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Lithoecotopes and vegetation of the Left -bank and the Right-bank dumps of the Southern Mining and Processing Plant

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Abstract. The article clarifies the peculiarities of the development of vegetation that is formed on the rock dumps of the Southern Mining and Processing Plant or their rock components (lithoecotopes), that is, only lithophilic vegetation. The problem of researching lithophilic plant communities from the point of view of forecasting their natural development and optimization is relevant not only for Kryvbas, but also for all industrial areas of open mining, in which significant masses of hard overburden rocks are brought to the surface of the earth. We have defined various lithoecotopes and described plant groups of varying complexity on plateau peaks, terraces and slopes depending on the specifics of their constituent rocks and typological features. Plant lithophilic groups of dumps of the Southern Mining and Processing Plant in accordance with the state of lithoecotopes, including all typological characteristics and geochemical nature of rocks, are marked by significant analytical (floristic and ecomorphic composition, occurrence, stratification, physiognomy, abundance, coverage) and synthetic (similarity, constancy) differences signs A detailed study of the condition of plants and their groups in lithoecotopes made it possible to make sure that their distribution and development have clearly defined substrate and relief-exposure dependencies, which can be used in phytotic and phytocenotic improvement of these man-made ecotopes. The natural overgrowth of all dumps has a mixed shrub-tree forest and grassy character in accordance with the typological characteristics and composition of the rocks. It was found that the change of plant communities on the lithoecotopes left without human influence is endoexogenous in nature, because the ecesis external pressure is imposed on intracenotic processes. As a result of such integration, both fluctuations and successions naturally occur against the background of one or another substrate. The occurrence of species, the species and petrophytic capacity of plant communities, and their petrophytic indices in the lithoecotopes of the dumps have discrepancies depending on the specifics of the conditions. In general, the taxonomic composition of the plant communities of the dumps of the Pidennoy GZK of Kryvbas is determined by 218 species belonging to 54 families, 84 species of which are petrophytes.

Key words: lithophilic groups, taxonomic composition, phytorecultivation

Літоекотопи та рослинність Лівобережних та Правобережних відвалів Південного гірничозбагачувального комбінату

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Анотація. В статті з'ясовано особливості розвитку рослинності, яка формується на скельних відвалах Південного гірничозбагачувального комбінату або їх скельних складових (літоекотопах), тобто тільки літофільної рослинності. Проблема досліджень літофільних рослинних угруповань під кутом зору прогнозування їх природного розвитку та оптимізації є актуальною не тільки для Кривбасу, але й для всіх промислових районів відкритого видобутку корисних копалин, в яких на земну поверхню виносяться значні маси твердих розкривних гірських порід. Нами визначені різні літоекотопи та описані рослинні угруповання різної складності на платовидних вершинах, терасах і схилах в залежності від специфіки складаючих їх гірських порід та типологічних особливостей. Рослинні літофільні угруповання відвалів Південного гірничозбагачувального

комбінату у відповідності до стану літоекотопів, включаючи всі типологічні характеристики та геохімічну природу гірських порід, відзначаються значними розбіжностями аналітичних (флористичний і екоморфічний склад, трапляння, ярусність, фізіономічність, ряснота, покриття) та синтетичних (схожість, константність) ознак. Деталізоване дослідження стану рослин і їх угруповань в літоекотопах дозволило переконатися, що їх поширення та розвиток мають чітко виражені субстратні та рельєфно-експозиційні залежності, що можливо використовувати в фітотичній і фітоценотичній меліорації цих техногенних екотопів. Природне заростання всіх відвалів має розріжено чагарниково-деревний лісний і травянистий характер відповідно до типологічних характеристик і складу порід. З'ясовано, що зміна рослинних угруповань на залишених без впливу людини літоекотопах носить ендоекзогенний характер, тому що ецезисний зовнішній натиск накладається на внутрішньоценотичні процеси. Внаслідок такої інтеграції на фоні того чи іншого субстрату закономірно реалізуються як флюктуації, так і сукцесії. Трапляння видів, видова та петрофітна ємкість рослинних угруповань, їх індекси петрофітності в літоекотопах відвалів мають розбіжності в залежності від специфіки умов. В цілому таксономічний склад рослинних угруповань відвалів Піденного ГЗК Кривбасу визначається 218 видами, які належать до 54 родин, з яких 84 види є петрофітами.

Ключові слова: літофільні угруповання, таксономічний скла, фіторекультивація

Introduction

All over the world, much attention is paid to the problem of reclamation of disturbed lands (Brovko, Yukhnovsky, 2010; Bashutska, 2002; Atmore, 1972; Prach, 1997; Loza, Chorna, 2018; Loza, Pakhomov, Chorna, Voroshilova, 2020, Chugh, Behum, 2014; Hayes, Root, Perdrial, Maier, Chorover, 2014; Kharytonov, Klimkina, Wiche, 2020..). To reduce the man-made load on the biota, waste dumps are rehabilitated. However, in the conditions of insufficient financing of reclamation works in Ukraine, most rock dumps are subject to natural overgrowth (natural phytomelioration). For effective biological reclamation, it is necessary to study the rocks that make up the dumps, the features of soil formation and the processes of formation of natural vegetation (Khlyzina, 2008; Paran'ko, Khlyzina, 2005; Malenko, 1999; Safonova, Reva, 2009; Shanda,, Voroshylova,, 2015 : Skrobala,, Popovych, Pinder, 2020).

In surface mining areas, large areas are occupied by quarry and dump tracts, which have a negative impact on the environment. Recently, the rates and volumes of reclamation of industrial waste in Ukraine have decreased significantly, and in many cases reclamation works are completely absent. Therefore, in the development of methods and techniques of biological reclamation of waste dumps, the results of their natural overgrowth are of great importance. Among the tailings of mining and processing plants, a significant part is occupied by those composed of rocky, detrital, detrital rocks and poor ores, the processing and industrial use of which is unregulated, slowed down and not yet sufficiently defined in terms of time. The natural overgrowth of such dumps and their phytoremediation are multifactorially complicated.

Plant communities formed on rocky substrates and their radical changes (successions) are lithophilic. The problem of researching lithophilic plant communities from the point of view of forecasting their natural development and optimization is relevant not only for Kryvbas, but also for all industrial areas of open mining, in which significant masses of hard overburden rocks are brought to the surface of the earth.

The relevance of the topic is determined by the urgent needs of optimizing the landscape of Kryvorizhye, phytoremediation of landfills, the use of naturally formed vegetation on the basis of practical field research, and the expansion of research in the general theory of vegetation to compensate for negative changes in the vegetation cover of the steppe zone and on a regional scale in the Dnipro region, as well as the prospects of extraction from agro-industrial use of part of arable land, substantiation of their use for afforestation, pastures, recreational areas.

The main goal of the work is to reveal the features of lithophilic plant communities and their successions, which are formed on the rock dumps of Kryvbas.

Material and methods

The «left bank» dumps of the Southern Mining and Processing Plant are located on the left bank of the Ingulets River, to the southwest of the quarry of the Southern Mining and Processing Plant. In the east, the dumps are directly connected to the «Voikovo» tailings storage facility. The «Livoberezhna» railway rock delivery station operates in the eastern part of the dumps. These are railway scraps of medium-old age (10-25 years). Main parameters: area – approximately 700 hectares, height – 70 m, rock volume – 270 million m^3. The western side of the dumps has five tiers, the eastern side has two tiers. The main central and eastern part of the dumps is composed of oxidized ferruginous quartzites, and the northwestern part is composed of rocky rocks (crystalline slates, ore-free and low-ore quartzites in a loosened state). Dumping of these dumps continues on the plateau and slopes of southern and southwestern exposures.

The Pravoberezhny tailings of the Southern Mining and Processing Plant are located on the right bank

of the Ingulets River, west part of the quarry of the Southern Mining and Processing Plant, between the villages of Rudnychne and Rakhmanivske. These are relatively old (25-40 years old), used, multi-tiered, large in area (over 258.8 ha), high (60 m), lumpy, complex in terms of surface characteristics, in which, mainly during railway delivery, stored 246.4 million m^2 of rocks. The northeastern part of the dumps consists of oxidized ferruginous quartzites in loose and dense states. The main part of the dumps is occupied by loose overburden rocks of the Cenozoic (loams, clays, sands, limestones).

During the research period, 231 geobotanical descriptions of plots with an area of 100 m^2 were performed. Square-shaped plots with an area of 100 m^2 (10 x 10m) were laid out on the plateau and terraces every 100 m. On the slopes, descriptive plots were oblong (5 x 20 m).

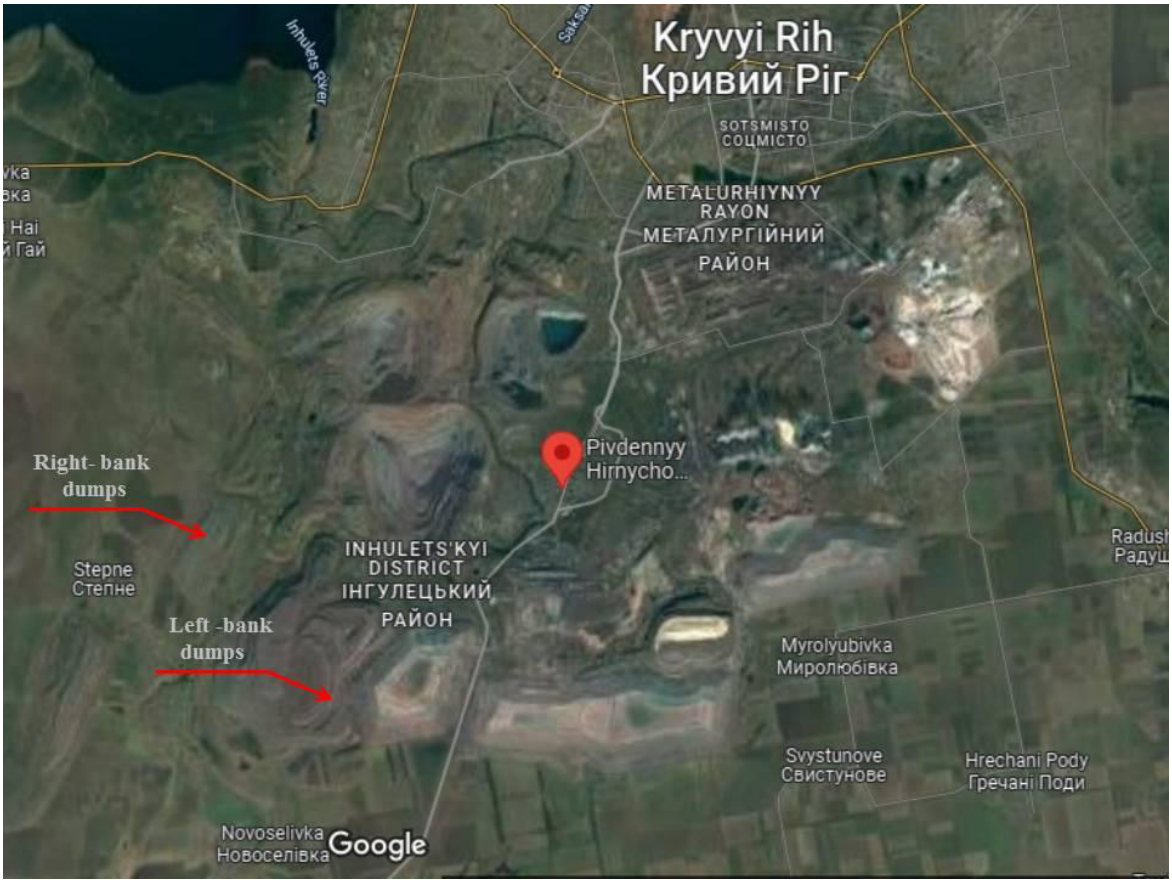

Fig. 1. Location of the «Livoberezhny» and «Pravoberezhny» landfills

Field research, geobotanical description of vegetation, and detailed analysis were carried out according to generally accepted methods (Shelyag-Sosonko, Dydukh, Dubyna., 1991; Osychniuk, 1998; Dobrochaeva., Kotov, Prokudyn., 1987; Tarasov, 2012.). We determined the occurrence, density, coverage of substrates. We determined the total species capacity of families (ZER) of lithophilic plant communities using the formula: ZER= -number of species/number of families; the total petrophyte capacity of families (PER) – according to the formula PER = number of petrophyte species / number of families, the petrophyte index (PI) of families and plant communities was determined by the formula PI = number of petrophyte species / total number of species.

In our opinion, it is possible to classify the lithoecotopes of quarry, dump tracts and dumps in accordance with the leading ideas of O. L. Belgard (1950) regarding the typology of forest and steppe edatopes, expanding the scope of criteria in a certain way. Among them, we highlight trophicity, moisture capacity, toxicity or plant suitability, mechanical composition of substrates, topographical and orographic features of dumps, etc., variations and combinations of which make it possible to predetermine certain types of lithoecotopes and their plant suitability. The relief of plateau terraces and peaks (plains) can be relatively flat, flat (a1), they can also have a large hilly surface (a2), or with a pronounced microrelief of a small hilly or hilly (a3) or wavy (a4) nature. At the same time, both the plateau and the terraces of the dumps can be oriented differently in various parts of the world: to the south (c1), to the southeast (c2), to the southwest (c3), to the north (c4), to the northeast (c5), to the

northwest (c6), to the west (c7), to the east (c8), and with the corresponding slopes (c1, c2, c3, c4, c5, c6, c7, c8). Trophicity (d), moisture capacity (e), toxicity (plant suitability) (f) of rock substrates that make up rock dumps or their parts can be of relatively different levels – low, medium, high, i.e. characterized by these levels as d1, d2 ,d3, e1,e2,e3, f1,f2,f3. Dumps or their parts (most often) can be composed of one rock (g1), two (g2) or three or more (g3). According to the size of the fragments that make up the dumps, they can be small fractions – 1-2 cm (h1), rubble – 2-5 cm (h2), medium fragments – 5-10 cm (h3), large fragments – 10-20 cm (h4) , large fragments – 20-30 cm (h5), large grains – 30-50 cm and more (h6), and variously combined (h7) in relation to each lithoecotope. Among the typological criteria of lithoecotopes of mining and processing plants, the time of dumping of the dump or its parts is mandatory – fresh – 1-5 years (t1), recent – 5-10 (t2), medium-old – 10-25 years (t3), relatively old – 25-40 years (t4), old – more than 40 years (t5).

On the basis of these criteria, it is possible to determine the typological formulas of lithoecotopes of peaks and terraces, also taking into account the orientation by parts of the world, the exposure of the slopes. There may be an indefinite number of such combinations with a complicated combinatorial calculation of their number. Regarding the typology of lithoecotopes of slopes, in our opinion, it is still necessary to introduce such a criterion as the steepness of the slope – from 3º to 30º – (i1), up to 45º – (i2), more than 45º – (i3) (Paran'ko, Khlyzina,, 2005).

At the same time, we note that the concept of «vegetation suitability», in which O. L. Belgard included, first of all, the trophicity and floodability of forest ecotopes, is quite comprehensive. However, with regard to lithoecotopes, it should take into account the specific features of petrophytes (petrophilic plants) and non-petrophilic species, their possible limitation or steno- or eurichority in various lithoecotopes, according to the special intensity of the hydrothermal regime on the slopes of southern exposure, extremes of overheating during the entire growing season, low humidity and trophicity, high mineralization of substrates. This approach is more detailed to the typology of man-made waste ecotopes of Kryvbas and was first initiated by I.A. Dobrovolskyi and V.I. Shanda (1975) based on the typological system of O. L. Belgard.

Results and interpretation

In lithoecotopes of the Left-bank dumps on flat pressed surfaces of fresh and recent dumping first communities consisting of few species, carpet-like monotonous communities or mosaic communities are formed. These communities include such species as *Kochia scoparia, Erigeron canadensis, Polygonum aviculare, Silene ucrainica, Linaria genistifolia, Centaurea diffusa, Crepis tectorum, Gypsophila perfoliat.* Later first of all such species as *Melilotus albus,* and then (under its cover) *Artemisia absinthium, Artemisia austriaca, species of Achillea, Poa angustifolia, Melica transsilvanica,* other Koeleria plants and plants of other families (especially representatives of Asteraceae) reinforce their coenotic positions.

Within the borders of Left-bank dumping sites (Table 1) there is a community represented by few species of many families which is due to specifics of lithoecotopes. Indexes of petrophytic properties of plant families vary within quite a wide range – from 16.67% to 100%. The most common species are those belonging to *Asteraceae, Brassicaceae, Caryophyllaceae, Chenopodiaceae, Fabaceae, Poaceae, Polygonaceae, Scrophulariacea* families.

Table 1. Petrophytic Properties of Lythophylic Plant Communities on Left-bank Dumps of the Southern Ore Mining and Processing Plant in Kryvbass

No.	Families	Number of species	Incl. petrophytes	Index of petrophylic properties, %
1.	Amaranthaceae	1	-	0
2.	*Apiaceae*	2	-	0
3.	*Aspidiaceae*	1	1	100
4.	*Asteraceae*	30	5	16.67
5.	*Boraginaceae*	1	-	0
6.	*Brassicaceae*	5	3	60.00
7.	*Caryophyllaceae*	5	1	20.00
8.	*Chenopodiaceae*	4	-	0
9.	*Convolvulaceae*	1	-	0
10.	*Dipsacaceae*	1	-	0
11.	*Elaeagnaceae*	1	-	0
12.	*Euphorbiaceae*	1	1	100
13.	*Fabaceae*	3	2	66.67
14.	*Geraniaceae*	1	1	100
15.	*Lamiaceae*	1	1	100
16.	*Papaveraceae*	1	-	0
17.	*Plantaginaceae*	1	1	100
18.	*Poaceae*	10	7	70.00
19.	*Polygonaceae*	1	-	0
20.	*Ranunculaceae*	3	-	0
21.	*Rosaceae*	4	1	25.00
22.	*Salicaceae*	1	-	0
23.	*Scrophulariaceae*	2	1	50.00
24.	*Ulmaceae*	2	1	50.00
25.	*Zygophyllaceae*	2	-	0
Total:		85	26	30.59

On the northeastern slope of the Left-bank dumps in the lithoecotope (typological formula $a_4i_2c_6d_2e_2f_2g_3h_2$-$_4t_4$) composed of sericite-chlorite shales and quartz-chlorite-biotite shales, unoxidized and oxidized quartzites there is a formed Melica-miscellaneous herbs community of fragmentary laciniate type of descending spacial spreading covering 32% of the substrate surface; density of plants is from 2 to 5 specimens per 1 m^2. The lower part of the slope with medium- and large-sized fractional (h_3-$_4$) composition of hard rocks is almost free of any vegetation except for some solitary plants of *Zygophyllum fabago* and *Crambe tataria.* The slope is supported by soft overburden grounds with spots of separate representatives of *Melica transsilvanica* and *Crambe tataria.* The last ones shows that in case of motor transport dumping the upper part of the slope was covered with a greater mass, with a thicker layer of hard rocks and the lower part with hard rocks is weakly covered with a thinner layer of soft rocks and this blocks development of plants (except for the above mentioned stable species presented on this rocky substrate). The grass stand of this lithoecotope is spotty: there are fragments of *Melica transsilvanica*, non-uniform diffuse sections of *Zygophyllum fabago, Crambe tataria, Artemisia absinthium, Erigeron canadensis, Grindelia squarrosa, Achillea submillefolium, Berteroa incana, Kochia scoparia, Polygonum aviculare, Linaria genistifolia, Poa compressa, Melilotus albus, Diplotaxis muralis, Gypsophila perfoliata, Senecio jacobaea.*

In the second lithoecotope of this slope (typological formula $a_1i_3c_7d_1e_1f_3$ $g_3h_4t_3$) with weak (12%) covering of the substrate a torn-fragmentary Melica-Crambe-Zygophyllum with insignificant (5 specimens per 1 m^2) density of plants was developed. Location of *Melica transsilvanica* cenopopulation on the slope is jet-torn, arc-shaped descending and in some places also spotted. *Crambe tataria* and *Zygophyllum fabago* arelocated unevenly by alone; in the lower part there are separate specimens of *Tribulus terrestris*; the foot of the slope is again occupied by *Melica transsilvanica* located linearly with admixtures of *Artemisia austriaca, Artemisia absinthium, Poa compressa, Taraxacum officinale, Grindelia squarrosa, Cichorium intybus, Bromus squarrosus, Diplotaxis muralis, Berteroa incana, Poa angustifolia, Crepis tectorum, Medicago romanica, Consolida regalis, Convolvulus arvensis.*

On the Left-bank dumps there are lithoecotopes separated by means of wide (up to 3 meters) hollows under equal descending spatial spreading of Melica-miscellaneous herbs communities and Melica-Koeleria communities and availability of such woody and shrubby species as *Populus deltoides, Elaegnus argentea, Rosa dumalis, Armeniaca vulgaris, Ulmus laevis on* tops and slopes.

In the lithoecotope where Melica-miscellaneous herbs community was developed the substrate is presented as a mixture of such rocks as quartz-sericite-biotite shales, unoxidized and oxidized quartzites (typological formula $a_4i_1c_7d_2e_2g_3f_2h_2$-$_3t_4$) *Melica transsilvanica* plants are located torn-fragmentary with density of 5 – 6 specimens per 1m^2, general covering of the slope surface is 28%, the grass stand includes the following species *Centaurea diffusa, Achillea submillefolium, Poa angustifolia, Melilotus albus, Medicago romanica, Lotus corniculatus, Potentilla argentea, Bromopsis inermis, Silene vulgaris, Linaria genistifolia, Polygonum aviculare, Senecio jacobaea, Crepis tectorum, Xeranthemum annuum, Serratula xeranthemoides, Chondrilla juncea, Artemisia austriaca, Artemisia absinthium, Dodartia orientalis, Dianthus lanceolatus, Erodium cicutarium, Diplotaxis muralis, Scabiosa ochroleuca, Stachys recta, Daucus carota, Crambe tataria, Linaria genistifolia, Solidago graminifolia.*

On the western slope of continuous line of the Left-bank dumps at the South Ore Mining and Processing Plant in the lithoecotope 1 (its substrate basis is presented as quartz-sericite-amphibole shales, quartz-biotite-amphibole shales and poor-ore unoxidized quartzites) (typological formula $a_4c_7i_2d_1e_1f_3h_2$-$_3t_4$) a Aremisia-Melica-mescellaneous herbs community has been developed; it is fragmentary disjoined in conditions of descending spacial spreading; substrate covering is 65%; and there are also some solitary Populus deltoides trees; and grass stand density is from 8 to 20 specimens per 1 m^2. Melica transsilvanica is present in all fragments of this community with dotted-uneven locations typical for its cenopopulation. Artemisia absinthium is located in separate beds and in dispersed groups; the grass stand includes separate plants of *Erigeron canadensis, Grindelia squarrosa, Lactuca saligna, Lactuca tatarica, Centaurea diffusa, Melilotus albus, Gypsophilla perfoliata, Crambe tataria, Linaria genistifolia, Kochia scoparia, Diplotaxis muralis, Euphorbia seguieriana, Consolida regalis, Silene ucrainica, Achillea nobilis, Senecio vulgaris, Crepis tectorum, Dianthus deltoides, Echium vulgare, Phragmites australis, Silaum alpestre, Atriplex tatarica, Ambrosia artemisifolia,* at the same time these latter species appeared in locations of washing soft overburden rounds away from the flat surface of the plateau-like top.

In the lithoecotope 2 of the Left-bank dumping sites (where quartz-sericite-amphibole shales, bio-

tite-chlorite shales and unoxidized quartzites have a significant admixture of freshly dumped quartzites) (typological formula $a_1c_7i_2d_2e_2f_1g_2h_1$-$_2t_2$) a Erigeron-Polygonum-Kochia-miscellaneous herbs pioneer community with sufficient density (up to 30-40 young plants per 1m^2) has developed; this community also has admixtures of other species providing diffuse, relatively even location of cenopopulation plants. The grass stand is composed of *Erigeron canadensis, Kochia scoparia, Polygonum aviculare, Centaurea diffusa, Gypsophila perfoliata, Diplotaxis muralis, Linaria genistifolia, Silene ucrainica, Senecio jacobaea, Crepis tectorum, місцями Melica transsilvanica, Achillea nobilis, Melilotus albus, Artemisia absinthium.*

In the lithoecotope of the eastern terrace slope (typological formula $a_1c_8i_2d_1f_1g_2h_3t_3$) on a biotite-chlorite shale substrate with unoxidized quartzites a single-species Melica community has developed under linear transverse ascending spacial spreading (density is 5-6 plants per 1 m^2). Just like in case with dumps of the Central Ore Mining and Processing Plant Melica transsilvanica is characterized by significant ecological capabilities (potential abilities or ecomorphic valence) as a pioneer species which is at the same time able to hold ecological positions on the second stage and even on further stages of restoring steppe indigenous vegetation.

In the lithoecotope of the northwestern part of Left-bank dumps (typological formula $a_1c_6i_1d_1e_2f$-$_1g_3h_2$-$_3t_3$) on substrates of ore-less and poor-ore ferruginous quartzites and quartz-sericite-amphibole and sericite-chlorite shales a Melica-Melilotus community with small spotty diffuse uneven location of *Melica transsilvanica* plants with typical descending spacial spreading with density of Melica plants from 8 to 12 specimens per 1 m^2. In the grass stand sufficient covering (62-75%) of the substrate surface has been created by*Melica transsilvanica*, at the same time there are some solitary specimen of *Crambe tataria, Artemisia absinthium, Achillea nobilis, Melilotus albus, Kochia scoparia, Senecio jacobaea, Silene ucrainica, Poa angustifolia, Crepis tectorum, Linaria genistifolia, Medicago romanica, Erigeron canadensis.* There are no plant remnants presented on the surface of the substrate. This fact proves that Melica transsilvanica is presented as a non-dense-bushy Koeleria species without intermediate stages and phases.

In the lithoecotope of the eastern slope of Left-bank dumps (typological formula $a_1c_8i_1d_2e_2f_3g_3h_3$-$_4t_4$) on amphibole-biotite shales and unoxidized quartzites a fragmentary disjoined Melica-miscellaneous herbs community has developed with separately growing specimens of *Populus deltoides, Rosa canina, Rosa corymbifera, Ulmus caprinifolia,* with general covering of the surface up to 46%, in conditions of a torn fan-woody spacial spreading. *Melica transsilvanica* with its disjoined band-like fragments and separate spots partially covers the slope alongside with solitary representatives of *Artemisia absinthium, Melilotus albus, Erigeron canadensis, Achillea nobilis, Senecio jacobaea, Kochia scoparia, Crepis tectorum, Centaurea diffusa, Crambe tataria.* The lower part of the slope with shale fractions of up to 20 cm is almost completely deprived of any vegetation.

In the neighboring lithoecotope (typological formula $a_1c_8i_1d_2e_2f_3g_3h_3$-$_4t_4$) in conditions of significant admixtures of unoxidized quartzites a Melica-miscellaneous herbs community has occupied only the upper part (20-30 meters) and it includes single-species lines of *Melica transsilvanica* and those mixed with *Phragmites australis, Silene ucrainica, Artemisia absinthium, Erigeron canadensis, Achillea nobilis, Poa angustifolia, Linaria genistifolia, Crepis tectorum, Achillea nobilis, Lactuca serriola, Polygonum aviculare, Kochia scoparia.*

On the northern slope of Left-bank dumps (lithoecotope typological formula $a_1c_4i_3d_2e_2f_3g_3h_2t_4$) on quartz-serecite-biotite shales, quartz-chlorite-biotite shales and unoxidized quartzites a dotty rarefied Crambe-Zygophyllum-Gypsophila has been formed with density of 1-3 specimens per 1 m^2. Among representatives of *Crambe tataria, Gypsophila perfoliata, Zygophyllum fabago* there are some specimens of *Polygonum aviculare, Kochia scoparia, Erigeron canadensis* (substrate covering is 12%).

On the plateau-like top of Left-bank dumps in the lithoecotope consisting of small and crushed stony fractions of oxidized and unoxidized quartzites with amphibole and quartz-sericite-biotite shales (typological formula $a_1i_1c_1d_2e_2f_1h_1$-$_2g_3t_3$), with sufficient surface consolidation the Erigeron-Kochia-Polygonum community is accompanied by species of the second phase and the third phase of hard-rock substrate overgrowing, i.e. *Erigeron canadensis, Kochia scoparia, Polygonum aviculare*, in some places creating a continuous carpet are supplemented by *Melilotus albus, Artemisia absinthium* as well as by available species of *Silene ucrainica, Achillea nobilis, Crepis tectorum, Centaurea diffusa, Grindelia squarrosa, Linaria genistifolia, Gypsophila perfoliata, Diplotaxis muralis, Crambe tataria.*

In separate places, among large lumps there are solitary specimens of *Dryopteris filix-mas*, which fully corresponds to the petrophylic nature of this species.

On Left-bank dumps of the South Ore Mining and Processing Plant lithoecotopes are variously composed of oxidized quartzites, unoxidized quartzites and shales.

In the lithoecotope of the plateau-like top of Left-bank dumps (typological formula $a_4в_2d_2e_2f_1g_3h_{4\text{-}6}t_1$) on the substrate with prevailing oxidized quartzites with admixtures of unoxidized quartzites an biotite-amphibole shales a torn-spotty pioneer community has been developed; it consists of *Kochia scoparia, Polygonum aviculare, Erigeron canadensis, Gypsophila perfoliata, Diplotaxis muralis* only in places of fine-fractured locations (h_2-h_3), and in addition to that there some *Centaurea diffusa* plants.

On the south-eastern slope of Left-bank dumps the lithoecotope substrate basis is presented by unoxidized quartzites, oxidized quartzites, amphibole shales and quartz-sericite shales with various sizes of fractions – rom fine fractions (h_1) to large lumps (typological formula $a_3c_2i_1d_2e_2f_3g_3h_7t_2$). In the process of natural overgrowing pioneer communities are formed: *Polygonum aviculare, Erigeron canadensis, Kochia scoparia, Gypsophilla perfoliata, Crambe tataria, Silene ucrainica, Ambrosia artemisifolia, Cyclachaena xanthifolia, Crepis tectorum, Centaurea diffusa, Linaria genistifolia, Herniaria besseri.*

On disturbed old-dumped break-stone areas of the plateau of Left-bank dumps with prevailing oxidized quartzites, unoxidized quartzites and amphibole shales (typological formula $a_1c_1d_2e_2f_1g_3h_2t_2$) a ruderal-miscellaneous herbs Erigeron-Lactuca-Gypsophyla serial community has been formed. Coverage of the substrate is up to 20-30%. These are floristically poor communities (8-14 species per 100 m^2). The number of plant specimens per 1m^2 varies from 20 to 115. The green mass is 0.9 kg/m^2 (in July), 0.7 kg/m^2 (in August), and the air-dry mass is 0.3 kg/m^2 0.17 kg/m^2 respectively. Dominating species in the grass stand are: *Erigeron canadensis, Lactuca tatarica Gypsophila perfoliata*. Sometimes the following species are met *Artemisia absinthium, Salsola iberica, Ambrosia artemisifolia, Grindelia squarrosa, Barkhausia rhoeadifolia, Tripolium vulgare, Diplotaxis muralis, Crambe tataria, Cyclachaena xanthifolia, Lactuca saligna, Melilotus albus, Silene ucrainica, Sisymbrium loselii, Erysimum diffusum, Silene cretaceae, Carduus acanthoides, Achillea ochroleuca.*

The lithoecotope (typological formula $a_1в_3c_1d_2e_2f\text{-}_2g_3h_1\text{-}_2t_1$) based on quartz-sericite shales, sericite-chlorite shales, ore-less unoxidized quartzites with insignificant admixtures of oxidized quartzites is characterized by a rarefied Erigeron-Kochia-Polygonum community which is continuously refilled with new representatives of these plants. The grass stand is composed of *Erigeron canadensis, Kochia scoparia, Polygonum aviculare, Centaurea diffusa, Gypsophila perfoliata, Silene ucrainica, Grindelia squarrosa.*

In the lithoecotope of the southern slope of Left-bank dumps on biotite-chlorite shales, quartz-biotite-amphibole shales, ore-free and oxidized quartzites (lithoecoformula $a_4i_2c_1d_1e_1f_2g_3h_3t_4$) in conditions of descending spacial spreading and local jet-like washing of loess loams away from the surface and diffused location of *Populus deltoides, Ulmus carpinifolia* a fragmentary Melica-miscellaneous herbs community has been developed. Alongside with *Melica transsilvanica, Poa compressa, Bromopsis inermis, Festuca valesiaca, Anisantha tectorum, Agropyron pectinatum* this community has local specimens of *Elytrigia repens* which is typical for revegetation on soft substrates. At the same time there are representatives of *Lactuca serriola, Lactuca tatarica, Carduus acanthoides, Tragopogon major, Ambrosia artemisiifolia, Grindelia squarrosa, Cirsium setosum, Chenopodium album, Atriplex tatarica, Salsola iberica, Crambe tataria, Amaranthus albus, Polygonum aviculare, Echium vulgare, Silene ucrainica, Plantago lanceolata, Consolida paniculata, Convolvulus arvensis, Scabiosa ochroleuca, Solidago virgaurea, Aster amellus, Ceratocephala testiculata, Glaucium corniculatum, Silaum alpestre.*

In general, families of flowering plants on Left-bank dumps are characterized by the following descending series: I. According to the number of species – *Asteraceae* (30) – *Poaceae* (10) – *Brassicaceae* (5) – *Caryophyllaceae* (5). II. According to the number of petrophytes – *Poaceae* (7) – *Asteraceae* (5) – *Brassicaceae* (3) – *Fabaceae* (2). III. According to the indexes of petrophytic properties (%%) – *Poaceae* (70,00) – *Fabaceae* (66,67) – *Rosaceae* (25,00) – *Asteraceae* (16.66).

85 species of flowering plants, including 26 petrophytes belonging to 25 families, were found in the studied lithophilic plant communities of the Left Bank dumps.

In the lithoecotope 1 of Right-bank dumping sites 1 (typological formula $a_1в_3c_1d_2e_2f_2g_3h_1\text{-}_2t_2$) on the same hard rocks a similar community of monotonous type has been developed; it creates an almost continuous covering of the surface and has an enriched species composition. Melilotus albus takes its firm positions in this composition and this corresponds to the abovementioned scheme of overgrowing of break-stone substrates with the so-called Melilotus phase of the weed stage of steppe revegetation. *Melilotus al-*

bus is clearly presented as a plant of the upper level but at the same time it is a component of heavy beds. The grass cover is composed of the same *Erigeron canadensis, Kochia scoparia, Polygonum aviculare, Centaurea diffusa, Gypsophila perfoliata, Silene ucrainica, Grindelia squarrosa, Crepis tectorum, Diplotaxis muralis, Barkhausia rhoeadifolia, Lactuca tatarica, Achillea nobilis, Artemisia absinthium,* there are local representatives of *Phragmites australis* on water resistant layers, *Linaria genistifolia, Erysimum canescens, Senecio jacobaea, Tripolium vulgare, Cirsium setosum, Taraxacum officinale, Dodartia orientalis.*

In the lithoecotope 2 of Right-bank dumps of medium-old dumping where the substrate basis is composed of shales, ore-less quartzites, poor-ore unoxidized quartzites and, partially, oxidized quartzites of the breakstone and medium fractional type (typological formula $a_1в_2c_5d_2e_2f_1g_3h_3t_3$) a Melilotus-miscellaneous herbs community has been developed. *Melilotus albus* forms a sufficiently dense but in some places spotty-disjoined grass stand in which the following species preserve their positions but have weaker development growth and density (they are moving to new locations): *Erigeron canadensis, Kochia scoparia, Polygonum aviculare, Gypsophila perfoliata, Centaurea diffusa, Silene ucrainica, Crepis tectorum, Barkhausia rhoeadifolia, Lactuca tatarica, Achillea nobilis, Artemisia absinthium, Bromus tectorum, somewhere Phragmites australis, Linaria genistifolia, Erysimum canescens, Senecio jacobaea, Tripolium vulgare, Cirsium setosum, Taraxacum officinale, Dodartia orientalis, Melica transsilvanica, Anisantha tectorum, Artemisia austriaca, Bromopsis inermis, Poa angustifolia, Helichrysum arenarium, Thymus dimorphus, Centaurea orientalis, Melilotus officinalis, Silaum alpestre, Crambe tataria, Potentilla argentea, Astragalus onobrychis, Echium vulgare, Cichorium intybus, Hieracium echinoides, Hieracium virosum, Rumex crispus, Plantago lanceolata, Linum perenne, Dianthus lanceolatus, Eryngium campestre, Consolida paniculata, Silene dichotoma.* Among shrubby and woody species, separate representatives of the following species are presented: *Elaeagnus argentea, Populus deltoides, Populus nigra, Armeniaca vulgaris, Ulmus caprinifolia, Rosa dumalis.*

On the same hard-rock substrates with approximately similar distribution of their fractions on the flat surface of the plateau-like top of the second dump (but these substrates are of a more recent dumping) (the lithoecotope has the following typological formula – $a_1в_3c_5d_2e_2f_1g_3h_3t_4$) an Artemisia-miscellaneous herbs community has been developed; these community is characterized by significant changes of its species composition when *Melilotus albus* and species belonging to the first stages of plant community development on break-stone substrates have a lesser density. The grass stand includes bare (uncovered) locations with plant remnants or sprouts (shoots) of various density. Dry and in some places yet vegetative plants include *Melilotus officinalis, Melilotus albus, Erigeron canadensis, Gypsophila perfoliata, Centaurea diffusa, Artemisia absinthium, Achillea nobilis, Centaurea orientalis, Lactuca saligna, Scorzonera latifolia, Chondrilla juncea, Silene ucrainica, Diplotaxis muralis, Poa angustifolia, Poa compressa* there are also some separate beds of *Melica transsilvanica, Silaum alpestre, Thymus dimorphus, Dianthus lanceolatus, Consolida paniculata, Anisantha tectorum, Linaria genistifolia.*

Artemisia-Achillea community of a fragmentary type has been developed on a mixed break-stone substrate of poor-ore, oreless unoxidized and oxidized quartzites and quartz-sericite-biotite shales and chlorite--amphibole shales of the lithoecotope on the southwestern slope of Right-bank dumps (typological formula $a_1c_3i_2d_2e_1f_1g_3h_2\text{-}_3t_3$); it is characterized by torn-band-like separation providing a descending spacial spreading and availability of separate specimens of *Populus deltoides, Rosa canina, Rosa corymbifera, Ulmus caprinifolia.* General covering of the substrate by the grass stand is 21%, species composition of plants is not sufficiently large: *Artemisia absinthium, Phragmites australis, Achillea nobilis, Melilotus albus, Artemisia austriaca, Erigeron canadensis, Kochia prostrata, Poa angustifolia, Melica transsilvanica.*

In a separate lithoecotope of the western slope of Right-bank dumps with its substrate basis composed of unoxidized poor-ore quartzites and oxidized quartzites (typological formula $a_1c_7i_1d_2e_2f_1g_3h_3\text{-}_4t_5$) a significant part is taken by a Melica-Koeleria-miscellaneous herbs community covering 75% of the substrate surface and having a spotty form which is due to large fractions coming to the surface. Sufficient species diversity is determined by an old dumping of this part and this hard rock section of the dump. The grass stand includes diffused and in some cases densely located *Poa compressa, Poa angustifolia, Agropyron pectinatum, Bromopsis inermis, Anisantha tectorum, Melica transsilvanica, місцями Koeleria cristata, Artemisia absinthium, Artemisia austriaca, Reseda lutea, Diplotaxis muralis, Berteroa incana, Erysimum cheiranthoides, Kochia scoparia, Leonurus quinquelobatus, Dracocephalum*

thymiflorum and other. Woody and shrubby species in the community are presented in a diffused way: *Populus deltoides, Rosa canina, Elaeagnus argentea, Ulmus caprinifolia.*

In the lithoecotope of this dump, where rocks (shales and quartzites) were dumped even earlier than in the previous case (typological formula $a_1в_5c5d_2e_2f_1g_3h_3t_5$) and surface of the substrate remained practically undisturbed a Koeleria-miscellaneous herbs community has been formed; this community is characterized by uneven density in its various locations (from 25 to 70 specimens per 1 m^2) with small beds (spots) of *Stipa capillata, Stipa lessingiana,* where plants are sufficiently separated (from 3-4 to 6 specimens per 1 m^2). In general, species diversity is changing in the direction of steppe formation. The following species prevail in the grass stand *Poa compressa, Poa angustifolia, Bromopsis inermis, Anisantha tectorum, Festuca valesiana, Melica transsilvanica, Koeleria cristata, Agropyron pectinatum, Bromus inermis, Coronilla varia, Lotus corniculatus, Medicago romanica, Medicago lupulina, Euphorbia seguieriana, Euphorbia virgultosa, Scabiosa ochroleuca, Scabiosa ucrainica, Plantago lanceolata, Plantago stepposa, Galium aparine,* Shrubby and woody representatives of these community include separate specimens of *Elaeagnus argentea, Rosa canina, Rosa corymbifera, Populus nigra, Populus deltoides, Armeniaca vulgaris, Acer negungo, Ulmus caprinifolia, Robinia pseudoacacia.*

Species Capacity and Petrophytic Capacity of plant communities on Right-bank dumps is sufficiently high under index of petrophytic properties up to 48.38%. Species with the highest petrotrophic saturation of plant communities include the following families *Asteraceae, Caryophyllaceae, Fabaceae, Poaceae, Polygonaceae, Scrophulariaceae* families.In summary it should be noted that Right-bank hard rock dumps are characterized by lithophylic plant communities where the main families of flowering plants may be presented in the following descending series: I. According to the number of species – *Asteraceae* (31) – *Poaceae* (13) – *Caryophyllaceae* (11) – *Lamiaceae* (11) – *Brassicaceae* (7). II. According to the number of petrophytes – *Asteraceae* (11) – *Caryophyllaceae* (8) – *Poaceae* (8) – *Lamiaceae* (6). III. According to the indexes of petrophytic properties (%%) – *Caryophyllaceae* (77.77) – *Poaceae* (61.53) – *Lamiaceae* (55.55) – *Asteraceae* (35.48) – *Rubiaceae* (33.33).

133 species in total, including 58 petrophytes belonging to 29 families of flowering plants, were found in the studies of the plant communities of the Right Bank Dumps.

Table 2. Petrophytic Properties of Lythophylic Plant Communities on Right-bank Dumps of the South Ore Mining and Processing Plant in Kryvbass

No	Families	The total number of species	Including petrophytes	Index of petrophytic properties, %
1.	Aceraceae	1	-	0
2.	*Apiaceae*	5	1	20.00
3.	*Asteraceae*	31	11	35.48
4.	*Boraginaceae*	3	1	33.33
5.	*Brassicaceae*	7	4	57.14
6.	*Caryophyllaceae*	11	8	72.73
7.	*Chenopodiaceae*	3	1	33.33
8.	*Dipsacaceae*	3	1	33.33
9.	*Elaeagnaceae*	1	-	0
10.	*Euphorbiaceae*	2	1	50.00
11.	*Fabaceae*	10	3	30.00
12.	*Geraniaceae*	1	1	100
13.	*Lamiaceae*	11	6	54.55
14.	*Limoniaceae*	2	2	100
15.	*Linaceae*	1	-	0
16.	*Onagraceae*	1	1	100
17.	*Papaveraceae*	1	-	0
18.	*Plantaginaceae*	2	2	100
19.	*Poaceae*	13	8	61.54
20.	*Polygalaceae*	1	-	0
21.	*Polygonaceae*	3	-	0
22.	*Ranunculaceae*	2	-	0
23.	*Resedaceae*	1	1	100
24.	*Rosaceae*	5	1	20.00
25.	*Rubiaceae*	3	1	33.33
26.	*Salicaceae*	2	-	0
27.	*Santalaceae*	1	1	100
28.	*Scrophulariaceae*	5	2	40.00
29.	*Ulmaceae*	1	1	100
Total:		133	58	43.61

Conclusions

The tailings of mining and beneficiation plants in Kryvbas, composed of rocky overburden rocks during open (quarry) mining of iron ores, are complexes of specific man-made ecotopes, which we define as lithoecotopes. Quarry and dump tracts and each dump are multifaceted landscape structures and successional systems, where vegetation naturally develops against the background of harsh environmental conditions, various groups, including lithophilic, are formed and lithophilic successions occur. Litho-

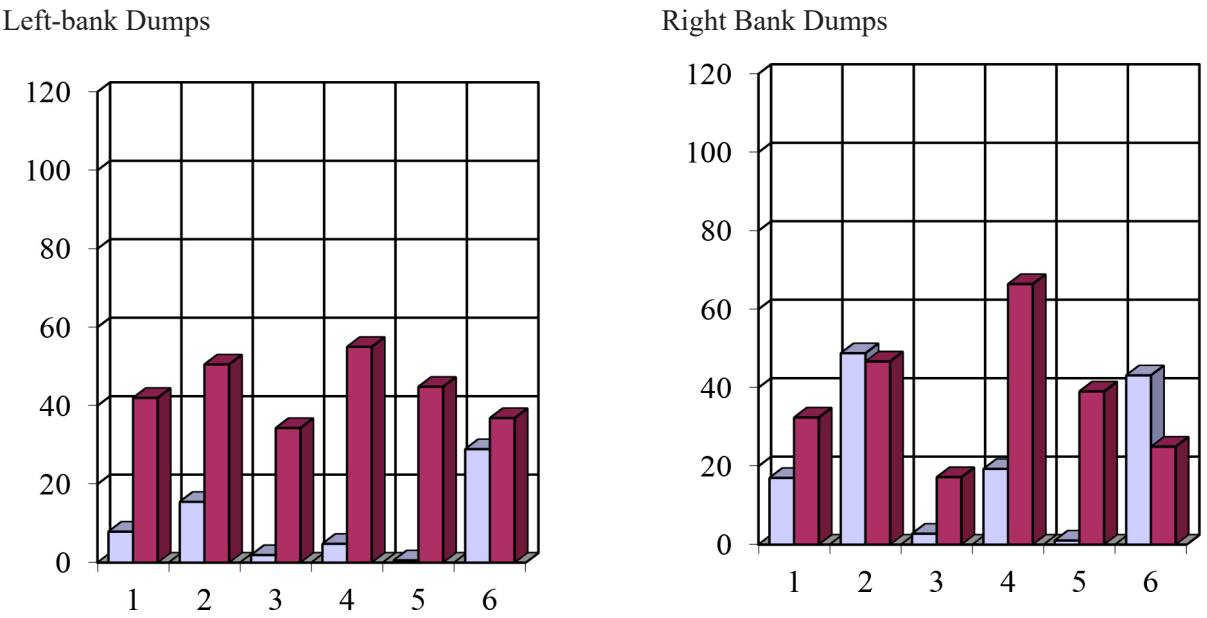

Fig.2. Consolidated indexes of generalized characteristics of lithophylic family communities: 1 – families; 2 – species; 3 – average species capacity of families; 4 – petrophytes; 5 – average petrophytic capacity of families; 6 – index of petrophytic properties of communities

philic plant communities are characterized by a relatively impoverished species composition, different taxonomic and petrophytic capacity, and petrophytic indices. Taxonomic and petrophytic spectra can serve only as auxiliary characteristics of lithophilic plant communities, because at each stage of natural overgrowth, species of different families can have the same cenotic significance.

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