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Reclamation of lands disturbed by mining activities in Bulgaria

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Abstract. Disturbed by the mining industry area in Bulgaria is about 24,113 ha of which only 8,253 ha are reclaimed. Reclamation of disturbed areas covers a complex of engineering, technical, ameliorative, agricultural, forestry and other activities, which aim at restoration of the disturbed terrains and their re-entry into economic turnover in accordance with environmental conditions and area landscape. All disturbed lands as well as their adjacent areas that have completely or partially lost productivity as a result of the negative impact of mining activities and land damage are subject to reclamation. Land reclamation is a two-step process which includes: technical reclamation and biological reclamation. Technical reclamation is performed by the land owner and covers cleaning and preparation of the terrain, leveling, final formation and laying a humus soil layer on site by adding appropriate “improvers” (e.g. fertilizers, texture enhancers, etc.). Biological reclamation covers restoration of the productivity of the disturbed areas. Reclamation technologies applied in Bulgaria as a whole have led to a state of these territories that requires both maintenance and search for new ways of integration of the reclaimed landscapes with modern economic activities. The aim of the study is analysis and applying reliable modern practices that ensure good results in visual qualities of landscape and more options for future use of the reclaimed land.

Keywords: mining activities, disturbed areas, technical and biological reclamation

Introduction

Mining activities lead to the most active form of destruction and contamination of soil. Mining of minerals by the underground method Pavlov (2014) causes partial disturbance of the soil due to construction of entrance and ventilation shafts, heaps of off-balance ore and waste excavation material as well as contingent subsidence above underground galleries, while the open method of mining disturbs really huge land territories. The open method is used for extraction of gravel, ferrous and nonferrous metals, coal, quarrying, etc. (Banov, 2011).

According to Kolesnikov (1974) reclamation is a complex of mining, technical and biological activities as well as engineering and ameliorative measures, which aim at acceleration of formation of optimal cultural landscapes with productive-soil-plant (biogeocenotic) cover. In fact, lower units of landscape classification – soil zones and territories are an object of reclamation. Zaitsev (1977) considers reclamation as technogenic impact, altering zoning restoration successive order. He defines reclamation as a complex of measures contributing to an accelerated transit of the successive restoration order. In order to forecast it is important to know the magnitude of the asymmetry of the restoration order, which can be found in the difference of duration of the stages of endogenous and exogenous units.

Lazareva (1968, 1972) has a more critical attitude to the term reclamation considering it as preparation of the disturbed terrains mainly for agricultural and forestry use or more precisely as a complex of agro-technical work and biological control of these terrains. Occasionally reclaimed terrains can be used for the construction of city parks, forest parks, sports facilities or urban development such as streets and roads. However, in this matter which according to the author acquires increasing circulation, the term reclamation does not cover the complex work for preparation of the area for other types of use such as housing development, construction of water reservoirs, etc. Such interpretation of the concept of reclamation cannot be used in reclamation activities in Bulgaria because great part of the disturbed terrains are located near settlements which are too densely populated and require not only areas for recreation, forests and parks, sport facilities, but also terrains for industrial enterprises or housing development. Therefore, in our opinion, the definition of Motorina and Zabelina (1968) is more appropriate. In the term reclamation of disturbed by industrial activity areas the authors include the complex of mining, technical, ameliorative, agricultural, forestry and civil engineering works, aiming at restoration of the disturbed fertility of soil on areas released from industrial development (planting of agricultural crops and forests, creation of water areas for different purposes, construction works, etc.). The more general definition of Motorina (1975) is similar. She considers reclamation as a complex of various activities (engineering, mining, technical, ameliorative, agricultural, forestry, etc.), which are performed for restoration of the productivity of areas disturbed by industry in a certain interval of time. These areas can be provided for different types of use.

Bulgaria accepted legislative measures for the successful recovery of damaged areas of mining activity in 1996 (Regulation No 26, 1996). However, the processes of restoring the damaged areas are difficult and problematic. This gave us reason to make an analysis of existing practices and provide technological solutions for restoring the fertility of degraded and contaminated land in Bulgaria, result of mining activity, and demand of current methods for the integration of reclaimed landscapes in modern economic activities. Another aspect of the study is realization of reliable modern practices that ensure good results on the properties of the landscape and more options for future use of the reclaimed areas.

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Areas disturbed by the mining industry in Bulgaria and their restoration

Mining industry provides more than 50% of the energy used in the country, supplies raw materials for industry, etc. Moreover, the necessity of mineral resources is continuously growing. The impact on the earth’s crust of mining industry, construction, urban planning etc. virtually affects all components of the biosphere - land, flora and fauna, water and air pool, subsurface. Nowadays the area disturbed by the mining industry in Bulgaria is about 24.113 ha, of which only 8.253 ha are reclaimed (NPASLMCDRB, 2014). The areas affected by extractive mining industry in the country and their location are given in Figure 1.

The impact of mining activities on the surface is direct (shortly called zone I) or indirect (zone II), which is a consequence of the first one. The prevalence of indirect impact is significantly greater than the direct one and, as a rule, in the zone of indirect impact there are not only elements of the biosphere, but other elements, too. Furthermore, except soils disturbed directly by the open pit mining around them, there are adjacent disturbed areas which are 4 and even 10 times larger (Figures 2, 3, 4, 5 and 6). These areas are characterized by changing the regime of underground water and natural geochemical migration of elements, as well as by erosion process stimulation (Tsolova, 2010).

Figure 1. Map of Bulgaria with areas affected by extractive mining industry.
The utmost disturbances and contamination of environment are due to mining industry in the country, enrichment of extracted raw materials, energy production and chemical industry. Therefore, when talking about restoration of disturbed land and soils, above all we mean recovery from the impacts of these anthropogenic activities. Some example for reclamation of disturbed areas are presented in Figures 7, 8, 9, 10 and 11.

![Figure 7. Spoil Heap of Maritsa Iztok Mine right next to some arable land (Zheleva, 2010)](image)

![Figure 8. Maritsa Iztok Mine – example for reclamation of disturbed areas (Banov, 2005)](image)

![Figure 9. Maritsa Iztok Mine – example for reclamation of disturbed areas (Banov, 2005)](image)

![Figure 10. Maritsa Iztok Mine – example for reclamation of disturbed areas, used for cultivation of cereals (Banov, 2005)](image)

![Figure 11. Maritsa Iztok Mine – example for reclamation of disturbed areas, used for pasture land (Banov, 2005)](image)

man needs his active intervention. The modern trend of environmental protection, which deals with the removal of the consequences of the negative impact of industry on natural complexes and restoration of their productivity, is reclamation of land (Petrova et al., 2009). This term appears in connection with the development and distribution of work on restoration of terrains completely or partially destroyed as a result of mining. The main task in restoring the environment disturbed by mining and construction work is to create an ecologically balanced system representing economic and aesthetic value (Petrova et al., 2011). As far as soil is concerned, restoration measures should ensure full use of disturbed land and should protect neighboring areas from the harmful effects of mining Banov (2014). Reclamation is one of the most radical methods of restoration and improvement of disturbed areas and their reentry in the national land fund.

**Classification of the destroyed land**

Petrova and Petrov (2011) divide the disturbed areas in two groups – land on which industrial waste is dumped (heaps), and areas disturbed as a result of the seizure of fossils (mines) from spoil heaps obtained in open pit mining of ores and from subsidence in areas of underground developments. That principles of
classification are used by Ivanov and Banov (2008) in the systematics of some reclaimed soils in Bulgaria.

Reclaimed soils are composed of a variety of geologic materials that define their structure and properties. This is one reason to offer specific taxonomic systems covering reclaimed soils from a given region. Such classification of reclaimed soils was developed by Ivanov (2007).

The creation dynamics and accumulation of organic materials on reclamation embankments uses different tree species and mineral melioration (Banov et al., 1994). The main indicators that are analyzed in connection with the investigation are: total quantity and fractional structure of the humus, basic nutritive elements and indicators that characterize some physical properties in depth of the profile (Banov and Hristov, 1997).

The analysis of the dynamics of the soil fertility of reclamation includes analytical data separated in three investigation stages. The data is presented in table format and most of them are processed with dispersal analysis for authenticity report of the influence of the mineral inclusion with different norms for the most important soil indicators. Acceleration of the humus formation in relation with mineral improvement has been found out by Zheleva (1998). Such classification of reclaimed soils in the region of Maritsa-Iztok Mines was developed by Banov and Hristov (1996). Later Hristov (2000) made up the classification to include humus reclaimed soils. Based on fundamental and experimental data Marinkina and Banov (2000) believe that the assessment of the suitability of geological materials for reclamation should be done based on more detailed chemical analysis.

Baklanov and Mazur (1975, 1976) classified spoil heaps of mines and mineral processing plants which are used for landscaping in Donbass. Four groups of heaps are established depending on the physicochemical properties of fossil rocks: a) heaps of materials obtained through penetration in vertical and horizontal mining galleries; b) heaps of materials caused by building pits for non-anthracite coal; c) heaps of materials caused by building pits for anthracite coal; d) heaps of materials obtained in coal enrichment.

Zheleva (1979) applies a scoring system of classification based on qualitative criteria under which the geological engineering specifics of mining developments in Poland is widely reported. For each soil type (from stripping or from heaps) a bonus value (LB), expressed in points, is determined. The more suitable for reclamation is the substrate with higher bonus value. Forest reclamation substrates are in class B and partly in class C with a bonus value of 50 <LB = 75 or 21 <LB = 50. In Class D there are unproductive substrates requiring fertilization or another kind of amelioration, with LB = 21. The rating value is determined on the basis of some permanent laboratory parameters obtained in soil research. Toxic substrates requiring neutralization refer to Class E as unsuitable for reclamation. The main factors authors use in the classification of disturbed terrains are as follows: origin of heaps, composition, structure and properties of their constituent rocks.

In the classification of Motorina and Zabelina (1968) various options to restore the disturbed areas are considered. Parched heaps can be restored to forests, grasslands and sports facilities. Heaps of iron ore and mining developments are usually recovered for agricultural purposes by compulsory leveling and covering with a soil layer. Afforestation activities are conducted on quarries for building materials and on leveled or uneven iron ore and mining developments. Deep lime and other quarries with a powerful industrial layer and large opening are considered suitable for recreation areas. Restoration of mining disruptions causes much trouble because of hampering the outflow of water and drainage.

The five-point rating classification developed in Germany and Czechoslovakia for heaps and overburdened materials are widely spread. This classification divides materials into five categories – from category I (very good, very suitable and suitable) to category V (very bad or unsuitable). This division is based on the agrochemical and agro-physical properties of materials and it allows the determination of the methods of reclamation (agricultural, forestry and landscape design) and the necessity of improving the technology of overburden (Motorina and Zabelina, 1968).

Land reclamation practices

Natural classification of industrial heaps in which they are united in subordinate classes, groups and types, according to the symptoms influencing biological reclamation and the nature of the preparatory mining and technical activities has been developed by Kolesnikov and Motorina (1975). The research of natural phytocenoses is a major part of the ecological research of the region, in which the biological reclamation will be performed, because the future biological activities on the disturbed and technically reclaimed terrains will be planned according to this research (Bozhinova et al., 2012).

Vegetation is one of the elements of soil formation (Tsolova et al., 2013). The forming of natural phytocenoses depends on the climatic and edaphic conditions of environment but soil formation is directly dependent on the vegetation cover. It is natural to anticipate that the soil formation process on disturbed terrains with appropriate environmental conditions, including fossil geological materials will take place in the same direction as under natural conditions.

The observations of vegetation in surrounding areas of mining enterprises indicate that in addition to direct disturbances mining causes other degradations on natural phytocenoses. They degrade depending on the remoteness of mining and the changes it causes in the hydrological regime of the area. In the forest phytocenoses different stages of the processes of secondary alteration of root forest phytocenoses are observed with derivatives and the nature of all successions is regressive. The anthropogenic impact on forest habitats leads to significant changes in their floristic composition with alteration of the edificatory types. In the place of the grass types typical of root habitats xerothermic plants grow often infiltrated there through secondary displacement. The vertical and horizontal structure is distorted and simplified. The existing instability of forest phytocenoses are in class B and partly in class C with a phytocenoses as a result of the xerophytization of the habitats and their degradation make their death very probable near areas with intensive anthropogenic activity (Zheleva, 2010). A study of geological and soil materials that will serve as the root layer is necessary to answer first of all the question if it is possible to use the areas for growing perennials (Ivanov et al., 2014).

Biological reclamation involves all activities related to the utilization of the terrain by vegetation, microorganisms, insects and animals, and to the acceleration of succession and creating conditions for a sustainable ecosystem which is similar to the natural one. These are all anti-erosion and other activities for the soil preparation for growing agricultural crops, for sowing grass seeds, planting saplings and flowers, soil melioration and care of vegetation up to its permanent accommodation on the terrain (Banov and Tsolova, 2013).

In order to determine the objectives and technology for biological reclamation it is necessary to study the environmental conditions in the area, habitat-forming and limiting factors of the natural ecosystem and finally the limiting factors for the reclamation itself. The first group of factors – the climatic ones: solar radiation
characterizing the thermal regime (temperatures: average monthly, minimal, maximal, absolute minimal and absolute maximal ones), humidity and rainfall, the index of humidification, droughts during the vegetation period, etc. (Zheleva, 2008).

The second group of factors which are equally important include the edaphic factors: physical, chemical, physico-chemical properties of substrates (Kostlova et al., 2013), mineralogical and mechanical composition, water properties, water regime, etc. As a complex, these factors reflect the soil fertility – actively in the initial stage of reclamation and potentially – that is what can be formed by the properties of the bulk substrates in particular climatic conditions through the application of certain ameliorative activities and by planting the most appropriate tree and bush types (Hristova et al., 2014).

The third group of factors that are directly dependent on the above stated - these are plant resources of the adjacent territories (Zheleva and Bozhinova, 2010). Their type composition determines the kinds of plants appropriate for biological reclamation. Changes in topography and land surface caused by excavation and backfilling along with the character of the surrounding terrains lead to local modifications of the macro- and microclimate. The distribution of rainfall, temperatures, wind conditions, air retention and the related effects on technical and biological reclamation are especially affected.

For the successful performance of biological reclamation it is important to know the factors of soil formation, the speed of formation of the soil profile, the transformation of materials in soil formation, the type and strength of the bond of the newly formed substance with minerals, the amount of supplies, the mobility of nutritious elements connected with minerals (Tsolova et al., 2013). The most important signs, by which one can judge the suitability of the soil for use are mineralogical composition, the amount of physical clay and silt, the maximum absorbency, stiffness in the dry state, the structuring, the content of humus and mobile aluminum, the reaction of the soil solution and the degree of salinity (Banov, 1989). According to these signs in principle all materials are suitable for use, but to a varying degree, which is quantified (Tsolova et al., 2014). The surface layer of the agricultural field should be made of earth, suitable for biological reclamation (Zheleva and Bozhinova, 2007).

For the purposes of biological reclamation crops with economic purpose are used. The selection of species is consistent with the environmental factors - climatic, edaphic, hydrological and others (Gentcheva et al., 1999).

The main directions for use of reclaimed lands as biological objects are for agricultural (farm) and silvicultural purposes. Depending on how economically and environmentally advantageous the second direction is, target crops for erosion, landslide, recreational crops or forest parks may be established (Petrova and Tsolova, 1998).

The basic method for reclamation of land for agricultural use includes spreading humus horizon on a technically recovered territory and plowing for mixing. This method is most commonly used creating conditions close to natural (Zheleva and Bozhinova, 2011). Reclamation for agricultural purpose is performed by another method, namely by spreading the affected terrain directly with suitable geological materials with specific physical and chemical properties - without soil humic materials. This method is suitable more for creating meadows and pastures where a humus horizon is subsequently naturally formed (Zheleva et al., 2005).

In the reclamation of a terrain for forest purposes the biological reclamation should be held on time before the start of the active erosion. Otherwise, the subsequent planting on the slopes is not only difficult, but harms the nearby lands (Gentcheva et al., 1994).

All trials and tests related to the recovery of degraded areas resulting from mining uranium ore must be based on sound scientific basis. One of the first conditions in this direction is the classification of these objects, method of disturbance of the area, the aim of the recovery, etc. (Petrova, 2011).

To determine the way of reclamation of a certain technogenic landscape or of a certain disturbed terrain in particular, it is necessary to know which method will be the most efficient and the most economically profitable, whereas the nature of the disturbance must be ascertained in advance (Petrova and Noustorova, 2000). For this purpose these areas must be typified and classified according to the type and origin of the disturbance and the need of reclamation and its performance in one way or another.

The continuously growing area of the damaged areas due to mining requires the application of new methods to accelerate reclamation activities on exhausted territories. The known methods for the restoration of contaminated lands with heavy metals are not so many. Contamination with them is very stable and durable because they are irreducible in the soil and accumulate in it and remain there for a long time or permanently. Furthermore, their low contents carry a certain risk, and some of them have phytotoxic effect (Bozhinova et al., 2012). After their reclamation the disturbed areas can be used for agriculture, pastures, meadows, forest crops as well as for other purposes such as sports facilities, parks, forests, camping sites, civil engineering. The requirements for the reclamation of disturbed land using different methods are in accordance with Regulation No. 26 (1996) for reclamation of disturbed areas, improvement of low productivity lands, removal and utilization of the humus layer.

Characteristics of each type of disturbed fields - quarries or embankments, require specific mining technical works that depend from the manner of extraction and technical capabilities of the mining company, and the ecological requirements of the harvest area (Petrov and Petrova, 2011).

Conclusion

In practice, the reclamation of lands disturbed by industrial activities is carried out in three stages:

First Stage (preparatory): Survey of disturbed areas, determining the method of reclamation, feasibility studies and preparation of the project for reclamation.

Second Stage (technical reclamation): Technical reclamation, depending on the environmental conditions may include an interim stage - chemical reclamation. Technical reclamation is typically carried out by mining companies or those who disturb the terrain. Transportation of bulk material by conveyor belts and filling them with an overburden spreader (absetzler) is practised most often in large open mining developments. The formed topography of the embankment is comb, which is then sealed and leveled by other machines, and fertile soil (humus materials) is packed on it. The reclaimed soil obtained by this method as a rule is used for agricultural production.

Third Stage (biological reclamation): Biological reclamation is performed after the entire completion of the mining technical stage. The biological stage of reclamation involves restoration of the soil fertility by growing different types of plants – agricultural crops, grass vegetation, bushes, trees, etc. The activities of this stage are performed in accordance with the anticipated use of the reclaimed
area and the agro-technical requirements to the soil cover for growing of particular agro technical or forest crops. Formation of a soil layer, structuring of soil, accumulation of humus and nutrients and adjusting the properties of the soil to a condition which meets the requirements of the crops to be grown are ensured.

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**Instruction for authors**

**Preparation of papers**

Papers shall be submitted at the editorial office typed on standard typing pages (A4, 30 lines per page, 62 characters per line). The editors recommend up to 15 pages for full research paper (including abstract references, tables, figures and other appendices).

The manuscript should be structured as follows: Title, Names of authors and affiliation address, Abstract, List of keywords, Introduction, Material and methods, Results, Discussion, Conclusion, Acknowledgements (if any), References, Tables, Figures.

The title needs to be as concise and informative about the nature of research. It should be written with small letter /bold, 14/ without any abbreviations.

**Names and affiliation of authors**

The names of the authors should be presented from the initials of first names followed by the family names. The complete address and name of the institution should be stated next. The affiliation of authors are designated by different signs. For the author who is going to be corresponding by the editorial board and readers, an E-mail address and telephone number should be presented as footnote on the first page. Corresponding author is indicated with “*: 

**Abstract** should be not more than 350 words. It should be clearly stated what new findings have been made in the course of research. Abbreviations and references to authors are inadmissible in the summary. It should be understandable without having read the paper and should be in one paragraph.

**Keywords:** Up to maximum of 5 keywords should be selected not repeating the title but giving the essence of study.

The introduction must answer the following questions: What is known and what is new on the studied issue? What necessitated the research problem, described in the paper? What is your hypothesis and goal?

**Material and methods:** The objects of research, organization of experiments, chemical analyses, statistical and other methods and conditions applied for the experiments should be described in detail. A criterion of sufficient information is to be possible for others to repeat the experiment in order to verify results.

**Results** are presented in understandable