COMPLEX SOLUTIONS FOR THE CONSTRUCTION OF INTEGRATED FACILITIES IN STOPED-OUT OPEN-PIT MINING FACILITIES

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ABSTRACT. An analysis of the generated solid household and mining non-hazardous waste in Bulgaria has been performed. A quantitative-territorial assessment of the exhaust space in open pit mines and quarries in the country has been made. The possibilities for construction of integrated facilities (landfills) for solid household and industrial waste in the waste areas (ditches) and subsequent environmentally friendly reclamation are considered.

Keywords: open pit mining facilities, integrated facilities, land reclamation

КОМПЛЕКСНИ РЕШЕНИЯ ЗА ИЗГРАЖДАНЕ НА ИНТЕГРИРАНИ СЪОРЪЖЕНИЯ В ОТРАБОТЕНИ ОТКРИТИ МИННИ ИЗРАБОТКИ

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РЕЗЮМЕ. Извършен е анализ на генерираните твърди битови и минни неопасни отпадъци в България. Направена е количествено-териториална оценка на отработените пространства в открити рудници и кариери в страната. Разгледани са възможностите за изграждане на интегрирани съоръжения (депа) за твърди битови и промишлени отпадъци в отработените пространства (котловани) и последваща екологосъобразна рекултивация.

Ключови думи: открити минни изработки, интегрирани съоръжения, рекултивация

Introduction

Mineral resources exploitation is undoubtedly related to the excavation of considerable volumes of rock unusable mass along with the ore. On a world-wide scale over 120 billion tons of ores, coal, oil, gas and construction materials are extracted annually (approximately a total of 20 t for all type of mineral resources per world capita). In terms of scale, the mining and processing industries exceed volcanic activity (10 million tons per year) and the erosive processes of the rivers worldwide (25 billion tons per year). At the same time only 5-10% (according to some authors 1-2%) from the extracted mineral resources are utilized. The remaining volumes include ores below the cut-off grade, overburden, processing waste (tailing waste, slags, coal ash, etc.), which form technogenic dumps. The magnitude of the utilization of these technogenic facilities as a source of mineral resources still remains very low.

Quantitative analysis of the generated solid waste

Data from the National Statistics Institute show that for the 2014 – 2018 period the total volume of the generated waste in Bulgaria is 663 million tons (which corresponds to 132,8 million tons annually) (nsi.bg, figure.1). The relative part of non-hazardous waste for the period remains in the interval 88,5 – 92,5%, according to the list of waste types from Regulation (EC) № 2150/2002, the remaining waste types are considered as hazardous (Regulation № 2 from 27.07.2014 by the Ministry of Environment and Water).

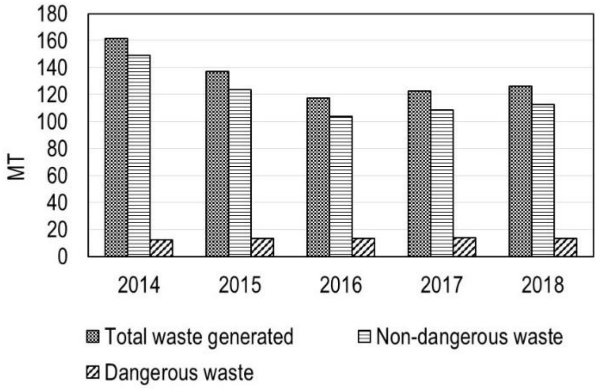

Fig.1. Total volume of generated waste in Bulgaria for the 2014-2018 period

The results, represented on Figure 1 show that the during the last three years of the examined period the total volume of generated waste has changed insignificantly from 3,03% to

4,27%. Nevertheless, when there is a possibility for waste treatment, it should be conducted so that the negative consequences of their dumping and accumulation are reduced. According to the waste types, the different courses of waste treatment are their utilization, hazard neutralization or export (fig. 2).

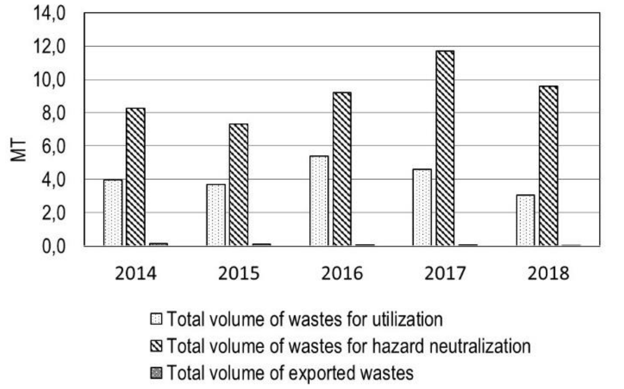

Fig.2. Distribution of the waste volumes, designated for utilization, hazard neutralization and export for the 2014 – 2018 period

After analyzing the data from Figure 2 it can be pointed out that the average annual waste volumes, designated for utilization are 4,14 million tons, which is approximately 3,12% from the total generated waste volumes (hazardous and non-hazardous) – 132,8 million tons.

A relatively higher part goes to the waste volumes, designated for hazard neutralization: 6,9%. Statistic data shows that only an insignificant part of the waste volumes in Bulgaria are exported: 0,07%.

The volumes of waste which are generated by the mining and processing industry, as well as the possibilities for their complex management are considered to be perspective. Figure 3 represents a diagram of the relative parts for the generated waste volumes according to their originating economic activity.

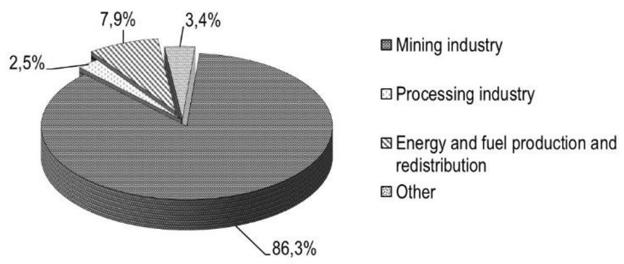

Fig.3. Distribution for the generated waste volumes according to their originating economic activities for the 2014 – 2018 period

The highest relative part goes to the mining industry – 86,3%, followed by the production and distribution of energy and fuel – 7,9%. The third place goes to the processing industry – 2,5%.

After extracting and processing mineral resources, their respective wastes are to be dumped in specialized facilities, which are classified as waste dumps (overburden embankments) and tailings. (Grigorova et al., 2014). They differ from each other significantly due their mineral and granular consistency. Overburden waste dumps are intended for mining waste (overburden) accumulation and the waste size varies with an average size of few centimeters. The ore content in these kinds of dumps is very low, which leads to the increased interest for the waste utilization as a construction material. Dumps of this type are built in open spaces and have a different special shape: pyramid-like shape, a truncated- cone-lke shape, etc.

Waste material from ore and mineral resources processing with a medium particle size from several microns to several millimeters. Depending on the processing technology, they could include some quantities of ore content, which is bigger than the cut-off grade. The tailing may be "wet" or "dry". While this type of waste is dry, it can be stored similar to waste dumps in depots. For the wet tailing waste, in order to reduce the necessary storage areas, tailing dams have to be made with safety ditches, which prevent their spread to the surface. A suitable place for their construction can be river valleys or gulches. In time the water level inside the tailings declines due to water filtration through the bed.

The distribution of waste depots around our country's territory is highly uneven. Usually they are situated right next to mining companies. Depending on the structure of the waste, they correspond with the extracted mineral resources during the mining and processing operations. Near the quarrying sites, which are extracting limestone sand, several outdoor depots are situated, which accumulate the overburden, clay rocks and part of the substandard mining reserves. In general, these waste dumps do not contain hazardous materials and the acting European laws does not enforce high technologic requirements towards them (National strategy for development of the mining industry, 2015).

The total number of dumps (hydraulic and granular) is 227. This means, then in each administrative region of Bulgaria, there are 10 waste dumps on average. During the reclamation of the areas in the sector of "Non-metallic mineral resources", there is a tendency of a gradual increase of these areas. During 2018 about 132,6 ha are reclaimed, while during 2019 – 176,5 ha. This is an indicator that the mining business from this sector is oriented towards the preservation of the environment and local ecosystems.

To this moment, 518 concessions for mineral resources are provided in Bulgaria, some which have been provided from 1997. While taking into consideration the term until each one lasts, in the next few years it is expected that mining will conclude in quarries such as: "Hristovo" deposit for filntstone concretions, Vetovo municipality (2024), „Iskar" deposit for quartz-feldspar sands, Dolna Mitropoliya municipality (2024), „Krivina" deposit for sands and gravel (2026), „Ahmatovo" deposit for sands, Sadovo municipality (2021), „Shishmantzi" deposit for limestones, Rakovski municipality, „Belashtitsa" deposit for marble, Rodopi municipality (2021), "Devnya" deposit, "Lyulyaka" sector и "Snezhno pole yugoiztok" sector for quartz sands (2025), „Yurt-dere" deposit, Dimitrovgrad municipality (2020), „Probuda" marl deposit, Targovishte municipality (according to the data from the Register of the active concessions for mineral resources mining and quarrying, updated to 16th July 2020). Each of the pointed quarrying sites has a potential for hard rock waste dumping and the site for building an environmentally friendly integrated waste facility.

Complex solutions for dumping solid wastes inside the stoped-out areas in open-pit mines

One of the promising possibilities for complex utilization of the natural resources, the waste treatment, the rational land usage and the disturbed areas reclamation is for that the stoped-out areas in open-pit mines should be used for their filling with solid industrial and household waste. Usually this is done when in the mining regions the soil layer is absent and the reclamation of the natural landscape is virtually impossible. This way some of the quarries are situated in the neighboring territories of towns or very close to industrial companies, which is an additional argument for transforming the stoped-out areas for waste depots. In addition, the problem with dumping and storing solid household wastes (SHO), especially for densely populated areas is difficult to be resolved. On the whole, transforming the stoped-out areas has a further practical usage and the initial landscape restoration is possible. For this purpose, it is required that during the mine site (or quarry site) design phase the volumes of the processed and utilized household wastes are taken into account, as well as the different stages of waste dumping for every waste type and their respective parameters with a consideration of the environmental protection. The waste dump body, as a base part of the integrated waste facility must ensure the hazard neutralization of the waste, while at the same time it does not threaten the health conditions of the working staff, as well as the neighboring populated areas. In addition, it must not induce a risk for polluting the air, the underground water sources, the soil, the flora and the fauna. A monitoring for noise and dust pollution has to be considered as well as the control of bad smells from the waste facility.

The placement of the solid wastes inside the depot have to be organized in such a manner, that ensured the stability of the waste material on the slopes in order to prevent landslides. The waste dump body is tested for its general stability in order to ensure its stability during the different stages of its utilization: construction until reaching 1/3 of its design height, 2/3 and the maximum design height. In order to determine the deformations (subsidence, failure, etc.) it is necessary that certain computational checks are made for forecasting the stability of the facility.

The construction of an integrated waste facility in the stoped-out areas of the mining (or quarrying) site starts with the following preparation (https://sites.google.com, fig.4):

- Slope adjustment for the open-pit mine (a frequent practice for open-pit mines and quarries land reclamation).

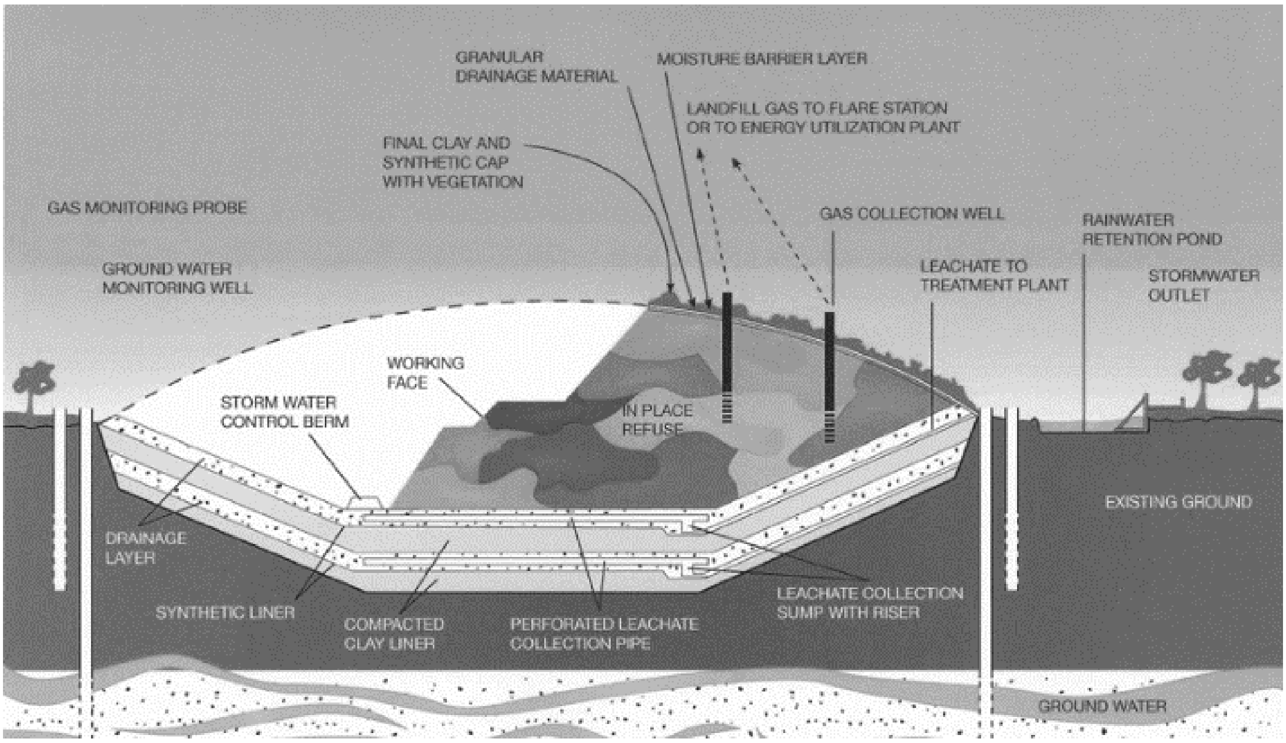

Fig.4. Technology for building an integrated waste facility in the stoped-out areas of an open-pit mine

- Consolidation of the dump's fundament by constructing a lower isolating screen for sealing the bed and the slopes. This is necessary for the case when the dump base does not suit the requirements for ensuring the sufficient resistance for preventing the risk of polluting the soil and waters. In this case the filtration index (coefficient) - K_f (determined by experimental from water assaying from a drill well) – does not suit the normative geological barrier requirements $K_f < 1 \times 10^{-6}$ m/s (Regulation №6). The lower isolation screen of the depot, in combination with the geologic basis must satisfy the requirements for permeability and thickness and the requirements for protecting the underground waters from the negative impact of the waste dump body and its satisfactory stability. It is designed as a system for sealing the bed and the slopes of the depot, which includes a mineral sealing layer, mineral obturation, an isolation geomembrane and a protecting layer of a drainage (fig.4).

- The placement of an isolation geomembrane takes place for absorbing the deformations and the subsidence of the mineral in the sealing layer and the geological base. Its purpose is that combined with the sealing layer, they ensure a protection for the soil and underground waters from leaks of the formed infiltrate inside the body of the waste dump. The geomembrane's main feature is that is chemically resistant to the infiltrating chemicals inside the body of the waste dump.

- In order to mechanically protect the foil, it is covered with a layer of geotextile;
- Placement of a drainage system in the lower isolating screen for collecting and leading the infiltrate from the dump body. It includes an area drainage with a thickness of at least 0,50 m from washed rubble with a granular composition which ensures K_f ≥1.10-3 m/s; a drainage pope for collecting and leading the infiltrate to a collecting shaft; a collecting and revision shaft; a submerged pump; a pipeline, leading the infiltrate outside the body of the waste depot. The drainage pipes (farcically perforated) are placed on the bed of each cell over the isolation layer. They lead the infiltrate to the collecting shaft. The free end of the drainage pipes is lead to the outer boundary of the ditch for revision and possible flushing.
- The network of drainage systems across the bed of the depot is covered with an area drainage – a two-layered filter of river gravel (5-40 mm with a thickness of 0,30 m) and coarse-grained sand (0,20 m thick over a layer of gravel) only around the pipes. The drainage system is designed to accumulated the maximal daily infiltration flow-off.
- Collecting the atmospheric waters on the upper boundary of the pit's surface is done by placing drain ditches.
- The infiltrating waters (IF) formed inside the body of the depot as drained to a drainage network inside a concrete shaft. The collected water from the shaft are lead to a pumping station with a retention volume for the IF.
- If it required, a passive or an active degasification system is built for the waste gas, which should lead to the burning of the collected gas (turning CH_4 into the less harmful CO_2
- Building on a surface isolating screen on the parts of the depot, which are full;
- The closing processes of the solid waste dump take place when it reaches its design height. The last layer of waste is covered with a layer of soil which is 1-2 m thick. The covering layer has to intact and firm across the whole area. In order to avoid erosion, the whole dump is reclaimed and grass is planted. For the kinds of waste dump which emit CH_4 a gas drainage layer is considered, which has the purpose of collecting the emitted gases.

A long-term monitoring is required for this type of integrated waste facility, which takes place during its construction and utilization, as well as its final reclamation. The monitoring project includes the following activities:

1) Control of the dumping activities – input control and technological control, isolation of the drianage system and the stability of whole dump facility. The dump's operator keeps track of a "Report book", which contains the information of the input control;

2) A system for independent monitoring – it includes the monitoring the research during the period of the waste dump exploitation, as well after its close down:

- meteorological date – information about the quantity of rainfall water, the air's teperature, the wind direction and force, as well as the evaporation and air humidity. This information is required for tracking the processes in the waste body and is gathered by the closes hydrometeorological service in the region.
- surface waters – they drain throught the ditches and follow the direction of the natural surface drainage.
- the condition of the waste depot body – for tracking the deformations of the body, certain observation points have to be chosen on the reclaimed grasses area of the waste dump.

Conclusion

The modern level of technologica ladvancement cannot ensure that each industry is waste-free. Therefore, in the near-future research for the reduction in the waste generation for different types of technology as well as their safe keeping in suitable conditions. The presented complex decisions for the waste dumping of hard material in the stoped-out mining areas in open-pit mines are only a part of the perspective tendencies for reducing the environmental impact from the generation of hard waste.

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