sredinu Cerova, odnosno širina pojasa gde se može očekivati promena ekoloških faktora oko površinskog kopa i flore zbog isušivanja tla iznosi:

X = 453,01 m za PK CPD, i

X=415,59 m za PK C1.

Levak površinskog kopa C2 (slika 4) posle završetka eksploatacije rude se zapunjuje jalovinom, pa za ovaj kop nije izračunata trajektorija zone uticaja na snižavanje nivoa podzemnih voda.

Sl. 4. *Izgled površinskih kopova na području Cerova na kraju veka eksploatacije*

ZAKLJUČAK

Na osnovu formule iz literature i usvojenih podataka za otkopne prostore površinskih kopova – depresija, prognoziran je uticaj površinske eksploatacije rude bakra u Cerovu na okolnu floru. Na lokaciji otvaranja površinskih kopova sa odlagalištima jalovine na kraju veka rudnika (slika 4.) degradirane površine će iznositi oko 362 ha. Na tom prostoru doći će do potpunog uništenja ekosistema (najviše šuma), a na području unutar trajektorije zone uticaja površinskih kopova na površini oko PK CPD- 312 ha i PK C1-206 ha što ukupno iznosi 518 ha dolazi do snižavanja nivoa podzemnih voda, a time i do pogoršavanja uslova normalnog razvoja biljaka u tom pojasu. Površinski kopovi svojim otkopnim prostorima - depresijama imaju uticaj na snižavanju nivoa podzemnih voda na velikom prostoru. Mere za ublažavanje isuši-vanja tla oko kopova je korišćenje tih depresija za odlaganje jalovine kao što se planira sa depresijom PK C2 da se posle završetka eksploatacije zapuni jalovinom sa PK CPD.

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DETERMINATION THE IMPACT ZONE OF OPEN PITS ON A LEVEL OF GROUND WATER IN THE CEROVO ENVIRONMENT[**]

Abstract

Mining works in Cerovo represent the potential risk to the water regime changes in the environment and their pollution with water from the open pits (Figures 1 and 2) that contain various chemical substances in the form of solution. A range of effect the excavated parts of copper ore deposit in Cerovo on ground and surface water within the exploration area of open pits is very important for organization the land protection in the environment from dryness, and the open pits from the water inflow (Figure 1). This paper specifically analyzes a possibility of evaluation the range of ground water level changes in the surrounding soil caused by mining of copper ore deposits in Cerovo.

Key words: *open pit, environment, ground water, copper*

INTRODUCTION

In the area of Cerovo, 20 km north of Bor in hydrothermal altered zone, the ore field Mali Krivelj – Cerovo is located with copper deposits: Cerovo Primarily, Cerovo 2, Drenovo and Kraku Bugaresku - Cerovo – Cementacija 1. Three open pits (Figure 1) are predicted for opening in this area with reconciled dynamics of continuous production of 7.5 million tones of copper ore annually. According to the business plan, the opening of open pits is in the following order:

1. First, the existing open pit Cerovo–Cementacija 1 is expanded (Figure 1), opened in 1993 on the Kraku Bugaresku locality. The open pit mining has lasted until 2002. Pre-explored copper reserves on the same deposit allow the expansion of this

For the needs of this open pit opening, it is necessary to carry out a relocation the part of the railway Bor – Majdanpek, in length of 1200.0 m with the railway station, a relocation of long-distance power line and river bed of the Cerovo river creating the appropriate tunnel which will implement the Cerovo river into the river bed of the Valja Mare river.

Figure 1 shows the open pit Kraku Bugaresku – Cementacija 1 that is expanded and deepened because the additional explorations have established a significant ore quantity that is minable.

Figure 2 shows the river after inflow of leaching solutions from the open pit C1.

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Figure 3 shows the mutual position of open pits in the exploitation field Cerovo – Kraku Bugaresku.

Table 1 shows the turning points of exploitation field Cerovo – Kraku Bugaresku in the rectangular coordinate system

Figure 1. *Open Pit Kraku Bugaresku –Cementacija 1 that is expanded*

Figure 2. *Leaching water from the open pit C1*

Table 1 shows the turning points of exploitation field Cerovo – Kraku Bugare sku in the rectangular coordinate system

Table 1 *Coordinates of tops of the exploitation field Cerovo – Kraku Bugaresku*

Ord.No.	POINT No.	X	Y
1	1	7 582 775.0	4 890 350.0
2	2	7 581 050.0	4 892 750.0
3	3	7 581 010.0	4 892 790.0
4	4	7 582 220.0	4 895 030.0
5	5	7 584 820.0	4 894 490.0
6	6	7 585 570.0	4 890 020.0

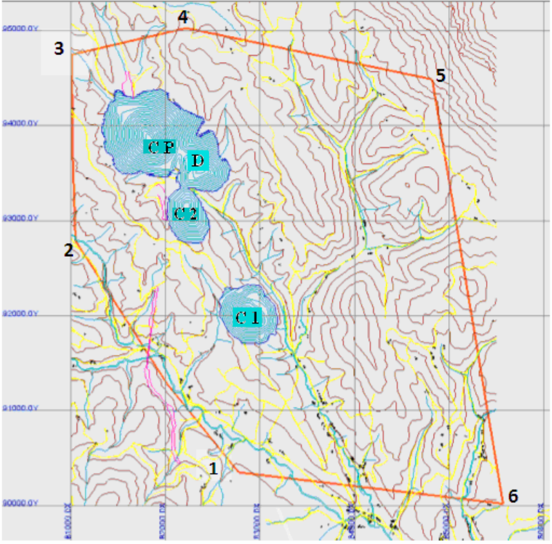

Figure 3. *Mutual position of open pits in the exploitation field Cerovo – Kraku Bugaresku*

Morphological - hydrological characteristics of the deposit Cerovo - Kraku Bugaresku

Terrain morphology, rocks cracking, hydrological and meteorological conditions affect the level of groundwater in the area of Cerovo. The terrain above the deposit Cerovo - Kraku Bugaresku – Cementacija is mountainous, cut with narrow river and stream valleys. In the area of Cerovo, the volcanic and hydrothermally altered rocks bounded to the copper deposits have the gratest representation.The main feature of relief is the existence of conical and gently rounded elevations with slopes. that are intersected with trenches. Limestones build the eastern parts of the area and also make the eastern rim of the Timok Mag matic Complex (TMC) and belong to the limestone massif of Veliki Krs. Limestone terrain is hypsometrically raised with peak elevations which reach 1148 m. It is intensively karstified, where the process of karstification reaches the waterproof bedrock consists of sandstones and conglomerates of Mesozoic age and older Paleozoic and Proterozoic formations. According to the granitoid of Gornjane, the steep sections and numerous phenomena of scree are typical for the limestone terrain. In the central parts of this terrain, several smaller speleological objects are registered.

The area of ore field Mali Krivelj – Cerovo, belongs to the river basin of the Kriveljska river, and generally to the river basin of Timok and Danube. The Crvena river, Valja Mare and Cerova river, that make the Kriveljska river near the village of Mali Krivelj, are significant in hydrological terms. The creek Urs and Ujova river inflow downstream into the Kriveljska river. During the summer, all of these water flows have water, and during the rainy periods take the floody character.

Watering of Cerovo – Kraku Bugaresku deposit is determined based on hydrogeological investigations, where it was stated that some parts of deposit are located above the local erosion base and formed of low water permeable, hydrothermally altered and mineralized rocks with cracks. The cracking aquifers, that are solely fed on the account of water from atmospheric precipitations, are present in these rocks.

According to the surveys, the groundwater levels in the deposits in the area of Cerovo are connected to the fractured aquifers, hydrometeorological conditions, terrain morphology and degree of rock mass cracking. The surveys have found that the groundwater levels are at 3-10 m below ground surface.

The deposit parts above the local erosionbase are characterized by relatively small amounts of groundwater. Greater inflow of ground water is expected at open pits under the elevation of local erosion base when there is infiltration of surface water.

THE EFFECT OF LOWERING THE GROUND WATER AT OPEN PITS ON FLORA IN THE VICINITY

According to the structure, the aquifers on Cerovo are of fractured type because they are found in cracks and fractures of solid impermeable rocks. Water permeability of those tocks depends primarily on nature and extent of cracks through which the movement of groundwater is according to the law of linear gravitational filtration. The movement of underground water can be directed towards the Earth surface, if they are present in aquifers under the hydrostatic pressure, particularly expressed in sections of various cracks. These pressures can be connected to the emanation of gases and temperature higher than 100 ° C, which is characteristic for active or relatively extinct volcanic areas.

The aquifer of fractured type is characterized by discontinuous aquifer zone or zone of saturation with free ground water. They are fed by infiltration of precipitation in surface aquifers, surface and ground contact with the surface of the basin as the local erosion base. The amount of water in aquifer primarily depends on the area of spreading, feeding zone and discharge zone, collecting area and thickness of aquifers.

The aquifers with free level are formed on the waterproof rocks in loose, usually quaternary and neogenetic sediments, but also in cracked and classified geological environments. They have wide distribution in the nature. Smaller accumulations of ground water could occur in the zones of aeration in lenses or inter-layers of impermeable rocks when the floating and false aquifer is formed.

The zone above the free level of aquifer up to the surface including the mining belt, is called the over-aquifer or aeration zone. The thickness of this zone depends on relief and climatic conditions. Trees are supplied with water and nutrients through roots in this zone. In the area of aeration, some kinds of water and movement of water could occur, as follows:

- In a form of vapor from rocks of higher humidity in the direction of rocks of less humidity,
- Hygroscopic (in a from of vapor at $t>100^{0}C$) and membranous water (adsorption force of particles with thick membrane in the direction of particles with a light membrane),
- Gravity free water in the zone of aeration (infiltration of surface water and atmospheric deposits under the influence of capillary and gravity forces),
- Gravity water in the zone of saturation-infiltration (through the pores, cracks and caverns).

The exploitation of copper ore deposit in the area Cerovo leads to the formation of depressions (funnels), thus lowering the level of ground water around open pits. Ground water under the depression curve at the open pit is static and does not move, while the water on boundary of depression funnel and aeration zone is moved.

Horizontal distance, between the intersections of open pit slopes and point where depression curve is connected to the static level of groundwater, is called the radius of funnel effect on the level of underground water in the first water-bearing horizon on the surface.If the level of groundwater, under the influence of mining areas of open pit, falls, the imperfect wells will dry (enter only with one part into water-bearing layer) deepened to the aquifer water and the zone will of aeration will become thicker. The movement of hygroscopic and membranous water will move in it from top to bottom and thus drying the soil and mining water. Lack of water in the surface layer causes a change of environmental factors for survival the certain types of flora in the environment of open pits in the area Cerovo. The additional disadvantage is also that the surfaces of open pit funnel pit and overburden dump because of exposure to the south and increased insolation - degraded and deforested areas (too much light and heat), and lack of atmospheric precipitation during the vegetation period (characteristic of the Bor region) to supply the mining zone with ground water and lack of water in the soil and ground layer of air overheating, lag in growth of plants, and sensitive species are completely disappeared. Storey flora due to lack of moisture to dry, and leaves of trees (beech forest) instead of dark green color, due to lack of water, takes a yellowish color.

In order to evaluate the belt around the open pits that will be affected, the scope of influence the mined areas on environment is determined using the known formulae from literature that rely on knowledge the zone of well action, and radius of action.

Determination of trajectory the impact zone of open pits on the level of groundwater in the area of Cerovo

Trajectory curve of free groundwater level, established after formation of depression funnels (mined areas of open pits), is determined in situ by measurements. However, open pits are in the stage of design (except the open pit C1 that needs to be expanded) and trajectory impact on lowering the level of ground water of open pits at the Cerovo is estimated using a formula that was derived according to professor M. Miljkovic.

To check the range of depression funnel influence on drainage the underground water in the vicinity of open pits and possible impact on flora, it was started from the fact:

- The final slopes of open pits in Cerovo cut one or more aquifer horizons, each separated by impermeable layers of rocks.
- At the intersection of water bearing rocks and slopes of open pits, water freely flows into formed depression where lowering of ground water levels appears from the intersecting point to the waterproof layer.
- Free ground water level within the waterproof rocks, with removal from intersecting point, has a position in a form of depression funnel of drainage the water bearing rocks.
- The rectangular coordinate system is set to zero in intersection point of impermeable rocks and flat of open pit slopes using the following formula:

$$X = 2\frac{K}{P} \times \ln S \text{ (m), where:}$$

K – filtration coefficient (according to the estimation of 15 m / day);
X – range of depression impact (m);
P – porosity of rocks (according to the estimation P = 0.40);
H – height of water column for peak elevation of 245 m (depth water bearing horizon to the intersecting point of open pit slopes with waterproof rocks H= S for PK CPD; H = 435 m); for PK C1, H=270 m
S – height of water level reduction (S = H - h),
h – height of benches that can be flooded is 15 m (bottom of the open pit), Figure 1.

The average vertical distance from the bottom of open pit to the estimated level of water in open pit CPD is S = 420 m, and for PK C1 is S = 255m.

According to evaluation, the range of depression impact (the mined areas of open pits) on the environment of Cerovo, or band-width, where the change of environmental factors could be expected around the open pits and flora due to the dryness of soil is: X = 453.01 m for PK CPD and X = 415.59 m for PK C1.

Funnel of the open pit C2 (Figure 4), after completion of exploitation, is filled with ore waste, and the trajectory of the impact zone on lowering the level of underground water was not calculated for this open pit.

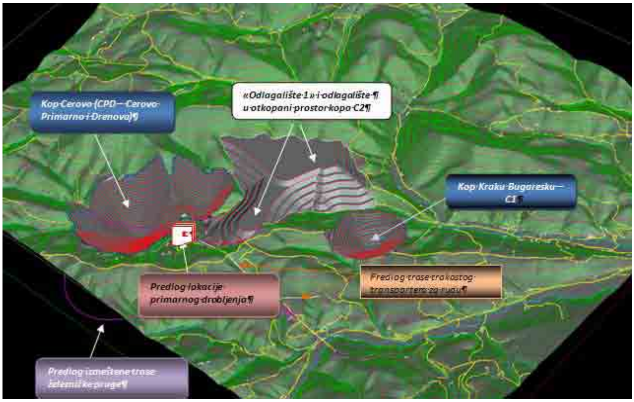

Figure 4. *View of open pits in the area of Cerovo at the end of exploitation century*

CONCLUSION

Based on the formula from literature and adopted data for mined areas of open pits – depressions, the effect of open pit mining of copper ore in Cerovo on the surrounding flora, was forecasted. At the location of opening the open pits with waste dumps at the end of mine century (Figure 4), the degraded areas will be about 362 ha. In this area there will be a total destruction of ecosystem (mostly forests), and in the area within trajectory of influence zone of open pits on the surface of about 312 ha PK CPD and PK C1 206 ha, which in total is 518 ha, the lowering of groundwater levels appeared, and thus deterioration of conditions for normal development of plants in this area. The open pits with their mined areas – depressions have the effect on lowering the level of ground water in a large area. Measures for prevention the dryness of soil around the open pits is usage of those depressions for waste disposal as it is planned with depression PK C2, that after finalization of exploitation will be filled with overburden from PK CPD.

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Mirko Ivković, Jovo Miljanović**

IZRAČUNAVANJE KONCENTACIJE GASOVA PRI PODZEMNOM SAGOREVANJU UGLJA

Izvod

Podzemna gasifikacija uglja (PGU) predstavlja tehnologiju dobivanja gasa neposredno u ležištu u procesu sagorevanja i suve transformacije uglja. Sastav gasa, njegove karakteristike i prinos zavise od vrste uglja, sastava smeše za uduvavanje i uslova zaleganja ugljenih slojeva. U zavisnosti od primene dobijenog gasa, često se, obavlja podešavanje koncentracija pojedinih komponenti te je neophodno vršiti izračunavanje sadržaja gasova u smeši.
Ključne reči:*eksploatacija, ugalj, uljni škriljci, podzemna gasifikacija*

UVOD

Efikasan način valorizacije vanbilansnih rezervi uglja, kao i bilansnih u pojedinim slučajevima, je podzemna gasifikacija (PGU). Tehnologija podrazumeva bušotinsku pripremu podzemnog gasgeneratora u ležištu, ostvarenje procesa dobijanja gasa nastalog u kanalima ugljenog sloja uzajamnim dejstvom uglja sa dotokom gasifikujećeg sredstva (vazduh, vodena para, kiseonik...).

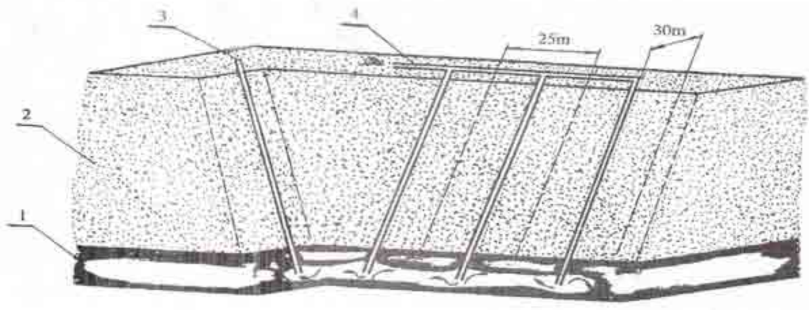
Stvaranje gasa nastaje posle zapaljenja ugljenog sloja i posledica je hemijskog, termičkog i mehaničkog dejstva na sloj uglja.

Podzemna gasifikacija uglja karakteriše se stepenom iskorišćenja uglja koji predstavlja odnos gasifikovanog uglja prema ukupno raspoloživoj količini uglja za PGU. Termička efikasnost procesa je definisana odnosom toplotne moći dobijene gasne smeše prema tolotnoj moći uglja, iz koga je nastala smeša, svedene na ekvivalentne dimenzije, što zavisi od vrste gasifikujućeg agensa, njegovog pritiska i temperature, osobina uglja koji je predmet gasifikacije, dubine zaleganja i tektonskih uslova.

Dobijeni gas iz podzemne gasifikacije uglja može se koristiti kao energetsko gorivo u termoelektranama za proizvodnju električne energije, za proizvodnju toplotne energije u kotlarnicima, za sušenje u građevinskoj i hemiskoj industriji i dr.

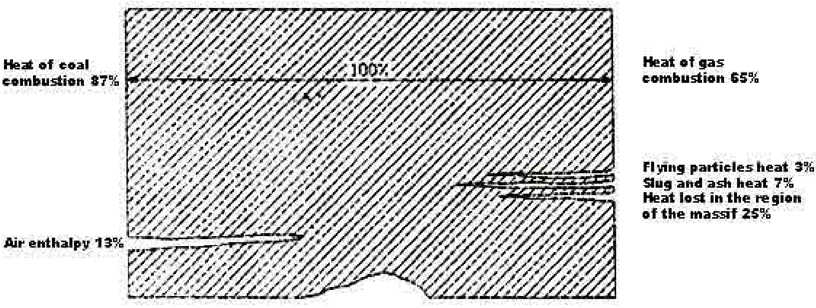
Šematski prikaz generatora PGU i toplotni bilans ovog procesa prikazani su na slikama 1. i 2.

* *JPPEU - Resavica*



Sl. 1. *Šematski prikaz generatora*

1 – sloj uglja, 2 – krovina, 3 – otvor za prijem gasa,
4 – kanali sa otvorima za dovođenje vazduha



Sl. 2. *Toplotni bilans*

ODREĐIVANJE KONCENTRACIJE GASOVA PRI PGU

Razvojem procesa sagorevanja zona gasifikacije pomera se i širi po ugljenom sloju i u reakcionoj zoni nastaju CO, CO_2, H_2, i CH_4. Pored toga prisutan je i azot koji je inertan, te vodena para koja nestaje na visokim temperaturama, kao i ugljenik koji ostaje u vidu šljake, te su ovo komponente na koje se ne računa u završnom bilansiranju komponenti.

Kiseonik se obično u završnom produktu gasifikacije manifestuje u vezanom obliku u vidu CO i CO_2 a u veoma maloj količini kao slobodan O_2, ali se prikazuje u matematskom modelu. Pri sagorevanju deo hemiskih reakcija je egzotermni, deo ima endotermni karakter a deo toplote se prenosi na masiv.

Za razmatranje ovih procesa koristi se Darcy-eva jednačina kontinuiteta, koja se u ovom slučaju primenjuje na difuziju kiseonika koji je gasifikujuće sredstvo.

Jednačina difuzije kiseonika ka ugljenom zidu pretpostavljenog cilindričnog kanala može se izraziti u sledećem obliku:

$$\frac{\partial C}{\partial \tau} + (\vec{v}\nabla C)' = D\left[\frac{\partial^2 C}{\partial z^2} + \frac{1}{r}\frac{\partial}{\partial r} r \frac{\partial C}{\partial r}\right] + \rho' \quad (1)$$

gde su:

$\vec{v}$ - brzina protoka:

$\vec{u}$ - srednja brzina toka po presjeku u kanalu

$\vec{v}'$ - pulzaciona brzina toka

D – koeficijent molekularne difuzije

z i r – cilindrične koordinate

ρ' - brzina iščezavanja kiseonika kao rezultat reakcija

Uzimajući u obzir da je brzina gorenja na zidu ugljenog sloja kanala, pri temperaturi većoj od 1000°C, dovoljno velika, u tom procesu odlučujuću ulogu ima difuzija kiseonika, a njegova koncentracija na zidu se približava nuli:

$$C_r \approx 0 \qquad (2)$$

U tom slučaju se stacionarni turbulentni fluks, zanemarujući uzdužnu difuziju – duž kanala, jednačina prelazi u sledeći oblik.

$$\vec{u}\frac{\partial C}{\partial z} = \frac{1}{r}\frac{\partial}{\partial r} D_T r \frac{\partial C}{\partial r} \qquad (3)$$

gde je:

D_r – koeficijent turbulentne difuzije

Diferencijalna jednačina (3) Dirichlet-ovim homogenim graničnim uslovom (2) se rešava pomoću metode konačnih diferenci. Ta metoda se u principu zasniva na aproksimaciji diferncijalnih operatora u diferencijalnim jednačinama odgovarajućim diferenčnim operatorima. Predhodno se pri tome područje proračuna razdjeli na određenu mrežu i to tako da bi ona najtačnije aproksimirala granice područja i unijela minimalnu grešku u konfiguraciju tog područja.

Pomenuta zamena diferencijalnih operatora odgovarajućim operatorima vrši se na sledeći način:

$$\left(\frac{\partial C}{\partial x}\right)_0 \approx \frac{C_1 - C_2}{2h};\left(\frac{\partial C}{\partial y}\right)_0 \approx \frac{C_3 - C_4}{2h}$$

$$\left(\frac{\partial^2 C}{\partial x^2}\right)_o \approx \frac{C_1 + C_2 - 2C_o}{h^2};$$

$$\left(\frac{\partial^2 C}{\partial y^2}\right)_o \approx \frac{C_3 + C_4 - 2C_o}{h^2}$$

Ovdje je „O“ središnja tačka u kojoj se vrši aproksimacija operatora koja je okružena tačkama „1“ i „2“ po x-osi, odnosno tačkama „3“ i „4“ po y-osi, dok je „h“ korak mreža.

Dalje se postupak koji je dat jednačinama za tačku „O“ napiše za svaku tačku mreže cijelog područja proračuna. Prema opisanom algoritmu metode konačnih diferenci rješavanje diferencijalne jednačine (3) se svodi na rešavanje sistema algebarskih jednačina.

Nakon numeričkog rešavanja tog sistema jednačina (Newton-Raphson-ovom metodom) dobiju se vrednosti koncentracije u čvorišnim tačkama mreže, tj. promjena koncentracije kiseonika po dužini kanala $C = C(z)$ u obliku diskretnih vrednosti. Pri tome je diskretizacija izvedena pomoću mreže kvadratnog oblika, koraka h.

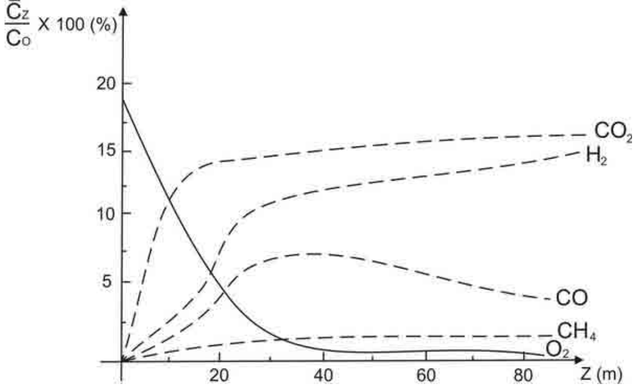
Slične diferencijalne jednačine mogu se napisati i za druge osnovne gasne komponente, kao što su vodonik H_2, ugljen-monoksid CO, ugljen dioksid CO_2 i metan CH_4, uzimajući pri tome u obzir njihove karakteristične parametre, pa riješiti po istom algoritmu kao i za kiseonik O_2.

Kao rezultat izvršenih numeričkih rešenja prema opisanom algoritmu, date su na sl. 3. krivulje promene koncentracije pojedinih gasnih komponenti po dužini kanala za jedan prosečan kameni ugalj.

Na slici je:

C_o - početna koncentracija komponenti gasa

$\vec{C}_z$ - usrednjena koncentracija komponenti gasa po presjeku kanala udaljenom na rastojanju „z“ od početka kanala.



Sl. 3. *Krivulje promene koncentracije pojedinih gasnih komponenti po dužini kanala za jedan prosečan kameni ugalj*

ZAKLJUČAK

Tehnologija konverzije uglja u gasovita goriva podzemnom gasifikacijom (PGU), je tehnološko dostignuće koje otvara put racionalnoj proizvodnji energije, a u slučaju Srbije i supstituciji dela uvoznih energenata i smanjenje energetske zavisnosti. Značajne rezerve uglja i uljnih škriljaca, za koje nije ekonomična primena klasične tehnologije podzemne eksploatacije, upućuju na potrebu izučavanja i primene tehnologije podzemne gasifikacije.

Samo u Aleksinačkom području preostale rezerve uglja iznose 27 miliona tona a na raspolaganju su i rezerve uljnih škriljaca u veličini od oko 2 milijarde tona.

U radu je obrađen numerički pristup izračunavanju koncentracije gasova pri podzemnom sagorevanju uglja u cilju efikasnijeg praćenja i regulisanja toka procesa.

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CALCULATION THE GAS CONCENTRATION IN THE UNDERGROUND COAL COMBUSTION

Abstract

Underground coal gasification (UCG) is a technology of gas extraction directly from a deposit in the process of dry coal transformation. The composition of gas, its characteristics and productivity depend on the coal type, the composition of blowing mixture and conditions of interposition the coal layers. Depending on the use of excavated gas, an adjustment of concentrations of particular components is carried out, and therefore it is necessary to calculate the composition of gases in mixture.

Key words: *exploitation, coal, oilshale, undergrond gas production*

INTRODUCTION

An effective way of evaluating the off-balance coal reserves as well as the balance reserves in some cases is the underground coal gasification (UCG). The technology consists of drillhole preparation of underground gas-generator in a deposit, the realization of extracting process of gas obtained in the channels of the coal seams by interaction of coal and inflow of gasification medium (air, water vapour, oxygen…). The generation of coal arises after the coal seam is ignited as the result of chemical, thermal and mechanical effect on the coal seam. The underground coal gasification is characterized by total available quantity of coal for UCG. Thermal efficiency of the process is defined by the ratio of calorific power of the obtained gaseous mixture and calorific power of coal, out of which the mixture has resulted, reduced to the equivalent proportion, what depends on a type of gasification agent, its pressure and temperature, the characteristics of coal subject to the gasification, the depth of occurrence and tectonic conditions.

The gas derived from the underground coal gasification could be used as a power fuel in thermal plants for electrical energy production in boiler-rooms, drying in civil engineering and chemical industry etc.

Figures 1 and 2 show the schematic diagram of UCG generators and thermal balance of this process.

* *PC for Underground Exploitation Resavica*

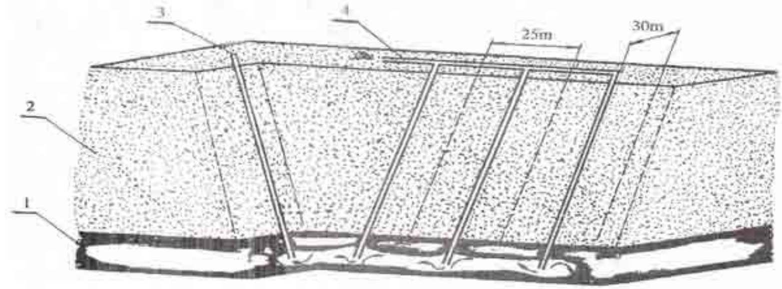

Figure 1. *Schematic diagram of generator*
1 – Coal seam, 2 – roof, 3 – gas inlet, 4 –channels with holes for air supply

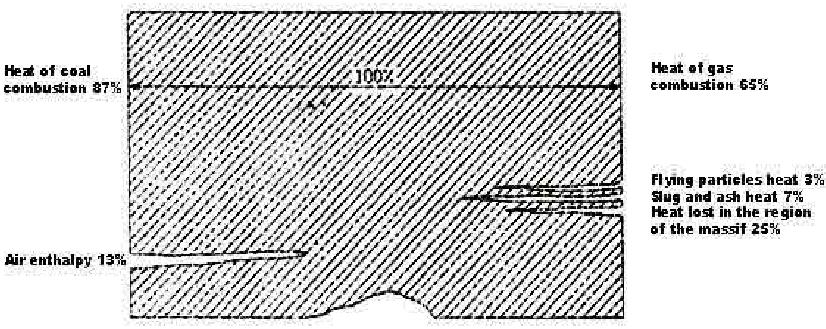

Figure 2. *Heat balance*

DETERMINATION OF GAS CONCENTRATION IN THE UCG

By development of combustion processes, the gasification zone is moved and extended along the coal seam, and CO, CO_2, H_2, and CH_4 are generated in the reaction zone. In addition to those, nitrogen is also present, that is inert, then water vapour that disappeared at high temperatures as well as carbon remaining in a form of slag, so these components are not counted into the final component balancing.

Oxygen, in the finished gasification product, is usually manifested in a bound form of CO and CO_2 and in very small quantities as free O_2, but it appears in the mathematical model. In the combustion, a part of chemical reactions is exothermic, a part is endothermic and a part of heat is carried over to the massif.

For the purposes of analysis of these processes, the Darcy's continuity equation is used, that is applied to the diffusion of oxygen being the gasification medium in this case.

The equation of oxygen diffusion regarding to the coal wall of pre-positioned cylindrical channel may be represented as follows:

$$\frac{\partial C}{\partial \tau} + (\vec{v}\nabla C)' = D\left[\frac{\partial^2 C}{\partial z^2} + \frac{1}{r}\frac{\partial}{\partial r} r \frac{\partial C}{\partial r}\right] + \rho' \quad (1)$$

Where:

$\vec{v}$ - velocity of flow: $\vec{v} = \vec{u} + \vec{v}'$

$\vec{u}$ - mean velocity of flow at section in the channel

$\vec{v}'$ - pulse velocity of flow

D – coefficient of molecular diffusion

z and r – cylindrical coordinates

ρ' - oxygen disappearance rate as the result of reactions

Considering that the rate of combustion on the wall of coal seam in the channel, at temperature higher than 1000^{o}C, is sufficiently high, the diffusion of oxygen has a decisive role in this process, where its concentration on the wall is approaching to zero:

$$C_r \approx 0 \qquad (2)$$

In such case, a stationary turbulent flux, disregarding the longitudinal diffusion – along the channel, equation becomes as follows:

$$\vec{u}\frac{\partial C}{\partial z} = \frac{1}{r}\frac{\partial}{\partial r} D_T r \frac{\partial C}{\partial r} \qquad (3)$$

Where:

D_T – coefficient of turbulent diffusion

Differential equation (3) with the Dirichlet's homogenous boundary condition (2) is resolved using the finite-difference method. This method is generally based on the approximation of differential operators in differential equations to the corresponding difference operators. Previously, the calculation domain is divided into a certain grid in such a way that it would approximate, the most accurately, to the boundaries of domain and include a minimum mistake into the configuration of such domain. The above replacement of differential operators by corresponding operators is made as follows:

$$\left(\frac{\partial C}{\partial x}\right)_0 \approx \frac{C_1 - C_2}{2h};\left(\frac{\partial C}{\partial y}\right)_0 \approx \frac{C_3 - C_4}{2h}$$

$$\left(\frac{\partial^2 C}{\partial x^2}\right)_o \approx \frac{C_1 + C_2 - 2C_o}{h^2};$$

$$\left(\frac{\partial^2 C}{\partial y^2}\right)_o \approx \frac{C_3 + C_4 - 2C_o}{h^2}$$

Here, „O“ is a midpoint where the approximation of operators is made, which is surrounded by „1“ and „2“ points at x-axis, that is, by „3“ and „4“ points at the y-axis, while „h“ step is the grid. The procedure, that is presented by the equations for „O“ point, is further written for each point of the grid of the whole calculation domain. According to the described algorithm of the finite-difference method, resolving the differential equation (3) becomes the resolving systems of algebra equations.

After numerical resolution of this system of equations (by the Newton-Raphson's method), the values of concentration in node points of the grid are obtained, i.e. change in concentration of oxygen at length of channel $C = C(z)$ in a form of discrete values. At that, the discretization is made using a square-shape grid, the h step.

Similar differential equations may be also written for the other basic gas components, such as hydrogen H_2, carbon monoxide CO, carbon dioxide CO_2 and methane CH_4, whereby their characteristic parameters are taken into account, and then the equations should be resolved according to the same algorithm as for oxygen O_2.

As the result of numerical solutions, according to the described algorithm, Figure 3 shows curves of changes in concentration of particular gas components at channel length for one average stone coal.

In Figure 3:

C_o - initial concentration of gas components

$\vec{C}_z$ - average concentration of gas components in the channel section at distance „z“ from the channel inlet

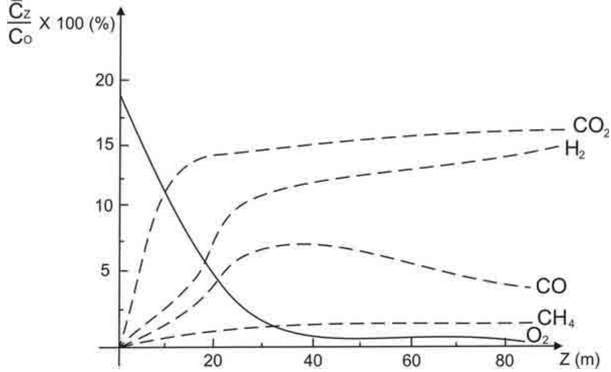

Figure 3. *Curves of changes in concentration of particular gas components at channel length for one average stone coal [4]*

CONCLUSION

Technology of coal converting coal into gaseous fuels by the underground coal gasification (UCG) is a technological achievement that opens the way to the rational power supply, and also for Serbia, to the substitution of a part of imported power fuels and reduction the energy dependence. Significant reserves of coal and oil shale, for which the use of standard underground mining technology is not cost-effective, refer to a necessity of researches and use the underground gasification technology.

Only in the Aleksinac area the residual coal reserves amount to 27 million tons and there are also the available reserves of oil shale to the amount of approximately 2 billion tons.

This work addresses the numerical approach to the calculation the concentration of gases in underground coal gasification to the aim of more effective process control and adjustment.

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IDENTIFIKACIJA RIZIKA U PROJEKTOVANJU RUDNIKA, EKSPLOATACIJI I SAGOREVANJU ULJNIH ŠKRILJACA

Izvod

Zaštita životne sredine na današnjem stepenu razvoja, kako u razvijenim, tako i u zemljama u razvoju, postala je neophodna, jer su zbog intenzivnog razvoja energetike uticaji na nju sve složeniji. Problem je posebno složen zbog toga što se između energetske politike i politike zaštite životne sredine mora postići kompromis jer praktično svi energetski izvori i postrojenja imaju veći ili manji uticaj na okolinu.

Razvoj proizvodnje primarne i sekundarne energije doprinosi sve većem zagađenju životne sredine. Zbog toga u svim zemljama zakonodavne i druge norme tretiraju zaštitu vazduha, voda, zemljišta, zaštitu od buke i dr. od uticaja, pored ostalog i energetskih postrojenja. Najveći uticaj na životnu sredinu ima proizvodnja sekundarne energije, posebno električne energije u termoelektranama. Svi problemi zagađenja okoline su prisutni i kod izgradnje termoelektrana na uljne škriljce, sa možda i većim intenzitetom zagađenja zbog sastava i kvaliteta uljnih škriljaca. U ovom radu se bavimo štetnim uticajem eksploatacije i sagorevanja uljnih škriljaca na životnu sredinu kao i identifikacijom rizika u ukupnom iskorišćenju uljnih škriljaca.

Ključne reči: *uljni škriljci, zaštita životne sredine, eksploatacija, sagorevanje, gasifikacija*

UVOD

Uljni škriljci predstavljaju slojeve stena, koje sadrže materijal, koji je praktično preteča nafte. Kada se pregreva, ovaj materijal, uglavnom kerogen, može biti destilisan iz stene u naftu. Obogaćivanjem i rafinisanjem ovog tečnog destilovanog materijala mogu se dobiti različite vrste korisnog goriva. Uljni škriljci se mogu eksploatisati površinskim i podzemnim putem i savremenim metodama podzemne gasifikacije.

U zavisnosti koja se tehnologija koristi, eksploatacija i sagorevanje uljnih škriljaca je povezana sa velikim poremećajima i rizicima u prirodnom staništu, podzemnim i površinskim izvorima, kvalitetu vazduha i klimi. Očekivani su trajni uticaji na topografiju na floru i faunu, kao rezultat komercijalne eksploatacije i prerade uljnih škriljaca.

U slučaju površinske eksploatacije, iskorišćeni tj. prerađeni uljni škriljci (otpad) imaju veliki uticaj na kontaminaciju podzemnih voda (imaju drastično veću koncentraciju soli nego ruda škriljca, a mogu da sadrže i druge toksične supstance). U slučaju podzemne „In-situ" eksploatacije, proces podrazumeva veliki rizik od kontaminacije podzemnih voda.[3]

* *Ministarstvo rudarstva i energetike*

ZAŠTITA KOD PROJEKTOVANJA RUDNIKA

U svakom poslovanju proces projektovanja treba pažljivo rasmotriti sa stanovišta zaštite životne sredine. Kod projektovanja rudnika za eksploataciju uljnih škriljaca u obzir se moraju uzeti nekoliko stavki:

- izvršiti dodatka istraživanja na zaštiti životne sredine koja će uveriti lokalno stanovništvo da toleriše uticaj eksploatacije na istu,
- rudnik treba biti lociran, po mogućstvu, što dalje od naseljenog mesta,
- u blizini naseljenih mesta, minerske radove netreba koristiti,
- rudarski radovi nesmeju oštetiti određene izdani, kako bi se sprečila kontaminacija voda,
- zalihe uljnih škriljaca, lomljenje i transportnu jedinicu treba po mogućstvu locirati u šumi kako bi se sprečila buka i širenje prašine,
- barijere za buku i prašinu treba takođe locirati između naseljenih mesta i postojenja rudnika. Za takve svrhe potrebno je čak i zasaditi drveće

Važni zahtevi koje treba uvažiti prilikom projektovanja su sledeći:

- kako negativni uticaj na životnu sredinu svesti na minimum?
- da li je moguće koristiti selektivan ili neselektivan metod eksploatacije?
- koja metoda eksploatacije garantuje određenje izlazne rezultate?
- kako reducirati upotrebu određenim mašina?
- da li kupiti ili iznajmiti mašine? [2]

ZAGAĐENJE ZEMLJIŠTA PRI EKSPLOATACIJI

Površinska eksploatacija prouzrokuje mnoga površinske poremećaje zemljišta i ima veliki uticaj na površinske vode, pripovršinske vode, na floru i faunu. Iskustva kod eksplatacije uglja i drugih sirovina ukazuju na to uticaj na okruženje je veoma veliko ali uz minimalni dugoročni efekat.

Podzemna eksploatacije prouzrokuje mnogo manje površinske poremećaje. Površinksi poremećaji su limitirani ali uključuju emisiju prašine prouzrokovano transportnom i skladištenje.

„In-situ" eksploatacija uključuje manje rudarskih radova, koja su ograničena na bušenje tzv. toplotnih bušotina i proizvodnih bušotina na malom rastojanju. Uticaj na životnu sredinu će biti sličan kao i kod proizvodnje gasa i nafte. Bušotine kod ove vrste eksploatacije zahtevaju obezbeđenje i plombiranje.

Drugi površinski uticaji u najvećem slučaju zavise od konstrukcije površinskog postrojenja, uključujući postrojenje za retortovanje, nadogradnju, deponovanje i transport. Novi cevovodi, putevi i prateći objekti, mogu takođe imati uticaja na površinsku kontaminaciju.

Iskorišćeni škriljac: površinske retorte proizvode velike količine obrađenog ili iskorišćenog uljnog škriljca. Tehnologija retortovanja nastoji da reducira zaostali ugljenik, čineći obrađeni škriljac bezbednijim za okruženje. Neki iskorišćeni škriljac se može koristiti kao komercijalni materijal za izgradnju ili kao materijal za rekultivaciju zemljišta.

ZAGAĐIVAČI VODE

Na većem rastojanju od rudarskih aktivnosti ili postrojenja za retortovanje dolazi do kontaminacije zemljišta i podzemnih voda. „In-situ" eksploatacija veoma utiče na kvalitet podzemnih voda. U ovim slučajevima se zahteva kontrola i zaštita površinskih i podzemnih voda. Efikasne tehnologije i upravljenje proce-sima su već demonstrirane i pokazane u drugim sličnim slučajevima komercija-lnog rudarenje. „In-situ" eksploatacija praktično već trpi izazove da zaštiti podzemne vode od kontaminacije od kerogenskog ulja i drugih proizvedenih gasova i sedimenata. Obećavajuća tzv. „freeze-wall” tehnologija je testirana da izoluje podzemne vode od pripovršinskog područja na kome se vrši „In-situ” proces, sve dok se postproizvodne aktivnosti i rekultivazija zemljišta ne završi. [7]

ZAGAĐIVAČI VAZDUHA PRI SAGOREVANJU ULJNIH ŠKRILJACA

Glavni zagađivači vazduha tokom sagorevanja uljnih škriljaca su oksidi azota, sumpor dioksid, hlorovodonik i čvrste čestice. Najštetniji gas koji se emituje je CO_2 . Koncentracija zagađivača vazduhu u izduvnim gasovima, prvenstveno zavisi od tehnologije sagorevanja i režima sagorevanja, dok je emisija čvrstih čestica određena efikasnošću uređaja za hvatanje pepela u letu. Što se tiče emisije zagađivača vazduha, uljni škriljac se karakteriše niskim sadržajem azota u organskoj materiji (0,3%), velika koncentracija organskog sumpora (1,6-1,8% u delu koji se prihvata kao gorivo), visok Ca/S odnos (8-10) i obilje minerala karbonata (16-19% minerala CO_2 – u delu koji se prihvata kao gorivo).

Tokom sagorevanja goriva NO_x može biti formiran na sledeće načine: u reakciji između azota i kiseonika iz vazduha (toplotni NO_x), u reakciji između radikala ugljovodonika i molekula azota (momentalni ili brzi NO_x) i azota iz goriva. Najvažniji parametar koji utiče na količinu oksida azota u izduvnim gasovima je koncentaciju kiseonika (veliki vazdušni faktor).

Glavna sumporna komponenta u uljnom škriljcu je kalcijum. S toga, da bi se okarakterisao potencijal u procesu hvatanja sumpora, koristi se odnos Ca/S. Iz razloga što uljni škriljci sadrže alkalne metale, deo sumpora je vezan sa ovim komponentama, najčešće u obliku sulfata. Međutim, nisu svi alkalni metali koji su prisutni u gorivu konvertovani u sulfate; jedan deo prevenstveno zavisi od isparljivosti alkalnih metala iz mineralne materije u procesu sagorevanja. Emisija sumpor-dioksida i obim pretvaranja u paru od dela sagorljivog sumpora, tokom sagorevanja uljnih škriljaca, zavisi od mnogo faktora.

Ugljen-dioksid spada u grupu gasova staklene bašte. Formira se u reakcijama sagorevanja organskog ugljenika i minerala prisutnih u gorivu kao karbonati. Puna konverzija organskog ugljenika u CO_2 je moguća samo kod kompletnog sagorevanja. Oslobađenje ugljen dioksida iz minerala karbonata, određena je ponašanjem minerala goriva, tokom procesa sagorevanja. Tehnologija sagorevanja koja se koristi za gorenje goriva, ne utiče značajno na efekte i količinu formiranja CO_2 od organskog ugljenika. Svakako tehnologija sagorevanja ima veliki uticaj na emisiju minerala CO_2. Koncentracija minerala CO_2, formirana od karbonatnih jedinjenja, određena je uslovima termičke razgradnje minerala i takođe direktnim sagorevanjem gasovitih komponenti prisutnim u izduvnim gasovima i minerala koji sadrže CO_2. [4]

UTICAJ PODZEMNE GASIFIKACIJE

Briga o životnoj sredini je jedan od važnijih činilaca koju treba uzeti u obzir kada se pristupa procesu podzemne gasifikacije (PG) i ako je njen uticaj na životnu sredinu jedva primetan i veoma nizak. Glavni proizvod gasifikacije je gas, iako izvesni nusproizvodi ostaju pod zemljom, ili se koriste od strane konvencionalnih procesa ili injektuju nazad u sloj. U isto vreme imamo još uvek nekoliko značajnih uticaja koji se moraju uzeti u obzir, naročito, podzemni i nadzemni uticaj. U osnovi hidrološka, geološka i hidrogeološka istraživanja i njihova ocena se moraju obaviti prvenstveno u skladu sa operacijama podzemne gasifikacije.

PG na životnu sredinu može imati uticaja na:

- Radno mesto,
- buku,
- emisija gasova u atmosferu,
- kontaminaciju podzemnih voda,
- sleganje terena.

Prednosti uticaja PG – a na tretiranje sloja su:

- Izostanak prašine na površini,
- proizvodnja čistog gasa,
- visoka efektivnost koja se ostvaruje u gasnim turbinama,
- odsustvo gasifikatora na površini.

Mane uticaja PG – a na tretiranje sloja su:

- Podzemna kontaminacija,
- površinska kontaminacija,
- procesni zagađivači.

Pripovršinska kontaminacija

Kontaminacija podzemnih voda

Imamo nekoliko komponenti koja su povezana sa kontaminacijom podzemnih voda. Značaj tih komponenti su posmatrani i istraživani u cilju minimiziranja i/ili eliminisanje rizika i povećanje značaja faktora koji su povezani sa kontaminacijom. Ispitivanja su pokazala da je mali procenat fenola i benzena nastao kao produkt procesa podzemne gasifikacije. Veći procenat zajedno sa proizvedenim gasom dolazi do površine gde se eliminiše u procesu prečišćavanja. Svakako, ostatak prolazi kroz okolno slojeve ili biva absorbovan od strane neporemećenih slojeva, a preostalo se zadržava u takozvanim izduvanim šupljinama.

Propustljivost, hidrogeološka i geološka struktura sloja uljnih škriljaca će imati najveći uticaj na rasejavanje kontaminacije. Od velike važnosti je da je hidrologija potpuno poznata, a sama struktura će pokazati gde je mogućnost kontaminacije najmanja.

Sam projekat mora potpuno da iscrpi najobimnije istražne radove koji su vezani za dubinu ugljenog sloja i monitoring pre i posle procesa gasifikacije na određenom području.

Na hidrologiju i kvalitet podzemnih voda, mogu imati uticaj produkti procesa kao rezultat sagorevanja uljnih škriljaca. Neki od njih su: prašina, katran, ćumur, fenoli, benzen, metil–benzol, ksilen, bor, cijanid i ugljovodonici.

Curenje gasa iz šupljina okolnih slojeva može biti problem kod procesa PG–a u plitkim slojevima tj. pri površinskim slojevima. U isto vreme čak i u uslovima gasifikacije na većim dubinama, zagađivači mogu da dopru do površine putem podzemnih voda, duž podzemnih fraktura samog terena. Veoma je važno da targetno područje bude što dalje od postojećih rudnika i birati rudnike na većoj dubini. U cilju minimiziranja curenje ili bežanja gasa, veoma je važno birati područja sa niskom propustljivošću slojeva i kontrolisati pritisak tokom samog procesa, da bude koliko je moguće približan hidrostatičkom pritisku.

Sleganje terena

Sleganje terena se obično javlja kada se naruši stabilnost tla, usled procesa PG–a u pripovršinskim slojevima. Ovo se pre svega odnosi na slojeve koji se nalaze bliže površini, dok su kod dubljih slojeva efekti minimalni. Činjenica je da se sa dubinom smanjuju efekti sleganja terena.

Površinska kontaminacija

Postrojenje za gasifikaciju koje se nalazi na površini uključuje: glave bušotina, opremu za bušenje, odgovarajuće cevovode, postrojenje za preradu i injektovanje/proizvodnju gasa, itd. Uticaj na životnu sredinu mogu imati:

- Otpadne vode koje nastaju tokom gasifikacije,
- otpadne vode koja nastaje tokom podzemne filtracije,

- Otpadne vode od samog postrojenja za proizvodnju gasa
- emisija gasova koja nastaje tokom proizvodnje/sagorevanjem,
- izlivanje ulja,
- moguće otpadne vode kao posledica izlivanja, izlivanja sa spojeva i hlađenja,
- moguće zagađenje od čvrstog ostatka sa deponija.

Osim toga, mora se voditi računa o sprečavanju emisija CO_2 koje nastaje kao razultat procesa, uticaju na površinske vode, uticaju na podzemne vode, zvucima (buka) koji nastaju tokom procesa i ostalih efekata i negativnih uticaja na čoveka i okolinu.

Emisija gasova

Imamo dva glavna činilaca koja utiču na emisiju gasova koju izazivaju i površinski i pripovršinski procesi. Najveća emisija štetnih materija nastala tokom procesa gasifikacije uključuje:

Gasovite materije:
- hidrogen, karbon – dioksid, karbon - monoksid, sumpor, kiseonik

Organske materije:

- Eterične ugljovodonike: metan, etan, etilen, propan
- Aromatični ugljovodonici: benzoli, metil – benzol, benzeni, naftaleni
- Organske kiseline: fenoli, alkil – fenoli, naftol, alkil – naftol
- Organske baze: piridin, metil – piridin, anilin, indolin, kinolin, isokinolin
- Zasićeni/Ciklični ugljnovodonici: N – alkali, ciklični alkali
- Nezasićeni ugljovodonici: olefini

Neorganske materije:

Bor, fluorid, bromid, hlorid, selika, litijum, sulfat, mangan, amonijak, sodijum, sulfid, gvožđe, kalcijum, cijanid, barijum, kalij, magnezijum.

Uticaj na:
- Kvalitet vazduha,
- ozonski omotač,
- staklena bašta.

Većina zagađivača nastala tokom procesa anuliraju se tokom samog procesa. Tokom rada samog generatora, tragovi SO_2 i NO_x, bivaju otpušteni u atmosferu, a CO_2 ostaje zaplenjen. Zaplena CO_2 uključuje izdvajanje CO_2 i delom injektovanje nazad pod velikim pritiskom.

Glavni problem kod zagađenja površinskih voda tokom procesa PG–a je ispumpavanje bez odgovarajućeg filtracionog procesa u rečni sistem, prirodne izvore i izlivanje tokom procesa i bušenja. U susret kontroli otpadnih voda, odgovarajuće mere moraju biti sprovedene, takođe i tokom samog procesa.

Uticaj procesa podzemne gasifikacije na čoveka je minimalan. Glavni faktori su povećanje buke, prašina i zagađenje pijaće vode. [1]

ZAKLJUČAK

Zaštita životne sredine na današnjem stepenu razvoja, kako u razvijenim, tako i u zemljama u razvoju, postala je neophodna, jer su zbog intenzivnog razvoja energetike uticaji na nju sve složeniji. Problem je posebno složen zbog toga što se između energetske politike i politike zaštite životne sredine mora postići kompromis jer praktično svi energetski izvori i postrojenja imaju veći ili manji uticaj na okolinu.

Iz svega navedenog može se izvući sledeće:

- Proizvodnja energije od uljnih škriljaca je veoma intenzivan proces. Po nekim procenama ulaganje energije u proizvodnju ulja od uljnih škriljaca je skoro isto toliko velika kao i prinos.

- Proizvodnja energije od uljnih škriljaca uzrokuje više gasova staklene bašte nego proizvodnja konvencionalnog gasa. Ovi zagađivači vazduha, kao što su sumpor dioksid, oksidi azota i fine čestice su povezane sa većom učestalošću respiratornih oboljenja, uključujući astmu, emfizemu i smanjenje kapaciteta pluća.
- Ovaj vid proizvodnje koristi između 3 i 5 barela vode, za svaki barel proizvedene nafte. Analiza količina vode koje su potrebne za tretiranje uljnih škriljaca moraju uzeti u obzir trenutre i očekivane potrebe za vodom.
- Nedovoljno se zna o tome kako sprečiti kontaminaciju voda sa površinskih i „in-situ” operacija.
- Ekstrakcija može imati dugotrajan ekološki uticaj, uključujući poremećenu oblast na kojoj su se vršili rudarski radovi i oblast deponija iskorišćenog uljnog škriljca. [5]

Moderni projekti iskorišćenja uljnih škriljaca, obuhvataće kontrolu i različite saglasnosti na idejno rešenje projekta i ekonomsku projekciju. Ekološke karakteristike specifičnih tehnologija će se morati ocenjivati na osnovu regulative zaštite životne sredine za svaku zemlju.

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RISK IDENTIFICATION IN THE MINE DESIGN, EXPLOITATION AND COMBUSTION OF OIL SHALE

Abstract

Environmental protection at the recent level of development, both in developed and developing countries, has became necessary, due to more intensive energy development, the impacts on it are much more complex. The problem is particularly complex because a compromise between the energy policy and environmental policy has to be achieved. Practically, all energy sources and plants have more or less impact on the environment.

Development in production of primary and secondary energy contributes to the increased environment pollution. Therefore, in all countries the legislative and other norms treat the protection of air, water, soil, noise protection, etc., among other things, and power plants. The biggest impact on the environment is the production of secondary energy, especially electricity in the power plants. All problems of environment pollution are also present in the construction of thermal power plants on oil shale, with perhaps greater intensity of pollution due to the quality and composition of oil shale. This paper deals with harmful effect of exploitation and combustion of oil shale on the environment and risk identification of risk in overall utilization of oil shale.

Key words: *oil shale, environmental protection, exploitation, combustion, gasification*

INTRODUCTION

Oil shales are the rock layers, which contain the material that is practically the forerunner of oil. When this material is overheated, mainly kerogen, it could be distilled from rocks in the oil. By enrichment and refining of this distilled liquid material, various kinds of useful fuel could be obtained. Oil shale could be exploited by surface, underground and using the modern methods of underground gasification.

Depending on which technology is in use, the exploitation and combustion of oil shale is associated with large disturbances and risks in the natural habitat, underground and surface sources, air quality and climate. The permanent impacts on topography and flora and fauna are expected as the result of commercial exploitation and processing of oil shale.

In a case of surface exploitation, the used, i.e. processed oil shale (waste) has a great impact on contamination of underground water (have dramatically higher concentration of mineral salt than slate, and may also contain other toxic substances). In a case of underground (in-situ) the exploitation, the process involves a risk on groundwater contamination [3].

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PROTECTION IN THE MINE DESIGNING

In any business, the design process should be carefully considered from the standpoint of environmental protection. In the mine designing for exploitation the oil shale, several items have to be taken into account:

- to carry out the additional researches to environmental protection that will convince the local population to tolerate the exploitation impact of the same,
- the mine have to be located, if possible, away from the settlements,
- in the vicinity of settlements, the blasting works should not be used,
- the mining works must not damage the certain aquifers in order to prevent the water contamination,
- oil shale stocks, breaking and transport unit should preferably be located in the forest to prevent the spread of noise and dust,
- barriers to noise and dust should also be located between the settlements and existence of mine . For such purposes it is even necessary to plant trees.

Important requirements that need to be taken into account during designing are:

- how negative environmental impacts be minimized?
- is it possible to use selective or non-selective method of exploitation?
- which method of exploitation guarantees determination of output results?
- how to reduce the use of certain machines?
- whether to buy or rent a machine? [2]

SOIL POLLUTION IN THE EXPLOITATION

Surface exploitation causes a lot of surface disorders of land and has a high impact on surface water, subsurface water, flora and fauna. Experiences in coal exploitation and other raw materials indicate that the impact on environment is very high but with minimum long-term effect.

Underground exploitation causes much less surface disorders. Surface disorders are limited but include dust emissions caused by transport and storage.

„In-situ" exploitation involves less mining works that are limited to drilling of so called thermal drill holes and production drill holes at a small distance. Impact on the environment will be similar to the production of gas and oil. Drill holes of this type of exploitation require security and sealing.

Other surface effects in most case depend on construction of surface facilities, including equipment for retorting, upgrade, dumping and transportation. New pipelines, roads and related facilities, may also have an impact on surface contamination.

Spent shale: surface retorts produce large quantities of processed or spent oil shale. Technology of retorting seeks to reduce the residual carbon, making the processed shale safer for the environment. Some spent shale could be used as a commercial material for construction or as a material for re-cultivation of the land.

WATER POLLUTANTS

At larger distance from the mining operations or facilities for retorting, the soil and ground water contamination appears. "In-situ" exploitation has high effect on the ground water quality. In these cases, a control and protection of surface and ground water sis required. The efficient technologies and process management have been demonstrated and shown in the other similar cases of commercial mining.

Practically, the "in-situ" exploitation suffers the challenges to protect the ground water on contamination by the kerogene oil and other produced gases and sediments. Promising so called "freeze-wall" technology has been tested to isolate the groundwater from subsurface area where the "in-situ" process is carried out until the postproduction and remediation activities of land is complete. [7]

AIR POLLUTANTS IN THE OIL SHALE COMBUSTION

The main air pollutants in the oil shale combustion are nitrogen oxides, sulfur dioxide, hydrogen chloride and solid particles. The most harmful gas that is emitted CO_2. Air pollutant concentration in the exhaust gases primarily depends on combustion technology and combustion regime, while the emission of solid particles is determined by the efficiency of device for catching the fly ash. Regarding to the emission of air pollutant, oil shale is characterized by low content of nitrogen in organic matter (0.3%), high concentration of organic sulfur (1.6 to 1.8% in a part that is accepted as a fuel), high Ca /S ratio (8-10) and an abundance of carbonate minerals (16-19% mineral CO_2 – in a part that is accepted as a fuel).

NO_x during fuel combustion can be formed in the following ways: in the reaction between the nitrogen and oxygen from the air (thermal NO_x), in the reaction between hydrocarbon radicals and molecular nitrogen (immediate or rapid NO_x) and nitrogen from fuels. The most important parameter that affects the amount of nitrogen oxides in the exhaust gases is oxygen concentration (high air factor).

The main sulfur component in the oil shale is calcium. Therefore, in order to characterize the potential in the process of sulfur capturing, the ratio Ca/S is used. Because oil shale contains the alkaline metals, a part of sulfur is linked with this component, usually in a form of sulfate. However, not all alkali metals present in the fuel converted to sulfate, primarily one part depends on the volatility of alkali metals from mineral matter in the combustion process. Emission of sulfur dioxide and volume of conversion into vapor from this part of combusted sulfur, during combustion of oil shale, depends on many factors.

Carbon dioxide is classified as a greenhouse gas. It is formed in the reactions of combustion the organic carbon and minerals present in the fuel as carbonates. Full conversion of organic carbon in CO_2 is possible only in complete combustion. Release of carbon dioxide from the carbonate mineral, is determined by the behavior of fuel mineral in the combustion process. Combustion technology that is used for fuel burning does not affect significantly the effects and quantity of CO_2 formation from organic. Certainly, the combustion technology has a great impact on emission of CO_2 mineral. Concentration of CO_2 mineral, formed by the carbonate compound, is determined by the conditions of thermal decomposition of minerals and also by direct combustion of gaseous components present in the exhaust gases and minerals that contain CO_2. [4]

EFFECT OF UNDERGROUND GASIFICATION

Care about the environment is one of the most important factors that have to be taken into account when it is accessed to the process of underground gasification (UG) and if its impact on the environment is barely noticeable and very low. The main product of gasification is gas, although some by-products remain under the earth, or used by the conventional processes or injected back into the layer. At the same time there are still some significant impacts that must be taken into account, in particular, the underground and above-ground impact. Basically, hydrological, geological and hydrogeological explorations and their evaluation must be primarily done in accordance with the operations of underground gasification.

UG on the environment could have an impact on:

- Position
- Noise
- Emissions of gases into atmosphere
- Groundwater contamination
- Ground subsidence

Advantages of UG impact on a treatment of layer are:

- The lack of dust on the surface
- Production of pure gas
- The achieved high efficiency in the gas turbines
- The absence of gasifier on the surface

Disadvantages of UG impact on a treatment of layer are:

- Underground contamination
- Surface contamination
- Process pollutants

Subsurface contamination

Groundwater contamination

There are several components linked to the contamination of ground water, importance of these components are monitored and investigated in order to reduce and / or eliminate risks and increase the importance of factors related to contamination. Tests have shown that a small percentage of phenol and benzene were formed as a product of underground gasification process. Higher percentage with produced gas comes to the surface where it is eliminated in the process of purification. Certainly, the rest passes through the surrounding layers or was absorbed by the undistributed layers, and the remaining is retained in the so-called blown out cavities.

Permeability, hydrogeological and geological structure of shale layer will have the greatest impact on dispersing contamination. It is of great importance that the hydrology is completely known, and structure itself will show where the smallest possibility of contamination is.

The project have to exhaust completely the most extensive exploratory works related to the depth of coal layer and monitoring before and after the gasification process in a particular area.

The process products as the result of oil shale combustion could have influence on hydrology and groundwater quality. Some of them are: dust, tar, charcoal, phenols, benzene, methyl benzene, xylene, boron, cyanide and hydrocarbons.

Leakage of gas from the cavities of surrounding layers may be a problem in the process of UG in the shallow layers, i.e. subsurface layers. At the same time, even in the conditions of gasification at great depths, pollutants may reach the surface by the ground water, along the underground fractures of the ground. It is vey important that the target area is as far as possible from the existing mines and to select mines at greater depth. In order to minimize leakage or escape of gas, it is very important to select the areas with low permeability of the layers and control the pressure during the process, to be as much as possible close to the hydrostatic pressure.

Ground subsidence

Ground subsidence usually occurs when you disturb the soil stability is disturbed due to the UP in subsurface layers. This primarily refers to the layers closer to the surface, while in deeper layers the effects are minimal. The fact is that the depth reduces the effects of ground subsidence.

Surface contamination

Gasification plant located on the surface includes: drilling heads, drilling equipment, appropriate piping, processing and injection / gas production plant, etc. Impact on the environment may have the following:

- Waste water created during the gasification
- Waste water created during the underground filtration
- Waste water from the plant for the gas production
- Gas emissions resulting from the production / combustion
- Oil spillage
- Possible waste water as the result of discharges, leakages from joints and cooling
- Possible contamination of solid debris from landfills

In addition, a care must be taken to prevent emissions of CO_2, formed as the result of process, the effect on surface water, the effect on groundwater, sounds (noise) that occur during the process and other effects and adverse impacts to humans and environment.

Gas emission

There are two main factors that affect the gas emissions caused by the surface and subsurface processes. The highest emission of harmful substances created during the gasification process includes:

Gaseous matters:

- Hydrogen, carbon dioxide, carbon monoxide, sulfur, oxygen

Organic matters:

- Essential hydrocarbons: Methane, ethane, ethylene, propane
- Aromatic hydrocarbons: Benzenes, methyl benzene, benzenes, naphthalenes
- Organic acids: Phenols, alkyl phenols, naphthol, alkyl naphthol
- Organic bases: Pyridine, methyl pyridine, aniline, indolyne, kinolyne, isokinolyne
- Saturated / Cyclic hydrocarbons: N - Alkali, cyclic alkali
- Unsaturated hydrocarbons: Olefins

Inorganic matters:

- Boron, fluoride, bromide, chloride, selika, lithium, sulfate, manganese, ammonia, sodium, sulfide, iron, calcium, cyanide, barium, potassium, magnesium.

Influence on:

- Air quality
- Ozone layer
- Greenhouse

The majority of pollutants created during the process are annulated in the process. During generator operation, the traces of SO_2 and NO_x, are discharged into the atmosphere, and CO_2 remains sequestered. Sequestration of CO_2 includes the elimination of CO_2 and partly its injection back under high pressure.

The main problem of pollution the surface water during the process of PG is pumping without proper filtering processes into the river system, natural resources and spilling during the process and drilling. Towards the control of waste water, adequate measures must be implemented, also in the process.

The influence of the underground gasification process to humans is minimal. The main factors are the increase in noise, dust and pollution of drinking water. [1]

CONCLUSION

Environmental protection at today level of development, both in developed and in developing countries, has become necessary because, due to intensive energy development, the impacts on it are more and more complex. The problem is particularly complex because a compromise must be achieved between the energy policy and environmental policy due to a fact that practically all energy sources and systems have a greater or less impact on the environment.

From all the above, the followings could be made:

- Energy production from oil shale is a very intensive process. By some estimates, an investment of energy in the production of oil from oil shale is almost as large as the yield.
- Energy production from oil shale causes more greenhouse gas than conventional gas production. These air pollutants like sulfur dioxide, nitrogen oxides and fine particles are associated with higher incidence of respiratory diseases, including asthma, emphysema, and reduce lung capacity.
- This type of production uses between 3 and 5 barrels of water for every barrel of produced oil. Analysis of water amount needed for treatment of oil shale must be taken into account for currently and expected needs for water.
- Not enough is known about how to prevent contamination of water from the surface and "in-situ" operations.
- Extraction could have long-term ecological effects, including the impaired area where the mining is carried out and the area of spent oil shale waste dumps. [5]

The modern projects of utilization the oil shale will include a variety of control and approvals of the project feasibility study and economic evaluation. Environmental characteristics of specific technologies will have to be evaluated on the basis of environmental regulations for each country.

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TERMOMINERALNE VODE BANJSKE, POTENCIJALNOST, KVALITET, MOGUĆNOST KORIŠĆENJA

Izvod

U ovom radu prezentovani su rezultati dosadašnjih saznanja o termomineralnim vodama Banjske u smislu uslova formiranja, geneze, ocene potencijalnosti, kvaliteta i mogućnosti iskorišćavanja. U cilju objašnjenja određenih karakteristika termomineralnih voda izvedena su i neophodna terenska, pre svega geološka i hidrogeološka istraživanja kao i laboratorijska istraživanja. Značaj istraživačkog procesa se ogleda u praktičnoj primeni, što su rezultati istraživanja i pokazali.Termomineralne vode Banjske oslikavaju uslove nastanka i nalaze primenu, kao lekovite vode, za ekološku i profitabilnu poljoprivrednu proizvodnju i u industriji.

Ključne reči: *termomineralna voda, uslovi formiranja, fizičko-hemijske karakteristike, balneološke karakteristike, mogućnosti korišćenja.*

UVOD

Termomineralne vode Banjske su posledica brojnih tektonskih i vulkanskih aktivnosti u prošlosti. Zahvaljujući svojoj toploti i lekovitosti vode Banjske su korišćene još za vreme vladavine kralja Stefana Uroša II Milutina, našta ukazuju arheološka istraživanja grada kralja Milutina u Banjskoj. Cilj ovog rada je da se da sinteza dosadašnjih saznanja, kao i saznanja proistekla novim, geološkim, hidrogeološkim i laboratorijskim istraživanjima (fizičko-hemijske analize, balneološke analize i dr.), u smislu ocene potencijalnosti, geneze, kvaliteta i mogućnosti korišćenja termomineralnih voda.

Selo Banjska se nalazi na dvanaestom kilometru severozapadno od Kosovske Mitrovice, na jugoistočnim padinama Rogozne (1.504 m), na 533 m nadmorske visine. Organizovano korišćenje termomineralnih voda u balneoterapeutske svrhe započeto je nakon drugog svetskog rata. Do pre desetak godina banja je predstavljala poznato lečilište na ovim prostorima, gde je boravilo i do 5.000 gostiju. O izgledu banje brinuo je RMHK „Trepča” u čijem sastavu se nalazi. Stagnacijom rada RMHK „Trepča” banja se postepeno zapostavljala i sada je gotovo napuštena, skoro bez korisnika.

GEOLOŠKI SASTAV I TEKTONSKI SKLOP ŠIRE OKOLINE BANJSKE

Kada se opisuju kartirane jedinice izdvojene na Rogozni, posebna pažnja posvećuje se onim jedinicama koje su značajne za olovo-cinkovo orudnjenje. To su tvorevine višefaznog tercijarnog magma-

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tizma. Pretercijarne tvorevine se mogu grupisati kao litostratigrafske celine: metamorfiti paleozoika, permotrijaske i trijaske tvorevine, dijabaz-rožnačka formacija, ultrabaziti i senonski sedimenti. Podaci o jedinicama prikupljeni su iz literature. Najviše je korišćen tumač za osnovnu geološku kartu list Novi Pazar 1:100 000 [10].

Metamorfiti paleozoika obuhvataju tvorevine starijeg paleozoika (tzv. "serija Rogozne") i mlađepaleozojske metamorfite. Serija Rogozne je predstavljena amfibolskim, amfibolitskim, muskovitskim i sericit-hloritskim škriljcima, kvarcitima, kristalastim krečnjacima, metamorfisanim dijabazima, gnajsevima, leptinolitima i biotitskim škriljcima. Metamorfiti mlađeg paleozoika su predstavljeni stenama nižeg stepena metamorfizma: filitima, metamorfisanim peščarima i krečnjacima i albit-hloritskim škriljcima. Permotrijaske tvorevine su diskordantne preko mlađepaleozojskih metamorfita a čine ih klastiti, pre svega kvarcni peščari, zatim kvarcni konglomerati i kvarcne breče, u karakteristično brzom smenjivanju. Donji i srednji trijas Banjske reke čine laporovito-peskoviti, laporoviti i masivni krečnjaci. Starost dijabaz-rožnjačke formacije je određena kao gornjojurska (oksford-kimeridž). Magmatiti su predstavljeni produktima gabroidne magme: dijabazima, spilitima, bazaltima, gabrovima i raznim prelaznim stenama. Od sedimenata zastupljene su breče, veoma često peščari, glinci, rožnaci, laporci, laporoviti krečnjaci i glineni škriljci. Kompleks ultrabazičnih stena čine harcburgiti, a znatno manje učešće imaju duniti, dijalagati i serpentiniti. Po mišljenju M. Uroševića i dr. (1973) ove stene predstvaljaju tvorevine inicijalnog magmatizma paleozojske geosinklinale. Prema novim shvatanjima ove stene su jurske starosti. U bazi flišnih sedimenata senona uglavnom su bazalne breče i konglomerati, masivni sprudni krečnjaci, laporoviti krečnjaci i laporci preko kojih su razvijeni pravi flišni sedimenti koji se mogu rasčlaniti na dva paketa. Niži paket karakterišu laporovito-peskoviti sedimenti sa retkim mikrokonglomeratima. Gornji paket predstavljen je bankovitim peščarima, u bancima debelim i do deset metara. Između banaka peščara mestimično sreću se tanki slojevi glinaca, laporaca i pelitomorfnih krečnjaka.

U toku tercijera Rogozna je zahvaćena intenzivnom magmatskom aktivnišću, koji se odvijao u tri međusobno jasno odvojene faze. Prema mineralnom sastavu vulkaniti prve faze odgovaraju uglavnom dacito-andenzitima. Retki su tipski daciti i kvarclatiti. Piroklastiti imaju malo rasprostranjenje, a po sasatvu su vulkanski konglomerati, tufovi i vulkanski peliti. Vulkaniti druge faze su predstavljeni kvarclatitima i latitima.Kvarclatitske mase predstavljaju uglavnom ispunjena grotla ili dovodne kanale vulkana, odnosno veoma plitke intruzije žičnog ili nepravilnog oblika. Piroklastiti druge vulkanske faze imaju karakterističnu građu: tufovi, tufiti i konglomeatične stene su u najnižim horizontima, a u višim su zastupljeni veoma debeli paketi (oko 350 m) vulkanskih konglomerata, tufova, vulkanskih breča u slabije ili jače stopljenim piroklastitima ignimbritskog karaktera. Vulkaniti teće faze predstavljeni su andezitbazaltima i trahibazaltima. Piroklastiti čine aglomerati bogati fragmentima starijih magmatskih stena. U njima su veoma česti i odlomci andezitbazalta i trahibazalta.

Od neogenih sedimenata razvijene su miocenske tvorevine i predstavljene su peskovitim glinama, glincima, laporcima i peščarima. Kvartarne tvorevine su predstavljene sedimentima rečnih terasa i aluvijonima kao i deluvijalnim naslagama i siparima.

Na Rogozni su izdvojene sledeće geotektonske jedinice: Drinsko-ivanjički element i Vardarska zona (eksterna subzona).

Drinsko-ivanjički element, naziv geotektonske jedinice je po M. Dimitrijeviću i M. Dimitrijević (1973), na osnovu čijih istraživanja i predstavlja eksternu jedinicu Dinarida prema Zvorni-čkom okeanu. Ova geotektonska zona prema severoistoku se graniči sa eksternom Vardarskom podzonom.

U Drinsko-ivanjičkom elementu, od nabornih struktura izdvajaju se Ibarska sinklinala i Kozarevačka antiklinala. Regionalno posmatrano Ibarska sinklinala je krajnji jugoistočni deo Novopazarskog sinklinorijuma, koji se od Novog Pazara preko Rogozne pruža na jug do Ibra i Kosovske Mitrovice. Predstavlja prostranu negativnu plikativnu strukturu. To je deformisana antiformna struktura sa osom pravca severozapad-jugoistok čije zapadno krilo leži preko istočnog krila Ibarske sinklinale.

Od razlomnih struktura, u ovoj zoni se ističu, nekoliko krupnih raseda; Kozarevački rased pravca pružanja, severozapad-jugoistok, predstavlja labilnu zonu u kojoj su pokreti vršeni tokom mezozojika i tercijera. To je deo Zvorni-čkog šava na kome su izbile velike mase ofiolita i miocenskih vulkanita, dok je u toku donjeg senona došlo do stvaranja melanža [1]. Čičavački dijagonalni rased, pravca pružanja severozapad-jugoistok, prolazi istočnim obodom planine Čičavice i dalje prema severozapadu do Banjske, gde se spaja sa Sitničkom dislokacijom i zajedno produžavaju u pravcu Leskove glave. Termalne vode u Banjskoj i Joševiku nalaze se na čičavičkom rasedu.

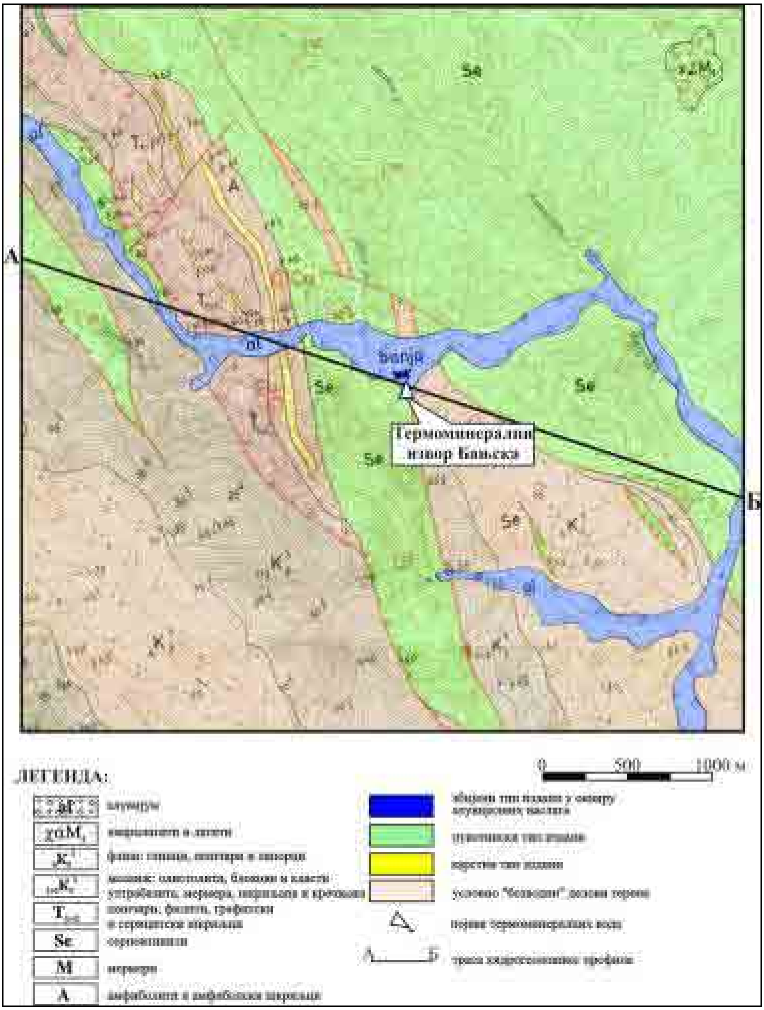
Vardarska zona predstavlja složenu strukturnu jedinicu koja se prema istoku graniči sa Srpsko-makedonskom masom, a na zapadu sa Drinsko-ivanjičkim elementom. Čini veoma značajno strukturno područje kontinentalnih elemenata na Balkanu. Savremena istraživanja su ukazala ispravnost zadržavanja podele na eksternu, centralnu i internu podzonu, koje se međusobno bitno razlikuju [1]. Eksterna vardarska podzona, je složene građe. Proteže se od Zvorničkog šava do poteza Beograd-Topola-Vrnjačka Banja-Podujevo-Gnilane-Nikuštak. Podeljena je na više blokova. U toku geološke istorije u opi-sanim geotektonskim jedinicama, dolazilo je do strukturnih deformacija stenskih masa usled snažnih bočnih potisaka. Potisci su prouzrokovali razlamanja i nastanak raseda, kuda su se termomineralne vode kretale ka površini terena.

USLOVI FORMIRANJA, POTENCIJALNOST I GENEZA TERMOMINERALNIH VODA BANJSKE

Uslovi formiranja termomineralnih voda dovode se u vezu sa tektomagma-tizmom Rogozne. Evolutivni razvoj planine karakterišu tektomagmatski procesi koji svojim produktima beleže pojedine faze razvića mezozojika i kenozojika. Magmatizam u trijasu i gornjoj kredi reprezentuju serpentinisani peridotiti, dijabazi sa efuzivnim ekvivalentima i gabro stene.U hronologiji tektomagmatizma najstarije i najrasprostranjenije magmatske stene su peridotiti. Po mineraloškom sastavu odgovaraju harcburgitskom tipu uz minimalno učešće ekvivalenata- lerzolita, dunita i dr. Karakteristika ovih stena je serpentinizacija-serpentinisani peridotiti i serpe-ntiniti. Hidrotermalnim procesima tercija-rnog magmatizma nastaju magnezitske žilice i žice. Procesi raspadanja su izraženi u serpentinitima (nontroniti, žični magnezit). Tercijarni magmatizam označava granitske intruzive praćene vulkanizmom u više sekvenci, kada se stvaraju vulkaniti (dacito-andenziti, kvarclatiti, piroksensko-amfibolitski andenziti, tufovi i konglomerati). U opisanim stenama, pojavljaju se termomineralne vode [5].

Rezervoar termomineralnih voda čini kompleks karbonatnih mezozojskih i paleozojskih stena. Najverovatnije se radi o trijaskim krečnjacima, s obzirom da su bili kratko izloženi eroziji tokom jure i donje krede. Vode u rezervoaru potiču iz perioda semiaridne klime (20000 god.) i imaju temperaturu oko 120^0C [3].

Termomineralni izvori Banjske nalaze se na posedu manastira Sv. Sava, na jugoistočnim padinama Rogozne. Pojave termominralnih voda u Banjskoj u neposrednoj su vezi sa rasednom strukturom, tako da se pojavljuju na kontaktu serpentinita i krednog fliša (slika 1). U selu su konstatovana ukupno 4 izvora, od kojih su 3 kaptirana. Dva su u samom selu, izdašnosti Q_1 =1 l/sec, Q_2 = 0.51 l/sec (dvorišta privatnih kuća), treći u banjskom bazenu izdašnosti Q_3 =1 l/sec, i četvrti kod manastira Sv. Sava koji se nalazi na bigrenoj terasi, izdašnosti Q_4=5 l/sec. Debljina bigrene terase je >20m. Nastala je izdvajanjem kalcijum – karbonata iz vode termomineralnog izvora kod manastira, na osnovu čega se tumači geneza termomineralnih voda. U samoj zoni Banjske izdvojene su pojave mermera i mermerisanih krečnjaka na površini terena. Termomineralne vode nastaju u okviru ovih stena. Serpentiniti predstavljaju tranzitnu zonu i utiču na hemijski sastav. Zagrevanje vode je u neposrednoj vezi sa tercijarnim vulkanizmom [5].



Sl. 1. *Hidrogeološka karta zone pojavljivanja termominerlanih voda Banjska (G. Milentijević, 2005.)*

Osmatrani režim izdašnosti i temperature vode u periodu avgust-novembar 2008. godine u bazenu lečilišta je stabilan, našta ukazuje duboka sifonalna cirkulacija termomineralnih voda. Izdašnost se veoma malo menjala, u garnicama 0,8-1,2 l/sec. Temperatura vode je 40,5 ^{o}C [6].

KVALITET TERMOMINERALNIH VODA BANJSKE

Termomineralne vode Banjske su već 100 godina predmet detaljnog interesovanja onih koji je hemijski mogu analizirati i na osnovu toga utvrđivati njena osnovna balneološka svojstva.

Prema rezultatima hemijske analize J. Rešovske i V. Nikolajevića (1921), glavni sastavni je deo kalcijum bikarbonat, količina slobodne ugljene kiseline nije određena. Spada dakle u red indiferen-tnih hiperterma sa karakterom slabo alkalno kiselih voda [2].

Prema rezultatima hemijske analize B.Vajića (1929), ova voda je karbonatna, (alkalna, alkalno-zemna), murijatična, sulfatična, topla 43-47^{0}C [7].

Prema rezultatima hemijske analize V. Protića (1995), termomineralne vode su HCO_3-Na tipa, ukupne mineralizacije 1,36 g/l, pH-6,7. Sadžaj HCO_3 je 806,00 mg/l a Na je 300,00 mg/l. Sadržaj radioaktivnih elemenata je nizak: Rn-3,7 Bq/l, Ra-0,17 Bq/l, U-0,0016 mg/l [9].

Na osnovu pregleda osnovnih karakteristika mineralnih voda reona Šumadijskokopaoničko-kosovske oblasti, termomineralne vode Banjske imaju sledeću formulu hemijskog sastava [11] :

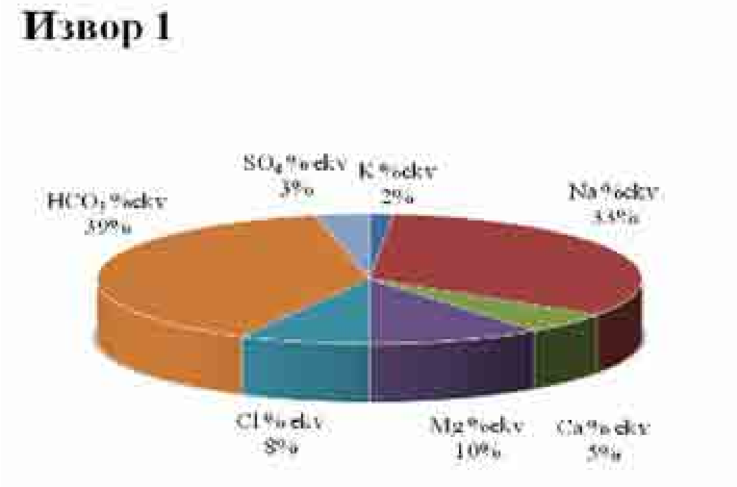
$$M_{1.36}\frac{HCO_{74}^{3}Cl_{16}}{Na+K_{70}Mg_{13}Ca_{11}}\quad Q>2.5$$

Institut za rehabilitaciju, Beograd, uradio je detaljna ispitivanja termomi-neralnih voda Banjske i za sva četiri izvora (izvor 1- voda koja dolazi u bazen; izvor 2- voda kod manastira Sv. Sava; izvor 3- voda iz dvorišta R. Milosavljevića; izvor 4- voda iz dvorišta U. Radosavljevića) konstatovao karaktereistike, koje su date u tabeli 1. [12]

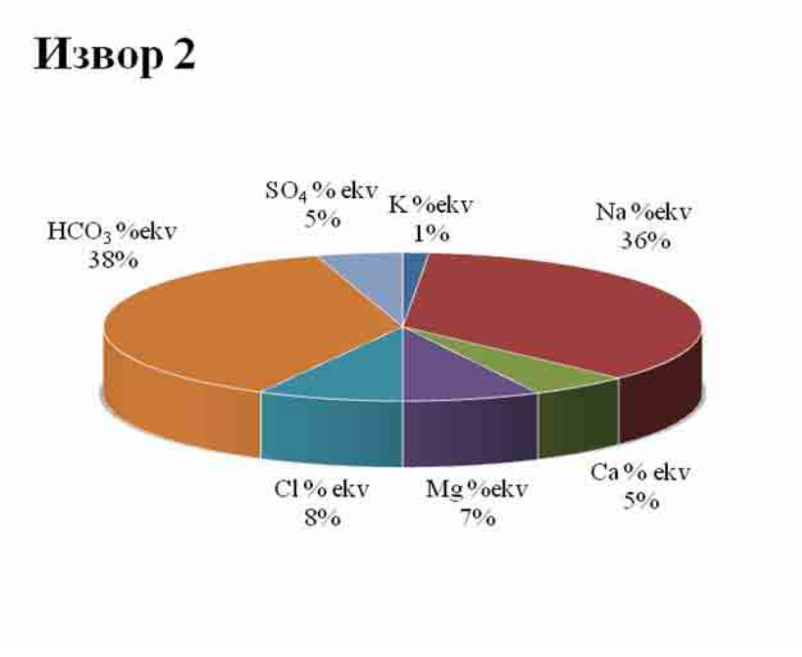
Tabela 1. *Fizičko-hemijske karakteristike termomineralnih voda Banjske (Institut za rehabilitaciju, Beograd, 1994. godine)*

Fizičko-hemijske karakteristike	Izvor			
	1	2	3	4
Temperatura, ^{0}C	40,1	58,1	28,3	38,4
pH	7,1	7,2	7,4	7,3
Ukupna mineralizacija, (mg/l)	1380	1090	1560	1390
Katjoni				
Kalcijum	33,8	37,8	46,5	38,5
Magnezijum	39,6	31,8	40,9	40,6
Natrijum	238,7	288,7	276,0	238,7
Kalijum	17,1	19,5	19,3	16,8
Anjoni				
Hidrokarbonati	774,7	817,4	884,5	762,5
Hloridi	89,5	99,4	94,4	89,5
Sulfati	50,4	80,1	71,6	71,4
Nitrati	4,7	4,3	4,2	5,1

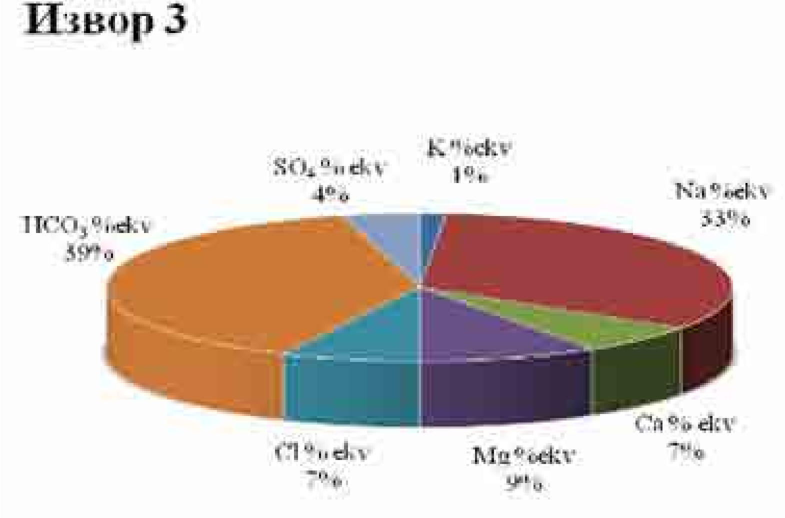
Za potrebe izrade ovog rada, hemijski sastav termomineralnih voda Banjske predstavljen je i na kružnim dijagramima (slike 2, 3, 4 i 5)



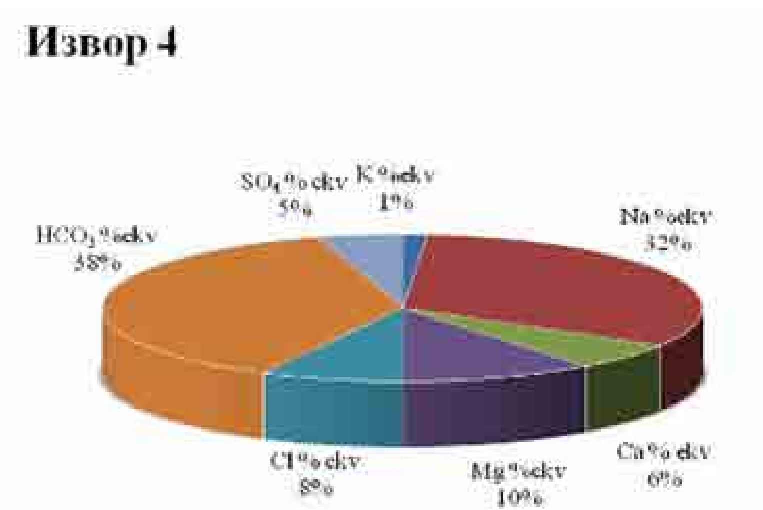
Sl. 2. *Kružni dijagram hemijskog sastava, izvor 1-voda koja dolazi u bazen*



Sl. 3. *Kružni dijagram hemijskog sastava, izvor 2- voda kod manastira Sv. Sava*



Sl. 4. *Kružni dijagram hemijskog sastava, izvor 3- voda iz dvorišta R. Milosavljevića*



Sl. 5. *Kružni dijagram hemijskog sastava, izvor 4- voda iz dvorišta U. Radosavljevića*

U sklopu istraživačkog projekta Hidrogeološka istraživanja mineralnih i termomineralnih voda severnog dela Kosova i Metohije, koji je finansirlo Ministarstvo za zaštitu životne sredine i prostornog planiranja, uzet je uzorak termomineralnih voda iz izvora u banjskom kupatilu prvenstveno sa gledišta njihovog iskorišćavanja u različite svrhe. Ove vode ispitivane su u laboratorijama Instituta za javno zdravlje "dr Milan Jovanović-Batut", Beograd, čiji rezultati su prikazani u tabeli 2.

Tabela 2. *Fizičko-hemijske karakteristike termomineralnih voda Banjske (Institut za javno zdravlje "dr Milan Jovanović-Batut", Beograd, 2008.godine)*

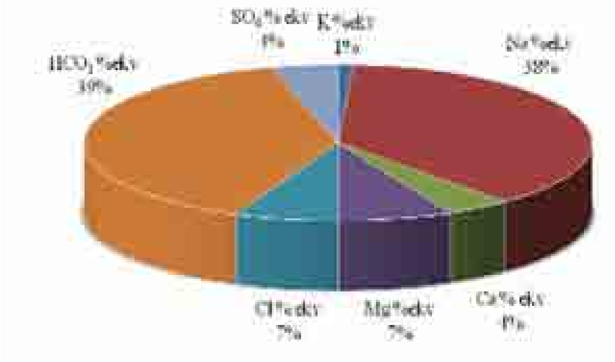
Redni boj	**Osnovne fizičko-hemijske veličine**	**Sadržaj**	**Oznaka metode**
1.	Temperatura (^{0}C)	40,5± 0,1	UP-501
2.	pH	7,0± 0,1	UP-503
3.	Boja (stepeni Pt-Co skale)	<5,0	UP-536#
4.	Elektroprovodljivost (μS/cm)	1200,0±100	UP-507
5.	Ukupna tvroća (^{0}dH)	12,0±0,4	UP-510
6.	Utrošak $KMnO_4$ (mg/l)	1,9±0,2	UP-506
	Rastvoreni gasovi (mg/l)		
1.	Kiseonik (O_2)	3,5±0,5	UP-508
2.	Ugljen-dioksid (CO_2)	176,0	UP-529#
	Makrokomponente		
	Katjoni	Sadržaj(mg/l)	Oznaka metode
1.	Kalcijum (Ca^{++})	31,00	UP-916#
2.	Natrijum (Na^+)	326,00	UP-916#
3.	Kalijum (Ka^+)	14,40	UP-917#
4.	Magnezijum (Mg^{++})	33,40	UP-917#
	Anjoni		
1.	Hloridi (Cl^-)	75,00±5	UP-521
2.	Sulfati (SO_4^{--})	65,00±5	UP-521
3.	Hidrokarbonati (HCO_3^-)	770,00±20	UP-509
4.	Nitrati (NO_3^-)	<0,5	UP-521

	Mikrokomponente		
		Sadržaj (mg/l)	Oznaka metode
1.	Bor (B)	2,36	UP-910
2.	Litijum (Li)	0,20	UP-910
3.	Stroncijum (Sr)	0,89	UP-910
4.	Gvožđe (Fe)	33,40	UP-907
5.	Mangan (Mn)	0,021± 0,003	UP-543#
6.	Aluminijum (Al)	<0,05	UP-543#
7.	Cink (Zn)	0,051± 0,003	UP-903
8.	Bakar (Cu)	<0,010	UP-902
9.	Barijum (Ba)	0,150	UP-910
10.	Arsen (As)	<0,004	UP-908
11.	Hrom (Cr)	<0,001	UP-905
12.	Olovo (Pb)	<0,010	UP-901
13.	Selen (Se)	<0,003	UP-914#
14.	Kadmijum (Cd)	0,0014±0,00005	UP-906

15.	Nikl (Ni)	0,012±0,00500	UP-919
16.	Živa (Hg)	<0,001	UP-909
17.	Antimon (Sb)	<0,003	UP-922#
18.	Amonijak (NH_4^+)	0,060	UP-511
19.	Nitriti (NO_2^-)	<0,005	UP-523
20.	Silikati (SiO_2)	52± 1	UP-520
21.	Fluoridi (F^-)	1,9± 0,1	UP-521
22.	Bromidi (Br^-)	2,0	UP-521

	Specifični pokazatelji		
		Sadržaj (mg/l)	Oznaka metode
1.	Cijanidi	<0,01	UP-512
2.	Fenoli	<0,001	UP-532#
3.	Deterdženti, anjonski	<0,01	UP-531#
4.	Ukupne masti i ulja	<0,01	UP-522
5.	Mineralna ulja	<0,01	UP-518
	Sadržaj organohlornih insekticida		
		Sadržaj (µg/l)	Oznaka metode
1.	Heksahlorbenzol (HCB)	<0,01	UP-801
2.	Aldrin /Dieldrin	<0,01	UP-801
3.	DDT	<0,01	UP-801
4.	Heptahlor/Heptahlor-epoksid	<0,01	UP-801
5.	Lindan	<0,01	UP-801
	Policiklični aromatični ugljovodonici (PAH)		
		Sadržaj (µg/l)	Oznaka metode
1.	Ukupni	<0,20	UP-801
2.	Benzoa(A)piren	<0,01	UP-801
	Aromatični ugljovodonici		
		Sadržaj (µg/l)	Oznaka metode
	Benzen	<1	UP-803
	Toulen	<7	UP-803
	Etilbenzen	<2	UP-803
	Ksileni	<5	UP-803
	PCB_s – Polihlorovani bifenili		
		Sadržaj (µg/l)	Oznaka metode
1.	Indetifikovani kao PCB mix 525	<0,5	UP-801

Za potrebe izrade ovog rada, hemijski sastav termomineralnih voda Banjske (uzorak vode iz bazena banje) predstavljen je i na kružnom dijagramu (slika 6)



Sl. 6. *Kružni dijagram hemijskog sastava termomineralnih voda Banjske, uzorak vode iz bazena banje*

Na osnovu tabelarnog prikaza fizičko-hemijskih karakteristika termomineralnih voda Banjske (tabela 1 i tabela 2) i na osnovu grafičkog prikaza hemijskog sastava istih (slike 2, 3, 4, 5 i 6) može se reći da one pripadaju istom tipu vode. Na osnovu dobijenih rezultata može se reći da od katjona dominira sadržaj natrijuma, ali je i visok sadržaj magnezijuma i kalcijuma. Od anjona, najviše ima hidrokarbonata, zatim hlorida, a ukupan sadržaj anjona oko tri puta je veći od sadržaja katjona. Ispitivane vode ulaze u kategoriju natrijum, kalcijum, magnezijum hidrokarbonatnih ugljenohidrokarbonatnih hipertermalnih mineralnih voda [6] . Na osnovu fizičko-hemijskih analiza termomineralnih voda Banjske, dato je i balneološko mišljenje o njenoj lekovitosti.

Merenja radioaktivnosti u uzorku termomineralne vode obavljena su u Institutu za medicinu rada i radiološku zaštitu „dr Dragomir Karajović”, u Beogradu čiji rezultati su dati u tabeli 3.

Tabela 3. *Tabelarni prikaz rezultata gamaspektrometrijske analize, (Institut za medicinu rada i radiološku zaštitu „dr Dragomir Karajović”, Beogradu 2008 godine):*

Vrsta uzorka	^{137}Cs (Bq/l)	^{134}Cs (Bq/l)	^{40}K (Bq/l)	^{232}Th (Bq/l)	^{238}U (Bq/l)	^{226}Ra (Bq/l)
Banja Banjska	**< 0.007**	**< 0.003**	**0.60 ± 0.04**	**< 0.02**	**< 0.10**	**< 0.03**

Rezultati gamaspektrometrijske analize vode (specifična aktivnost) ukazuje da su analizirane vode u skladu sa propisima za vode za piće (shodno propisima S. L. SRJ br. 9/1999).

KORIŠĆENJE TERMOMINERALNIH VODA BANJSKE

Mogućnosti korišćenja termomineralnh voda Banjske su: balneotrapija, sport i rekreacija, kao grejni fluid, kao energent i dr.

Termomineralne vode Banjske pružaju brojne mogućnosti za razvoj i unapređenje balneoterapijskih i sportsko-rekreativnih aktivnosti. Početak korišćenja termomineralnih voda vezuje se za srednji vek. Arheološkim istraživanjima grada kralja Milutina u Banjskoj otkrivena su banjska kupatila čime se i potvrđuje da su u to doba korišćene termomineralne vode. Noviji kaptažni radovi izvršeni su od 1954 do 1956. godine, kojim je izdašnost važnijih izvora povećana od 1,75 na 4,9 l/s vode, a donekle i temperatura.

U sklopu istraživačkog projekta Hidrogeološka istraživanja mineralnih i termomineralnih voda severnog dela Kosova i Metohije,koji je finansiralo Ministarstvo za zaštitu životne sredine i prostornog planiranja, na osnovu fizičko – hemijskih analiza prof dr T. Jovanović je dao balneološko mišljenje za termomineralne vode Banjske: U balneoterapiji vode se mogu koristiti kupanjem na odgovarajućoj temperaturi i kao dopunsko sedstvo lečenja hroničnih oboljenja (stanjima zglobnog i vanzglobnog reumatizma, rehabilitaciji posle hiruških intervencija na koštano zglobnom sistemu ne malignog porekla, postreumatskim stanjima, rehabilitaciji povreda perifernih nerava i kičmene moždine, sportskih i rekreativnih povreda lokomotornog sistema, u situacijama gde su korisnici terapijskih procedura za navedena stanja deca pre puberteta nužno je u terapijsku proceduru svesti temperaturu vode na temperaturu njihove životne dobi, u terapiji urogenitalnih poremećaja ženske populacije u gernminativnom periodu) i pijenjem u posebnim indikacijama hipermortiliteta gastro interstinalnog trakta i hepatobilijarnog sistema pod posebnom kontrolom stručnog medicinskog kadra na izvornoj ili na tempeaturi ne ispod 32^0C. Na taj način bi se afirmisao turizam a selo Banjska, sa odgovarajućim ambijentalnim vrednostima šire okoline i spomenicima kulture razvio u banjski centar [6].

Hidrogeotermalna energija omogućava intenzivnu proizvodnju hrane kada se postižu ekonomski, kvalitativni i ekološki efekti. Geotermalna energija, po jedinici proizvedene toplotne energije, jeftinija je od svih drugih energenata. Korišćenjem hidrogeotermalne energije moguće je u plastenicima i staklenicima za gajenje povrća i cveća, rasada i baštinskih sadnica.

Prema uobičajenim standardima, za gajenje plastenika pokrivenog polietilenskom folijom, potrebno je oko 200 kJ/h, odnosno, za grejanje plastenika dužine 30 m, širine 4 m i prosečne visine 3 m, potrebno je [8]:

$$30 \times 4 \times 3 \times 200 = 72.000 \text{ kJ/h}$$

Kvalitativni i ekološki efekti korišćenja termalnih voda odnose se na obogaćenost poljoprivrednih proizvoda mineralnim materijama što je istovrmeno preduslov ostvarivanja ekoloških ciljeva tj. proizvodnje zdrave hrane. Zalivanje useva termomineralnom vodom sve je prisutnije u proizvodnji hrane koja ima visoko energetske zahteve. Najveći deo obradivog zemljišta siromašan je u esencijalnim mikroelementima i drugim mineralnim materijama i hranljivim sastojcima. Oni se nalaze u dubljim termalnim vodama, u rastvore-nom i jonskom obliku (najpovoljniji oblik), pa ih biljke i životinje mogu koristiti [4].

Širok je spektar mogućnosti korišćenja termalnih voda u industriji (sušenje, isparavanje, destilacija, hlađenje, pečenje, ekstrakcija, pranje i bojenje, procesno zagrevanje i gajenje industrijskih postrojenja). Korišćenje hidrogeotermalne energije za toplifikaciju još uvek je u početnim fazama i skromno u odnosu na raspoložive resurse.

ZAKLJUČAK

Banjska ima dugu tradiciju korišćenja termomineralnih voda (zanemarujući stagnaciju razvoja poslednjih deset godina), a i mogućnosti eksploatacije hidrotermalnih resursa su realne. Lekovitost termomineralnih voda su dokazane izradom balneološke analize, te se one mogu koristiti kao pomoćno sredstvo u lečenju različitih oboljenja kod čoveka kupanjem i pijenjem. Potencijalnost, kvalitet i kulturno-istorijsko nasleđe čini Banjsku interesantnim za proučavanja u smislu razvoja banjskog turizma, višenamenskog korišćenja za ekološku i profitabilnu poljoprivrednu proizvodnju i u industriji. Zaštita i racionalno korišćenje termomineralnih voda, trebaju biti primarna opredeljenja banjskog centra.

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THERMO-MINERAL WATERS OF BANJSKA, POTENTIALITY, QUALITY, USAGE POSSIBILITIES

Abstract

In this paper there are presented the results of study of thermo-mineral waters of Banjska, referring to the formation conditions, genesis, potentiality assessment and exploitation possibilities. For the explanation of certain characteristics of thermo-mineral waters there were performed the necessary filed investigations, first of all geological and hydro-geological investigations, as well as laboratory research. The significance of this research process is showed in the practice, and proved by the research results. Thermo-mineral waters of Banjska reflect the genesis conditions and could be applied as medical waters, for the ecological and profitable agriculture production and in industry.
Key words: *thermo-mineral waters, formation conditions, physical-chemical characteristics, balneology characteristics, usage possibility*

INTRODUCTION

Thermo mineral springs of Banjska are formed as a consequence of numerous tectonic and volcaneous activities in the past. Thanks to its thermal and medical properties, the waters of Banjska were used even during the reign of the King Stefan Uros II Milutin. That was proved by the archeological explorations of the King Milutin city Banjska. The purpose of this paper is to synthetyse the known information and results obtained by new geology, hydrogeology and laboratory investigations (physical chemical analyses, balneology analysis etc.) for the estimation of potentiality, genesis, quality and possibility of use the thermo mineral waters.

Banjska village is situated on 12th kilometer on the north west of Kosovska Mitrovica, on the southeastern slopes of Rogozna (1 504 m), at the altitude of 533 m. The organized usage of the thermo mineral waters for the balneology purposes started after the II World War. Until the last decade, the spa was well known medical resort in this region, where some 5 000 guests used the benefits of the thermo mineral water. The Mining, Metallurgy and Chemical Company Trepca was taking care about the Banjska Spa, as its asset. By the stagnation of Trepca development, the spa was left with no maintenance and almost deserted, with no beneficiaries.

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GEOLOGY COMPOSITION AND TECTONIC SYSTEM OF THE WIDER SURROUNDING OF BANJSKA

When describing mapping units allocated to Rogozna, special attention is given to those units that are important for lead-zinc mineraliztion. These are the creations multi phase tertiary magmatism. Pre Tertiarry structures can be grouped as lithostratigraphic units: metamorphite Paleozoic, and permo-Triassic creation, Diabase-hornstone formations ultra-basic rocks and Senonian sediments.

The data on these units were collected from the literature. Most of the interpreters used basic geological map sheet Novi Pazar 1:100 000 [12].

Metamorphite Paleozoic structures include Old Paleozoic (so-called „series Rogozna") and Late Paleozoic Metamorphite. The series Rogozna is present by amphibole, amphibolite, muscovite and sericite-chlorite schists, quartzite, crystalline limestone, metamorphosed diabase, gneiss, lepidolite and biotite shale. Metamorphite of Late Paleozoic rocks are represented by a lower degree of metamorphism: phyllite, metamorphosed sandstone, limestone and albite-chlorite shale. Permo-Triassis creations are discordance over Late Paleozoic metamorphite and are consisted by clastic, mainly quartz sandstones, quartz conglomerates and breccias, in a characteristic rapid removal. Lower and Middle Triassic of Banjska river are consisted by marled-sandy, marled and massive limestone. Age of the diabase-hornstone formation was determined as Upper Jurassic (Oxford-Kimmeridgian). Magmatites are presented by the products of Gabbro magma: Diabase, spilite, basalt, Gabbro and various transitional rocks. Since the sediments are represented by breccias, sandstones often, slates, hornstone, marl, marled limestone and clay shale. The complex consists of ultrabasic rocks harzburgite, much less share a dunite, diallage and serpentinite. By the opinion of M. Urosevic and others. (1973) these rocks represent the products of initial magmatism of Paleozoic Geosyncline. Under the new understanding, these rocks are of Jurassic period. In base of Senonian flysch sediments there are mostly basal breccias and conglomerates, massive reef limestone, marled limestone and marl where real flysch sediments were developed which can be divided in two packages. Lower package is characterized bythe marled-sandy sediments with rare micro-conglomerates. The upper package is presented by sandstone stratified in thick beds, up to ten meters. Between the sandstone banks there are periodically thin layers of slates, Marl and pelite-morphite limestone.

During the Tertiary Rogozna is affected by intense igneous activity, which took place in three clearly divided phases. According to the mineral composition of volcanic rocks of the first phase correspond mainly to dacite-andesite. Only a few of them are typical dacite and quartzlatite. Pyroclastic rocks have little distribution, and they are volcanic conglomerates, tuffs and volcanic pelite . Volcanic rocks of the second phase are presented by quartzlatite and latite. Quartzlatite masses are mostly filled holes of volcano or volcano feeder channels, or a shallow intrusion of wired or irregular shapes. The second phase of volcanic pyroclastic rocks are with characteristic composition: tuffs, tuffite and conglomerate rocks are in the lowest horizons, and higher packages, which are very thick (350 m) are characterized by volcanic conglomerates, tuffs, volcanic breccia in weaker or stronger fused pyroclastic rocks of ignimbrite character. Volcanic rocks of the third phase are presented by andesite basalts and trachybasalts. Pyroclastic rocks are made by the agglomerates rich in fragments of older magmatic rocks. Very often there are also the fragments of andesite basalts and trachybasalts.

From the Neogene sediments of Miocene structures are developed and presented by the sandy clays, slates, marls and sandstone. Quaternary structures are represented by sediments of river terraces and alluvium and deluvium deposits and rock debris. On Rogozna mountain there were extracted the following geotectonic units: Drina-Ivanjica element and the Vardar zone (external subzone).

Drina-Ivanjica element, the name of geotectonic unit by M. Dimitrijevic and M. Dimitrijevic (1973), on the basis of whose research is presented as external unit of the Dinarida against Zvornik ocean. This geotectonic zone is bordering on the north-east with the external Vardar sub-zones.

In Drina-Ivanjica element from the folder structure there are separated Ibar Syncline and Kozarevo anticline. By the regional point of view Ibar Syncline is the final south-eastern part of Novi Pazar syncline area which is situated from Novi Pazar across Rogozna to the south to the Ibar river and Kosovska Mitrovica. It represents a broad negative compressive structure. It is a deformed anti-formed structure with the axis of direction northwest-southeast which western wing lies over the eastern wing of the Ibar Syncline.

From the fractioned structure in this area, several major faults are noted; Kozarevo Faulting in the northwest-southeast direction is labile zone where movements are carried out during Mesozoic and Tertiary. It is part of Zvornik geosutures on which they broke out the great mass Miocene ophiolite and volcanic rocks, while in the lower Senonian there was the creation of Melange [1]. Cicavica diagonal fault, in direction northwest-southeast, is passing the eastern rim of the mountain Čičavica continues to Banjska to the northwest, where it connects with Sitnička dislocations and extend along the direction of Leskova head. Thermal water in Banjska and Joševik are on Cičavica faults.

Vardar zone is a complex structural unit that is bordering the Serbian-Macedonian mass on the east, and to the west with the Drina-Ivanjica element. It is very important structural region of the continental elements of the Balkans. Modern research has indicated the validity of retaining the division of external, central and internal sub-zones, which are mutually substantially different [1]. Vardar external sub-zones, has a complex structure. It extends from Zvornik stitches to the line Belgrade-Poplar-Vrnjacka spa-Podujevo-Gnilane-Nikuštak. It is divided into several blocks. During the geological history of geotectonic units described above, there were structural deformations of rock mass due to strong lateral thrusts. The thrusts caused fraction and the development of faults, where the thermal water moved towards the surface of the terrain.

CONDITIONS OF FORMATION, POTENTIALITY AND GENESIS OF THERMO-MINERAL WATERS OF BANJSKA

Conditions of formation of mineral water are connected with tectonic magmatism of Rogozna. Evolutionary development of the mountain are characterized by tectonic magmatic processes that recorded individual stages and development of Mesozoic and Cainozoic era. Magmatism in the Triassic and Upper Cretaceous is represented by serpentine Peridotite, with extrusive equivalents diabase and gabbro rocks. In tectonic magmatism chronology of the oldest and most widespread igneous rocks are Peridotite. According to their mineralogical composition they correspond to harzburgite type with minimal involvement of equivalents-lherzolite, dunite and others.

A characteristic of these rocks is serpentinization-serpentinited Peridotite and serpentinites. Hydrothermal processes of tertiary magmatism caused magnesite venation and wires. The processes of decomposition are expressed in the serpentinites (nontronite, wire magnesite). Tertiary magmatism indicates granite Intrusions followed by the volcanic processes tracked in several sequences, when volcanic rocks (dacite-andesite, rhyodacite, pyroxene-amphibolite andesite, tuffs and conglomerates) were formed. The thermal waters occurred in these described rocks [7].

Reservoir of mineral waters constitutes complex of carbonate Mesozoic and Paleozoic rocks. Most likely this is a Triassic limestone, given that they were briefly exposed to erosion during the Jurassic and lower Cretaceous. Water in the reservoir originates from the semi-arid climate (20,000 yr.) and have a temperature of about 120^0C [3].

The springs of thermo-mineral water of Banjska are located on the land of St. Sava monastery, on the south-eastern slopes of Rogozna. The occurrence of thermo mineral water of Banjska is directly related to fault structure, so that they appear to contact serpentinites and cretaceous flysch (Fig.1.). In the village there were noted a total of 4 springs, but 3 of them are capped. Two of them are in the village, with yield of Q_1= 1 l/sec, Q_2 = 0.5 l/sec (in the courtyards of the private houses), the third is in the Spa Pool, with the yield Q_3 = 1 l/sec, and the fourth is at the monastery (Milutin city) that is located on the tufa terrace, with the yield of Q_4 = 5 l/sec. Thickness of tufa terrace is > 20 m. It was created by the separation of calcium - carbonate from the thermo mineral water spring at the monastery, on the basis of which it is interpreted the genesis of mineral water. In zone Banjska there were extracted phenomenon of marble and limestone on the surface of the terrain. Thermo-mineral water is formed in these rocks. Serpentinites are a transit zone and affect the chemical composition. Warming water is directly related to tertiary volcanic process [5].

From the monastery, according to the latest available data, a yield about 5 l / s, with temperature of 54^oC. Almost certainly it could be said that the early yield was much higher, when a large amount of deposited tufa is shown. This source is capped for the spa, but due to a damage of piping, water does not come to the spa.

The observed yield regime capacity and water temperature in the period August-November 2004 and September-November 2008 in the spa pool is stable, indicating by deep siphonal circulation of thermal waters. Yield is little changed in interval of 0.8-1.2 l / s. Water temperature is 40.5^0C [6].

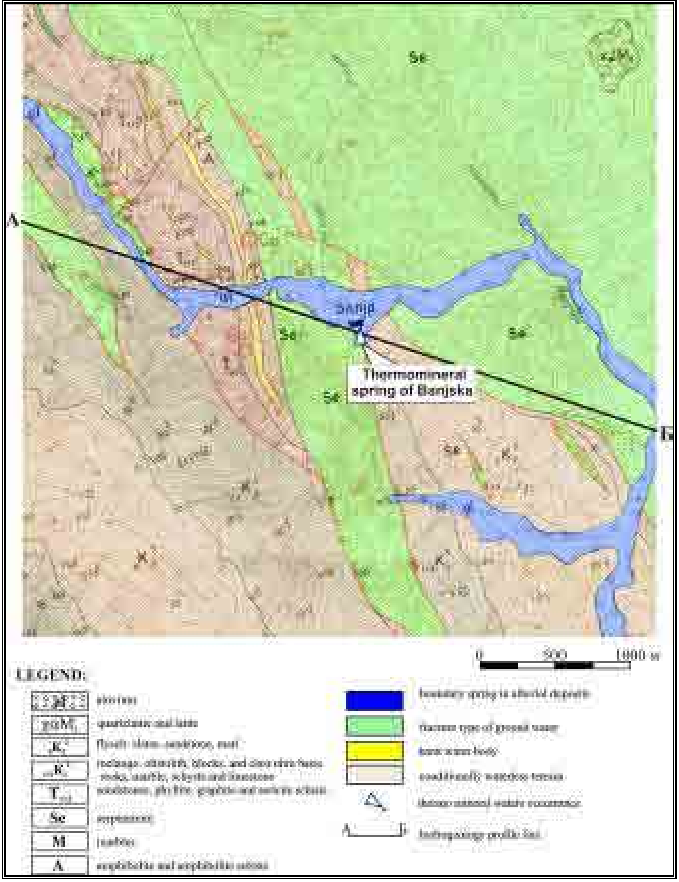

Figure 1. *Hydro-geology maps of the thermomineral spring Banjska*

QUALITY OF THERMO-MINERAL WATER OF BANJSKA

Mineral water of Banjska is the subject of extensive interest in 100 years for it can be chemically analyzed and determined based on its basic balneology properties.

According to the results of chemical analysis made by V. J. Rešovske Nikolaevich (1921), the main component is calcium bicarbonate, while the amount of free carbonic acid was not determined. Therefore it is in order of indifferent hipertherma with characteristics of weak alkaline acidic water [3].

According to the results of chemical analysis Vajića B. (1929), this water is carbonate (alkaline, alkaline-natural), muriate, sulphate, hot 43-47^{0}C [10].

According to the results of chemical analysis of V. Protic (1995), mineral water is HCO_3-Na type, the total mineralization 1.36 g / l, pH 6.7. The content of HCO_3 was 806.00 mg/l and Na was 300.00 mg/l.

Content of radioactive elements is low: Rn-3.7 Bq/l, Ra-0.17 Bq/l, U-0.0016 mg/l [9].

Based on the review of the basic characteristics of mineral waters in the region of Šumadija-Kopaonik-Kosovo area, thermo mineral waters of Banjska have the following chemical composition formula [11].

The Institute for Rehabilitation, Belgrade has made the detailed investigations of thermo-mineral waters of Banjska for all four springs (spring 1- inflow to the pool; spring 2 - water near Monastery St. Sava; spring 3 – water from the yard of R.Milosavljevic; spring 4 – water from the court yard of U. Radosavljevic) and noted the characteristics, given in Table 1.[12].

Table 1. *Physical-chemical characteristics of thermo-mineral waters of Banjska (The Institute for Rehabilitation, Belgrade, 1994.)*

Physical-chemical characteristics	Spring			
	1	2	3	4
temperature, ^{0}C	40.1	58.1	28.3	38.4
pH	7.1	7,2	7.4	7.3
Total mineralization, (mg/l)	1380	1090	1560	1390
Cathions				
Calcium	33.8	37.8	46.5	38.5
Magnesium	39.6	31.8	40.9	40.6
Sodium	238.7	288.7	276.0	238.7
Potassium	17.1	19.5	19.3	16.8
Anions				
Hydrocarbonates	774.7	817.4	884.5	762.5
Chlorides	89.5	99.4	94.4	89.5
Sulfates	50.4	80.1	71.6	71.4
Nitrates	4.7	4,3	4.2	5.1

For the purpose of this paper, the chemical composition of thermo-mineral waters of Banjska was presented on charts (Fig. 2, 3, 4 and 5).

Spring 1

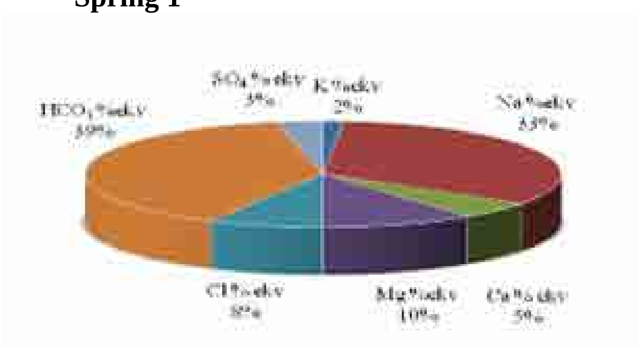

Figure 2. *Circle diagram of chemical composition, spring 1- water inflow into the pool*

Spring 2

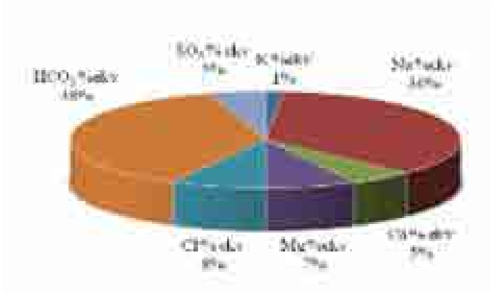

Figure 3. *Circle diagram of chemical composition, spring 2- water at the Monastery St. Sava*

Spring 3

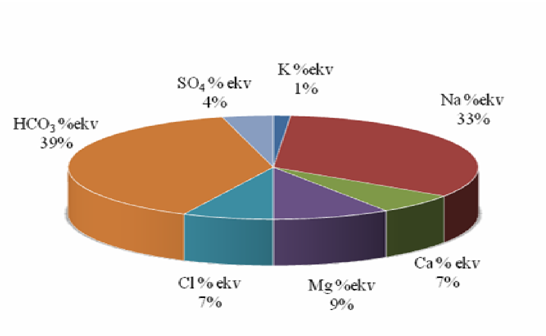

Figure 4. *Circle diagram of chemical composition, spring 3- water from the courtyard of R. Milosavljevic*

Spring 4

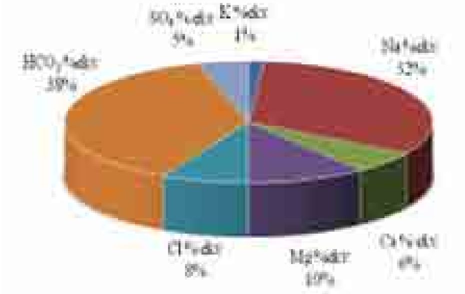

Figure5. *Circle diagram of chemical composition, spring 4- water from the courtyard U. Radosavljevic*

In the frame of the research project Hydrogeology investigation of mineral and thermo mineral waters of the northern part of Kosovo and Metohija, financed by Ministry for environmental protection and planning, the sample was taken from the Spa bath for the analyse for the investigation of the possibilities of its exploitation. These samples were analyzed in the laboratories of the Institute for public health "dr Milan Jovanovic Batut", Belgrade, and the results were showed in Table 2.

Table 2. *Physical-chemical characteristics of thermo-mineral waters of Banjska (Institute for public health "dr Milan Jovanovic Batut", Belgrade, 2008.)*

No.	**Basic physical-chemical properties**	Content	method
1.	temperature (^{0}C)	40,5± 0,1	UP-501
2.	pH	7,0± 0,1	UP-503
3.	Color (degrees Pt-Co scale)	<5,0	UP-536#
4.	Electric conductivity(μS/cm)	1200,0±100	UP-507
5.	Total hardness(^{0}dH)	12,0±0,4	UP-510
6.	Spent $KMnO_4$ (mg/l)	1,9±0,2	UP-506
	Dissolved gases (mg/l)		
1.	Oxygen(O_2)	3,5±0,5	UP-508
2.	Carbon dioxide (CO_2)	176,0	UP-529#
	Macro components		
	Cathions	Content(mg/l)	method
1.	Calcium(Ca^{++})	31,00	UP-916#
2.	Sodium (Na^+)	326,00	UP-916#
3.	Potassium(Ka^+)	14,40	UP-917#
4.	Magnesium(Mg^{++})	33,40	UP-917#
	Anions		
1.	Chlorides (Cl^-)	75,00±5	UP-521
2.	Sulfates (SO_4^{--})	65,00±5	UP-521
3.	Hydrocarbonates(HCO_3^-)	770,00±20	UP-509
4.	Nitrates (NO_3^-)	<0,5	UP-521
	Micro components		
		Content (mg/l)	method
1.	Bor(B)	2,36	UP-910
2.	Lithium (Li)	0,20	UP-910
3.	Strontium (Sr)	0,89	UP-910
4.	Iron (Fe)	33,40	UP-907
5.	Manganese (Mn)	0,021± 0,003	UP-543#
6.	Aluminum (Al)	<0,05	UP-543#
7.	Zinc (Zn)	0,051± 0,003	UP-903
8.	Copper(Cu)	<0,010	UP-902
9.	Barium (Ba)	0,150	UP-910
10.	Arsenic (As)	<0,004	UP-908
11.	Chromium (Cr)	<0,001	UP-905

12.	Lead (Pb)	<0,010	UP-901
13.	Selenium (Se)	<0,003	UP-914#
14.	Cadmium (Cd)	0,0014±0,00005	UP-906
15.	Nickel (Ni)	0,012±0,00500	UP-919
16.	Mercury (Hg)	<0,001	UP-909
17.	Antimony (Sb)	<0,003	UP-922#
18.	Ammonium (NH_4^+)	0,060	UP-511
19.	Nitrite (NO_2^-)	<0,005	UP-523
20.	Silicate (SiO_2)	52± 1	UP-520
21.	Fluoride(F^-)	1,9± 0,1	UP-521
22.	Bromide (Br^-)	2,0	UP-521
	Specific parameters		
		Content (mg/l)	method
1.	Cyanide	<0,01	UP-512
2.	Phenol	<0,001	UP-532#
3.	Detergents, anions	<0,01	UP-531#
4.	Total fat and oil	<0,01	UP-522
5.	Mineral oils	<0,01	UP-518
	Content of organic chlorine insecticide		
		Content(µg/l)	method
1.	Hexachlorine benzol (HCB)	<0,01	UP-801
2.	Aldrine/dieldrine	<0,01	UP-801
3.	DDT	<0,01	UP-801
4.	Hepta chlorine /hepta chlorine epoxide	<0,01	UP-801
5.	lyndane	<0,01	UP-801
	Polycyclic aromatic hydrocarbons (PAH)		
		Content(µg/l)	method
1.	Total	<0,20	UP-801
2.	Benzoa(A)pyren	<0,01	UP-801
	Aromatic hydrocarbons		
		Content (µg/l)	method
	Benzene	<1	UP-803
	Toulene	<7	UP-803
	Ethyl benzene	<2	UP-803
	Xilene	<5	UP-803
	PCB_s –Poly chloride bi phenile		
		Content (µg/l)	method
1.	Identified as PCB mix 525	<0,5	UP-801

For the purpose of this work, the chemical composition of the thermo-mineral waters of Banjska (sample taken from the Spa pool) was presented on the circle diagram (Fig. 6.)

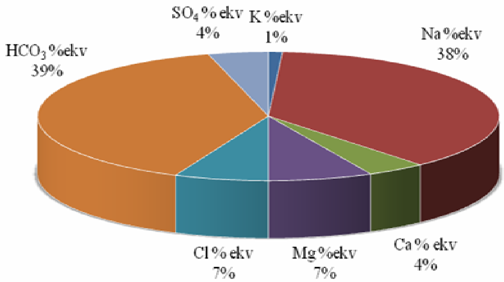

Figure 6. *Circle chart of the chemical composition of thermo mineral waters of Banjska, sample taken from the Spa pool*

Based on the results of physical-chemical characteristics of thermo-mineral waters of Banjska (Table 1 and Table 2) and based on the graphic presentation of their chemical composition (Figures 2,3,4,5 and 6) it can be concluded that those belong to the same water type. Based on the obtained results it can be said that in the group of cathions the sodium is dominating, but there is also high content of magnesium and calcium. From the group of anions hydro-carbonate is mostly present, than chlorides and the total anions content is three times higher than cathions content. The investigated waters are in the group of sodium, calcium, magnesium hydro carbonated carbon hydro carbonated hypothermal waters [6]. Referring to physical-chemical analyze of the thermo-mineral waters of Banjska, the balneology estimation of their medicinal properties was made.

The radioactivity testing in the sample of thermo mineral water was made in the institute for professional medicine and radiology protection "Dr Dragomir Karajovic" in Belgrade, whose results were presented in Table 3.

Table 3. *Results of gama spectrometry analysis (institute for professional medicine and radiology protection " dr Dragomir Karajovic" in Belgrade, 2008):*

Sample type	^{137}Cs (Bq/l)	^{134}Cs (Bq/l)	^{40}K (Bq/l)	^{232}Th (Bq/l)	^{238}U (Bq/l)	^{226}Ra (Bq/l)
Banjska Spa	< 0.007	< 0.003	0.60 ± 0.04	< 0.02	< 0.10	< 0.03

The results of gama spectrometry analysis of water (specific activity) point on the fact that the analyzed waters are adequate by the regulation of drinking water quality (according to the regulative S.L.SRJ No.9/1999)

USAGE OF THERMO MINERAL WATERS OF BANJSKA

The possibilities of using thermal water Banjska are: balneo therapy, sport and recreation, heating fluid, fuel et al.

Mineral water Banjska provide numerous opportunities for development and improvement balneotherapy sports and recreational activities. The beginning of usage of mineral water is related to the Middle Ages. By archaeology explorations of the King Milutin city of Banjska, the spa baths were discovered, what proves that the mineral waters were used even in that time.

Recent capture works are executed 1954-1956, which is a major source of yield increase of 1.75 to 4.9 l/s water, and to some extent and the temperature.

In the research project of Hydrogeology investigation of mineral and thermo mineral waters of the northern part of Kosovo and Metohiaa, financed by Ministry for environmental protection and planning, based on physical-chemical analysis, the balneology opinion for thermo mineral waters of Banjska was given by Dr. T. Jovanovic:

In balneo-treatment water can be used in swimming on the appropriate temperature and the additional treatment of chronic diseases (states and non ancular rheumatism, rehabilitation after surgical interventions on the bone ancle system of non malignant origin, post rheumatism states, the rehabilitation of injuries of peripheral nerves and spinal cord injuries, sports and recreational injuries of the locomotive system in the situations where the beneficiaries of the therapy procedures for listed diseases are children before the puberty it is necessary to decrease the water temperature to the temperature of their age, in the treatment of uro-genital disorders in women natal period) and drinking in specific indications hypermortality of gastro interstinal tract and hepatobiliary system under special control of professional medical personnel at the source or temperature not below 32^0 C. This would be recognized tourism and Spa Village, with the environmental values of the surrounding area and the monuments of culture could be developed in the spa centre [6].

Hydrogeothermal energy intensive food production allows you to achieve economic, qualitative and ecological effects.

By using of mineral water in agriculture to achieve economic effects, as lower production costs achieved higher yields. Geothermal energy, per unit of heat produced, cheaper than all other energy sources. By using hydrogeothermal energy it is possible in greenhouses growing vegetables and flowers, nursery plants and planting materials.

For the heating of the green houses covered by polyethylene film, some 200 kJ per hour needed, i. e., for heating of greenhouse which is 30 m long, 4 m wide and average height of 3 m, it is needed [8]:

$$30 \text{ x } 4 \text{ x } 3 \text{ x } 200 = 72.000 \text{ kJ/h}$$

Qualitative and ecological effects of thermal waters usage are referred to high content of minerals in agriculture products, that is also a condition for achieving of acology goals i. e. health food production. Crops irrigation by thermominearl water is more and more present in food production, with high energy efficiency. The largest part of agricultural land is lacking of essential micro elements and other mineral particles and nutritients. They are situated in deeper thermal waters, in dissolved and ionic form (the most adequate form) so the plants and animals can use them [4].

There is a wide range of possibilities of using thermal water in industry (drying, evaporation, distillation, cooling, roasting, extraction, washing and dyeing, process heating and cultivation of industrial plants). Hydrogeothermal energy application for heating is in the beginning stage and very modest considering the resources.

CONCLUSION

Occurrence of thermal water Banjska are very important in the area of the northern part of Kosovo and Metohija.

Spa has a long tradition of using mineral water (neglecting the development stagnation of the last ten years), and the possibilities of exploiting hydrothermal resources are real. Medicinal properties of mineral water were proved by balneology analysis, and they can be used as accessories in the treatment of various diseases in humans by bathing and drinking. Potentiality, physical-chemical characteristics and cultural and historical heritage makes Banjska interesting to study in terms of development of spa tourism, multi-purpose usage for environmental friendly and profitable agricultural production and industry. Protection and rational use of mineral waters should be the primary destination spa centre.

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