Reproduction of soil fertility: research of physical and chemical characteristics of soils

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Abstract. This paper presents some results of studies of the physical and chemical parameters of the rock dump of the section of “Koksovy” Plot” LLC, Prokopyevsky District, Kemerovo Region. The influence of physical and chemical characteristics, in particular temperature, humidity, soil acidity, nitrate nitrogen content on the intensity of the emergence and development of microbial and plant communities, and, consequently, restoration of soil fertility, was studied.

1. Introduction

Among the modern problems of nature management, reclaiming of land disturbed by mining occupies a special position. Firstly, huge arrays of valuable lands are alienated, and often destroyed, and secondly, the environmental situation is changing. At the same time, prevailing geochemical flows and migration cycles are disrupted, including in the biological cycle, large quantities of “new”, often toxic, elements are involved, and functional connections between various components of ecosystems are disorganized [1,2].

It is known that technogenic landscapes are found in almost all countries of the world, therefore, the main problem of its restoration of soil and vegetation cover on it is of global importance. Thus, the properties and functions of the technogenic landscape, altered by reclaiming, are determined by the method of formation of this landscape and the method of reclaiming. For this reason, it is important to study the properties of the emerging soil in order to further predict the processes of pedogenesis and assess the ability to manage it [3].

The main problem of rational use of natural lands that have been disturbed by mining is reclaiming of disturbed lands occupies a special position. Firstly, huge arrays of valuable lands are alienated, and often destroyed, and secondly, the environmental situation is changing. At the same time, prevailing geochemical flows and migration cycles are disrupted, including in the biological cycle, large quantities of “new”, often toxic, elements are involved, and functional connections between various components of ecosystems are disorganized [4,15].

The most significant problem for the Kemerovo Region is the problem of reclaiming, since on its territory as a result of mining, construction of roads, industrial and other facilities, the destruction of the natural cover occurs annually. The average area of land disturbed in the region for the year is more than 1000 ha [5,14].

When studying the physical and chemical properties of the soil, a lot of useful information about the quality and suitability of the soil for the biological stage of reclaiming can be obtained by examining such indicators as humidity, environmental reaction, nitrate nitrogen content and soil temperature.
Soil acidity affects the solubility and digestibility by the plant of various nutrients. In acidic soils the most digestible nutrients such as phosphorus (in certain conditions), iron, zinc, manganese, boron, etc. However, a low pH can strongly inhibit the growth and even have a damaging effect on plants. For each plant species, there are limits to the value of the environment reaction, in which its growth is possible, but for most plants the most favorable is weakly acidic (pH = 5-6) or neutral (pH = 7) reaction. A significant change in the pH value in one direction or another has a harmful and sometimes destructive effect on the plant. Less harmful is the shift of the soil pH to the alkaline side. This is because plant root cells release CO$_2$, and sometimes organic acids, which neutralize excess alkalinity. A sharp shift of the soil reaction in the acidic side, has undesirable consequences due to several circumstances: direct damaging effect on the surface layers of protoplasm; inhibition of the entry of nutrient cations into the root cells; transition from soil absorbing complex to solution of salts of aluminum and iron. The latter translates phosphoric acid into an indigestible form for plants, and also supports a direct toxic effect on the plant organism [6,7].

Humidity is not a stable sign of any soil or soil horizon. It depends on many factors: meteorological conditions, groundwater level, mechanical structure of soil, nature of vegetation, etc. Soil moisture has a very great practical importance, being one of the main factors of plant growth that consumes during its development a huge amount of moisture (200-500 times more of the weight produced by its of dry matter).

The direction of reclaiming and the type of subsequent use of land are established on the basis of soil conditions, and not a small role in this is the provision of moisture, which should be sufficient to ensure optimal conditions for the growth of agricultural and forestry crops [8,13].

Classification of overburden and host rocks for biological land reclaiming is not carried out on the basis of one indicator, a complex of chemical and granulometric characteristics (GOST 17.5.1.03-86) is taken into account. Focusing on the acidity index, there are three groups of disturbed lands: soils suitable for reclaiming have pH value of 5.5-8.4, unsuitable soils have a more acidic reaction, and unsuitable strongly acidic, with pH of less than 3.5. Less suitable soils also include soils containing easily soluble salts, gypsum, carbonates whose pH is greater than 6.5.

The formation of a rock dump from solid rocks of different aggregate composition determined the choice of the method of measuring temperatures. It was also taken into account that the rocks of rock dumps contain carbonaceous inclusions, and therefore may have pockets of elevated temperatures due to the slow current processes of self-oxidation. Under these conditions, the most rational method of measurement is a thermometric method that allows measuring temperatures away from power sources and at the same time quite portable [9,10].

In the process of restoring the biological activity of the applied fertile soil layer or intensifying the soil-forming process in potentially fertile rocks, a number of agrotechnical measures are used, determined on the basis of laboratory analyses of the chemical and physical properties of soils and soil mixtures [11,12].

Nitrogen is one of the main elements necessary for the life of plants. It is a part of proteins, enzymes, nucleic acids, chlorophyll, vitamins, alkaloids and other compounds. The level of nitrogen nutrition determines the size and intensity of protein synthesis, which significantly affect the growth processes.

The main source of nitrogen for plants is salts of nitric acid and ammonium.

Its absorption from the soil occurs in the form of anions NO$_3$ and cations NH$_4^+$, as well as some simple organic compounds. Nitrate nitrogen as a result of oxidation of carbohydrates is converted into ammonia. For the plants themselves, nitrates are harmless and can accumulate in its tissues in significant quantities. However, an excessive amount of nitrate is harmful to warm-blooded, because it prevents the formation of hemoglobin, disrupts the supply of oxygen to the body and causes the formation of carcinogenic compounds.

Normal nitrogen nutrition increases plant productivity. At the same time, the leaves have a dark green color, the plants are well bushed, form large leaves and full reproductive organs, in which protein synthesis is accelerated, and they remain viable for a long time. This determines the age of the plant and
its organs, the level of supply of carbohydrates, the movement of synthesis products, the provision of phosphorus, sulfur, potassium, calcium and microelements [16].

2. Materials and methods of the study
Scientists of the Kemerovskiy state agricultural Institute are conducting the study in the field of improvement of technologies of reclaiming of disturbed lands at coal mining enterprises of the Kemerovo region, in particular, the soils of the rock dump of one of the sections of the Kemerovo region were investigated.

First of all, a study of the climatic conditions of the area, found that the climate of the area is continental with long cold winters and short warm and humid summers. The change of negative and positive temperatures occurs in spring in April, in autumn - in October. Precipitation over the area is extremely uneven.

Stable snow cover is established in late October - early November and completely disappears in late May. Snow area of uneven lies. Snow depth depends on the ruggedness of the relief, population areas, the strength and direction of winds and varies from 4 m in depressions of relief, up to 0.1-0.5 m in upland areas. The depth of soil freezing varies from 0.3 to 1.5 m depending on the capacity of the snow cover.

The soil cover in the city of Kiselevsk represented mainly by leached humus, medium thin, perhaps a combination of the latter with meadow-humus soils of the fat medium.

The peculiarity of soil moisture is that the role of autumn and summer precipitation in the accumulation of available moisture reserves in the soil is not effective. Clearly appear two minimum moisture during the growing season - spring and summer.

Spring minimum over a long period of time and dry to wilting of plants in May, the summer is short in early August with a reduction in the amount of available moisture to a minimum level in the rooting zone in the north exposures and to the critical level in the south.

Based on the nature of the soil moisture regime of re-cultivated areas, planting is advisable on the slopes of eastern expositions in early spring (late April – first decade of May) and late spring (end of last decade of May – first decade of June). On the slopes of the southern expositions only summer planting in July.

In the present work, some results of studies of physical and chemical parameters of a rock dump of a section of “Plot “Koksovy” LLC of Prokopevsky district of the Kemerovo region are presented.

Sampling carried out in accordance with GOST 17.4.4.02-84 “Protection of nature. Soils. Methods of sampling and preparation of samples for chemical, bacteriological, helminthological analysis”

3. Results and its discussion
Soil moisture (expressed as a percentage of the mass of absolutely dry soil) shows the content of water in it. Not all moisture contained in the soil is equally accessible to plant roots. During the experiments, two main forms of soil moisture are taken into account: sorbed or bound, inaccessible for plants, and free, accessible for plants (minus moisture of stable wilting), which is called productive moisture.

Figure 1 shows the averaged data of the three-fold definition of productive soil moisture during the vegetation period according to variants of experience: 1 - experimental plot with the application of topsoil (soil), 2 - experimental plot with the application of a potentially fertile layer of soil (loam), 3 - pilot area without any layers (technosol).
Figure 1. Soil moisture at stationary points according to the variants of the experiment.

For all stationary of variant “technosol” the soil moisture unambiguously below the indicators of the variants of “Loam” and “Soil” (by 7 and 9.6%, respectively). The average humidity in variant 1 was 2.9%. The maximum soil moisture of 6.06% and minimum of 0.69%, with fluctuation of humidity of tehnosol is 5.37%, indicating that the uneven wetting of the substrate, and with this factor, connected the uneven distribution of vegetation on record site.

To assess the quality of the soil is important to know the level of its acidity, which corresponds to the degree of concentration of hydrogen ions in the soil solution, in common practice is indicated by Latin letters pH and called the hydrogen index. The reaction of the soil solution is of great importance for plants and microorganisms living in the soil. The reaction of the medium has a great influence on the biological and chemical processes in the soil. It depends on the nature of the receipt of nutrients in the plant. The results of the study of the substrate on the degree of acidity of the soil are shown in figure 2.

Figure 2. The degree of acidity of the soil at stationary points on the variants of the experiment.
Acidity, like other physical and chemical properties, primarily depends on the origin of the soil (natural or artificial bulk). Most plants grow best when soil extraction is neutral or slightly acid/alkaline of reaction of soil extract. A highly acidic or highly alkaline environment is detrimental for the plants.

The smallest range of oscillations at stationary points is set at the experimental site “Soil”, the average pH=7.6, min=7.5, max=7.9, which corresponds to the slightly alkaline reaction of the medium. For most plants pH=7.5 is favorable, such a substrate is suitable for biological recloaaimin without preliminary measures to improve it.

The reaction of medium of soil extract by the variant “Loam” averaged 7.9, which tells about the alkalisation of the substrate, with a maximum pH=8.2. On the territory of the experimental site, the acidity of the substrate is not uniform and varies by 0.55 pH units, which is slightly wider than the range of oscillations of the “Soil” variant. Variant “Technosol” has an average pH of 7.97, with a maximum of 8.2 and the range of oscillations, within experimental platforms 0.76 pH units, which is 3 times higher than on the “soil” variant. Strong clogging of the soil requires acidification measures, and the uneven distribution of acid-base balance on the site creates certain difficulties and requires measures to equalize the overall background of pH.

One of the main directions of prevention and reduction of harmful emissions into the atmosphere is the control of the thermal state on the surface of rock dumps. The results of temperature measurements at the experimental sites during the growing season are presented in figures 3-5.

![Figure 3](image_url)

**Figure 3.** Soil temperature of the rock dump at a depth of 0-10 cm in May.
Figure 4. Soil temperature of the rock dump at a depth of 0-10 cm in July.

Figure 5. Soil temperature of the rock dump at a depth of 0-10 cm in August.

The results of measuring the soil temperature of the rock dump during the growing season are shown in figure 6.
The analysis of data of measurement of soil temperatures of a rock dump during the vegetation period shows:

- ground temperature covers a wide range of values: from 11 °C to 62 °C;
- in 5 stationary points, the temperature is extremely high (55-62 °C) during the experimental period of the study, due to self-oxidation of carbonaceous particles and does not depend on weather conditions;
- all extreme points are grouped in the South-Eastern part of the dump on an area of about 1 ha;
- soil temperature in most stationary points varied greatly during the study period depending on weather conditions (air temperature, solar radiation intensity);
- the greatest temperature differences depending on the intensity of solar radiation are typical for the southern part of the rock dump;
- the highest values of soil temperature were observed in July, and the lowest – in August, due to weather conditions, namely air temperature;
- the highest values of ground temperature were observed on the experimental platform without depositing a fertile layer (technosol), which testifies to the ongoing processes self-oxidation of carbonaceous particles.

The determination of nitrate nitrogen in the soils of the rock dump at stationary sites was conducted by means of sampling at the depth of 0-10 cm. Analysis of the data indicates that the content of nitrate nitrogen in the soils of the rock dump with the application of topsoil is significantly different from the content of nitrate nitrogen variants with the application of loam and without the application of topsoil, and the range of values ranged from 9.8 to 22.3 mg/kg, which is directly related to the heterogeneity of the substrate.

Organic nitrogen (humus nitrogen) is not directly available for plants. Therefore, the provision of plants with soil nitrogen is judged by the content of mineral nitrogen compounds (nitrates) in the soil. Determination of nitrate nitrogen content gives an idea of the presence in the soil and ground of the most easily digestible nitrogen substances for plants.

The highest content of nitrate nitrogen found in the samples of the variant with the application of topsoil, the average value 18.32 mg/kg. Fluctuations in the content of nitrate nitrogen in this variant from 9.8 mg/kg to 22.3 mg/kg that by Gamzikov (1981) is a medium security potentially fertile soil nitrate nitrogen and its application for planting.
Unsuitable for biological reclaiming is the soil variant without layers, since the nitrate nitrogen content on average at points is very low, is 6.47-7.46 mg/kg with a minimum value of 1.6 mg/kg.

4. Conclusions

According to the results of the studies, the substrates most suitable for biological reclaiming should be considered loam and fertile soil. The soil moisture index is favorable for the growth and development of plants on the experimental sites “Loam” and “Soil”. The soil acidity index is most close to the optimal in variant “Soil” (7,6), the substrate of the site “Loam” needs acidification, but is generally suitable for plant life.

Unsuitable for carrying out biological reclaiming in the investigated indicators recognized the area without any fertile and potentially fertile soil layers “Technosol”, this area is the most heterogeneous in the degree of acidity, and the humidity level does not exceed 5%, which is insufficient for full activity of plants and microorganisms.

Unsuitable for biological reclaiming is the soil variant without layers, since the nitrate nitrogen content on average at points is very low, is 6.47-7.46 mg/kg with a minimum value of 1.6 mg/kg.

According to the results of the studies, it was concluded that more favorable conditions for the biological stage of reclaiming when applying a fertile layer (soil) of rock dump to the soil and forest planting should be carried out in May or August, as evidenced by the data obtained.

References

[1] Artemyev V 2004 Coal 2 p 3-7
[2] 2006 Deputy hearings “On the problems of disturbed lands in the Kemerovo region” (Kemerovo) p 80
[3] Androkhanov V, Kulyapina V 2004 Soils of technogenic landscapes: Genesis and evolution (Novosibirsk: Publishing house of SB RAS) p 50-51
[4] Potapov V, Mazikin V, Schastlivtsev E, Vashlaeva N 2005 Geocology of coal-mining areas of Kuzbass (Novosibirsk: Science) p 7
[5] Prosyannikova O 2005 Anthropogenic transformation of soils of the Kemerovo region monograph (Kemerovo: Kemerovskiy State agricultural Institute) p 300
[6] Yakovenko M, Kosolapova A, Vedrova E, Belov K 2016 Science: Science and education: experience, problems, prospects of development: materials of XIV international scientific-practical conference (Krasnoyarsk: Krasnoyarsk state agricultural University) p 486
[7] Yakovchenko M, Kosolapov A, Belov K 2016 Collection of articles I of International scientific-practical conference “Modern environmental problems and their solutions” dedicated to the anniversary of the Lugansk national agrarian University (Lugansk: GOU LNR Lugansk scientific agrarian university) p 492
[8] Aber S, Salari D, Parsa M 2010 Chemical Engineering Journal 162 1 pp 127-134 doi: 10.1016/j.cej.2010.05.012
[9] Armeanu M, Cincu C, Zaharia C, Degeratu C-N, Tudora R-M 2010 Materiale Plastice 47 3 pp 274-277
[10] Arslan-Alaton I, Gursoy B, Akyol A, Kobya M, Bayramoglu M 2010 Water Science and Technology 62 1 pp 209-216 doi: 10.2166/wst.2010.256
[11] Ahmed Basha C, Soloman P, Velan M, Miranda L, Balasubramanian N., Siva R 2010 Journal of Hazardous Materials 176 1-3 pp 154-164 doi: 10.1016/j.jhazmat.2009.10.131
[12] Beltrán-Heredia J, Sánchez-Martín J, Gómez-Muñoz M 2010 Chemical Engineering Journal 162 3 pp 1019-1025 doi: 10.1016/j.cej.2010.07.011
[13] Braz R, Pirra A, Lucas M, Peres J 2010 Desalination 263 1-3 pp 226-232 http://www.sciencedirect.com doi: 10.1016/j.desal.2010.06.063
[14] Acero J, Benitez F, Teva F, Leal A 2010 Chemical Engineering Journal 163 3 pp 264-272 doi: 10.1016/j.cej.2010.07.060
[15] Wright J, White C, Gabrielson K 2011 Document Modified amine-aldehyde resins and uses
thereof in separation processes (Georgia: Pacific Chemicals LLC)

[16] Al Momani F, Jarrah N 2010 *Journal of Environmental Science and Health - Part A Toxic Hazardous Substances and Environmental Engineering* **45** pp 719-731 doi: 10.1080/10934521003648933

[17] Yakovenko M 2015 *IOP Conf. Series: Materials Science and Engineering* **91** 012078 doi:10.1088/1757-899x/91/1/012078