Soil-agrochemical analysis of the fertile soil layer from the Erunakovskiy field of the Taldinskiy coal mine

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Abstract. Activity of mining enterprises lead to significant changes in the orography, composition and patterns of movement of groundwater, disruption of microbiota and impact on vegetation, which result in ecosystem destruction of vast land areas. The upper layer of the soil is subjected to serious changes due to physical impact during the extraction of minerals, thus it forms a technogenic relief. To restore the biological diversity of soils disturbed by surface and underground mining operations, a reclamation process is used, including the all typemanagement of physical, chemical and biological disturbances of the soil cover. Reclamation of abandoned mines' territories is a very complex process. Vegetation restoration is the most widely recognized and practical way to reduce nitrogen losses and erosion, increase soil nutrients, and protect soils from degradation. Substantiation of the scale to remove the fertile soil layer of mining operations is a compulsory condition for approving a plan of measures to restore the land quality. This work includes the study of the main properties of the potentially fertile soil layer of the Taldinskiy coal mine, Novokuznetsk district of the Kemerovo region of the Russian Federation, for the possibility of using it when carrying out work to restore its biological diversity.

1. Introduction
Renewal of the ability to transform rocks into soil, reproduction of natural consortia, and self-cleaning capacity of soil are the main tasks of biological diversity restoration. Biodiversity conservation is one of the areas for implementation of the National Project "Ecology", as Kuzbass has actively joined it in recent years, which is important for the sustainable development of the region's mining industry. The challenges associated with mining and subsequent landscape restoration are global, national and local. Biological diversity is a natural resource for the progressive evolutionary development of human civilization. The goal of restoring biodiversity is to ensure the sustainability of ecosystems and the biosphere as a whole. In Siberia, for many mining enterprises, a very urgent task is to use the natural potential of territories to restore disturbed lands and change the procedure for carrying out reclamation work due to the favorable circumstances that have arisen. The fundamental issue is the remediation of territories that have already passed the stage of vegetation restoration [1].

The problem of lands disturbed by opencast mining of coal deposits entails an imbalance of the ecosystem entirely. It should be noted that the intensification of industrial processes for coal mining
leads to disruption of the soil cover, degradation and redistribution of land, changes in the biological system in the region. [2]. There are many data on the rate of natural pedogenesis in different regions. And a soil layer formation of 18-cm-thickness takes from 1500 to 7000 years, since the rate of pedogenesis in different regions of the planet is 0.5-2.0 cm per 1000 years, which draws the prospects in a negative way [3-6].

The process of soil formation on dumps, caused by interaction of natural factors, has a technogenic nature [7]. Measures for reclamation of disturbed lands have a positive effect on the main stages of soil self-development [8].

Natural soils are complex natural systems that integrate physical, chemical and biological processes. They are capable of self-regulation, which include buffering of nutrients, preservation of soil density, porosity, aeration, water-holding capacity, detoxification, and self-restoration [9, 10].

Quality of the fertile soil layer plays an important role in the aspect of environmental regulation. Some parameters such as soil pH, the quantitative content of metals in the soil and the rooting zone are significant in determining the thickness and quality of the fertile soil layer for biological remediation. Reclamation of an area covered with coal waste includes a complete restructuring of the soil surface. The new landscape can be enriched with chemical and organic additives. Soil compaction and pollution are two common factors in land degradation in areas reclaimed after surface coal mining [11, 12, 13].

The results of restoration work do not always achieve the set of goals that creates difficulties in the development of reclaimed territories. This is a consequence of the insufficient amount of information at the design stage, namely, data on the composition and properties of the soil cover and the spent rock mass, the lack of special technical support to carry out restoration measures at the proper level, when working with disturbed mining soils, the landscape of the deposit is not taken into account [14, 15].

The intensive use of the studied territories of the Erunakovskiy coal deposit in the mining industry led to changes in the balance of the natural biocoenosis. In this work, there were studied soil-agrochemical characteristics on different genetic horizons of zonal soils of the Erunakovskiy coal mine, for the possibility of their use in biological reclamation. It is necessary to consider all aspects of the formation and properties of soils in the technogenicKuzbass landscapes.

2. Result and Discussion

The operating section "Erunakovskiy" is located within the geological area "Yerunakovskiy South" of the Yerunakovskiy coal deposit, in the south-eastern part of the Yerunakovskiy geological and economic region. Within a radius of six kilometers to the north-west of the Erunakovskiy open-pit mine field, there are fields of operating coal-mining enterprises developing coal deposits under independent licenses: the Ulyanovskaya and Erunakovskaya mines. The “Yerunakovskiy South” site is located 50-55 km east of the largest industrial centers of Kuzbass - the cities of Kiselevsk, Prokopyevsk and Novokuznetsk.

Climate of the region is sharply continental. The cold winter lasts five months - from November to April. The lowest temperatures are observed in December and January. The absolute minimum at this time reaches -43.9°C, and in some winters -50-54°C. A stable snow cover persists from early November to late April and along the northern slopes - until mid-May. The thickness of the snow cover on the northern slopes of the ravines reaches 2.0m. Soil freezing depends on the thickness of the snow cover and ranges from 0.2 to 2.0 m. The hottest month is July, the average monthly temperature of which rises to +19.4°C with a maximum of +36.7°C. Seasonal temperature fluctuations are of the order of 80.6°. Precipitation is of particular importance for mining conditions. The average annual precipitation varies from 400 to 700 mm. The distribution of precipitation is uneven: 40-45% falls in summer with an absolute maximum in June-July. It should be noted that precipitation in summer is of a stormy nature, and in autumn it is prolonged for several days, which leads to the largest runoff of atmospheric precipitation in the section in September - October. The prevailing winds in the region are south and south-west. Winds in these directions have a maximum speed of 17-24 m/s, with gusts up to 30-35 m/s, an average annual speed of 4.9-5.2 m/s (according to the Project).
The soil cover of the territory depends on the main factors of soil formation and is formed under the influence of climate, relief, vegetation, parent rocks and anthropogenic factor. The territory is characterized by the uniformity of rock parents, which are mainly represented by loessial uliginous-silty heavy loams or uliginous-silty light clays. The thickness of loess deposits is from 15 to 20 m (Trofimov, 1975). According to the soil-geographical zoning of the Kemerovo region (S.S.Trofimov, 1975), the territories of the land plots of the Taldinskiy coal mine are located in the south-western part of the Kuznetsk Alatau, included in the group E - Kuznetsk-Alatau high-altitude soil district with four belts of vertical soil zoning ... The formation of the soil cover was influenced by such factors as: relief, underlying rock, high precipitation (from 700 to 1000 mm), with very little evaporation, due to the dense cover of the black taiga. The underlying rocks of the western slope of the Kuznetsk Alatau are thick loose bedding. There are extensive stone fields (uronniks) and thick deposits of brown carbonate-free cover clays (Trofimov, 1975). A humid and cool climate, a powerful cover of the Quaternary covering clays, a dense cover of taiga, lush forbs, almost complete absence of soil freezing in winter contributed to the formation of podzolized taiga soils. The site is closely related to its intensive use in the mining industry. The zonal soil cover of the soil-geographic region, including the site for environmental surveys based on the collection materials and on the materials of the soil map of the Kemerovo region, M 1: 300,000, is represented by zonal types and subtypes of soils for this soil-geographical region: sod-medium podzolic; mountain-soddy-podzolic; light gray forest; gray forest soils.

In the studied fields, the following soil profiles were laid out: No. 1 (plot 1), No. 8 (plot 2), No. 9 (plot 3).

Plot 1 with an area of 47 hectares (coordinates: N - 54° 04.6291. E - 0,87° 24.1621) is located on the slope of the northern exposure with an angle of inclination of the earth's surface of 5-7°; the relief is represented by a crumpled surface with gullies in ravines, bumps of plant origin, anthills. The parent and underlying rocks are represented by heavy brown carbonate-free mantle loams and clay. Soil: deep-soddy deep-podzolic heavy loam soil.

Plot 2 with an area of 6.5 hectares (coordinates: N - 54° 05.2021. E - 0,87° 26. 8941) is a southern slope with a slope of 4-6°. The surface is flat, there are depressions. Soil-forming and underlying rock: stone placers (uronniks). Soil: light gray podzolized undeveloped lithogenic soil.

Plot 3 with an area of 4.5 hectares (coordinates: N - 54° 06.8221. E - 0,87° 27. 2091) is a mound of northern - northeastern exposure with a gentle slope (4-6°) with a rugged surface, hollows and depressions. Parent and underlying rock: heavy brown carbonate-free cover loams and clays. Soil: deep-soddy fine-podzolic heavy loam soil.
All the plots with developed soil, with three main horizons identified, and the formation of the profile of soil horizons is schematically shown in the graph (Fig. 1)

The following soil horizons are distinguished in the soil profiles:
- Plot 1: A1 – A2 – A2В – В – ВС – С;
- Plot2: A1 – В – ВС;
- Plot3: A1 – А1А2 – В – ВС – С.

The upper part of the soil profile of all the studied plots presents a humus-eluvial layer A1 with a size of 14 to 26 cm. The soil is dry, gray in color. The structure of the soil is fine-lumpy (plot 1) or lumpy-nutty (plots 2,3), loose, there is an abundance of roots of woody and herbaceous plants, a noticeable transition in density (plot 1), structure (plots 2,3), in color (plot 2).

For the upper horizon of the profile’s transitional part in plot 1, an independent eluvial horizon A2 of whitish-gray color is isolated, with a heavy loamy soil of a lumpy-layered structure with a whitish dusting, characteristic of the processes of washing out humus, ash and other mobile elements into lower soil horizons, with a thickness of 7 and 14 cm respectively. The soil is compacted, permeated with single plant roots with a gradual transition in density.

In plot 3, a subhorizon А1А2, 5 cm thick, with dry heavy loamy gray soil, lumpy-lamellar structure, is distinguished. The soil forms a loose-dense mass with plant roots occurring, a noticeable transition in density.

In plot 1, a subhorizon A2В, 15 cm thick, is distinguished. It is fresh, light brown in color with a whitish tint, heavy loamy, coarsely nutty with a noticeable silica powder, dense, and with single roots, its transition is gradual.

The illuvial horizon is a transitional layer from humus to rock, represented in all the plots. On plot 1, horizon B is with a thickness of 21 cm. The soil is very dense, heavy loamy, moist, light brown in color with a gradual transition in color, with a large prismatic structure. In plot 2, the thickness of horizon B is 18 cm. The soil is dry, gray, unevenly colored with a gradual transition, medium loamy, the structure is silty-lumpy-crumby, loose, solid inclusions in the form of silt, etc. In plot 3, horizon B has a thickness of 14 cm, moistened, brown-gray, heavy loamy, coarse-lumpy-prismatic, silica powder (SiO2), dense, gradual transition.

In all the studied plots (1, 2, 3), a transitional horizon BC of light brown color was identified, which gradually passes into the parent rock with a thickness of 29, 31 and 29 cm, respectively. In plot 1, the BC subhorizon is moistened, heavy loamy, lumpy, dense, gradual; in plot 2 - dry, lumpy-

![Figure 1. Soil horizons of the studied areas](image-url)
crumbly, loose-dense, solid inclusions in the form of small and large silts, the transition is noticeable in density; in plot 3 - moist, heavy loamy, prism-like lumpy structure, dense.

In plots 1 and 3, horizon C represents heavy loamy, moist, unstructured, dense soils of 64 and 50 cm thick, respectively. The color of the horizon in plot 1 is light brown, the carbonate horizon is not exposed, and in plot 3 it is brownish brown, rusting in the upper part of the horizon, gleyzation in the lower part.

![Granulometric soil composition according to the method of N.A. Kachinskiy](image)

In the granulometric composition of the soil in plot 1, the content of fine sand is 15.3%, coarse dust 39.4%, silt fraction 30.4%, which reflects the composition of the parent rock; in plot 2, a high content of sandy fraction was revealed: coarse and medium sand - 14.3%, fine - about 30%; in plot 3, the content of fine sand is 15.3%, coarse dust - 39.4%, silt fraction - 30.4%, which reflects the composition of the parent rock. Accordingly, there are differences in the ratio of clay and sandy fraction, physical clay is almost half (49.8%; 47.3% in plots 1 and 3, respectively), and in plot 3 - 26.3%.

Thus, the granulometric composition of the medium-sod fine podzolic soils of plots 1 and 3 is represented by coarse uliginous silty heavy loam, and plot 2 is light loam (Fig. 2).
Soil structure is a set of aggregates of various sizes, shapes and qualitative composition. The most agronomically valuable (optimal) for cultivated plants are meso-aggregates 0.25-10 mm in size with high porosity (more than 45%), mechanical strength and water resistance. The samples under study were investigated to determine the number of aggregates of different sizes by the "dry" sieving method. Structural analysis showed that in the studied samples of plots 1, 2, and 3 there are practically no agronomically valuable aggregates, as evidenced by the data on the size and content of aggregates of 14.8%, 10.7%, and 15.8%, respectively.

During the study, the agrochemical properties of the soil were determined.

### Table 1. Agrochemical soil characteristics

| Horizon, depth, cm | pHsal. | Humus, % | H | Hydr. | $S = \frac{Ca^{2+}+Mg^{2+}}{mEq/100 \text{ g of soil}}$ | E n. | V % | P2O5 | K2O |
|-------------------|-------|----------|---|------|------------------------------------------|------|-----|------|-----|
|      |       |          |   |      |                                          |      |     |      |      |
| A 0-18           | 5.2   | 8.0      | 3.82 | 38.2 | 25.5                                      | 29.3 | 87  | 46.6 | 162.1 |
| A2 18-25         | 4.3   | 3.4      | 4.71 | 47.1 | 18.5                                      | 23.2 | 79  | 12.4 | 43.9  |
| A2B25-40         | 4.1   | 1.9      | 4.52 | 45.2 | 16.0                                      | 20.5 | 78  | 8.3  | 37.4  |
| B 40-61          | 3.8   | 0.07     | 5.11 | 51.1 | 15.2                                      | 20.31| 74  | 8.1  | 36.1  |
| BC 61-90         | 3.6   | 0        | 5.77 | 57.7 | 14.1                                      | 19.87| 71  | 8.0  | 36.9  |
| C 90-154         | 3.6   | 0        | 5.94 | 59.4 | 13.9                                      | 19.84| 70  | 7.0  | 35.0  |

Plot 2

| A 0-14 | 5.2 | 3.1 | 3.65 | 36.5 | 26.8 | 30.5 | 88  | 52.6 | 60.3 |
| B 14-32 | 4.8 | 1.4 | 4.89 | 48.9 | 20.2 | 25.1 | 80  | 24.3 | 52.6 |
| C 32-63 | 4.7 | 0  | 5.03 | 50.3 | 17.3 | 22.3 | 78  | 11.0 | 60.4 |

Plot 3

| A 0-26 | 5.0 | 5.0 | 4.32 | 43.2 | 24.5 | 28.32| 83  | 47.2 | 154.1|
| A2B 26-37 | 4.1 | 1.2 | 5.70 | 57.0 | 17.0 | 22.70| 75  | 12.0 | 50.8 |
| B 37-51 | 4.1 | 1.2 | 5.52 | 55.2 | 15.0 | 20.52| 73  | 7.0  | 35.4 |
| BC 51-80 | 3.8 | 0.9 | 5.16 | 51.6 | 13.8 | 19.0 | 72  | -    | -    |
| C 80-130 | 4.0 | 0  | 5.30 | 53.0 | 13.0 | 18.3 | 71  | -    | -    |

Analysis of the test data (Table 1) shows that the humus content in the upper horizon is low and varies in the range from 3.1 to 8%, then sharply decreases in the horizon in plot 1 in the A2 horizon to 3.4%, A2B to 1.9%, in plot 2 in horizon B only 1.4%, in plot 3 in horizons A2B and B it is 3.4% and
1.2%, respectively. In the transitional horizon BC, only traces of humus were found, and in horizon C (underlying rock), no humus was found.

The soils are characterized by a relatively low absorption capacity on average 29.4 mEq with insignificant variation in all the plot (3.7%), the amount of cations sharply decreases with depth in plot 1 in the layer of 18-25 cm - 23.2 mEq/100g; in plot 2 in the layer of 14-32 cm - 26.8 mEq/100g, in plot 3 in the layer 26-37 cm - 22.7 mEq/100g, which is confirmed by the reaction of the soil.

Hydrolytic acidity in the upper soil layer averages 3.93 mEq/100g with variation over the plots (8.8%) - medium acidic, increasing with depth, which indicates a high content of hydrogen and aluminum cations in the soil. The reaction of the soil solution in the upper horizon A in all plots is weakly acidic (pH 5.0-5.2), below in plots 1 and 3 it is strongly acidic (pH 4.1-3.8), and in plot 2 it is moderately acidic (pH 4.8 -4.7).

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Figure 4. The content of the main elements of mineral nutrition in different soil horizons,%

The provision of soils in plot 1 with the main nutrients with gross forms of nitrogen is relatively high (0.48%) than in plots 2 and 3 (0.31% and 0.35%, respectively); this also reflects the higher humus content in plot 1. The content of gross and labile phosphorus throughout the soil horizon is from low to very low, respectively (0.12-0.13%) and (from 46.6-52.6 to 7.0-11.0 mg/kg). The gross potassium content is average over the entire profile; the parent rocks are heavy loams and clays, in the crystal lattice of which there is a lot of potassium. The content of exchangeable (available) potassium in the upper horizon is high, and in the deep one it is low (according to the classification and diagnostics of soils in Western Siberia).

3. Conclusion
The territories of the studiedplots of the "Erunakovskiy field" of the Taldinskii coal open-pit mine are included in the group E - Kuznetsk-Alatau high-altitude soil district of the black taiga zone. The
surface of the soil cover of plots 1 and 3 of the Erunakovskiy field is represented by deep-soddy deep and fine podzolic heavy loam soils, and plot 2 is represented by light gray undeveloped lithogenic light loam soils. Morphological analysis of the established sections, polys and pits showed: the humus accumulative horizon (A) ranges from 18 to 26 cm with a humus content of 5 - 8%. Illuvial horizons B are characterized by a dense build, lumpy-prismatic structure, the humus content is 3.4%. The reaction of the soil solution is from weak to strongly acidic in the lower horizons.

The fertile soil layer (FSL) of the studied areas of the Erunakovskiy field of the Taldinskiy coal mine is not suitable for removal and storage, since the surface of the entire field is heavily forested, crumpled, with gullies and there is a lot of windbreak.

The potentially fertile soil layer (PFSL) of the studied areas of the Erunakovskiy field of the Taldinskiy coal mine is also not suitable for removal and storage, since the use of the lower horizons, which are significantly inferior in their agronomic value to the upper horizons, requires even greater financial costs.

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