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Assessment of soil properties in technogenically disturbed lands of Kemerovo Oblast – Kuzbass

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Abstract— Recultivation is a critical operation after mining operations. In Kemerovo Oblast – Kuzbass, Russia, a lot of land has suffered degradation due to stripping operations. The purpose of the study is to examine the technical, technological, and biological properties of lands technogenically disturbed as part of coal mining operations in Kuzbass. The object under study is soil and soil cover in the Talda coal mine at the experimental site and adjacent territories. The research goal is achieved through the following methods. The granulometric composition of soil is assessed using the areometric method. The structural-aggregate analysis is performed based on the distribution of aggregate content by size with a set of soil sieves. Water stability is established using the method of disintegration of soil aggregates under a layer of water up to 2 cm high for 10 minutes. The ecological condition of the soil is assessed based on its enzyme and biological activity. The conducted investigation reveals increased stoniness, hygroscopicity, and low humus content of soils on technogenically disturbed land plots. Technogenically disturbed lands are marked by more acidic and heavy metal-contaminated soils. No exceedances are detected for pesticides and radionuclides. The results demonstrate weak enzymatic (cellulolytic, catalase, dehydrogenase, urease, phosphatase, invertase, and soil respiration) and catalytic activity of the soils. All obtained results of assessment of soil conditions on the experimental site and adjacent territories should be used in planning further experimental work on conducting the biological recultivation phase to minimize random experimental errors associated with the influence of native vegetation cover and primary soil conditions on the survival of crops sown on the site.

Keywords— Recultivation, Kemerovo Oblast – Kuzbass, Technogenically Disturbed Landscape, Toxic Elements, Radionuclides, Pesticides, Soil.

1. INTRODUCTION

Pesticides make up a large group of chemical compounds used for various industrial purposes. Depending on their purposes, these chemicals are distinguished into products for plant protection against pests and diseases, herbicides, and pre-harvest soil treatment products. These toxic chemicals may include organochlorines, organophosphates, and inorganic compounds of Hg, Pb, As, and other elements. The need to use chemical agents to protect crops from pests and diseases comes from the fact that yield losses without the use of pesticides can be extremely high. However, all poisons used in agriculture as a means of controlling plant pests and diseases are poisonous to plants and humans to some extent [1].

Soil has the main role in the self-purification of agrophytocenoses from pesticides. Its self-cleansing capacity is determined by hydrothermal conditions and biological activity. If the removal of pesticides is exceptionally slow, even moderate annual application of pesticides leads to undesirable consequences over time. The rate of microbial degradation of pesticides in soil is determined by soil humus content, temperature, moisture, the presence of detritus, nutrient content, and other factors. Conditions that benefit the development of soil microorganisms intensify the biological detoxification of pesticides. Pesticides

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that enter agrophytocenoses accumulate in individual objects and environments and get involved in various migration chains. This is especially the case for persistent pesticides that can last in the environment [2].

The hazard of soil contamination is defined by the level of its potentially harmful impact on the contacting environments (air, water), food products, as well as on humans, directly or indirectly, and the biological activity and self-purification of soil [3]. Soil survey results are considered when predicting the level of danger to people’s health and living conditions in different settlements, as well as in the development of recultivation measures. Assessment of the degree of chemical pollution hazard considers several regularities, one of which is determined by the buffering capacity of soils. The danger of pollution is the greater the lower the buffering capacity of the soil, which depends on its mechanical composition, organic matter content, and acidity. Lower humus content, lower pH, and lighter mechanical composition of the soil are associated with a greater risk of chemical pollution.

Heavy metals are priority pollutants that are mandatorily observed in all environments [4]. Heavy metals include over 40 elements with atomic masses greater than 50 unified atomic mass units (u). Among these are V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Mo, Cd, Sn, Hg, Pb, Bi, etc. Thus, the number of elements assigned to the group of heavy metals varies greatly. The criteria used for this classification include many characteristics, such as atomic mass, density, toxicity, prevalence in the natural environment, and degree of involvement in natural and anthropogenic cycles.

Important conditions in defining the category of heavy metals are their high toxicity to living organisms in relatively low concentrations, as well as their bioaccumulation and biomagnification ability. Virtually all metals that fall under this definition (except for Pb, Hg, Cd, and Bi, whose biological role is currently unclear) actively participate in biological processes, being part of many enzymes [5].

According to N. Reĭmers’ classification, heavy metals are those whose density exceeds 8 g/cm3. By this criterion, heavy metals include Pb, Cu, Zn, Ni, Cd, Co, Sb, Sn, Bi, and Hg [6]. To understand the factors that regulate metal concentrations in natural waters, their chemical reactivity, bioavailability, and toxicity, it is necessary to know not only the gross content but also the fraction of free and bound forms of the metal [7, 8].

The foundation for determining soil pollution hazard is the indicators of harmfulness that reflect the probability of contaminants migrating from soil into atmospheric air (soil-air migration indicator), water (soil-water migration indicator), and plants (translocation indicator), as well as the degree of impact on soil microorganisms (general sanitary indicator). The translocation indicator of harmfulness is fundamental to substantiating the threshold limit value (TLV) of chemicals in soil. This owes to the fact that plant-based food products account for about 70% of the toxic chemicals that enter the human body. The level of translocation thus defines the degree of accumulation of toxic chemicals in food products and affects their quality [9].

The quantitative expression of the content and activity of soil enzymes is closely tied to the functioning of soil biota. In environmental monitoring, the biochemical activity of a soil microbiocenosis is assessed through the study of its biocatalytic functions [9, 10].

Analysis of research and methodological literature suggests that sufficient simplicity in realization and high informativeness are provided by methods utilizing enzymes from the oxidoreductase and hydrolase classes. These methods were found to be informative [11-13]. From the class of oxidoreductases, the most frequently studied in soils are the activities of catalase, dehydrogenase, peroxidase, and polyphenol oxidase.

Catalase decomposes hydrogen peroxide, which is formed as a result of the respiration of aerobic soil into water and molecular oxygen. In addition to the enzyme catalase, the decomposition of peroxide may involve abiotic catalysts, e.g., clay materials and organics [13, 14].

Heavy metals in high concentrations severely affect the biological and particularly enzymatic activity of soils. As noted by a leading specialist in this direction of research, F. Khaziev [15], Pb, Zn, Cu, and Cd strongly inhibit the activity of hydrolytic and redox enzymes.

Dehydrogenases catalyze redox reactions by dehydrogenating organic substances. Dehydrogenases participate in the process of respiration by splitting hydrogen from oxidizable substrates. They are intracellular enzymes and, theoretically, can only function in viable cells. Therefore, many researchers recognize dehydrogenase activity as an essential biochemical indicator and suggest using this enzyme as a measure of microbial activity in soil.

The goal of the present study is to explore the technical, technological, and biological characteristics of technogenically disturbed soils as part of coal mining in Kemerovo Oblast – Kuzbass, Russia. The novelty of this research lies in the fact that comprehensive research generalizing recent publications, as well as experimental studies of the properties of technogenically disturbed lands of the Taldinsky coal mine in Kuzbass, are carried out for the first time.

2. METHODS AND MATERIALS

A. *Research Objects*

The object of study is constituted by soil and soil cover of the Taldinsky coal mine owned by the UK Kuzbassrazrezugol JSC in the experimental land plot and adjacent territories.

First, the study examined background soil on the adjacent territory of the mining enterprise UK Kuzbassrazrezugol JSC in the Taldinsky coal mine. In 2022, a reference point was set up to the southwest of a settlement – Bolshaya Talda village, Prokopyevsky district. This point is taken as the Control and/or Background. Second, we studied soil on the experimental plot located in the Kazachenkovskoye auto dump on the Tayechnoye field of the Taldinsky coal mine, located in the northeastern direction from the control point (Figure 1).

Fig. 1. General view of the study area and the location of the reference point (Control and/or background) and sampling points in the experimental area (Zone 1-5).

The land plot is a technogenic formation represented by a mix of overburden rocks piled during the production process of the coal mine. It is composed of a coarse clastic mixture of siltstones, sandstones, and mudstones. The microrelief of the dump surface is bumpy, leveled in some places, but uneven. The slopes have varying steepness. The dump is not recultivated, left for self-overgrowing. Vegetation cover is sparse. The soil cover restoration is at the initial stage, there are young soil-like bodies, initial embryosemes and organo-accumulative embryosemes, which in the modern Russian soil classification system [16] belong to technogenic surface formations (TSF).

At the anthropogenic site, reference points were established, designated zones 1-5 during sampling, where soil samples were collected (Figure 2).

Fig. 2. The location of zones or points of soil sampling, relative to each other.

B. *Analysis Methods*

In field conditions, samples were taken for chemical analyses to assess the qualitative state of soils, estimated by the content of humus, mobile elements, hydrogen index, and several other indicators. To obtain data on regional background levels of soil pollution, background soil samples were taken outside the area of local anthropogenic impact. Background soil was sampled at a sufficient distance from settlements, in this case, from Bolshaya Talda, on the windward side, and at least 500 m away from highways, on lands where pesticides and herbicides had not been applied.

Changes in the properties of overburden and host rocks that make up the Kazachenkovsky dump and on which TSFs associated with natural climatic conditions have developed need to be considered when designing further recultivation measures on the experimental land plot based on the main indicators of chemical and granulometric composition.

The structural aggregate (macro-aggregate) analysis was performed in accordance with the methodology of G.I. Antonov et al. [5]. Under this method, the structure of the soil is evaluated quantitatively based on the distribution of aggregate content (air-dry) by their sizes on a set of soil sieves with different hole diameters: 10, 7, 5, 5, 3, 2, 2, 1, 0.5, 0.25 mm.

Water stability was examined by the method of disintegration of soil aggregates under a layer of water up to 2 cm high for 10 minutes. Soil aggregates of the same size were placed on a grid of a certain size with cells corresponding to the size of the aggregates and carefully placed in a container. After this, water was slowly poured over the aggregates. At the end of the experiment, the percentage of water-resistant aggregates was calculated.

The ecological state of soil was evaluated by its enzymatic and biological activity. The indicators used as criteria were cellulolytic activity, catalase, dehydrogenase, urease, phosphatase, invertase, and soil respiration.

The cellulolytic activity was assessed using Christensen's method modified by T.A. Ovchinnikova as follows [9]. A sterile disk of filter paper of 7 cm diameter (of a certain weight) was placed on the bottom of a sterile Petri dish. Paper filters were covered with a nylon cloth mesh, and 40 g of soil moistened to 60% of the total moisture capacity was placed on it. The dishes were placed in a humid chamber and incubated at 27°C. The experiment was set up in a fivefold repetition. Over 30 days, the development of cellulolytic bacteria was observed on filter paper from the bottom of the cup. After the time had elapsed, the decomposed cellulose was registered. For this purpose, the soil was discarded from the cup, the nylon cloth was carefully detached, and the remaining filter paper was scraped from the bottom of the cup, dried to air-dry condition, and weighed. The degree of cellulose degradation was calculated as the difference between the initial and final mass of filter paper and expressed as a percentage of the initial mass.

The enzymatic activity of soils was determined based on the amount of substrate processed during the reaction or on the formation of the reaction product under optimal conditions (reaction medium, temperature, substrate concentration, soil sample) [10].

Enzyme activity was estimated through the gasometric method based on the amount of oxygen released by the action of hydrogen peroxide on the substrate. The unit consists of two burettes with a rubber hose, connected through a tee to an equalizing pear-shaped funnel. The burettes were filled with water, the level was balanced by lowering or raising the funnel, then the latter was fixed at a certain height. Then the tee was closed in such a way as to exclude communication of the device with the external environment. A soil sample was introduced into a 100 ml flat-bottom flask, and a glass beaker with 3% hydrogen peroxide was lowered in with tweezers and tightly closed with a rubber stopper with a glass tube connected to a measuring burette with a rubber hose. Next, the flask was rocked in a circular motion to tip the beaker and pour the peroxide into the flask with soil. From the moment of peroxide mixing with the soil, a stopwatch marked the beginning of the experiment. The mixture was shaken throughout the experiment. After the specified time (1-2 minutes), the amount of displaced air was registered by divisions on the burette. The main conditions for the catalase activity test are freshly prepared hydrogen peroxide (H2O2) and air temperature no higher than 20°C. Catalase activity was expressed in milliliters of O2 emitted in 1 min from 1 g of soil. The indicators calculated were: ΣCA – total catalytic activity; CEA – catalase enzyme activity; CANE – non-enzymatic catalytic activity.

The method for assaying soil dehydrogenase activity is based on the reduction of colorless TTC (2, 3, 5-triphenyl tetrazolium chloride) salts into red triphenylformazan (TTF) compounds under the action of the enzyme. To determine dehydrogenase activity, a 1 g sample was placed in a 20-25 ml test tube, adding 1 ml of 0.1 M glucose solution and 1 mL of freshly prepared 1% TTF solution. The tubes were placed in an anaerostat and the air was pumped out with a vacuum of 10-12 mm Hg for 2-3 minutes. The tubes were then incubated at 30°C for 24 hours.

After the specified incubation time, the contents of the test tubes were extracted in several steps with 25 ml of ethanol. A small amount of alcohol was added to the test tube and shaken for 5 minutes until the appearance of red coloration. The resulting stained TTF solution was filtered and colorimetrically analyzed using a 550 nm light filter. Dehydrogenase activity was expressed as mg TTF per 10 g soil per 24 hours.

Invertase hydrolyzes sucrose into fructose and glucose by breaking the bond located at the p-glucoside carbohydrate atom of the fructose residue in the sucrose molecule. The method for determining soil invertase activity was based on the change in optical properties of sucrose solution before and after exposure to the enzyme.

To determine the activity of invertase, a 5 g sample was placed in 50 ml flasks, adding 10 ml of 5% sucrose solution, 10 ml of acetate buffer with pH 4.7, and 5-6 drops of toluene. The flasks were corked, shaken, and placed in the TV-80 thermostat for 24 hours at 30°C. After incubation, the contents of the flasks were filtered into 25 ml measuring flasks and brought to the mark. From the filtrates, 6 ml of solution was taken into large tubes. Next, 3 ml of Seignet’s salt solution and 3 ml of copper sulfate solution were added and mixed well, and then the solution was boiled in a water bath for 10 min. The tubes were cooled, and the red precipitate was filtered off. The clear filtrate was colorimetrically analyzed using a 630 nm light filter. Invertase activity was expressed as mg glucose per 1 g of soil per 24 hours.

The method for estimating soil urease activity was based on the amount of ammonia formed from urea hydrolysis. To determine urease activity, 5 g of air-dry soil was placed in 100 ml flasks, adding 20 ml of a 2% solution of urea in phosphate buffer (pH 6.7) and a couple of drops of toluene. The flasks were tightly closed and placed in the thermostat at 37°C for 4 hours. After exposure, 1 ml of 50% trichloroacetic acid solution and 50 ml of 1.0 N sodium hydroxide were added. KCl solution was used for displacement from ammonia soil. The contents of the flasks were filtered. Next, 2 ml of the filtrate was pipetted into a 50 ml volumetric flask, the volume was brought to 30 ml with distilled water, then 2 ml of Nessler's reagent and 50% solution of Seignet's salt were added alternately. The solution in the flask was brought to the mark, stirred, and colorimetrically analyzed on a spectrophotometer at a wavelength of 400 nm. Urease activity was expressed in mg of NH4 per 10 g of soil per 24 hours.

Phosphatase catalyzes the hydrolysis of various organophosphorus compounds through phosphoester bonds. The method is based on considering the amount of the organic part of the substrate being hydrolyzed (p-nitrophenol), which gives a yellow color in an alkaline medium. Phosphatase is assayed against the background of natural reaction of soil solution in the soil, without adding buffer solution. To test phosphatase, 1 g of air-dry soil was placed in a 50 ml conical flask, and 3 ml of 0.5% aqueous solution of sodium salt of p-nitrophenyl phosphate was added. The contents of the flasks were stirred, covered with a rubber stopper, and placed in the thermostat at 30°C for 30 min. During incubation, the flasks were shaken 2 times. After incubation, 22 ml of distilled water was added to each flask, the contents were shaken and filtered into a 50 ml measuring flask. To the resulting filtrate, 5 mL of 1 n NaOH solution was added, after which the solution was stirred and brought to the mark with distilled water. The resulting bright yellow solution was colorimetrically analyzed at 400 nm. Phosphatase activity was expressed in mg P2O5 per 10 g of soil per 1 h.

Soil respiration intensity under laboratory conditions was estimated according to the method described by N.D. Sorokin and E.N. Afanasova [17]. The method relies on determining the intensity of soil respiration by considering quantitative changes in the carbon dioxide content in a certain enclosed space using wide-necked conical flasks. NaOH solution formed by respiration of CO2 by microorganisms in moist soil was used as an absorbent. The amount of remaining unreacted NaOH was determined by titration with a standard acid solution. The obtained value gives an indication of the amount of carbon dioxide that has reacted with the alkali. To determine soil respiration, 10 g of fresh soil in a gauze bag was suspended by a hook in a cork. The flask was filled with 25 ml of 0.1 n NaOH solution, closed with a cork with a bag, and placed in the thermostat at 28-30°C for 24 hours. Simultaneously with the experimental flask, a control flask with the same alkaline solution, but without soil, was placed to account for CO2 in the air inside the flask. The flasks were periodically shaken. After incubation, 2-3 drops of phenolphthalein were added to the flasks and titrated with 0.1 N HCl until the pink color disappeared. BaCl2 was used for Na2CO3 to sediment from the solution.

The method of cellulolytic activity has been used for many years to assess soils and subsoils. In the assessment of soils from the Taldinsky mine, the results obtained through this method are ambiguous.

This indicator is widely used to assess the biological activity of soils subjected to degradation for various reasons, from the destruction of the fertile soil layer as a result of construction, mining, or contamination with substances and wastes toxic and hazardous to humans and biota. In essence, the method is associated with the activity of microflora inhabiting the soil or subsoil under study and its ability to utilize cellulose over a certain period. These indicators are important to examine in the conditions of continuous transformation. Assessment of the soil of the Taldinsky coal mine brings ambiguous results. The scale of fiber degradation intensity and cellulolytic activity for agroecosystems was as follows:

- very weak – less than 10%;
- weak – 10-30%;
- average – 30-50%;
- strong – 50-80%;
- very strong – over 80%.

3. RESULTS

A. *Granulometric Composition of the Studied Soils*

TABLE I. GRANULOMETRIC COMPOSITION OF THE STUDIED SOILS

Point number	Content of physical sand (particles > 0.01 mm), %	Content of physical clay (particles < 0.01 mm), %	Soil name according to granulometric composition
Zone 1	68.37	31.63	Medium loamy
Zone 2	74.43	25.57	Light loamy
Zone 3	55.82	44.18	Heavy loamy
Zone 4	70.24	29.76	Light loam
Zone 5	64.76	35.24	Medium loamy
Control (Background)	62.13	37.87	Medium loamy

A classification of soils of native cover and technogenic landscape by the degree of stoniness based on the analysis of the content of skeletal elements is given in Table 2.

TABLE II. DEGREE OF STONINESS OF THE STUDIED SOILS

point number	The content of skeletal elements (particles > 1mm), %	Content of coarse-grained elements (particles > 3 mm), %	Stoniness degree
Zone 1	-	39.54	strongly stony
Zone 2	-	38.21	strongly stony
Zone 3	-	24.41	strongly stony
Zone 4	-	25.51	strongly stony
Zone 5	-	22.44	strongly stony
Control (Background)	Less than 0.4	-	non-stony

Substrates of anthropogenic landscapes are a chaotic mixture of dense rocks (siltstones, mudstones, sandstones of different degrees of weathering) and loose rocks, which may be represented by loess-like loams and clays, and there may be inclusions of coal particles, which together make the soils of the technogenic landscape of the experimental site stonier in comparison with the natural soil.

B. *Assessment of Hygroscopic Moisture Content in the Studied Soils*

In this study, we analyzed only the data from soil samples collected from the upper horizons of the studied soils (Table 3).

TABLE III. HUMIDITY OF THE STUDIED SOILS AND THE CONTENT OF HYGROSCOPIC MOISTURE IN IT.

point number	Humidity, %	Hygroscopic moisture content %	Grading
Zone 1	16.3	1.95	Medium loamy
Zone 2	10.8	1.48	Light loamy
Zone 3	15.5	2.28	Heavy loamy
Zone 4	11.8	1.65	Light loamy
Zone 5	14.2	1.81	Medium loamy
Control (Background)	19.2	3.07	Medium loamy

The obtained results show a consistent increase in hygroscopicity from an increase in the content of physical clay, which determines the granulometric composition of the studied soil.

C. *Assessment of Humus State*

The humus state of soil is characterized by the mass fraction of organic matter and total nitrogen content (Table 4).

TABLE IV. ANALYTICAL CHARACTERISTICS OF THE HUMUS STATE OF THE STUDIED SOILS

Point number	Content of organic matter, %	Content level	Total nitrogen content, %	Enrichment of humus with nitrogen
Zone 1	5.1	average	0.14	very low
Zone 2	5.1	average	0.15	very low
Zone 3	4.6	average	0.13	very low
Zone 4	2.6	low	0.11	very low
Zone 5	4.6	average	0.14	very low
Control (Background)	7.2	high	0.35	high

The studied soils of the anthropogenic landscape have a lower level of humus content in comparison with the soil of the natural landscape, which is associated with their initial stage of development, insignificant input of plant fall, and low rate of destructive processes.

D. *Soil Acidity Assessment*

Evaluation of the acidity of the soil environment of the studied soils is presented in Table 5.

TABLE V. ANALYTICAL DATA ON THE ACIDITY OF THE STUDIED SOILS

point number	water pH	water pH	Soil acidity level	pH sol	S mmol/100	H mmol/100	Degree of saturation, % (need for liming)
Zone 1	8.6	8.69	highly alkaline	7.4	-	0.28	-
Zone 2	9.1	8.92	highly alkaline	7.8	-	< 0.23	-

Zone 3	8.6	8.96	highly alkaline	7.3	-	0.32	-
Zone 4	8.8	9.01	highly alkaline	7.6	-	< 0.23	-
Zone 5	8.8	9.02	highly alkaline	7.4	-	0.28	-
Control (Background)	6.3	6.74	subacid	5.2	40.7	4.71	89.63

*Data obtained by the Testing Center of the Federal State Budgetary Institution Kemerovsky Agrochemical Service Center

**Data obtained by the Testing Laboratory of the Nauchno-Proektnyi VostNII LLC

***Sum of absorbed bases

****Hydrolytic acidity

The studied soil samples of the technogenic experimental site zone 1-5 are characterized by a strongly alkaline reaction of the environment. The background soil of the native soil layer has a slightly acidic reaction. All the soils do not require liming.

E. Assessment of Soil Absorption Capacity

Based on the developed classification of ecological and genetic evaluation of exchange absorption capacity [6], the studied soils can be attributed to a certain level of absorption capacity based on a set of indicators (Table 6).

TABLE VI. ASSESSMENT OF THE EXCHANGE ABSORPTION CAPACITY OF THE STUDIED SOILS

Point number	**exchange forms**				**ECO, mmol/100**	**Absorbency level**
	NH, mg/kg	**Na, mmol/100g**	**Al, mmol/100g**	**Mg, mmol/100g**		
Zone 1	3.0	< 0.10	< 0.12	5.5	19.9	average
Zone 2	-	< 0.10	< 0.12	4.5	15.9	average
Zone 3	2.1	< 0.10	< 0.12	3.8	17.9	average
Zone 4	2.7	< 0.10	< 0.12	5.8	17.9	average
Zone 5	3.1	< 0.10	< 0.12	3.8	15.9	average
Control (Background)	7.6	< 0.10	< 0.12	1.8	45.8	very high

Data analysis reveals that the native cover soils have the highest exchange absorption capacity compared with the TSFs of the considered technogenic landscape. The cation exchange capacity of natural soils is 2-3 times higher than in anthropogenic landscape soils. In soils of the same mechanical composition, the absorption capacity is greater the more humus they contain, since the primary particles of the latter consist of colloids. The TSFs are characterized by a relatively young age, beginning processes of soil formation, and insufficient organic matter content.

The composition of absorbed ions determines many physical and chemical properties of soils. The greater the absorption capacity, the higher the soil fertility. By regulating the composition of absorbed ions, it is possible to improve many soil properties. The physical and physicochemical absorption capacity of soils is of great importance as a factor that keeps various mineral fertilizers applied to soils from leaching out. Soils of light mechanical composition, having low natural absorption capacity, are subject to various meliorations, which provide for an increase in their colloidal fraction.

F. *Assessment of Pollutant Components Content in the Studied Soils*

During the experimental work, we analyzed data on the content of polluting elements of organic origin in the soils of the experimental technogenic site, planned for recultivation, in comparison with the soils of the background area. The results are given in Table 7.

TABLE VII. CONTENTS OF POLLUTING ELEMENTS OF ORGANIC ORIGIN IN THE STUDIED SOILS.

Sample name	**Nitrate nitrogen, mg/kg**	**Exchangeable ammonium, mg/kg**	**Chlorides, %**	**Sulfates, %**	**Oil products , mg/kg**
Zone 1	6.5	3.0	0.007	< 0.024	< 20.0
Zone 2	6.6	-	0.007	< 0.024	< 20.0
Zone 3	3.3	2.1	0.007	< 0.024	40.0
Zone 4	7.9	2.7	0.007	< 0.024	28.3
Zone 5	3.6	3.1	0.007	< 0.024	21.7
Control (Background)	3.9	7.6	0.007	< 0.024	40.0
MPC	130	-	-	-	1000

Nitrates and exchangeable ammonium are found in the background soil and control point soils (zones 1-5) of the experimental area within the normal range. The amount of nitrates in the background soil sample is slightly lower than in the soils of control points (samples zone 1, zone 2, zone 4). Nevertheless, their content does not exceed the permissible level and is below the TLV.

In all control point soils (zones 1-5) of the experimental site, the content of exchangeable ammonium is lower than in the background soil. The bulk of soil nitrogen is concentrated in organic matter. Nitrates and ammonium are mineral nitrogen compounds, and their content is subject to large fluctuations depending on moisture and temperature conditions.

Chlorides are easily soluble compounds, so they are easily leached from soils, especially those of light granulometric composition. They are observed in the studied samples in small quantities. No exceedances of chloride concentration are found in the control background soil sample. Furthermore, there is no excess of sulfates, and the soil parameters of the experimental area coincide with the control data.

The obtained data show the lack of organic pollution in the soil samples.

The permissible content of petroleum products in soil is under 1,000 mg/kg. As can be seen from Table 7, the amount of petroleum products in the studied samples is much less than this limit. The amount of petroleum products in the samples of control points of zone 1, zone 2, zone 4 and zone 5 is not above the level of background soil. The highest content of petroleum products is observed in the control point and zone 3, although they also stay under the TLV.

Assessment of the pollution of technogenic landscape soils of the experimental site with petroleum products as compared with background soil and the TLV demonstrates the lack of such pollution. As previously noted, most of the soil of the forest-steppe zone was used for agricultural production. It is possible that the soils of the experimental site, which were transformed from zonal gray forest soils into technogenic soils during the development of the coal deposit, were also cultivated at some point. Moreover, the soil of adjacent territories is still used in agricultural production. Thus, the collected data allow for assessing the danger of soil contamination with pesticides in accordance with the maximum permissible concentrations of pesticides in soils. Assessment of pesticide contamination of technogenic landscape soils of the experimental area and the control background soil is given in Table 8.

TABLE VIII. CONTENT OF ORGANOCHLORINE PESTICIDES IN THE STUDIED SOILS (MG/KG)

Sample name	**Hexochlorane (HCCH and its a and b isomers)**	**Lindane (Gamma-HCCH)**	**DDT**	**DDE**	**DDD**
Zone 1	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Zone 2	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Zone 3	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Zone 4	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Zone 5	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Control (Background)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
MPC	0.1	0.1	0.1	-	

The soils of the experimental technogenic territory and the control background soil show no difference in the content of organochlorine pesticides. Furthermore, the TLV is not exceeded in any of the analyzed samples, which characterizes the soil samples as not contaminated by organochlorine pesticides.

G. Assessment of Soil Pollution with Heavy Metals and Arsenic

The content of heavy metals in the examined soils is provided in Table 9.

TABLE IX. THE CONTENT OF HEAVY METALS IN THE STUDIED SOILS

Sample name	**Heavy metals, mg/kg**								
	Movable forms		**Acid soluble forms**					**Gross form**	
	Zn	**Co**	**Pb**	**Cd**	**Cu**	**Zn**	**Ni**	**Hg**	**As**
Zone 1	5.65	1.56	12.3	<1.0	22.0	50.4	14.2	<0.1	4.1
Zone 2	5.28	2.81	11.6	<1.0	20.8	47.4	10.0	<0.1	3.4
Zone 3	2.69	<1.0	10.8	<1.0	20.0	42.0	17.1	<0.1	4.0
Zone 4	6.36	2.85	11.9	<1.0	20.1	56.7	18.3	<0.1	3.5
Zone 5	6.83	1.05	13.4	<1.0	20.9	52.1	10.4	<0.1	2.4
Control (Background)	2.05	<1.0	11.9	<1.0	15.7	52.5	17.3	<0.1	2.4
ODC	23/	5/			3.0			2.1	2.0/
UEC *sand. and supesch.	-	-	/32.0	/0.5	/33	/55	/20	-	/2.0
APC*Acidic pH KCl<5.5 sugl. and clay.	-	-	/65.0	/1.0	/66	/110	/40	-	/5.0
UEC* neutral. pH KCl>5.5 arb. and clay.	-	-	/130.0	/2.0	/ 132	/220	/80		/10.0

The divergence of heavy metal concentrations in background soil (Control) and control point soils (zones 1-5) is insignificant, while Co and Hg content is the same.

The elements whose content does not exceed the TLV are Zn, Cd, Pb, Cu, Co, Ni, and Hg. Exceedance of TLV is observed only for arsenic in all soil samples, including the background sample (Control) by 1.2 times. Comparing arsenic content in the studied soils with the TLV, the soil samples of Zones 1 and 4 exceed the limit by 2 times, while the remaining samples, including background soil (Control), show a minimal exceedance of the TLV.

However, considering approximate permissible concentration levels (APC) in accordance with granulometric composition, the data describe soil not contaminated with arsenic. The investigated soils of the experimental technogenic landscape territory are of a loamy granulometric composition, have salt extract pH values above 5.5, and demonstrate gross arsenic content values below APC.

The total Zc pollution coefficient for background soil (Control) and control points of Zones 1-5 shows a value less than 16, which is defined as acceptable pollution.

H. *Assessment of Soil Pollution with Radioactive Substances*

Assessment of the pollution of technogenic landscape soils from the experimental plot and the control background soil by radioactive substances is presented in Table 10.

TABLE X. THE SPECIFIC ACTIVITY OF RADIONUCLIDES IN THE STUDIED SOILS, BQ/KG

Sample name	**Radium-226**	**Thorium-232**	**Potassium-40**	**Cesium-137**	**Strontium-90**	**Aeff***
Zone 1	22.1	36.4	611.9	< 10.0	73.8	122.0
Zone 2	31.6	30.78	610.9	< 10.0	55.0	124.0
Zone 3	< 20.0	38.2	578.1	< 10.0	63.5	106.0
Zone 4	24.2	36.3	570.9	< 10.0	93.6	120.0
Zone 5	23.6	38.4	643.3	< 10.0	76.7	129.0
Control (Background)	< 20.0	32.2	415.6	< 10.0	69.0	85.9
TR TS EAEU 022/2011 (vegetables, root vegetables, including potatoes)	-	-	-	80 (600)	40 (200)	-
NRB 99/2009 (sand, gravel, gravel)	-	-	-	370	370	370
OSPORB-99/2010	100	100	1000	-	-	-

* Specific effective activity of natural radionuclides (NRN)

Proceeding from the obtained results and their analysis, in accordance with normative documents, the examined soils are found to not be polluted by radioactive elements.

In the event of radical changes in the environment, the condition of the ecosystem needs to be assessed using not only physical, physicochemical, and chemical methods but also biological ones. In the last two decades, researchers have started to actively study the biological activity of natural and anthropogenic environments.

TABLE XI. CELLULOLYTIC ACTIVITY OF SOILS

Sample name	**Intensity of fiber destruction, %**	**Characteristic**
Control	57.8	strong
Sample No. 1	21.4	weak
Sample No. 2	0	did not appear
Sample No. 3	0	did not appear
Sample No. 4	23.1	weak
Sample No. 5	9.1	very weak

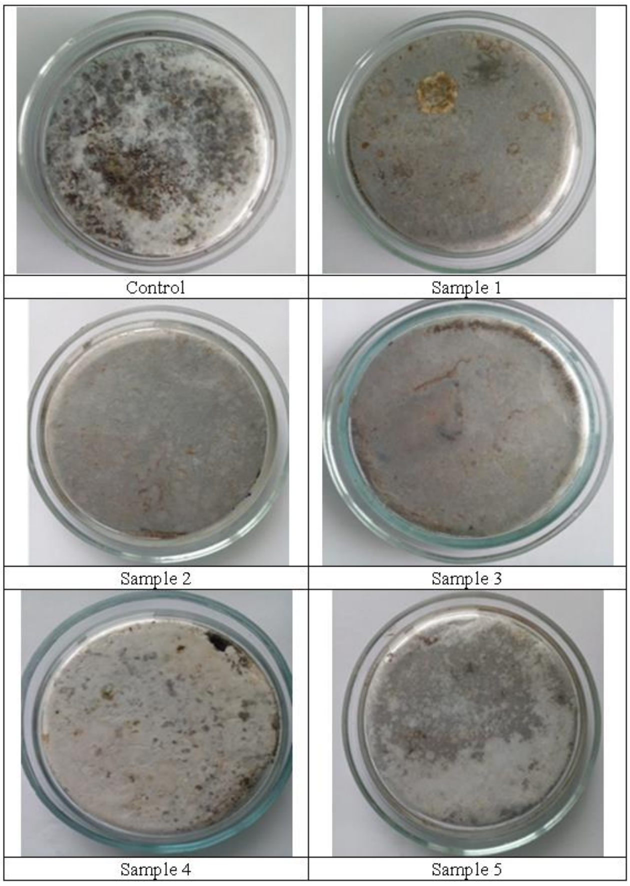

Fig. 3. Cellulolytic activity of soils.

Analysis of the results indicates weak and very weak cellulolytic activity, which is expected based on the results of the assessment of species composition and structure of vegetation, projective coverage of soils, their physical and chemical properties, and a low level of nitrifying and total nitrogen. It can be assumed with a high probability that the number, structure, and species composition of specialized microorganisms at the dumpsite are insufficient.

Catalytic activity is found to be not very high (0.47-0.97 cm^3 O$_2$ g^{-1}·min^{-1}). On average, it reaches 0.84 cm^3 O$_2$ g^{-1}·min^{-1}, which is 5 times lower than the control (Tables 12 and 13).

TABLE XII. CATALYTIC ACTIVITY OF THE SOIL, CM^3 O$_2$ G^{-1} MIN^{-1}.

Indicators	**Control**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**
∑CA	7.23	3.44	3.13	3.49	2.71	3.56
$\mathrm{CA_{NE}}$	3.67	2.52	2.22	2.56	2.24	2.59
$\mathrm{C_{EA}}$	3.56	0.92	0.91	0.93	0.47	0.97

According to D.G. Zvyagintsev’s scale [14], this is considered an insignificant activity, even though in some points of sampling organic matter content reached 4.5-5.1%. The composition and quality of organic matter are rather low, while the presence of toxic chemicals in the form of heavy metals significantly restricts the biological (enzymic) activity of soil because they inhibit the development of microflora.

TABLE XIII. THE BIOLOGICAL (ENZYMATIC) ACTIVITY OF THE SOIL

Indicators	**Control**	**Soil sample**					**Average**
		1	**2**	**3**	**4**	**5**	
Catalase	3.56	0.92	0.91	0.93	0.47	0.97	0.84
Dehydrogenase	17.55	0.35	0.27	0.46	0.33	0.25	0.33

Urease	12.38	3.21	2.35	2.43	3.90	3.22	3.02
Invertase	1.97	0.31	0.15	0.24	0.37	0.24	0.26
Soil respiration	13.2	4.3	5.6	4.2	5.7	4.9	4.9

Assessment of the control sample shows the level of dehydrogenase activity of 17.55 mg TPF per 10 g per 24 hours. In experimental samples, it is almost 50 times lower, averaging 0.33 mg TPF per 10 g per 24 hours.

The control sample of natural origin shows an average release of 12.38 mg NH_4 per 10 g per 24 hours. In the soil of the Talda dump, urease is at its maximum in relation to other enzymes, with its activity ranging from 2.35 to 3.90 mg NH_4 per 10 g per 24 hours. The average value is 3.02 mg NH_4 per 10 g per 24 hours.

Analysis of the results on invertase enzymatic activity demonstrates its low level – from 0.15 to 0.37 mg of glucose per 1 g per 24 hours. On average, it is 7.6 times lower than in the control soil sample.

The factors that reflect biological activity affect soil respiration. This criterion positively correlates with organic matter content, biomass, and microbial activity. In the control version, respiration intensity amounted to 13.2 mg CO_2 per 10 g per 24 hours. In the transect soil, respiration intensity decreased by 2.7 times.

4. DISCUSSION

The conducted analyses of soils in the technogenically disturbed areas in Kuzbass allow us to give a comprehensive characterization of soils based on key evaluation criteria and make a decision on their detoxification and improvement.

A comprehensive soil survey assumes the use of a set of techniques to study soil properties, which focuses on examining the soil as a single whole. This approach requires a well-substantiated selection of control methods, in particular:

1) the complex of controlled soil properties of different nature (chemical, biological, physical, morphological, microbiological, etc.) [18-20];

2) the complex of soil properties differing by the nature of the impact of controlled chemical substances on them (direct specific indicators of pollution, indirect non-specific indicators of pollution, indicators of soil resistance to pollution) [4];

3) the complex of soil components to be controlled (soil horizons acting as biochemical barriers, fine soil fractions that absorb pollutants, etc.) [14];

4) the complex of soil condition levels and soil contamination [12, 21].

The diversity of natural conditions and anthropogenic impacts on soils, as well as the complexity of soil structure within the studied territory, raises the need for an extensive soil survey program [22-24].

All the obtained results of assessment of soil conditions on the experimental site and adjacent territories should be used in planning further experimental work on conducting the biological recultivation phase to minimize random experimental errors associated with the influence of native vegetation cover and primary soil conditions on the survival of crops sown on the site.

5. CONCLUSIONS

The conducted research reveals that technogenically disturbed land plots are marked by increased stoniness and hygroscopicity, as well as a low humus content. Technogenically disturbed lands are further characterized by more acidic and heavy metal-contaminated soils. No excess of pesticides and radionuclides are detected. The study results indicate weak enzymatic (cellulolytic, catalase, dehydrogenase, urease, phosphatase, and invertase activity and soil respiration), as well as the catalytic activity of the soils.

Given that there were no field studies in 2022 and we lack data on the soil profiles of the studied soils, which can only be obtained through morphological studies, the present study does not consider some indicators, such as humus reserves and the profile distribution of humus.

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REFERENCES

[1] V. Antonenko, A. Dovgilevich, A. Zubkov, A. Polikarpov, and Y. Savushkin, “Variation of the Rate of Pesticides Decomposition used Together in the Process of Agricultural Production,” *Brazilian Journal of Biology*, vol. 84, art. no. e273645, 2024. https://doi.org/10.1590/1519-6984.273645

[2] I. Temreshev, A. Tursynkulov, Y. Dutbayev, A. Makezhanov, and G. Suleimanova. “Evaluation of the Efficacy of Entolek K Planteco® Biopesticide Based on Akanthomyces Lecanii Fungus Against Pest Orthopterans in Soybean Agroecosystems in Southeast Kazakhstan,” *OnLine Journal of Biological Sciences*, vol. 22, no. 4, pp. 502-511, 2022. https://doi.org/10.3844/ojbsci.2022.502.511

[3] D. Bekezhanov, G. Kopbassarova, A. Zhunispayeva, T. Urazymbetov, and R. Seilkassymova, “Environmental Problems of International Legal Regulation of Transboundary Pollution,” *Journal of Environmental Management and Tourism*, vol. 12, no. 2, pp. 392-405, 2021. https://doi.org/10.14505//jemt.v12.2(50).08

[4] N. Sarsembayeva, T. Abdigaliyeva, Z. Utepova, A. Biltebay, and A. Aidarbekova, “Assessment of Heavy Metals Migration in the Water – Soil – Fodder – Milk Food Chain in the Almaty Region,” *OnLine Journal of Biological Sciences*, vol. 21, no. 2, pp. 365-375, 2021. https://doi.org/10.3844/ojbsci.2021.365.375

[5] G. I. Antonov, I. N. Bezkorovainaya, A. V. Klimchenko, and D. A. Semenyakin, “Enzymatic Activity of Soils after the First Set Selection Cutting in the Krasnoyarsk Forest-Steppe Pine Foresrts,” *Vestnik KrasGAU*, vol. 7, pp. 61-66, 2011.

[6] V. F. Val'kov, N. V. Eliseeva, I. I. Imgrunt, K. Sh. Kazeev, and S. I. Kolesnikov, “Soil Assessment Handbook,” 2004, 236 p.

[7] G. V. Motuzova, and O. S. Bezuglova, “Ecological Monitoring of Soils,” 2007, 237 p.

[8] I. O. Plekhanova, and Yu. D. Kutukova, “Soil Science. Accumulation of Heavy Metals by Agricultural Plants: A Textbook for Universities,” 1992, 176 p.

[9] E. V. Dadenko, T. V. Denisova, K. Sh. Kazeev, and S. I. Kolesnikov, “Evaluation of the Applicability of Indicators of Enzymatic Activity in Biodiagnostics and Monitoring of Soils,” *Povolzhsky Ecological Journal*, vol. 4, pp. 385-393, 2013.

[10] K. Sh. Kazeev, and S. I. Kolesnikov, “Biodiagnostics of Soils: Methodology and Research Methods,” 2012, 260 p.

[11] A. I. Fakhrutdinov, and T. D. Yampolskaya, “Enzymatic Activity and Nutritional Regime of Soils in Forest Clearings,” *Proceedings of the Samara Scientific Center of the Russian Academy of Sciences*, vol. 18, no. 2(2), pp. 530-533, 2016.

[12] Y. Geng, J. Dighton, and D. Gray, “The Effects of Thinning and Soil Disturbance on Enzyme Activities under Pitch Pine Soil in New Jersey Pinelands,” *Applied Soil Ecology*, vol. 62, pp. 1-7, 2012.

[13] E. M. Perminova, Yu. A. Vinogradova, T. M. Schemelinina, and E. M. Lapteva, “Catalase Activity of Podzolic Soils and its Change during Natural Reforestation in Clearings in Middle Taiga Spruce Forests,” *Proceedings of the Samara Scientific Center of the Russian Academy of Sciences*, vol. 18, no. 1, pp. 27-33, 2016.

[14] E. M. Tulskaya, and D. G. Zvyagintsev, “Comparative Study of Catalase and Catalytic Activity of Upper Soil Horizons,” *Soil Science*, vol. 10, pp. 92-97, 1979.
[15] F. Kh. Khaziev, “Ecological Connections of Enzymatic Activity of Soils,” *Ecobiotech*, vol. 1, no. 2, pp. 80-92, 2018.
[16] L. L. Shishov, V. D. Tonkonogov, I. I. Lebedeva, and M. I. Gerasimova, “Classification and Diagnostics of Russian Soils,” 2004, 342 p.
[17] N. D. Sorokin, and E. N. Afanasova, “Microbiological Diagnostics of the State of Soils and Phyllospheres of Siberian Forest Ecosystems,” *Izvestiya RAN. Ser. Biological*, vol. 1, pp. 100-108, 2013.
[18] D. Ghosh, and S. K. Maiti, “Can Biochar Reclaim Coal Mine Spoil?” *Journal of Environmental Management*, vol. 272, art. no. 111097, 2020. https://doi.org/10.1016/j.jenvman.2020.111097
[19] K. Zhao, Y. Yang, H. Peng, L. Zhang, Y. Zhou, J. Zhang, *et al.*, “Silicon Fertilizers, Humic Acids and their Impact on Physicochemical Properties, Availability and Distribution of Heavy Metals in Soil and Soil Aggregates,” *Science of the Total Environment*, vol. 822, art. no. 153483, 2022. https://doi.org/10.1016/j.scitotenv.2022.153483
[20] B. Nasiyev, T. Vassilina, A. Zhylkybay, V. Shibaikin, and A. Salykova, "Physicochemical and Biological Indicators of Soils in an Organic Farming System", *The Scientific World Journal*, vol. 2021, art. no. 9970957, 2021. https://doi.org/10.1155/2021/9970957
[21] M. Ahmad, A. U. Rajapaksha, J. E. Lim, M. Zhang, N. Bolan, D. Mohan, *et al.*, “Biochar as a Sorbent for Contaminant Management in Soil and Water: A Review,” *Chemosphere*, vol. 99, pp. 19-33, 2014. https://doi.org/10.1016/j.chemosphere.2013.10.071
[22] A. A. Stepanov, P. S. Shulga, D. D. Gosse, and M. E. Smirnova, “Application of Natural Humates for Remediation of Polluted Urban Soils and Stimulation of Plant Growth,” *Bulletin of Moscow University. Series 17: Soil Science*, vol. 2, pp. 30-34, 2018.
[23] M. V. Gilmanova, and I. V. Grekhova, “Evaluation of the Use of Humic Preparations for Biological Reclamation,” *World of Innovations*, vol. 1, no. 40, pp. 6-12, 2018.
[24] J. Broda, P. Franitza, U. Herrmann, and R. Helbig, “Reclamation of Abandoned Open Mines with Innovative Meandrically Arranged Geotextiles,” *Geotextiles and Geomembranes*, vol. 48, no. 3, pp. 236-242, 2020. https://doi.org/10.1016/j.geotexmem.2019.11.003