Miomir Mikić, Daniel Kržanović*, Milenko Jovanović*, Miroslava Maksimović**

REVIEW OF THE OPEN PIT SOUTH MINING DISTRICT - MAJDANPEK IMPACT ON THE ENVIRONMENT AND PROTECTIVE MESUARES**

Abstract

There are more than 50 years of the copper surface mining in Majdanpek, Serbia. During this period, the impact of mining activities on the environment was multifaceted: degradation of the land - mostly forestS, air pollution, water and soil and others. This paper presents measures to protect the environment from the impact of the open pit South Mining District and reclamation of tailings.

Keywords: mining, degraded areas, environmental protection, reclamation

INTRODUCTION

The negative impact of surface mining in addition to a temporary (or long term) occupation and changes in land use, where the deposit is situated, is reflected also on: - occupation of additional agricultural land that is used for disposal of waste (external landfill); - drainage of the open pits has the effect on the level and regime of groundwater regime; - protection of the open pits from surface water changes the water flows and affects the ability of irrigation the surrounding parcels; - dust and air pollution adversely affects the population and agricultural crops in the vicinity of the open pits; - excavation of mineral raw material changes the relief of land, affecting the climate and displacement the existing facilities or building the new infrastructure for exploitation the mineral raw materials, thereby also reducing the area of agricultural land; - impairment the aesthetic value of the environment and occurrence of noise due to the mechanization operation.

In addition to degradation and transformation of land surfaces to another "lower"

shape, the open pits may also affect the pollution of land closer to or further away from the open pit with heavy metals from dust immission created during deposit mining or technological operations at the open pits.

The concept of pollution means the imission of pollutants (dust, gases) in the atmosphere of the open pits. The air pollutions, carried by the wind streams from the open pits, threaten the space in a direction even out of the open pits or the environment around them. Chemical pollutants that occur in the atmosphere of the open pits are formed as the result of technological processes in order to obtain the ore and in case of mass blasting, loading, transport, crushing and at the effect of natural factors - winds [1]. The matters in the form of gases and dust get into atmosphere of the environment from the open pits. The major air pollutants arising from the open pit mining operations include total suspended particulate (TSP) matter and particles with an equivalent aerodynamic diameter less than 10 microns (PM10) [2].

* Mining and Metallurgy Institute Bor, Serbia

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Air pollution in the area of the open pit mines depends on the extent of annual production and intensity of pollutant emission, terrain configuration around the open pit mines and climatic parameters [3]. In this case, the entire area of open pit mine is a source of environmental pollution. Outside the open pit mines, the dust is spread by wind, usually in a direction of dominant winds and the air pollution dispersion plume is formed. [3]. The highest air pollution from the open pits is on their edge while moving away from the edge of pits in direction of winds blowing; the air pollution is reduced or diluted (dispersion) [1]. This rule is applied to dust because gases are mainly diffused. Immission of dust in the environment of the open pits depends on the size of dust particles that are dispersed from the open pits by the wind currents. The largest particles (greater than 10 mm) begin to deposit near the edges of the open pits, while the finer particles smaller than 10 mm (PM10, PM2.5) are transported by the wind energy in a direction of its blowing and deposited away from the edge. The finest particles, dispersed by the wind currents from the open pits are not deposited, but remain flying in the air.

The open pits are a line source of dust for immediate surroundings. Removal of dust from the open pits depends on natural ventilation scheme that can be: flow, recirculation, convective and inverse. The TSP

and PM10 levels in the open pit mining regions reduce the air quality and can cause silicosis, black lung (CWP), and increased mortality. They also reduce the visibility and affect surrounding flora and fauna [4]. Particles in the air are also known to play a critical role on climate [5], human health [6] and multi-phase atmospheric processes [8,9].

Due to the complexity of mining activities on the floors of the open pit South Mining District and large amounts of water on the bottom of the open pit and specificity of the flotation tailing dump facilities and unpredictability of the exact time and place of possible emergence of an accident and size of accidents, it is necessary to formulate the protective measures of working and living environment in the expansion of the open pit South Mining District [7].

1 SITE OF THE OPEN PIT SOUTH MINING DISTRICT MAJDANPEK

Majdanpek is located Eastern Serbia, near the town of Bor. North of Majdanpek is the Danube river which also represents the border between Serbia and Romania (Figure 1).

The open pit South Mining District is located on the south side of Majdanpek in Serbia and it is surrounded on all sides by hills and high waste dumps (overburden), Figure 2.

Figure 1 Majdanpek with surroundings

The only opening of the open pit is to the north or the town, Figure 1. All procedures at the open pit South Mining District are aimed to obtain copper ore by drilling

and blasting operations and heavy loading and transport machines capable of contributing to the overall quality of the atmosphere at the open pit and beyond it.

Figure 2 Open pit South Mining District - Majdanpek

Longer axis of the open pit is approximately 2,450m, while shorter axis is 1,600 m. The highest point of the open pit is approximately at the level of +588 m. The lowest point at the open pit is at 120.4 m. Height of floor is 15 m. This presents a potential threat to the environment because it can cause large-scale landslides at the open pit and endangering the regional asphalt road, the river bed of Mali Pek River and occurrence of cracks in buildings in the lower part of the town and endangering the occupants.

2 DATA ON EMISSION SOURCES OF POLLUTANTS

Expanding the open pit and operation of mining machinery create dust, which, due to the terrain configuration around the open pit, is dispersed by wind currents in the urban area.

Dust and gases are emitted by the mining equipment operation at the open pit dust and atmosphere of the open pit is polluted. In addition to the technological processes, the atmosphere quality at the open pit area is affected by natural factors - winds. All of pollution occurring at the open pit is dispersed by natural ventilation schemes and concentrated in the town. The air flow at the open pit occurs as the result of action the solar energy (insolation) and winds. The most common schemes of natural air movement at the open pit are: inverse and convective. The main sources of gas and dust emissions are machines that operate on technological phases of copper ore obtaining at the open pit South Mining District.

According to the previous measurements at the copper open pits in RTB Bor, the possible emission of dust were forecasted in copper ore obtaining per machine and they are shown in Table 1.

Table1 *Forecasted dust emissions at the open pit South Mining District*

Ord. No.	Type of equipment	Concentration (mg/m ³)	
	Period	In summer	In winter
1	Truck	3.77	1.05
2	Excavator	3.92	3.14
3	Drill	5.51	4.61
4	Loader	3.40	2.27
5	Bulldozer	8.66	3.10
6	Grader	7.20	2.10

Based on the number of machines in operation and known power of mobile machines that will work at the open pit as well as the composition of outlet gases

from engines, the forecast emissions of exhaust gases that occur at the open pit by operation of mobile equipment is given in Table 2.

Table 2 *Forecasted gas emissions per one machine*

Type of equipment	Engine power kW	Amount of exhaust gases m ³ /s	Total gas emissions (m ³ /s) at their content in exhaust gas				
			CO ₂ =10%	CO =0.12	NO _x =0.04	SO ₂ =0.04	Aldehydes 0.002
Truck KOMATSU HD785-7	875	0.6125	0.0611	0.00003	0.000245	0.000245	0.000001
Loader L-950	783	0.548	0.055	0.000657	0.0002192	0.0002192	0.000010
Bulldozer D8T	231	0.1615	0.016	0.00019	0.0000646	0.0000646	0.00000032
Grader	208	0.145	0.015	0.000174	0.000058	0.000058	0.0000029
Tank truck	450	0.315	0.032	0.000378	0.000126	0.000126	0.0000063

For combustion of 1 kg of oil, the amount of gas that is released during operation of internal combustion engines is between 13 and 15 m³/kg. Concentration of gases at the open pit depends on the ratio of combustible components in the fuel, such as: carbon, hydrogen and sulfur as well as the proper chemical relations fuel-air. At the open pits in Majdanpek, the fuel D₂ is used where sulfur is from one weight percent, and it is 500 ppm of SO₂. The required amount of air for dilution the harmful components in exhaust gases of internal combustion engines depends on concentration of these components.

In liquid fuel D₂, the dominant factor which defines the required air amount for dispersion of gases from atmosphere of the open pit is taken as SO₂ due to its MDK value that is equal to 4 ppm. For dilution

1.0 m³ SO₂ in the atmosphere of the open pits, 125 m³ of air is required to reduce the harmful concentration in the air to MDK value.

3 MEANS AND METHODS FOR REDUCING THE ENVIRONMENTAL IMPACT

To protect the atmosphere in the mine and the town, it is needed to undertake the proposed complex measures of protection at the open pit.

Protective measures for drilling the boreholes

Protection measures to be taken at the open pit for air protection from dust and gases in drilling and blasting are the following:

- Dry and wet dedusting of boreholes,
- The explosive must have a positive oxygen balance which ensures a complete detonation,
- The stability conditions of explosives at least 3 months,
- Good homogenization of the components in the preparation of explosives,
- Organized and systematic testing of toxic gas in the laboratory conditions,
- Elimination of the paper - paraffin tread cartridge explosives and its replacement with shells that are suitable in terms of the balance of oxygen,
- Proper storage of explosives according to the instructions of the manufacturer and the use of the prescribed period,
- Setting the firing of the cartridge at the bottom of the borehole (increased efficiency of blasting, and small quantities of gases),
- The application of water stoppers made of plastic for clogging the boreholes during blasting or water balloons over the boreholes (volume of 50 l with a primer explosive 50 g/barrel),

Protective measures on loading

- Spraying of blasted material with water before loading by road tankers with installation and device for spraying (water displaces CO from cavities and associated nitrogen oxides).

Protective measures on transport

- Necessarily sprinkling (spraying) of transport routes during the dry season by road tankers with installation and device for spraying; 0.5 to 2.0 l/s is needed for 1.0 km of road.
- The use of diesel fuel of the constant elemental composition,
- Replacement of truck transport with the belt conveyor system.

Protective measures on disposal

- Spraying of level plateaus on the waste rock landfill
- Reclamation of the waste rock landfills according to the Project of remediation

3.1 Protective measures of the town on the dust from the open pit

The adequate protective measure is obtained by placing the PVC piping around the edges of the open pit toward the town with a device for creating a water curtain to overthrow dust. The pipeline can be connected to the system for dewatering from the open pit South Mining District.

The other measures include: the introduction of additional organizational-technical measures and strict application of the machine manufacturer's instructions for efficient suppression of gas and dust in the operation of production machines at the open pit.

4 RECLAMATION OF DEGRADED AREAS OF THE WASTE ROCK LANDFILL OF THE OPEN PIT SOUTH MINING DISTRICT

In expanding the open pit South Mining District in stages from 1 to 6, the waste rock is excavated and formed four landfill sites, out of which three with finite boundaries and one with a space for storage under the new future projects. (Figure 3).

On the eastern side of the open pit is formed the landfill Kovej. On the western side of the open pit were formed the landfills Andesite Finger and Bugarski Stream. The disposal Ujevac is formed away from the open pits South and North Mining District and transport of waste rock is done by the belt conveyor system that can hold the waste rock from both open pits in Majdanpek and until now there are no final borders and it is not considered for reclamation.

The waste rock landfills are formed on already degraded areas and in the industrial zone. Due to the savings on transport costs, the waste rock is deposited from the final level to form the high slope inclinations of 31°.

Figure 3 2D view of the final condition of the open pit and landfill

4.1 Data on structure and purpose of the land use

Remediation of degraded areas on the waste rock landfills Andesite Finger, Kovej, Bugarški Stream and Deponija includes the works aimed to the remediation of land. Since the soil of degraded areas does not contain enough nutrients for normal development of plants, the optimal form should be used with stages of agro-technical, technical and biological reclamation to the aim of remediation.

According to the physical and chemical properties of soil, geomorphology of the waste rock landfill, the exposure of areas to the south, climate and natural vegetation in the region, the optimal biological stage of remediation should be considered, including:

- Final planes of the waste rock landfills - afforestation,
- Final slopes of the waste rock landfills - afforestation.

Total degraded areas on the waste rock landfills of the open pit South Mining Dis

trict South for remediation by locations are shown in Table 3.

Table 3 *Total degraded areas for reclamation*

Landfills	Level, m altitude	Flat surfaces, m ²	Level, m altitude	Inclined surfaces, m ²	Total surface, m ²
Andesite Finger (AP)	500	106 049	500/425	11 340	117 389
Kovej	596	48 659	596/575	15 033	63 692
Bugarski Stream	595	220 710	595/550	147 563	368 273
Landfill	580	64 564	580/415	173 332	237 896

4.2 Data on the selection of culture for remediation

Distribution of species on the surfaces of landfills during afforestation is given in Table 4 and it was carried out on the basis of micro-cellular conditions and research conducted in the period from 1988 to 1989

in Majdanpek at the landfill AP by the Institute of Forestry, Belgrade, Technical Faculty Bor and Copper Institute Bor and on the basis of the results obtained on remediation in Veliki Krivelj and Cerovo.

Table 4 *Structure of species by surfaces*

Waste dump	Surface structure	Structure of species	Surface, m ²
Andesite Finger(AP)	Final slope	Black pine	106 049.00
	Final slope	Birch + cilia	11 340.00
Kovej	Final slope	Red oak	48 659.00
	Final slope	Acacia	15 033.00
Bugarski Stream	Final slope	Brest	318 730.00
	Final slope	Acacia	203 240.00
Landfill	Final slope	Birch + cilia	64 564.00
	Final slope	Acacia	173 332.00

5 DESCRIPTION OF REMEDIATION METHODS OF DEGRADED AREAS

The aim of the revitalization of degraded areas at the waste rock landfills in Majdanpek is the protection of the environment. Degraded areas belong to the class of technogenic soil with insufficient proportion of nutrients making it necessary to apply the optimal re-cultivation of the stages of agro-technical, technical and biological reclamation [7].

- 1 Stage of optimal agrotechnical remediation** represents the stage in which a series of measures are conducted aimed at establishing the productivity of the artificial creations - antroposalts. In the case of degraded areas in Majdanpek, it involves rehabilitation the existing access roads and subsequent planning area

on the final level (at the final disposal process to prevent the formation of lakes on flat surfaces to leave the vicious circle of waste piles).

- 2 **Technical stage of optimum remediation** includes: excavation, loading, transport and unloading of humus.
- 3 **Biological stage of optimum remediation** involves a complex of biotechnical and phytomeliorative measures for growing the forest plantations on waste rock landfills for the purpose of restoring the ecosystem.

5.1 Total costs of remediation

Total costs of remediation include the following costs of: agrotechnical phase (135,900 €), technical phase (11,291 €), biological phase (409,505 €), care and protection (87,447 €), unplanned costs (16,000 €). Total cost of remediation amounts to 660,143 €.

CONCLUSION

The Copper Mine Majdanpek is an important part of the system of Mining and Smelting Basin Bor. The extension of the open pits South Mining District and North Mining District in Majdanpek with the application of complex protective measures provides continuity in the production of copper ore which gives a **positive impact** on the social structure (national and ethnic) of population in terms of creation the new jobs and staying young to work and live in Majdanpek as well as the revival of villages in the surrounding municipalities.

An optimal form of remediation the degraded areas combined with auto rehabilitation and semi-remediation is a permanent solution for preservation the environment of the town of Majdanpek, provides better microclimate conditions as well as better appearance of the surroundings.

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Miomir Mikić*, Daniel Kržanović*, Milenko Jovanović*, Miroslava Maksimović*

PRIKAZ UTICAJA POVRŠINSKOG KOPA JUŽNI REVIR - MAJDANPEK NA ŽIVOTNU SREDINU I ZAŠTITNIH MERA**

Izvod

Više od 50 godina se obavlja površinska eksploatacija bakra u Majdanpeku, u Srbiji. Tokom ovog perioda, uticaj rudarskih aktivnosti na životnu sredinu je bio višestruki: degradacija zemljišta-uglavnom šume, zagađenja vazduha, vode i zemljišta i dr. Ovaj rad predstavlja mere za zaštitu životne sredine od uticaja površinskog kopa Južni Revir i rekultivaciju jalovišta.

KLjučne reči: rudarstvo, degradirane površine, rekultivacija, zaštitne mere

UVOD

Negativan uticaj površinske eksploatacije, pored privremenog (ali dugotrajnijeg) zauzimanja i izmene namene zemljišta, gde se nalazi ležište, odražava se još i na: – zauzimanje dodatnog poljoprivrednog zemljišta koje se angažuje za smeštaj jalovine (spoljašnje odlagalište); – odvodnjavanjem površinskih kopova vrši se uticaj na nivo i režim podzemnih voda; – zaštitom površinskih kopova od površinskih voda menjaju se vodni tokovi i utiče na mogućnost navodnjavanja okolnih parcela; – zagađenje vazduha prašinom utiče negativno na stanovništvo i poljoprivredne kulture u blizini kopova; – otkopavanjem mineralne sirovine menja se reljef zemljišta, utiče na klimu, izmeštaju se postojeći objekti infrastrukture ili grade novi koji služe eksploataciji mineralne sirovine ili objektima pripreme, čime se takođe smanjuju površine poljoprivrednog zemljišta; – narušavaju se estetske vrednosti okoline i dolazi pojave buke usled rada mehanizacije.

Pored degradiranja i transformisanja zemljišnih površina u drugi „niži” oblik, površinski kopovi mogu da utiču i na zagađivanje zemljišta bliže ili dalje od kopa teškim metalima iz imisijom prašine koja nastaje pri eksploataciji ležišta, odnosno tehnološkim operacijama na kopovima. Površinski kopovi ruda metala su značajni zagađivači atmosfere.

Pod pojmom zagađenja podrazumeva se emisija zagađujućih materija (prašine, gasova) u atmosferu površinskih kopova. Nošena vetrenim strujama iz kopova, aerozagađenja ugrožavaju prostor na pravcu vetrova i izvan kopova, odnosno životnu okolinu oko njih. Hemijski štetne materije koje se javljaju u atmosferi površinskih kopova nastaju kao posledica tehnoloških procesa u cilju dobijanja rude i to pri masovnom miniranju, utovaru, transportu, drobljenju i pri dejstvu prirodnih faktora-vetrova [1]. U atmosferu životne okoline iz površinskih kopova dospevaju materije u vidu gasova i prašine. Glavni zagađivači

* Institut za rudarstvo i metalurgiju Bor

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vazduha koje proističu iz površinskih rudarskih radova obuhvataju ukupne suspendovane čestice (USČ) i materije sa ekvivalentnim aerodinamičkim prečnikom manjim od 10 μm (PM10) [2].

Žagađenje vazduha u oblasti površinskih kopova zavisi od stepena godišnje proizvodnje i intenziteta emisije zagađujućih materija, konfiguracije terena oko površinskim kopova i klimatskih parametara [3]. U tom slučaju, cela oblast površinskog kopa je izvor zagađenja životne sredine. Izvan površinskih kopova, prašina se širi vetrom, obično u pravcu dominantnih vetrova i formira se oblak disperzije zagađenja vazduha [3].

Najveće aerozagađenje koje se iznosi iz kopova je na njihovoj ivici dok se sa udaljavanjem od ivice kopova u smeru duvanja vetrova aerozagađenje smanjuje, odnosno razređuje (dekoncentriše) [1]. Ovo pravilo važi za prašinu jer gasovi, uglavnom, difunduju. Imisija prašine u životnoj okolini kopova zavisi od veličine čestica prašine koje se vetrenim strujama iznose iz kopova. Najkrupnije čestice (veće od 10 mm) počinju da se talože u neposrednoj blizini ivice kopova, dok se sitnije čestice manje od 10 mm (PM10, PM2,5) energijom vetra u pravcu njegovog duvanja transportuju i talože dalje od ivice. Najsitnije čestice prašine iznete vetrenim strujama iz kopova se ne talože, već ostaju da lebde u vazduhu. Površinski kopovi za bližu okolinu predstavljaju linijski izvor prašine. Iznošenje prašine iz

kopova zavisi od prirodnih šema provetranja koje mogu biti: protočne, recirkulacione, konvektivne i inverzne. Nivoi USČ i PM10 u regionima površinskih rudarskih radova smanjuju kvalitet vazduha i mogu izazvati silikozu, crna pluća (CWP), kao i povećanu smrtnost. Oni takođe smanjuju vidljivost i utiču na okolnu floru i faunu [4]. Čestica u vazduhu su takođe poznato imaju ključnu ulogu delovanja na klimu [5], ljudsko zdravlje [6] i multi-fazne atmosferske procese [8,9].

Zbog složenosti izvođenja rudarskih radova na etažama površinskog kopa Južni revir i velike količine vode na dnu površinskog kopa i specifičnosti objekata flotacijskih jalovišta i nepredvidivosti tačnog vremena i mesta mogućeg nastajanja udesa i veličine havarija, neophodno je predvideti mere zaštite radne i životne sredine pri proširenju površinskog kopa Južni revir [10].

1. LOKALITET POVRŠINSKOG KOPA JUŽNI REVIR MAJDANPEK

Majdanpek se nalazi u Istočnoj Srbiji, u blizini grada Bor. Severno od Majdanpeka se nalazi reka Dunav koja ujedno predstavlja i granicu Srbije i Rumunije (slika 1).

Površinski kop Južni revir nalazi se na južnoj strani Majdanpeka u Srbiji i okružen je sa svih strana brdima i visokim odlagalištima jalovine (raskrivke), slika 2.

Sl. 1. Majdanpek sa okolinom

Jedini otvor površinskog kopa je prema severu, odnosno gradu., slika 1. Svi postupci u površinskom kopu Južni revir usmereni na dobijanju rude bakra uz pomoć bušačko

minerskih radova i snažnih utovarno transportnih mašina doprinose ukupnom stanju kvaliteta atmosfere u kopu i van njega.

Sl. 2. Površinski kop Južni Revir - Majdanpek

Duža osa površinskog kopa iznosi približno 2.450 m, dok kraća osa iznosi 1 600 m. Najviša tačka kopa je približno na nivou +588 m. Najniža tačka na kopu je na 120,4 m. Visina etaža je bila 15 m. To predstavlja potencijalnu opasnost po životnu sredinu, jer može doći do pojave klizišta većih razmera u kopu i ugrožavanja regionalnog asfaltnog puta, korita reke Mali Pek i pojave pukotine na zgradama u donjem delu grada i ugrožavanja stanara.

2. PODACI O IZVORIMA EMISIJE ŠTETNIH MATERIJA

Proširivanjem površinskog kopa i radom rudarskih mašina stvara se prašina koja se, usled konfiguracije terena oko kopa, vetrenim strujama iznosi u gradsku sredinu.

Radom rudarske opreme u kopu emituje se prašina i gasovi i zagađuje se atmosfera kopa. Pored tehnoloških procesa na kvalitet atmosfere u prostoru kopa utiču i prirodni faktori - vetrovi. Sva zagađenja koja nastaju u površinskom kopu se prirodnim šemama provetravanja iznose i koncentrišu u grad. Strujanje vazduha na kopu javlja se kao posledica delovanja sunčeve energije (insolacije) i vetrova. Najčešće šeme prirodnog kretanja vazduha na kopu su: inverzna i konvektivna. Glavni izvori emisije gasova i prašine su mašine koje rade na tehnološkim fazama dobijanja rude bakra u površinskom kopu Južni revir.

Prema ranijim merenjima na površinskim kopovima bakra u RTB-u Bor, prognozirane su moguće emisije prašine pri dobijanju rude bakra po mašini i prikazane su u tabeli 1.

Tabela 1. Prognozirana emisija prašine na površinskom kopu Južni revir

Red broj	Vrsta opreme	Koncentracija (mg/m ³)	
		Leti	Zimi
1	Kamion	3,77	1,05
2	Bager	3,92	3,14
3	Bušilica	5,51	4,61
4	Utovarivač	3,40	2,27
5	Buldozer	8,66	3,10
6	Grejder	7,20	2,10

Na osnovu broja mašina u radu i poznatih snaga motora mobilnih mašina koje će raditi na kopu kao i na osnovu sastava izlaznih gasova iz motora, prognoza emisije izduvnih gasova koji nastaju u kopu radom mobilne opreme data je u tabeli 2.

Tabela 2. Prognoza emisije gasova po jednoj mašini

Vrsta opreme	Snaga motora	Količina izduvnih gasova	Ukupne emisije gasova (m ³ /s) pri njihovom sadržaju u izduvnom gasu				
			CO ₂ =10%	CO =0,12	NO _x =0,04	SO ₂ =0,04	Aldehidi 0,002
Kamion KOMATSU HD785-7	875	0,6125	0,0611	0,00003	0,000245	0,000245	0,000001
Utovarivač L-950	783	0,548	0,055	0,000657	0,0002192	0,0002192	0,000010
Buldozer D8T	231	0,1615	0,016	0,00019	0,0000646	0,0000646	0,0000032
Gejder	208	0,145	0,015	0,000174	0,000058	0,000058	0,0000029
Autocisterna	450	0,315	0,032	0,000378	0,000126	0,000126	0,0000063

Za sagorevanje 1 kg nafte, količina gasova koja se oslobađa pri radu motora sa unutrašnjim sagorevanjem se kreće između 13 i 15 m³/kg. Koncentracija gasova u kopu zavisi od odnosa sagorljivih komponenti u gorivu, a to su: ugljenik, vodonik i sumpor kao i od hemijskog ispravnog odnosa gorivo-vazduh. Na površinskim kopovima u Majdanpeku koristi se gorivo D₂ kod koga se sumpor kreće do jednog težinskog procenta, a to je 500 ppm SO₂. Potrebna količina vazduha za razređenje škodljivih komponenti u izduvnim gasovima motora sa unutrašnjim sagorevanjem zavisi od koncentracije tih komponenti.

Kod tečnog goriva D₂, dominantni faktor kojim se definiše potrebna količina vazduha za dekoncentraciju gasova iz atmosfere kopa

uzima se SO₂ jer je njegova MDK vrednost jednaka 4 ppm. Za razređenje 1,0 m³ SO₂ u atmosferi kopa potrebno je 125 m³ vazduha da bi se štetna koncentracija u vazduhu kopa svela na MDK vrednost.

3. SREDSTVIMA I METODE ZA SMANJENJE UTICAJA NA ŽIVOTNU SREDINU

Da bi se zaštitila atmosfera u kopu i gradu potrebno je na kopu preduzeti predložene kompleksne mere zaštite.

Zaštitne mere za bušenje bušotina

Mere zaštite koje treba preduzeti na površinskom kopu za zaštitu vazduha od prašine i gasova pri bušenju i miniranju:

- Mere zaštite na **bušenju** minskih bušotina:
- Suvo i mokro otprašivanje bušotina,
- Eksploziv mora imati pozitivan kiseonički bilans koji osigurava potpunu detonaciju,
- Uslove stabilnosti eksploziva najmanje 3 meseca,
- Dobra homogenizacija komponenti pri izradi eksploziva
- Organizovano i sistematsko ispitivanje stvaranja otrovnih gasova u laboratorijskim uslovima
- Eliminisanje papirno – parafinskog omotača patrona eksploziva i njegova zamena omotačima koji su pogodniji u pogledu bilansa kiseonika.
- Pravilno skladištenje eksploziva prema uputstvu proizvođača i upotreba u predviđenom roku trajanja
- Eksplozivi kojima je prošao rok upotrebe vratiti proizvođaču
- Postavljanje udarne patrone na dnu bušotine (povećana efikasnost miniranja, a manja količina gasova)
- Primena vodenih čepova od plastične mase za začepljenje bušotina pri miniranju ili vodenih balona iznad minskih bušotina (zapremine 50 l sa kapislom eksploziva 50 gr/buretu)
- Dovoz eksploziva na radilište vrši proizvođač,

Mere zaštite na utovaru

- Orošavanje izminiranog materijala vodom pre utovara pomoću autocisterne sa instalacijom i uređajem za orošavanje (voda istiskuje CO iz šupljina i vezuje okside azote).

Mere zaštite na transportu

- Obavezno polivanje (orošavanje) transportnih puteva u toku sušnog perioda autocisternom sa instalacijom i uređajem za orošavanje, za 1,0 km puta potrebno je 0,5 do 2,0 l/s
- Korišćenjem dizel goriva konstantnog elementarnog sastava,

- Zamena kamionskog transporta tračnim transportnim sistemom.

Mere zaštite na odlaganju

- Orošavanje etažnih platoa na odlagalištu jalovine,
- Rekultivacija odlagališta jalovine po Projektu rekultivacije

3.1. Mere zaštite grada od prašine sa kopa

Aдекватna mera zaštite se dobija postavljanjem cevovoda od PVC po ivici kopa prema gradu sa uređajem za stvaranje vodene zavese radi obaranja prašine. Cevovod može da bude povezan sa sistemom za odvodnjavanje površinskog kopa Južni revir.

Druge mere su: uvođenje dodatnih organizaciono-tehničkih mera i striktna primena uputstva proizvođača mašina radi efikasnog suzbijanja gasova i prašine pri radu proizvodnih mašina u kopu.

4. REKULTIVACIJA DEGRADIRANIH POVRŠINA ODLAGALIŠTA JALOVINE PK JUŽNI REVIR

Pri proširivanju površinskog kopa Južni revir po fazama od 1 do 6, otkopava se jalovina i formiraju se četiri odlagališta od čega tri sa konačnim granicama i jedno na kome ima prostora za odlaganje po novim budućim projektima. (Sl. 3.)

Na istočnoj strani površinskog kopa formirano je odlagalište Kovej. Na zapadnoj strani površinskog kopa formirana su odlagališta Andezitski prst i Bugarški potok. Odlagalište Ujevac je formirano dalje od površinskog kopova Južni i Severni revir i transport jalovine je tračnim transportom i može da primi jalovinu sa oba površinskog kopa u Majdanpeku i za sada nema konačne granice i ne razmatra se za rekultivaciju.

Odlagališta jalovine se formiraju na već degradiranim površinama i u industrijskoj zoni. Zbog uštede na transportnim troškovima, jalovina se odlaze sa završne ravni pri čemu nastaju visoke kosine nagiba 31°.

Sl. 3. 2D prikaz završnog stanja površinskog kopa i odlagališta

4.1. Podaci o strukturi i nameni korišćenja zemljišta

Rekultivacija degradiranih površina na odlagalištima jalovine Andezitski prst, Kovej, Bugarški potok i Deponija podrazumeva radove usmerenih na ponovnom kultivanju površina. S obzirom da tlo degradiranih površina ne sadrže dovoljno hranljivih materija za normalan razvoj biljaka u cilju rekultivacije treba koristiti optimalni vid sa fazama agrotehničke, tehničke i biološke rekultivacije.

Prema fizičko hemijskim osobinama tla, geomorfologiji odlagališta jalovine, ekspoziranost površina jugu, klimatskim uslovima i prirodnoj vegetaciji u okruženju u obzir dolazi biološka faza optimalne rekultivacije i to na:

- Završnim ravnima odlagališta jalovine - pošumljavanje,
- Završnim kosinama odlagališta – pošumljavanje.

Ukupne degradirane površine na odlagalištima jalovine površinskog kopa Južni

revir za rekultivaciju po lokacijama prikazane su u tabeli 3.

Tabela 3. *Ukupne degradirane površine za rekultivaciju*

Odlagališta	Kota, mnv	Ravne površine, m ²	Kota, mnv	Kose površine, m ²	Ukupne površine, m ²
Andezitski prst (AP)	500	106 049	500/425	11 340	117 389
Kovej	596	48 659	596/575	15 033	63 692
Bugarski potok	595	220 710	595/550	147 563	368 273
Deponija	580	64 564	580/415	173 332	237 896

4.2. Podaci o izboru kultura za rekultivaciju

Raspored vrsta po površinama odlagališta prilikom pošumljavanja dat je u tabeli 4 i vršen je na osnovu mikrostaničnih uslova i istraživanja koja su vršena u periodu od 1988-1989 godine u Majdanpeku na odlagalištu AP od strane Instituta za Šumarstvo Beograd, Tehničkog fakulteta Bor i Instituta za bakar u Boru i na osnovu rezultata postignutih na rekultivaciji u V. Krivelju i Cerovu.

Tabela 4. *Struktura vrsta po površinama*

Odlagališta jalovine	Struktura površina	Struktura vrsta	Površine, m ²
Andezitski prst (AP)	Završna ravan	Crni bor	106 049,00
	Završna kosina	Breza+trepetljika	11 340,00
Kovej	Završna ravan	Crveni hrast	48 659,00
	Završna kosina	Bagrem	15 033,00
Bugarski potok	Završna ravan	Brest	318 730,00
	Završna kosina	Bagrem	203 240,00
Deponija	Završna ravan	Breza+trepetljika	64 564,00
	Završna kosina	Bagrem	173 332,00

5. OPIS NAČINA REKULTIVACIJE DEGRADIRANIH POVRŠINA

Cilj revitalizacije degradiranih površina na odlagalištima jalovine u Majdanpeku jeste zaštita životne sredine. Degradirane površine pripadaju klasi tehnogenih zemljišta sa nedovoljnim udelom hranljivih materija zbog čega je potrebno primeniti optimalnu rekultivaciju sa fazama agrotehničke, tehničke i biološke rekultivacije [10].

- Faza agrotehnička optimalne rekultivacije** predstavlja etapu u kojoj se sprovodi niz mera usmerene na uspostavljanju produktivnosti na veštačkim tvorevinama – antroposolima. U slučaju degradiranih površina u Majdanpeku podrazumeva se osposobljavanje postojećih pristup-

nih puteva i naknadno planiranje površina na završnih ravni (pri završnom procesu odlaganja zbog sprečavanja stvaranja jezera na ravnim površinama se ostavljaju neisplanirane gomile jalovine).

2. **Tehnička faza optimalne rekultivacije** uključuje: otkopavanje, utovar, transport, i istovar humusa.
3. **Biološka faza optimalne rekultivacije** podrazumeva kompleks biotehničkih i fitomeliorativnih mera za uzgajanje šumskih kultura na odlagalištima jalovine u cilju obnavljanja ekosistema.

5.1. Ukupni troškovi rekultivacije

Ukupni troškovi rekultivacije obuhvataju sledeće troškove: agrotehničke faze (135.900 €), tehničke faze (11.291 €), biološke faze (409.505 €), nege i zaštite (87.447 €), neplanirane troškove (16.000 €). Ukupni troškovi rekultivacije iznose 660.143 €.

ZAKLJUČAK

Rudnik bakra Majdanpek predstavlja važan deo sistema Rudarsko topioničarskog basena Bor. Proširenje površinskog kopa Južni revir i Severni revir u Majdanpeku uz primenu kompleksnih mera zaštite omogućava kontinuitet u proizvodnji rude bakra što daje **pozitivan uticaj** na socijalnu strukturu (nacionalnu i etničku) stanovništva u smislu otvaranja novih radnih mesta i ostajanja mladih da rade i žive u Majdanpeku kao i oživljavanje sela u okolnim opštinama.

Optimalni vid rekultivacija degradiranih površina kombinovana sa autorekultivacijom i polurekultivacijom predstavlja trajno rešenje za očuvanje životne sredine grada Majdanpeka, omogućava bolje uslove mikroklimе kao i bolji izgled okoline.

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