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STUDY OF PHYSICAL AND CHEMICAL PROPERTIES OF EDAPHOTOPES OF THE WASTE DUMPS AT COAL MINES IN THE NOVOVOLYNSK MINING AREA

Purpose. To define the influence of physical and chemical properties of edaphotopes that are formed at mine dumps within the Novovolynsk mining area (Ukraine) on the biogenic component of the region's ecological safety.

Methodology. The genetic horizons and the soils classification have been described according to the provisions of "Atlas of Soils". Physico-chemical research on edaphotopes and soils within the horizons were conducted by the methods of N.B. Myakina and E. V. Arinushkina. The granulometric soil composition was determined by N. A. Kachinskii Method, with preparation by the pyrophosphate method; humus – by the Tyurin Method in the modification of Nikitin; pH of water and salt extracts – by the potentiometry method; hydrolytic acidity and the sum of imbibed bases – according to Kappen Method; degree of saturation with bases – by the calculation method; exchangeable calcium and magnesium – by the method of complexometry; easily hydrolyzable nitrogen – according to the Kornfield Method; mobile potassium – by the methods of Chirikov (non-carbonate samples) and Protasova (carbonate samples); mobile phosphorus – by the methods of Chirikov (non-carbonate samples) and Machigin (carbonate samples); CO_2 of carbonates – by means of a calcimeter according to Geisler-Maksimyuk Method. The software included a package of application programs Surfer, MS Excel, MS Visio, Paint. The rock temperature was set using an HP-1300 pyrometer. Rock moisture was measured using a MG-44 moisture meter. The level of radiation background was measured with the use of "Soeks" environmental tester.

Findings. During field studies in the Novovolynsk mining area, it was found that coal mine dumps are represented by three types of edaphotopes – rock (black) refuse, burnt (gray) rock and bulk soil mixtures. It has been established that the black burnt rock of the waste heap (light loamy soils) contains a significant amount of nitrogen, while the clay mass and middle loamy burnt rock has a very high content of easily hydrolyzable nitrogen (46.2 mg/100 g of rock). The study of burnt gray rock near the ignition sources at No. 9 Novovolynska mine showed that it is characterized by a high content of organic acids of unknown origin. The humus content in reclaimed soils is 0.45–4.52 %, and according to the humus gradation, they can be assigned to the group of soils with low humus content. The high acidity of the soil mixtures on the reclaimed waste heap at No. 2 Novovolynska mine suppresses the development of tree-shrubbery vegetation and slows its growth.

Originality. It has been found that edaphotopes of waste dumps at coal mines of the Novovolynsk mining area are characterized by a low level of supply with organic substances, but high acidity. The patterns of changes in the temperature and humidity conditions of the waste dump have been determined, where the combustion processes are still observed. It has been proved that burning of dumps determines the change in the physical-chemical properties of the rock refuse and has a direct influence on the development of tree-shrubbery vegetation.

Practical value. The established physical and chemical properties of edaphotopes, which are formed under the influence of temperature and humidity conditions at mine dumps within the Novovolynsk mining area, are recommended to be taken into account for substantiation of the choice of tree and shrub vegetation types when conducting the works on phytomelioration. The obtained data on temperature conditions should be taken into account when developing the plans to prevent spontaneous ignition and extinguishing of waste dumps, as well as in case of their further reclamation.

Keywords: *coal mine, waste dump, edaphotope, temperature field, ecological hazard, ecological safety*

Introduction. Coal mining is accompanied by irreversible direct and indirect environmental changes, leading to the formation of disturbed lands of various types, scale and genesis. Numerous studies are being carried out in Ukraine on the reclamation of devastated landscapes, formed as a result of piling the rock refuse. In particular, in order to select the directions for the further waste dumps use, scientists in the work [1] have presented an algorithm of technologies for rock utilization based on an improved technological passport. Ecological passports of waste dumps provide an opportunity to develop perspective plans of measures to reduce the waste formation, as well as to prevent their negative impact on the environment and human health. The algorithms for conducting the electronic ecological certification of waste dumps (case study of waste dump No. 23 at Y. M. Sverdlov Mine), including the stages of input, accumulation, processing and systematization of information, as well as mapping the sites of waste disposal, are represented in the studies [2]. It should be noted that the concept of using the graph theory to construct a chronolithologic model of waste dump, which will identify the pockets of harmful substances and provide recommendations for the further use of these substances, was previously formulated in the work [3]. Based on the presented model, it is possible to develop recommendations for the control of hazardous substances in mining areas and directions for their further use.

The Novovolynsk mining area belongs to the Lviv-Volyn coal basin, which is located in the Lviv and Volyn regions. Coal has been mined in the Novovolynsk mining area since the 50s of the 20th century. Mining of coal within the Lviv-Volyn coal basin, in particular, the Novovolynsk mining area, has led to significant changes in the biotic and physical-chemical properties of soils, reducing plant viability and productivity [4]. The devastated soils restoration is a slow process with the participation of various biotic organisms [5].

According to physical-geographical regionalization, the area of the region belongs to Small Polissia, which is located between Volyn Polissia in the north and Podilsk Forest-Steppe upland in the south. Small Polissia extends from east to west, from the cities of Shepetivka and Slavuta of the Khmelnytskyi region to the city of Rava-Ruska, Lviv region, where it stretches out in Poland. Conditions for soils existing in the studied region are related to the natural factors of the Volyn Forest-Steppe and Small Polissia. Here, the soil formation occurred with the participation of soil-forming rocks of both the Forest-Steppe and Western Polissia. In geobotanical respect, the soils of the Volyn Forest-Steppe belong to the broad-leaved Eastern European region. The Volyn Forest-Steppe covers the Volyn Upland, which is bounded from the east by the left bank of the Goryn River, from the west – by the Bug River Valley, and in the north and south lengthens by well projecting ledges into Volyn and Small Polissia, respectively.

There are 78 business entities in the city of Novovolynsk with stationary emissions of pollutants into the environment. These are mainly enterprises of mining, foundry and light industry. The mining industry causes significant technogenic impact on the environment of the region. As a consequence of rock refuse having been piled in an open area, surface and subterranean waters are contaminated, soils lose their fertility, hazardous substances and combustion products enter the air [6]. There is an increased level of radiation background in coal-mining regions. To solve the environmental problem of the regions, land reclamation is used, which provides for the planting of forest stands on the waste dumps surface. In the region under research, forest reclamation has not been carried out efficiently, due to insufficient study of the physical-chemical properties of edaphotopes. As a result, there are frequent cases of drying out and stop in the growth of tree-shrubbery vegetation on the waste dumps surface. Only three out of 24 waste dumps in the studied region have been reclaimed to full extent.

In order to solve the immediate situation, it is necessary to study in detail the properties of artificial edaphotopes, as well as bulk soil mixtures (technosoils) that were used in works on remediation and to propose measures to increase the productivity of edaphotopes and forest stands.

Literature review. A lot of scientific works by domestic and foreign scientists are devoted to the edaphic research of the rock refuse at mines. In particular, the main measures for the formation and reclamation of coal mine dumps, as well as their ecological hazard were discussed at various native events. It is noted in the work [7], that mining industry causes the formation of contaminated territories, which, despite the fact that they are full of valuable metals, have high concentrations of toxic heavy metals which pollute the environment. One of such contaminated regions is the Sokalsky District of the Lviv Region, where the Lviv-Volyn coal basin operates. The functioning of the coal basin causes significant pollution of all biosphere components and causes the incidence of the population morbidity [8]. It is noted that owing to vegetation, valuable metals can be extracted from the waste dumps, the extraction of which from the earth's crust is economically unviable [9]. The success of phytoremediation (especially phytoextraction) largely depends on the bioavailability of elements, which, among others, are a function of the mineral phases of the soil, organic substance of the soil, pH and oxidation-reduction potential.

Rather dangerous processes that are observed in the mine dumps are the rock self-ignition with subsequent combustion process. This is an exothermic process, which is accompanied by an increase in temperature accelerating the oxidation process, and ultimately leads to spontaneous ignition of the entire waste dump [10]. One of the most promising ways to deal with the ecological hazard of mine dumps is phytomelioration. To reduce the negative impact of coal mines on the environment, it is necessary to monitor and implement environmental protection measures [11].

Having analyzed the advanced research studies into functioning of the coal mine dumps, it should be noted that they are conducted in three directions:

1) determining the ecological hazard in the zone of their influence;

2) peculiarities of their surface and sides formation;

3) biological (phytomeliorative) recovery.

Scientific work [12] is devoted to the study of the main components of the ecological hazard of coal mine dumps. This work presents the data on burning the Eliska mine dump (the Czech Republic), whose intensity was especially high in the 1960s and 1980s of the 20th century. It has been found that the concentrations of Hg, Pb, Cd in the wastewater from the waste dump exceeds the maximum permissible concentrations in compliance with the European Union legislation. There is an active leaching of hazardous substances and compounds with rainwater, which increases the level of regional ecological hazard. The work [13] is devoted to research on methods for the sulphates identification during waste dumps burning. It has been found that during burning, the specific rare minerals are formed in their stratum.

In respect to the peculiarities of mine dumps formation (storage of the rock refuse), it is worth noting the study [14], where the authors prove that the surface method of mining is the most economically viable and environmentally friendly, since the dumping areas are being reduced. The work focuses on the necessity to reclaim already formed waste dumps. The scientists in the work [15] present the results of modelling the water-physical properties of soils used for waste dumps reclamation, and also determine the physical parameters of the bulk layer formation under the conditions of the Forest-Steppe zone.

A lot of scientific studies, covered in a number of scientific articles, were devoted to questions of biological and phytomeliorative recovery of the coal mine dumps surface. These studies are directed based on two approaches: promoting the natural regeneration of vegetation and creating the artificial sustainable stands. However, they all have a common goal – to improve the ecological safety in coal-mining regions. In the work [16], positive dynamics has been established with respect to the reduction of carbon emissions from the waste dumps surface after phytomelioration. In the work [17], spontaneous vegetation has been studied of brown-coal dumps in Germany, the Czech Republic, and Hungary. It has been found that spontaneous regeneration proved to be more valuable and economically effective from the point of view of nature conservation than forest reclamation and should be considered as an alternative strategy for the recovery of forestry in Central Europe. Scientists from China University of Earth Sciences (Beijing) since 1986 have been conducting research on anthropogenically disturbed lands. They have found that the effectiveness of reclamation means to restore the covering with vegetation to 40–60 % in 5 years and increases to 60–100 % in 8 years [18]. The authors in the work [19, 20] note that the ecosystem has improved significantly after the measures taken on reclamation. The scientists in the work [21] have investigated the relationship between the particle sizes of soil substrate fractions and the species diversity of spontaneous vegetation in mine dumps of Upper Silesia (Southern Poland). The analyses were based on 2567 test sites of developed spontaneous vegetation, and soil substrate samples were collected from 112 mine rocks. It has been found that the highest abundance of species and high values of diversity indices were observed in rocky areas. At the same time, the biggest difference in the participation of species representing different habitats, life forms, was found on gravel substrates.

The study of edaphotopes in the context of research on the physical-chemical properties that are formed under the influence of temperature and humidity conditions in the places of burning and extinguishing has not been implemented in full extent. This refers to the Novovolynsk group of mines of the Lviv-Volyn coal basin.

Purpose, tasks, and methods of research. Purpose of the work is to study the physical and chemical properties of edaphotopes that are formed under the influence of temperature and humidity conditions on mine dumps within the Novovolynsk mining district (Ukraine) and their influence on the biogenic component of the region's ecological safety.

Sampling and processing of samples from the waste dumps of No. 2 Novovolynska mine, No. 6 Novovolynska mine and No. 9 Novovolynska mine were performed in accordance with the requirements set out in a number of regulatory documents. In particular, sampling has been performed in accordance with DSTU 4287:2004 and DSTU ISO 10381-8. Storing of samples and processing of the results for physical and chemical analysis were performed according to DSTU ISO 18512 and DSTU ISO 11464:2007. Soil fertility indicators were set in accordance with DSTU 4362:2004. The genetic horizons were described under the provisions of the "Atlas of Soils". The identified soils have been classified in accordance with generally accepted methods, which are described in the same book.

Physical-chemical studies on edaphotopes and soils within the horizons were conducted according to well-known methods. In particular, the granulometric soil composition was determined by the method of N. A. Kachinskii, with preparation by the pyrophosphate method; humus – by the Tyurin Method in the modification of Nikitin; pH of water and salt extracts – by the potentiometry metod; hydrolytic acidity and the sum of imbibed bases – according to the Kappen Method; degree of saturation with bases – by the calculation method; exchangeable calcium and magnesium – by the method of complexometry; easily hydrolyzable nitrogen – according to the Kornfield Method; mobile potassium – by the methods of Chirikov (non-carbonate samples) and Protasova (carbonate samples); mobile phosphorus – by the methods of Chirikov (non-carbonate samples) and Machigin (carbonate samples); CO_2 of carbonates – by means of a calcimeter according to the Geisler-Maksimyuk Method. The software included a package of application programs Surfer, MS Excel, MS Visio, Paint. The rock temperature was determined using an HP-1300 pyrometer. Rock moisture was measured using a MG-44 moisture meter. The level of radiation background was measured with the use of "Soeks" environmental tester.

Results. During field studies in the Novovolynsk mining area, it was found that coal mine dumps are represented by three types of edaphotopes – rock (black) refuse, burnt (gray) rock and bulk soil mixtures. Rock (black) refuse was selected on the surface of the waste dump of No. 9 Novovolynska mine. Burnt (gray) rock was selected on the surface of the waste dump of No. 6 Novovolynska mine near the ignition sources. Bulk soil mixtures (reclaimed soils) were selected on the surface of the waste dump of No. 2 Novovolynska mine in the places of vegetation development (Fig. 1).

Properties of the black burnt rock on waste heap. Analysis of the black burnt rock of the waste heap, which was hoisted with coal to the surface of No. 9 Novovolynska mine, showed that it has a different granulometric composition – from sandy loam to clay, and contains from 2.36 to 9.96 % of organic substances (Table 1).

The rock is characterized by a very strong acid reaction (pH ranging from 2.5 to 3.8), high hydrolytic acidity, and a low degree of saturation with bases. Soil, which has a significant hydrolytic acidity adversely affects the growth and development of many plants. In order to create favorable conditions for the development of plants in such soil, it is necessary to change its acidity.

Acid-base properties are an important characteristic of soils, which are closely related to the physical-chemical imbibing capacity. The reaction of the soil medium on the waste heaps of the Lviv-Volyn coal basin is the result of intervention of the human activity. It depends on the combined edaphic factors action: the chemical and mineralogical composition of the soil mineral part, the presence of highly soluble salts, the content and quality of organic substance, the composition of soil air, soil moisture, and vital activity of organisms. An important regulator of the soil medium reaction is salts contained in it. Neutral, acid, and alkaline salts, having changed from the solid phase to the solution when moistened and vice versa, affect the nature of the soil solution, which, in turn, affects soil fertility.

The black burnt rock of the waste heap (light loamy soils) contains a significant amount of nitrogen available for plants, while the clay mass, as well as middle loamy burnt rock has a very high content of easily hydrolyzable nitrogen (46.2 mg/100 g of rock). The increase in the amount of easily hydrolyzable nitrogen is explained by an increase in the content of organic substances in the rock (up to 10 %). It is obvious that when developing this area, additional organic fertilizers were applied in the form of lake ooze (sapropel), which is confirmed by the high content of physical clay here – 40.8 %. It has been found that the burnt rock is saturated with N (easily hydrolyzable), Ca^{2+}, Mg^{2+}, K_2O, P_2O_5.

Properties of burnt rock in the combustion sources. During field studies on waste heaps in the Novovolynsk mining area, burning dump sites were identified.

The combustion processes were observed at No. 1 waste dump of No. 9 Novovolynska mine, which was started to pile in 1961. The combustion processes were observed immediately

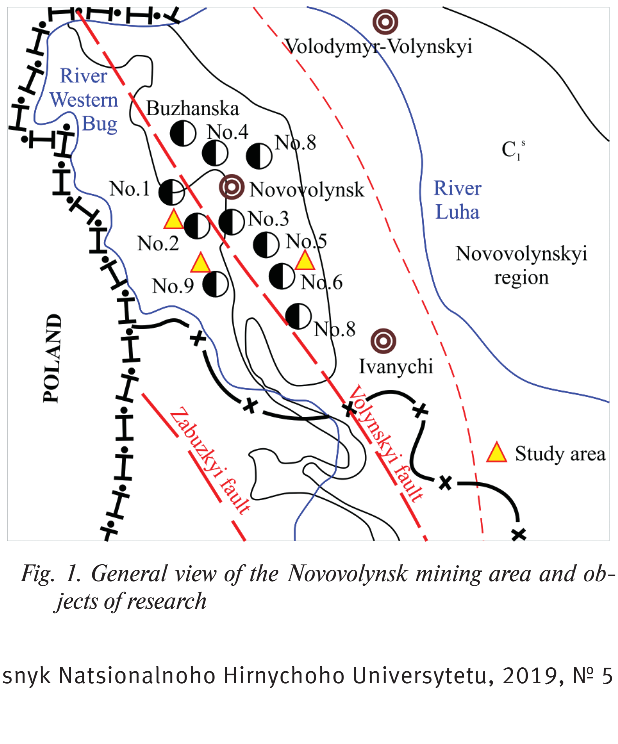

Fig. 1. General view of the Novovolynsk mining area and objects of research

Table 1

Physical-chemical properties of the black burnt rock of waste heap

Slope exposition	Depth of sampling, cm	Physical clay (sum of particles <0.01 mm), %	Organic substances (of unknown origin), %	Salt pH	Hydrolytic acidity	Sum of imbibed bases	Degree of saturation with bases *V*, %	Ca^{2+}	Mg^{2+}	N easily hydrolyzable	K_2O	P_2O_5
					mg equiv/100 g of soil			mg equiv/100 g of soil		mg/100g of soil		
South	0-20 / 20	23.84	2.86	3.81	10.85	17.40	61.59	46.00	80.40	28.00	15.60	2.36
East	0-20 / 20	16.98	2.36	3.67	10.15	30.60	75.09	66.40	63.60	15.40	13.70	1.15
North	0-20 / 20	40.80	9.96	2.46	14.70	20.00	57.64	25.60	8.00	46.20	4.20	0.25
West	0-20 / 20	57.30	5.67	2.61	16.80	17.20	50.59	24.40	16.00	11.20	4.20	0.20

after snow melt in April 2017 in the three areas of the southern exposition of the slope, which is still ongoing (Fig. 2).

The temperature on the waste heap surface was measured at 8 sites: *1* – at the foot from the northern side of the waste heap; *2* – on top of the waste heap; *3* – at the foot from the eastern side of the waste heap; *4* – at the foot from the western side of the waste heap; *5–7* – in the places of burning on the southern exposition of the slope; *8* – at the foot from the southern side of the waste heap. The period of research was April 2017. The average outside temperature was +8.1 °C.

The highest temperature indices for sites No. 5–7 were +32–39 °C. At other sites of the waste heap, the surface temperature was +6–14 °C, which is optimal for the conditions of the spring. As it was noted by the scientists in the work [22], temperature variations at different sites of the waste heap surface are caused by the influence of sublayer combustion of the rock.

The temperature fields of No. 1 waste dump at No. 9 Novovolynska mine are presented in Fig. 3.

Along with the research on temperature conditions, the rock moisture was determined at the studied sites at different depths from the waste heap surface. Relative rock moisture was determined at the same sites as the temperature at a depth of 5, 30 and 50 cm (*1* – at the foot from the northern side of the waste heap; *2* – on top of the waste heap; *3* – at the foot from the eastern side of the waste heap; *4* – at the foot from the western side of the waste heap; *5–7* – in the places of burning on the southern exposition of the slope; *8* – at the foot from the southern side of the waste heap).

It was found that in the places of burning at a depth of 5 cm the relative rock moisture was 13.8–16 %, at a depth of 30 cm – 6.1–14.6 %, at a depth of 50 cm – 5–16.5 %. General rock moisture values at the studied sites are presented in Fig. 4.

The study of burnt gray rock near the ignition sources at No. 9 Novovolynska mine has shown that it is characterized by a high content of organic acids of unknown origin (Table 2).

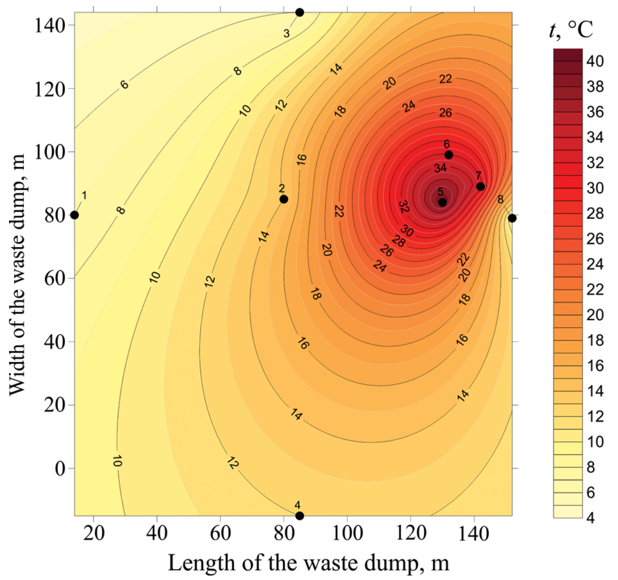

Fig. 3. Temperature fields of No. 1 waste dump at No. 9 Novovolynska mine

Fig. 2. Combustion processes at the waste heap of No. 9 Novovolynska mine

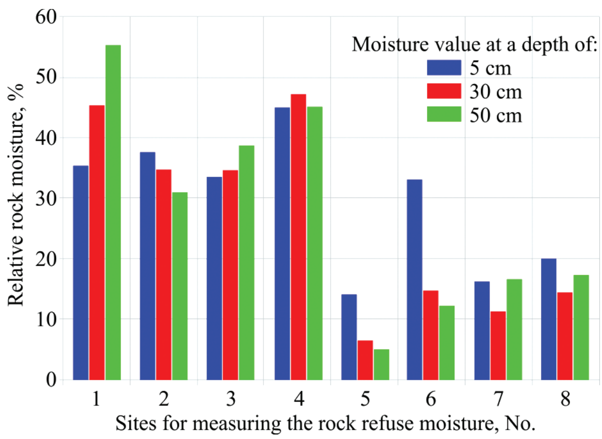

Fig. 4. Rock moisture of No. 1 waste dump at depths of 5, 30 and 50 cm

Table 2

Physical-chemical properties of the burnt gray rock at the waste heap (near the ignition sources)

Sites of burning, №	Depth of sampling, cm	Organic substances (of unknown origin), %	Salt pH	Hydrolytic acidity	Ca^{2+}	Mg^{2+}	N easily hydrolyzable	K_2O	P_2O_5
				mg equiv/100 g of soil			mg/100 g of soil		
5	0-20 / 20	5.22	5.24	4.96	8.25	6.60	9.80	30.00	10.15
6	0-20 / 20	3.28	4.79	6.72	16.00	4.00	4.20	43.20	5.55
7	0-20 / 20	5.22	4.62	6.13	10.50	1.75	9.80	9.00	5.35

The reaction of medium of these rocks is predominantly acid (medium acid), the value of pH is in the range of 4.6–5.2. Hydrolytic acidity corresponds to the value of acid reaction of the medium. There are enough of easily available nutrients for natural and artificial phytomelioration, potassium level is even higher than normal (30–43.2 mg/100 g of soil). Mobile P_2O_5 also has high values in the places of burning (5.35–10.15 mg/100 g of soil). There is no $CaCO_3$ in the places of burning. It was also found that the rock moisture content in the places of burning (W = 13.8–16.5 %) is significantly lower than the soil moisture at a distance of 12–15 m from the waste heap (W = 30–36 %).

Properties of bulk soil mixtures. A study has been done on the soils in the reclaimed part of the waste heap at No. 2 Novovolynska mine. The samples taken on the reclaimed part of the waste heap are accepted to be called as technosoils, that is, they are technogenic soils with a bulk soil layer. To the site where the research was conducted, in order to include it into the biological stage of reclamation, the soils with heavy granulometric composition (medium-textured loam, heavy loam) were bulked, the content of physical clay ranged from 31.26 to 51.94 % (Table 3).

This bulk soil mass was a sufficiently fertile soil with a content of organic substances within 4 %. However, this soil has a very strong acid reaction. The high level of acid reaction of this soil mass is confirmed by high hydrolytic acidity values, a very small amount of exchangeable bases – calcium, magnesium. Thus, this does not make it possible to improve the reaction of the soil medium in order to improve the conditions for the growth of cultivated vegetation in this territory. These soils have a poor content of available forms of nutrients (exchangeable potassium and mobile phosphorus), and there is also a lack of easily hydrolyzable nitrogen. This bulk soil mass is ineffective for forest reclamation of coal mine dumps.

The value of the soil pH plays an important role in the development of vegetation and significantly affects the phytomelioration process. The acid soil reaction is unfavorable for most cultivated vegetation and beneficial microorganisms. Acid soils are characterized by negative physical properties. Due to the insufficient amount of bases, organic substance is not fixed in these soils; therefore, there is a lack of nutrients in these soils. A strong alkaline reaction is also unfavorable for most of vegetation. High alkalinity level causes the low fertility of many soils, their unsatisfactory physical-chemical properties. In our case, there are no such soils. Therefore, to increase the fertility of very acid and alkaline soils, the pH should be greatly changed, which is achieved by measures of chemical reclamation: the introduction of lime into acid soils, gypsum and sulfur-containing substances – into alkaline soils.

The humus content in these reclaimed soils is 0.45–4.52 %, and according to the humus gradation, they can be assigned to the group of soils with low humus content. Humus is a source of plant nutrition, because it contains reserves of nutrients: carbon, nitrogen, phosphorus, calcium, iron, manganese, etc.

Despite the high acidity, representatives of the following families are developing on the reclaimed waste heap of No. 2 Novovolynska mine: Asteraceae Dumort., Menyanthaceae Dumort., Scrophulariaceae, Urticaceae, Rosaceae, Compositae, Fabaceae, Lamiaceae Lindl., Caryophyllaceae Juss., Brassicaceae Burnett (Cruciferae Juss.), Poaceae, Plantaginaceae, Violaceae, Umbelliferae, Malvales, Apiacaeae. Mostly, the species of such families are identified: Asteraceae Dumort., Rosaceae, Fabaceae, Poaceae (Fig. 5).

Table 3

Physical-chemical properties of soils in the reclaimed part of the waste heap

Depth of sampling, cm	Physical clay (sum of particles <0.01 mm), %	Humus, %	pH		Hydrolytic acidity	Sum of imbibed bases	Degree of saturation with bases V, %	Ca^{2+}	Mg^{2+}	N easily hydrolyzable	K_2O	P_2O_5	Content of $CaCO_3$
			salt	water	mg equiv/100g of soil			mg equiv/100 g of soil		mg/100 g of soil			%
0-20 / 20	51.94	3.97	3.09	not identif.	9.45	20.20	68.13	4.80	3.20	5.60	11.40	0.80	not identif.
0-20 / 20	47.64	4.52	3.77	not identif.	3.15	13.60	81.19	5.60	4.80	2.80	20.00	1.45	not identif.
0-20 / 20	51.24	3.77	3.58	not identif.	7.35	19.00	72.11	5.60	4.00	2.80	19.80	1.25	not identif.
0-20 / 20	35.34	0.45	not identif.	7.33	not identif.	not identif.	not identif.	not identif.	not identif.	2.80	12.48	0.60	9.40
0-20 / 20	31.26	2.09	not identif.	7.48	not identif.	not identif.	not identif.	not identif.	not identif.	4.40	19.20	1.60	9.80

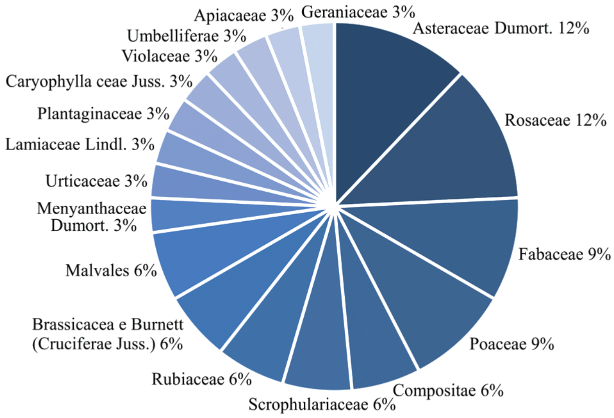

Fig. 5. The family composition of the vegetation at the reclaimed waste heap

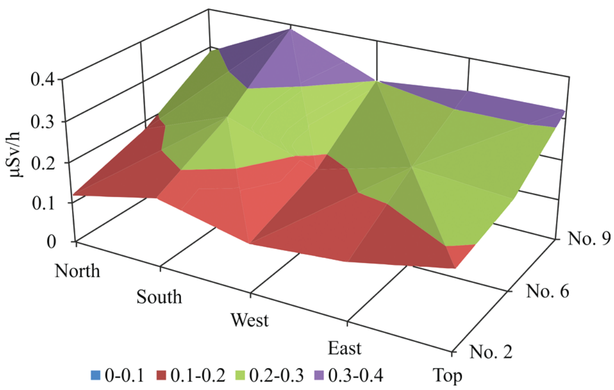

Fig. 6. Data on the radiation background of waste dumps (µSv/h)

Along with the physical-chemical parameters of edaphotopes and the family spectrum of vegetation, the indicators have been determined of the power of the equivalent dose of photon-ionizing radiation in the zone of influence of all the mines under study (Fig. 6).

It has been determined that the highest levels of background radiation are characteristic of areas where the rock combustion processes occur (0.32–0.39 µSv/h). The levels of the background radiation at the waste dumps, where the embankments spread, are slightly lower (0.18–0.26 µSv/h). At the reclaimed waste heaps, background levels do not exceed the norms (0.12–0.17 µSv/h) permissible according to the radiation safety standards of Ukraine (0.3 µSv/h) dated on 14.07.94, No 208.

Conclusions. The paper describes the research results of edaphic factors at coal mine dumps within the Novovolynsk mining area in Ukraine. It has been found that coal mine dumps are represented by three types of edaphotopes – rock (black) refuse, burnt (gray) rock and bulk soil mixtures, which were used in the process of reclamation. Physical-chemical analyses of the presented types of edaphotopes was conducted, that make it possible to assess the effectiveness of the conducted measures, directions of future reclamation measures, as well as activities for environmental protection.

It has been found that edaphotopes of waste dumps under study at coal mines of the Novovolynsk mining area are characterized by a low level of supply with organic substances and high acidity. The soil mixtures at the reclaimed dumps have been selected poorly, since they are acid and not suitable for the biological stage of reclamation. The vegetation development is suppressed on such soils. To increase the vegetation productivity at waste heaps which are characterized by an acid medium of the substrate, it is necessary to neutralize the soils with limestones, as well as to fertilize in accordance with existing standards.

It should be taken into account that the burnt rock is characterized by a very strong acid reaction (pH ranging from 2.5 to 3.8), high hydrolytic acidity, and a low degree of saturation with bases. Edaphotope, which has a significant hydrolytic acidity, adversely affects the growth and development of tree-shrubbery vegetation. The burnt rock of the waste heap (light loamy soils) contains a significant amount of nitrogen available for plants, while the clay mass, as well as middle loamy burnt rock has a very high content of easily hydrolyzable nitrogen (46.2 mg/100 g of rock). An increase in the amount of easily hydrolyzable nitrogen is explained by an increase in the content of organic substances in the rock (up to 10 %).

The waste dumps, where the rock combustion processes occur, cause additional technogenic pressure on the environment resulting in release of combustion products, heating of the rock (+32–39 °C), an increased level of radiation background (0.32 °C 0.39 µSv/h), as well as landslide formation. There is no $CaCO_3$ in the places of burning. It has also been found that the rock moisture content in the places of burning (W = 13.8–16.5 %) is significantly lower than the soil moisture at a distance of 12–15 m from the waste heap (W = 30–36 %).

Activities for environmental protection in the framework of impact of the coal mine dumps in the Novovolynsk mining area should be directed in the following areas: complying with the technology of piling the dump mass, which provides for the layer-by-layer rock isolation with soil mixtures; extinguishing the ignition sources of waste mass with inert substances; contributing to colonization, conservation, formation of vegetation, which has been formed on the waste dumps surface as a result of natural overgrowing; neutralization of acid edaphotopes; forest reclamation of waste dumps surface.

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Дослідження фізико-хімічних властивостей едафотопів породних відвалів вугільних шахт Нововолинського гірничопромислового району

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Мета. Встановити вплив фізико-хімічних властивостей едафотопів, що формуються на відвалах шахт у межах Нововолинського гірничопромислового району (Україна), на біогенну складову екологічної безпеки регіону.

Методика. Опис генетичних горизонтів і класифікація ґрунтів здійснені згідно з положеннями „Атласу ґрунтів“. Фізико-хімічні дослідження едафотопів і ґрунтів у межах горизонтів здійснювали згідно з методиками Н. Б. Мякіної та Є. В. Аринушкіної. Гранулометричний склад ґрунтів визначали за методом Качинського, з підготовкою пірофосфатним методом; гумус – за методом Тюріна в модифікації Нікітіна; pH водної й сольової витяжки – потенціометрично; гідролітичну кислотність і суму ввібраних основ – за методом Каппена; ступінь насиченості основами – розрахунково; обмінні кальцій і магній – комплексонометричним методом; азот легкогідролізований – за методом Корнфілда; рухомий калій – за методами Чірікова (не карбонатні зразки) та Протасової (карбонатні зразки); рухомий фосфор – за методами Чірікова (не карбонатні зразки) та Мачигіна (карбонатні зразки); CO_2 карбонатів – на кальциметрі за методом Гейслера-Максим’юк. Програмне забезпечення – пакет прикладних програм Surfer, MS Excel, MSVisio, Paint. Температура породи встановлена за допомогою пірометра HP-1300. Вологість породи вимірювалася за допомогою вологоміра МГ-44. Радіаційний фон вимірювався за допомогою екотестера довкілля „Soeks“.

Результати. Під час польових досліджень у Нововолинському гірничопромисловому районі було виявлено, що відвали вугільних шахт представлені трьома типами едафотопів – відвальною (чорною) породою, перегорілою (сірою) породою та насипними грунтосумішами. Встановлено, що чорна перегоріла порода терикону (легко суглинкова) містить значну кількість азоту, у той час як глиниста маса й середньо суглинкова перегоріла порода має дуже високий вміст легкогідролізованого азоту (46,2 мг/100 г породи). Дослідження перегорілої сірої породи біля осередків горіння шахти „№ 9 Нововолинська“ показали, що вона характеризується високим вмістом органічних кислот невідомого походження. Вміст гумусу в рекультивованих ґрунтах становить 0,45–4,52 %, і згідно із градацією гумусованості, їх можна віднести до групи низькогумусних ґрунтів. Висока кислотність грунтосумішей на рекультивованому териконі шахти „№ 2 Нововолинська“ пригнічує розвиток деревно-чагарникової рослинності та сповільнює її ріст.

Наукова новизна. Встановлено, що едафотопи породних відвалів вугільних шахт Нововолинського гірничопромислового району характеризуються низьким рівнем забезпечення органічними речовинами й високою кислотністю. Встановлені закономірності зміни температурних і вологісних умов породного відвалу, на якому спостерігаються процеси горіння. Доведено, що горіння відвалів зумовлює зміну фізико-хімічних властивостей відвальної породи та має безпосередній вплив на розвиток деревно-чагарникової рослинності.

Практична значимість. Встановлені фізико-хімічні властивості едафотопів, що формуються під впливом температурних і вологісних режимів на відвалах шахт у межах Нововолинського гірничопромислового району, рекомендується враховувати для обґрунтування вибору видів деревно-чагарникової рослинності при проведенні фітомеліоративних робіт. Отримані дані щодо температурних режимів слід урахувати при розробці планів запобігання самозапалюванню, гасіння й розбирання породних відвалів, а також їх подальшої рекультивації.

Ключові слова: *вугільна шахта, породний відвал, едафотоп, температурне поле, екологічна небезпека, екологічна безпека*

Изучение физико-химических свойств эдафотопов породных отвалов на угольных шахтах Нововолынского горнопромышленного района

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Цель. Установить влияние физико-химических свойств эдафотопов, которые формируются на отвалах шахт в пределах Нововолынского горнопромышленного района (Украина), на биогенную составляющую экологической безопасности региона.

Методика. Описание генетических горизонтов и классификация почв выполнено в соответствии с положениями „Атласа почв". Физико-химические исследования эдафотопов и почв в пределах горизонтов проводили согласно методикам Н. Б. Мякиной и Е. В. Аринушкиной. Гранулометрический состав почв определяли по методу Качинского, с подготовкой пирофосфатным методом; гумус – по методу Тюрина в модификации Никитина; pH водной и солевой вытяжки – потенциометрически; гидролитическую кислотность и сумму впитанных основ – по методу Каппена; степень насыщенности основаниями – расчетным методом; обменные кальций и магний – комплексонометрическим методом; азот легкогидролизуемый – по методу Корнфилда; подвижный калий – по методам Чирикова (некарбонатные образцы) и Протасовой (карбонатные образцы); подвижный фосфор – по методам Чирикова (некарбонатные образцы) и Мачигина (карбонатные образцы); CO_2 карбонатов – на кальциметре по методу Гейслера-Максимюк. Программное обеспечение – пакет прикладных программ Surfer, MS Excel, MSVisio, Paint. Температура породы устанавливалась с помощью пирометра HP-1300. Влажность породы измерялась с помощью влагомера МГ-44. Радиационный фон измерялся с помощью экотестера окружающей среды „Soeks".

Результаты. Во время полевых исследований в Нововолынском горнопромышленном районе было обнаружено, что отвалы угольных шахт представлены тремя типами эдафотопов – отвальной (черной) породой, перегоревшей (серой) породой и насыпными почвосмесями. Установлено, что черная перегоревшая порода террикона (легкосуглинистая) содержит значительное количество азота, в то время как глинистая масса и среднесуглинистая перегоревшая порода имеют очень высокое содержание легкогидролизуемого азота (46,2 мг/100 г породы). Исследование перегоревшей серой породы у очагов возгорания шахты „№ 9 Нововолынская" показали, что она характеризуется высоким содержанием органических кислот неизвестного происхождения. Содержание гумуса в рекультивированных почвах составляет 0,45–4,52 %, и согласно градации гумусности, их можно отнести к группе низкогумусных почв. Высокая кислотность почвосмесей на рекультивированном терриконе шахты „№ 2 Нововолынская" подавляет развитие древесно-кустарниковой растительности и замедляет ее рост.

Научная новизна. Установлено, что эдафотопы породных отвалов угольных шахт Нововолынского горнопромышленного района характеризуются низким уровнем обеспечения органическими веществами и высокой кислотностью. Установлены закономерности изменения температурных и влажностных условий породного отвала, на котором наблюдаются процессы горения. Доказано, что горение отвалов предопределяет изменение физико-химических свойств отвальной породы и имеет непосредственное влияние на развитие древесно-кустарниковой растительности.

Практическая значимость. Установленные физико-химические свойства эдафотопов, формирующихся под влиянием температурных и влажностных режимов на отвалах шахт в пределах Нововолынского горнопромышленного района, рекомендуется учитывать для обоснования выбора видов древесно-кустарниковой растительности при проведении фитомелиоративных работ. Полученные данные по температурным режимам следует учитывать при разработке планов по предотвращению самовозгорания, гашения и разборки породных отвалов, а также в случае их дальнейшей рекультивации.

Ключевые слова: *угольная шахта, породный отвал, эдафотоп, температурное поле, экологическая опасность, экологическая безопасность*

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