Green technologies in land recultivation for coal mining enterprises

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Abstract. The importance of the issue is determined by the fact that coal extraction in the form of open and underground methods is accompanied by the violation of land, change in relief, and a technogenic landscape formation. In these conditions, it becomes vital to develop new scientifically grounded approaches to the restoration of anthropogenically disturbed agro landscapes based on the formation of recultivation and mining technologies, comprehensively ensuring the stabilization of quality and conservation of soil resources. The article presents an overview of the most popular methods of land recultivation with the use of green technologies to increase the efficiency of the recovery on the basis of a systematic approach.

1. Introduction and Background
The resource potential of coal industry in Russia exceeds 1.1 trillion tons of coal, with only 235 billion tons of them being estimated [1]. More than half (61%) of the resources are available for mining in the high-open way, 88% were concentrated in the Siberian Federal District. Annually, the coal mining process results in the natural landscape disruption of sufficiently large areas and irreparable damage to the environment. In addition, disturbed lands become a cause of water, soil and atmosphere pollution, which indicates the scale of the damage caused by coal mining enterprises to the environment and the national economy.

Irkutsk region has significant resources and coal reserves. The estimated coal resources make 27.9 billion tons. The explored balance reserves of coal (14.7 billion tons) are mainly represented by black coal (11.7 billion tons). Coal reserves in the region at current production levels will take 600 years to deplete.

In Irkutsk region, coal mining is one of the main extractive industries. In 2018, coal production increased compared to previous years. [2].

Figure 1 shows the dynamics of coal production in Irkutsk region over a ten-year period.

The coal extraction in Irkutsk region until 2030 is estimated at a level of 13-15 million tons per year [3]. To ensure this level of production it is necessary to strengthen the material-technical base of coal-mining enterprises, upgrade current production facilities, and introduce new technologies.

Recently, the intensity of growth of the area of annually disturbed lands has become more and more noticeable; given the rapid growth of open-cast coal mining, the complication of mining engineering conditions and the characteristics of the traditionally used coal mining technologies, the area of disturbed
lands will continue to grow in the future. In these conditions, the issue of recultivating the disturbed lands using new methods, including green technologies, becomes particularly relevant.

Coal mining is accompanied by the violation of land, change of the terrain and the formation of technogenic landscapes. In 2016, industry enterprises violated 5161.4 hectares, recultivated 964.2 hectares, as the figures in table 1 show.

Table 1. Areas of disturbed and recultivated lands in 2016.

| Coal industry, basins and regions | Area of disturbed lands per year, ha | Area of recultivated lands per year, ha | Total area of disturbed lands at the end of 2016, thousands ha |
|----------------------------------|--------------------------------------|----------------------------------------|----------------------------------------------------------|
| Coal industry                    | 5161,4                               | 964,2                                  | 111,5                                                    |
| Donetsk pool                     | 7,1                                  | 0                                      | 0,2                                                      |
| Kuznetsk pool                    | 3171,5                               | 152,7                                  | 68,5                                                     |
| Kansk-Achinsk pool               | 158,4                                | 50,2                                   | 5,8                                                      |
| Pechora pool                     | 28,1                                 | 0                                      | 1,0                                                      |
| Yakut pool                       | 790,2                                | 237,7                                  | 6,6                                                      |
| Moscow region pool               | 0                                    | 19,0                                   | 0,2                                                      |
| Ural                             | 0                                    | 0                                      | 2,4                                                      |
| Eastern Siberia                  | 517,9                                | 319,6                                  | 16,5                                                     |
| Far East                         | 488,2                                | 185,0                                  | 10,3                                                     |

Specific land intensity of mining operations amounted to 13.4 hectares per million tons of coal production. The share of recultivated lands in the total amount of damaged lands varies over the years and in 2016 was 18.7%.

With the increase in coal production volumes and the advance growth of opencast mining in coal industry there was a steady growth of the annually disturbed lands area. Thus, for the period of 5 years (2012-2016) there was an increase of 23.4%. The area of annually recultivated lands for the same period decreased by 5.6%. Annual recultivation volumes yield to those of violation processes, the total area of disturbed lands in the industry is growing every year. By the end of 2016, the area of disturbed lands
reached the figure of 111.5 thousand hectares. At the same time, the majority of enterprises, except the newly introduced ones and those with modest life span, there are significant areas of waste lands which are not used in the production processes, will not be used in future and, thus, are subjects to recultivation. The largest areas of disturbed and waste lands are found at the enterprises of Kuzbass, Eastern Siberia and the Far East, that is, in regions with a high level of coal production using the open method.

The purpose of this research is to conduct a comparative analysis of domestic and foreign development of land recultivation techniques using green technologies to increase recovery efficiency of agricultural landscapes based on a systematic approach that ensures the stabilization of quality and conservation of the generated soil resources.

2. Object and Methods
The research conducted according to the method of comparative analysis. Green technologies and approaches to land recultivation proposed by Russian and foreign scientists make the object of our research.

3. The Analytical Section
Land recultivation is carried out in two stages: technical and biological. The technical stage includes the layout of the surface and its covering with a fertile layer or soil or its improvement, the construction of roads, hydrotechnical and land-improvement facilities as well as other works in compliance with the project. The biological stage consists of agro-technical and phyto-reclamation measures to restore soil fertility, accelerating soil formation processes, and the revival of flora and fauna on uncultivated lands [4].

In recent years, recultivation techniques where the biological stage consists of effective, active independent overgrowth of technogenic soil formations gained increasing popularity [5]. This includes organic, lime and mineral fertilizers, use of manure, liming of acid rocks, and use of peat compost.

One of the widely used methods of recultivation is the introduction of organic fertilizers into the soil and sowing of perennial herbs. When using this method, a fertilizing-sowing granular seed material obtained through microbiological transformation of a lignin-bird-sawdust mixture is injected; the seeds of perennial grasses are added there afterwards. [5]. This method is a time-consuming process due to the composting of a mixture lignin with sawdust and poultry manure in the presence mikobionta Paecillomices variottii, and pelletization of this compost with mineral fertilizers and grass seeds. To improve the access of nutrients mycorrhizal fungi (simbiotrofy) are sometimes used together with earthworms [6].

Scientists have shown the possibility of using coal waste in the form of coal fertilizers to accelerate the accumulation of humus in dumps [8]. It is proved that the introduction of coal waste and products of their bioconversion accelerates the biogeocenotic recovery processes [9]. It has been established that humates have a positive effect on the growth and development of plant organisms, as well as the formation of soil structure in conditions of disturbed lands mining. [9] [11].

The use of microorganisms which help to transfer the difficult nutrition forms into easily assimilated be the higher plants gained popularity both in Russia and abroad.

The investigations showed that as a result of inoculation of the surface by active microflora dumps create conditions for the formation of sustainable phytocenosis [11] [13]. To provide microorganisms with nutrients, biological preparations include substances that stimulate their active development.

LLC VNIIS Coal Institute suggests using microorganisms and household wastewater treatment plants to accelerate land recultivation processes with the sowing of grass-legume mixture of herbs afterwards [14].

Under the influence of the metabolism of microorganisms, the agrochemical properties of soil improved: the amount of assimilable forms of nitrogen, potassium and phosphorus increased, and the
acidity decreased. A.P. Krasavin et al. [14], developed a recultivation technology that includes: surface planning, the introduction of coal waste, humic acids, planting seeds of plants previously treated with humic acids and bacterial culture, and the inoculation with Azotobacter chroococum and Bacillus megaterium microorganisms [15]. As a result of using this method, the rate of adaptation of the introduced strains of microorganism’s increases and the aboriginal microflora develops rapidly, which helps to create conditions for the vegetation growth.

There is a focal method of recultivation which is based on creation of centers of biodynamic formations in the hollows of technological crests [16]. This technology uses the sowing of seeds cultivated with biodynamic preparations which consist of adaptive microorganisms, mycorhizas, blue-green algae from the cyanides group accumulated in modified charcoal with its following spread throughout the whole area of dumps.

4. Results and Discussion

Green technologies in the process of disturbed lands restoration are used at the biological stage of recultivation. These include: planting trees and bushes, sowing perennial grasses, carrying out agrotechnical measures, phytomeliorative and other works aimed at restoring flora and fauna. Conducting recultivation is a necessary activity, since the recultivation of disturbed lands is of great economic and environmental importance because of the shortage of land resources and the negative environmental impact of industrial development.

The choice of recultivation direction is carried out with the following issued being taken into account:
– the need for the recultivation of all disturbed lands in the region;
– limitations being imposed by technical capabilities depending on environmental-technogenic features of disrupted lands and those in the process of disruption, as well as standard allowable properties of the area being recultivated (square, configuration, slopes etc.);
– the highest possible level of satisfaction of economic and social-ecological needs of the region (foodstuffs, recreational areas and areas intended for building, etc.) through recultivation mainly in trends corresponding to most vital types of needs.

The arguable questions in the sphere of recultivation in coal industry include:
– low demand (if any) for recultivation and further purposeful use by regional and local executive power in some regions;
– absence of research results, usually at the planning stage, of mineralogical and disperse composition, physico-mechanical, agrophysical and agrochemical properties of soil allowing the grounded choice of course and recultivation technology;
– lack of special technical equipment to perform recultivation procedure at high level as well as limited possibilities of its usage;
– absence of landscape approaches to revival of damaged lands;
– absence of efficient economic stimuli and mechanisms of quickest revival of disturbed lands being not exploited.

The divergence of methods and conditions of coal deposits extraction causes urgent need for modernization of technological methods of recultivation of lands, which were damaged due to mines, reserves and enriching plants industrial activities. Normally, the dumps-areas lack fertile layer of soil and the processes of natural soil-creation need a lot of time.

Some sources note that for a layer of soil 18 cm thick to be formed 1500-7000 years are required, as the process of soil-creation in different corners of the Earth flows with the speed of 0.5-2.0 cm per 100 years. However, the recultivation of technogenic lands sufficiently quickens the process of soil forming.
The usage of traditional methods of biological recultivation through dumps surface coverage with a layer of soil or potentially fertile samples need sufficient financial infusions. Thus, researches focusing on economically expedient means of revival of biological efficiency of the damaged lands become more and more essential. The main goal of this approach is to create sustainable vegetable associations in order to improve ecological and sanitary-hygienic conditions in areas where coal plants are located.

5. Summary and Conclusion
The article covers different ways of recultivation process and the technologies used in this process based on Russian and foreign scientists’ experiences. It’s important to note that the priority trends of disturbed lands recultivation in coal industry are: agricultural, forestry-based and sanitary-hygienic. Moreover, the quality of recultivated areas is not always kept at a wanted level which causes a number of difficulties in case of further usage. Main reasons of low quality of recultivation are: absence, at a planning stage, of needed volume of initial data on the composition and properties of the soil and the mining bed of dumps, lack of special technical equipment to perform the recultivation process at a high level, absence of landscape approach to revival issue of damaged areas.

The article also poses arguable questions in recultivation sphere and touches upon the list of activities to improve the state of soil resources protection. We also note the to improve the conditions in the field of soil resources protection in coal industry it is vital to modernize the technologies used in mining operations in order to reduce their soil damaging rate, to consolidate the overburden operations on open-pit mines with the technical stage of recultivation, to use fire-safe technologies of dumps-forming, to improve the quality of recultivation projects and the performance of recultivation works.

To improve the situation in the field of soil resources protection in coal-mining industry it’s important to perform:
- constant modernization of current technologies in mining sphere in terms of reducing their soil-damaging rate, as well as vastest possible dislocation of overburden operations into inner dumps;
- consolidation of overburden operations and dump-creation in open-pit mines with the technical stage of recultivation;
- modernization of current and development of new and more efficient ways of technical and biological recultivation with climate and environmental conditions in mind;
- the execution of recultivation projects on the basis of full volume of initial data, including the data on composition and properties of the soil and mining rocks;
- application in the recultivation of dumps which consist of rocks disposed to self-ignition of formation technologies which together with crumble ensures the conduction of ignition-prevention activities as well as conduction of recultivation works;
- an opportunity to widen the current researches on ecological state of disturbed lands and recultivated lands, the dynamics of change of properties and regimes of forming eco-systems, creation of artificial landscapes for different purposes.

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