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ANALYSIS OF COMPLEX PHYTOCENOSES OF IRON ORE COMPANIES DUMPS OF THE KOSTANAY REGION

Restoring the biodiversity of technogenic landscapes, including quarry dump areas, is an acute global problem. The study of the patterns of spontaneous formation of vegetation cover will make it possible to determine the composition of the flora that is most suitable for potential reclamation work.

This article presents the results of a study of the degree of self-overgrowing of dump sites of Sokolovsko-Sarbai Mining and Processing Production Association (SSGPO) JSC and Kachary Ruda JSC at the stage of a complex phytocenosis, which is characterized by the presence of a closed vegetation cover; with a capacity of phytocenoses of 20-40 species; and dominance of zonal flora species. In total, in the course of our study, 63 geobotanical descriptions were compiled, 22 of which describe complex phytocenoses, 26 – group-thicket communities, 15 – pioneer groups.

It was found that the rate of change in the stages of syngenesis and the general patterns of development of the vegetation cover, including at the stage of a complex phytocenosis, differ on saline and non-saline soils. The age of dumping has a lesser effect on the processes of flora restoration than edaphic factors. On non-saline soils, a parazonal meadow-steppe community is formed, birch-aspen plantations are formed with a small admixture of pine. On saline soils, communities form species with a wide ecological amplitude.

Key words: complex phytocenosis, technogenic landscape, self-overgrowing of dumps, iron ore companies dumps, syngenesis

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Қостанай облысының темір рудасы кәсіпорындарының күрделі фитоценоздарын талдау

Техногендік ландшафттардың, оның ішінде карьер үйінділерін биоәртүрлілігін қалпына келтіру өткір жаһандық проблема болып табылады. Өсімдік жамылғысының өздігінен қалыптасу заңдылықтарын зерттеу потенциалды рекультивациялық жұмыстарға қолайлы флора құрамын анықтауға мүмкіндік береді.

Бұл мақалада «Соколов-Сарыбай тау-кен байыту өндірістік бірлестігі» (ССКӨБ) АҚ және «Қашары руда» АҚ үйінділерінің күрделі фитоценоз сатысында өздігінен өсу дәрежесін зерттеу нәтижелері келтірілген. Бұл кезең сипатталады: жабық өсімдік жамылғысының болуы; 20-40 түрдегі фитоценоздардың сыйымдылығы; және аймақтық флора түрлерінің басымдылығы. Біздің зерттеу барысында барлығы 63 геоботаникалық сипаттама жасалды, олардың 22 – сі күрделі фитоценоздарды, 26-сы топтасын өскен өсімдіктер жиынтығы, 15-і Пионер топтарын сипаттады.

Сингенез кезеңдерінің өзгеру жылдамдығы және өсімдік жамылғысының дамуының жалпы заңдылықтары, соның ішінде күрделі фитоценоз кезеңінде, тұзданған және тұзданбаған топырақтарда ерекшеленетіні анықталды. Үйінді төгу жасы эдафиялық факторларға қарағанда флораны қалпына келтіру процестеріне аз әсер етеді. Тұзданбаған топырақтарда паразональды шалғынды дала қауымы қалыптасады, қарағайдың аздаған қоспасы бар қайың көктерек екпелер түзіледі. Тұзданған топырақтарда қауымдастықтар кең экологиялық амплитудасы бар түрлер құрайды.

Түйін сөздер: күрделі фитоценоз, техногендік ландшафт, үйінділердің өздігінен өсіп кетуі, темір кені өнеркәсібінің үйінділері, сингенез.

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Анализ сложных фитоценозов на отвалах железорудных предприятий Костанайской области

Восстановление биоразнообразия техногенных ландшафтов, в том числе карьерно-отвальных территорий, является острой глобальной проблемой. Изучение закономерностей самопроизвольного формирования растительного покрова позволит определить состав флоры, наиболее подходящий для потенциальных рекультивационных работ.

В данной статье приведены результаты исследования степени самозарастания отвалов АО «Соколовско-Сарбайское горно-обогатительное производственное объединение» (ССГПО) и АО «Качары руда» на стадии сложного фитоценоза, которая характеризуется наличием сомкнутого растительного покрова; емкостью фитоценозов в 20-40 видов; и доминированием видов зональной флоры. Всего в ходе нашего исследования было составлено 63 геоботанических описания, в 22 из которых описаны сложные фитоценозы, 26 – группово-зарослевые сообщества, 15 – пионерные группировки.

Было установлено, что скорость смены стадий сингенеза и общие паттерны развития растительного покрова, в том числе на этапе сложного фитоценоза, отличаются на засоленных и незасоленных почвах. Возраст отсыпки отвала оказывает меньшее влияние на процессы восстановления флоры, чем эдафические факторы. На незасоленных грунтах формируется паразональное лугово-степное сообщество, происходит формирование березово-осиновых насаждений с небольшой примесью сосны. На засоленных грунтах сообщества формируют виды с широкой экологической амплитудой.

Ключевые слова: сложный фитоценоз, техногенный ландшафт, самозарастание отвалов, отвалы железорудной промышленности, сингенез.

Abbreviations

As – aspen, B – birch, CC – class of constancy, CP – cenopopulation, LF – life form, P – pine, PP – projective cover, TMF – Technogenic mineral formations, TPC – total projective cover.

Introduction

The biodiversity of the planet is under constant threat of decline due to human activities. The search, extraction and processing of minerals necessary for mankind to function and develop requires a change in natural landscapes. Technogenic landscapes, formed as a result of these processes, are strikingly different from natural ones: soil and vegetation cover, fauna, hydrological and geochemical regime, meso- and microrelief change up to the complete destruction of individual components and entire systems [1-5].

In addition, there is a clear violation of biogeochemical cycles, resulting in dangerous phenomena: dust emissions, water and wind erosion of soils, subsidence and landslides, endogenous fires [1-5].

To restore even the semblance of systems close in characteristics to natural ones, it is necessary to carry out reclamation after the end of backfilling. However, the high cost and resource consumption, gaps and inaccuracies in the legislation, and more often the lack of scientifically based technologies suitable for a certain type of soil in given natural conditions, lead to the fact that mining and processing industries abandon this idea [3, 6-9].

The mining industry, using open pit methods, turns large areas into a desert, since in addition to the quarry itself, waste sterile rock dumps are formed. Scientists from various countries are studying the impact of industry on the environment. Many works are aimed at finding ways to reduce the anthropogenic impact, preserve biodiversity, and restore disturbed territories [1, 3-14].

Let us dwell on the main ideas common to most of these studies. For example, Feng Yu et al believe that vegetation, which is an efficient biomass generator, is the dominant factor in renewable systems. Jesús D. Peco et al also emphasize the role of vegetation and describe methods for recultivation of open-pit dump areas, including the possibility of phytoremediation, as a cheaper, but effective, method of restoring disturbed areas. Reconstruction of soil and vegetation cover are interrelated and have mutual influence, therefore, when bioremediation, it is necessary to carefully select local zonal species, as indicated by other authors, such as Swab R.M et al, Fernández-Caliani J.C. et al. They also believe that it is especially important to create favorable edaphic conditions, including the formation of an uncompacted soil environment [5, 8, 12, 14].

According to Pratiwi et al, revegetation of former mining lands not only protects soils from erosion, but also improves the quality of the soil cover itself. Also, as trees and shrubs grow, microclimatic conditions in dump areas improve: lighting intensity decreases, temperature decreases, air humidity increases [13].

Hendrychová M. et al conducted a study of the territories of coal mines and quarries, that completed the mining, of the Czech Republic. The authors, describing the reclamation methods adopted in the country, draw attention to the negative impact of purely technical reclamation, including the annihilation of local species, the destruction of natural ecosystems and the depletion of the habitat in general. Near-natural restoration is a more acceptable alternative. Scientists have identified potential and existing habitats in man-made landscapes after the start of reclamation, and only 9.85% turned out to be unproductive (scree-surface sites, saline soil, orchards, and xerothermic grasslands) out of 6326 identified points, which proves the overall effectiveness of reclamation [6].

All authors, to one degree or another, point to the high cost of reclamation, while there is a watchful waiting policy with a minimum investment of resources. Self-overgrowing of technogenic landscapes is the second, slower, way to restore vegetation. The study of all stages of this process (pioneer group, group-thicket community, and complex phytocenosis) will, first of all, make it possible to determine the composition of the flora that inhabits the disturbed territories and successfully survives under these conditions. Establishing the rate of change of stages on different soils will also make it possible to draw up recommendations for accelerating the processes of partial restoration of landscapes in accordance with the zonality [1, 3-14].

It should also be noted that scientists from neighboring countries showed the greatest interest in the problem of self-overgrowth of open-pit dump territories of various industries. In the course of separate studies, they found that the formation of plant communities on dumps is subject to the general patterns of primary successions. For the emergence of the initial vegetation cover on technogenic landscapes, the proximity of natural vegetation massifs, which are the source of seeds and have a significant impact on the species composition, number and distribution of seedlings, is most important. Settlement on the dumps of plants that are not typical for a certain territory has been repeatedly noted, which indicates the potential possibility of moving plant ovules over considerable distances. In the process of restoration of vegetation cover on technogenic landscapes, zonal and introzonal types of vegetation are formed. Depending on the intensity of environmental factors, this process can continue for tens and hundreds of years [1, 15-22].

The problem of overgrowing of technogenic landscapes formed by industrial facilities is also relevant for the Kostanay region. The growing volumes of open mining of metal ores by enterprises of the region lead to an increase in the formation of waste rock dumps, which in turn leads to a violation of the state of the surrounding natural ecosystem and its significant transformation. According to the "Sixth National Report of the Republic of Kazakhstan on Biological Diversity" (2018), Kostanay region ranks third in terms of the number of disturbed lands in the Republic of Kazakhstan [23].

The purpose of our work is to study the patterns of self-overgrowing of dumps of the iron ore industry in the Kostanay region. This article presents the results of studying the stage of a complex phytocenosis on the dumps of the enterprises of SSGPO JSC and Kachary Ruda JSC.

Materials and мethods

There are two large enterprises processing iron ore on the territory of the Kostanay region: SSGPO JSC (Sokolovsky, Sarbaisky and Kurzhunkulsky quarries) and Kachary Ruda JSC (Kacharsky quarry) [24].

The studied dumps belong to deposits of magnetite ores: Sokolov, Sarbay, and Kachar, are located in the northwestern part of Kazakhstan in the Turgai belt. The Turgai deposits are associated with volcanic-sedimentary rocks of the Trans-Ural zone. These deposits, together with other smaller satellite deposits and manifestations, form an extended magnetite-bearing belt extending in the NNE-SSW directions [25, 26].

In the course of this study, the dumps of SSGPO JSC (in the vicinity of the city of Rudny) were studied: South-East of the Sokolovsky deposit, South-West of the Sarbaysky deposit, South-West of the Yuzhno-Sarbaysky site. The railway dump No. 7 of Kachary Ruda JSC within the boundaries of the village of Kachar was an object of the study along with previously mentioned dump sites.

It is important to note that dumps are the most common type of technogenic massifs in the mining industry, formed as a result of the placement of waste (overburden) rocks or substandard mineral raw materials on the surface. Technogenic mineral formations (TMF) in the form of loose sandy-argillaceous overburden rocks of the platform cover, formed from gaize, sands and clays, were transported to these dumps by road and rail transport. The genetic type of the deposit-source of TMF is contact-metasomatic [27-30].

The study was carried out in the spring and summer period of 2022.

The objects of study are located in the Kostanay region – in the northwestern part of the Republic of Kazakhstan. A sharply continental climate with a wide range of temperatures in winter and summer, day and night, is typical for the entire territory of the region. The northern and central part of the Kostanay region, the territory of the city of Rudny belong to a slightly humidified moderately warm agroclimatic zone, which in general can be considered favorable for plant growth [31].

The studied territories are characterized by the presence of southern, loamy, low-humus, soloniform chernozems. The mechanical composition is dominated by heavy loamy and clayey soils, and a large proportion of soils is sandy loam [27-31].

The route-expeditionary reconnaissance research method was used to study the flora of technogenic ecotopes. Trial areas of 100 m² were determined for the study. A total of 63 geobotanical descriptions were compiled.

Floristic data were processed using the IBIS 7.2 program developed by A.A. Zverev [32].

Qualitative and quantitative accounting of plants was carried out in accordance with accepted general botanical methods; occurrence (%), total and partial projective cover (TPC, %) were noted [1].

Calculation of numerical data: herbage density (pcs/m2), number of species (pcs), occurrence (%), partial projective cover (%) – was carried out according to the previously mentioned indicators. The occurrence rate made it possible to single out classes of constancy (CC) in the descriptions:

I – 0-20%; II – 21-40%; III – 41-60%; IV – 61-80%; V – 81-100% [1].

The geographical structure of the flora of the dumps of the third stage of syngenesis was determined according to the classification adopted in the works of Manakov Yu.A.; life forms – according to Serebryakov I.G. [1].

Results and discussion

As a rule, the stage of a complex phytocenosis (also known as 'diffuse community') begins to form 15-30 years after the dumping of the TMF finished. At this stage, well-formed layers appear with the predominant participation of species of zonal phytocenoses.

Criteria for determining this stage:

- the formation of a closed vegetation cover;
- the capacity of phytocenoses is from 20 to 40 species;
- dominance in the vegetation cover of species of zonal flora [1].

At the diffuse community stage, 22 geobotanical descriptions were made during this study: 11 on saline soils and 11 on non-saline soils. During our research we identified a division of edaphic environmental conditions: favorable – non-saline soils, unfavorable – saline soils. This affects number of species, activity, projective cover etc.

The age (end of dumping) of the studied dumps is from 14 to 40 years: CP-58-63 formed on relatively young dump sites (14 years), those on the oldest dump sites include CP-16-26 (40 years).

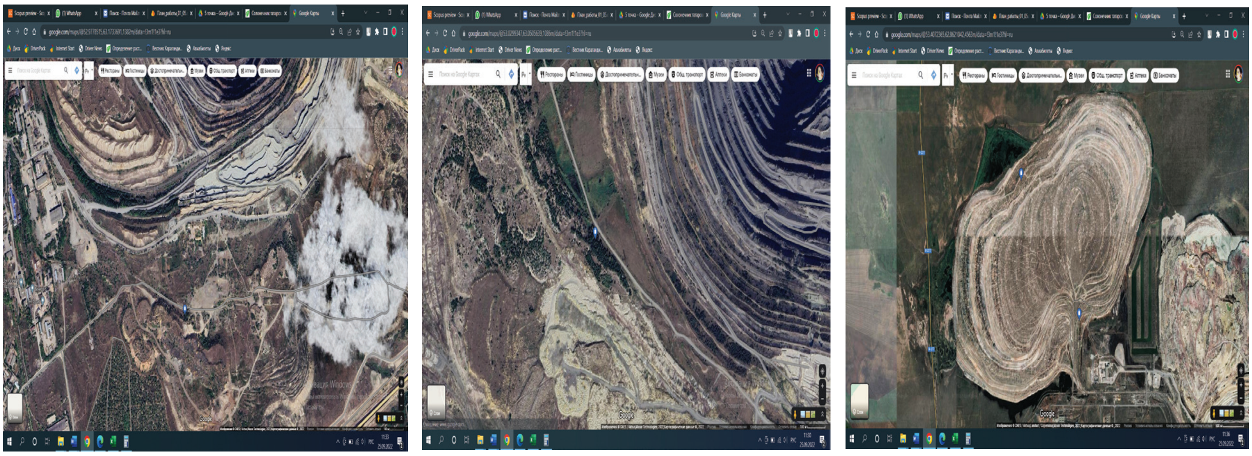
The beginning of the dumping of the oldest dump – 1960 (Table 1, Fig. 1) [24].

In the course of the study of complex phytocenoses on the iron ore dumps, a characteristic of the communities was compiled. Characteristics of cenopopulations of a complex phytocenosis are presented in Tables 2 and 3. The CP numbers are indicated taking into account all 63 geobotanical descriptions made in the course of the whole study of the iron ore dumps of the Kostanay region:

- CP-1-5, CP-43-52 – pioneer groups,
- CP-6-15, CP-27-42 – group-thicket communities,
- CP-16-26, CP-53-63 – complex phytocenosis.

The number of species in a CP at the described stage of syngenesis varies widely from one (CP-60) to nineteen (CP-22), which is associated with differences in edaphic conditions.

The total projective cover on saline soils is 47%, on non-saline soils – 36%. 32 species were found on saline soils, and 58 species on non-saline soils. Most often, *Calamagrostis epigeios, Phragmites australis* and *Festuca valesiaca* are the dominant or co-dominant in the presented CPs (Table 1).



A B C

Figure 1 – Location of the studied plant ecotopes at the stage of complex phytocenosis
A – dump site of the Sokolovsky quarry;
B – dump site of the Sarbaisky quarry;
C – dump site of the Kacharsky quarry

Table 1 – Characteristics of cenopopulations of complex phytocenosis

CP No.	Dominants	Density	Forest stand formula	TPC %	Species quantity
CP-16	*Hieracium umbellatum, Festuca valesiaca*	03	9As+B	40	18
CP-17	*Artemisia austriaca, Bromopsis inermis, Calamagrostis epigeios*	05	10P	20	13
CP-18	*Poa angustifolia, Calamagrostis epigeios*	04	10As+B	30	10
CP-19	*Hieracium umbellatum, Poa angustifolia*	03	10As	30	11
CP-20	*Festuca valesiaca, Artemisia dracunculus*	04	10As	30	14
CP-21	*Artemisia dracunculus, Festuca valesiaca*	04	5B5As	40	15
CP-22	*Tanacetum vulgare, Festuca valesiaca*			30	19
CP-23	*Festuca valesiaca, Galium verum*			30	15
CP-24	*Astragalus buchtormensis, Phragmites australis*			70	13
CP-25	*Hieracium virosum, Calamagrostis epigeios*	04	9B1P	50	12
CP-26	*Festuca valesiaca, Phragmites australis*	04		40	12
CP-53	*Calamagrostis epigeios Phragmites australis*	04	9B1As	25	6
CP-54	*Calamagrostis epigeios Phragmites australis*	03	5B5As	60	7
CP-55	*Calamagrostis epigeios Phragmites australis*	03	5B5As	10	5
CP-56	*Phragmites australis*	03	8B2As	30	3
CP-57	*Phragmites australis*	03	7B3As	50	3
CP-58	*Calamagrostis epigeios, Polygonum salsugineum*			90	14
CP-59	*Artemisia dracunculus, Calamagrostis epigeios*			65	11
CP-60	*Calamagrostis epigeios*			40	1
CP-61	*Calamagrostis epigeios, Polygonum salsugineum*			40	4
CP-62	*Calamagrostis epigeios, Polygonum salsugineum, Artemisia dracunculus*			40	7
CP-63	*Calamagrostis epigeios*	0,3	5B5As	70	6

On the oldest dump sites, the age of which exceeds 40 years, birch-aspen plantations with a density of 05 are formed, the forest stand formula is 8B2As. *Salix caprea* and *Rosa majalis* occur in the undergrowth. On saline soils, mosaic communities are formed with the participation of single pines (*Pinus sylvestris*) and birches (*Betula pendula*) (Table 2).

Since often saline soils are associated with the release of groundwater, numerous self-seeding of birch was noted. In the CP on highly saline soils, mass death of young trees often occurs (Figure 2 A).

Table 2 – Characteristics of communities at the stage of complex phytocenosis on saline soils

Plant species	V*	PPC	A	CC	Plant species	V*	PPC	A	CC
Calamagrostis epigeios (L.) Roth	81.8	24.55	44.82	**V**	*Melilotus albus* Medikus	18.2	0.09	1.28	I
Achillea nobilis L.	54.5	0.27	3.84	**III**	*Pinus sylvestris* L.	18.2	0.09	1.28	I
Betula pendula Roth	54.5	0.16	2.95	**III**	*Conyza canadensis* (L.) Cronqist	9.1	0.05	0.67	I
Phragmites australis (Cav.) Trin. ex Steud.	54.5	10.91	24.39	**III**	*Lactuca serriola* L.	9.1	0.05	0.67	I
Artemisia dracunculus L.	45.5	6.5	17.19	**III**	*Sonchus arvensis* L.	9.1	0.05	0.67	I
Polygonum salsugineum Bieb.	45.5	0.68	5.56	**III**	*Cirsium setosum* (Willd.) Besser	9.1	0.05	0.67	I
Taraxacum officinale F.H.Wigg.	36.4	0.18	2.56	II	*Erigeron acris* L.	9.1	0.05	0.67	I
Chamaenerion angustifolium (L.) Scop.	27.3	0.14	1.95	II	*Senecio jacobaea* L.	9.1	0.05	0.67	I
Populus tremula L.	27.3	0.12	1.81	II	*Lactuca tatarica* (L.) C.A.Mey.	9.1	0.05	0.67	I
Chenopodium album L.	27.3	0.14	1.95	II	*Artemisia sieversiana* Willd.	9.1	0.05	0.67	I
Agropyron cristatum (L.) Gaertn.	18.2	0.09	1.28	I	*Trommsdorffia maculata* (L.) Bernh.	9.1	0.05	0.67	I
Chelidonium majus L.	18.2	0.09	1.28	I	*Elaeagnus oxycarpa* Schltdl.	9.1	0.05	0.67	I
Cichorium intybus L.	18.2	0.09	1.28	I	*Melilotus officinalis* Medikus	9.1	0.05	0.67	I
Crepis tectorum L.	18.2	0.09	1.28	I	*Vicia sepium* L.	9.1	0.05	0.67	I
Hieracium umbellatum L.	18.2	0.09	1.28	I	*Populus × sibirica* G. Kryl. et Grig. ex A. Skvortsov	9.1	0.09	0.9	I
Artemisia nitrosa Weber	18.2	0.09	1.28	I	*Solanum kitagawae* Schonb.-Tem.	9.1	0.05	0.67	I

*V – occurrence, %; PPC – partial projective cover, %; A – activity, points; CC – class of constancy

On saline soils, the only species *Calamagrostis epigeios* has V class of constancy, its activity is 48.8 points. There are 5 species with a high CC – III: *Achillea nobilis, Betula pendula, Phragmites australis, Artemisia dracunculus,* and *Polygonum salsugineum*. Sixty-nine percent of species are characterized by class I constancy.

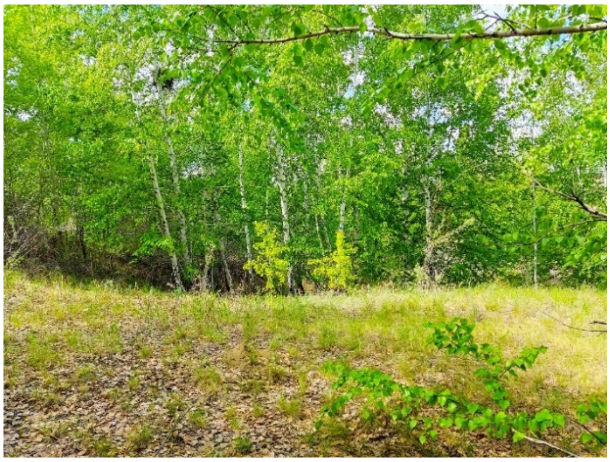
Due to the high degree of salinity, a complex phytocenosis may have a small number of species; such communities are found on highly saline clays in the Betpak-Dala desert [33].

Despite the significant age of the dump sites studied, the presence of weedy plants remains high at this stage: *Artemisia sieversiana, Chenopodium album, Conyza Canadensis, Lactuca serriola, Melilotus officinalis* etc. On non-saline soils at the stage of a diffuse community, natural birch-aspen plantations are formed, and on saline soils separate spots of tree plantations are formed.

Tanacetum vulgare, Festuca valesiaca, Artemisia austriaca, Betula pendula have the highest constancy class V – 7%, other species: IV – 3%, III – 9%, II – 19%, I – 62% of all species on non-saline soils.

The taxonomic structure of complex phytocenoses of dumps of SSGPO JSC and Kachary Ruda JSC is presented in Table 4. The total number of families represented in these communities on saline and non-saline soils is 28, genera – 65, species – 79.

A



B

Figure 2 – The stage of a complex phytocenosis
A – on saline soils
B – on non-saline soils

Table 3 – Characteristics of communities at the stage of complex phytocenosis on non-saline soils

Plant species	V*	PPC	A	CC	Plant species	V*	PPC	A	CC
Tanacetum vulgare L.	90.9	1.14	10.18	**V**	*Stipa lessingiana* Trin. et Rupr.	18.2	0.32	2.41	I
Festuca valesiaca Gaudin	90.9	6.6	24.49	**V**	*Galium verum* L.	18.2	0.32	2.42	I
Artemisia austriaca Jacq.	81.8	1.73	11.9	**V**	*Veronica spicata* L.	18.2	0.09	1.28	I
Betula pendula Roth	81.8	0.37	5.5	**V**	*Veronica incana* L.	18.2	0.09	1.28	I
Artemisia dracunculus L.	63.6	0.55	5.92	**IV**	*Acer negundo* L.	9.1	0.05	0.67	I
Calamagrostis epigeios (L.) Roth	63.6	3.14	14.13	**IV**	*Eryngium planum* L.	9.1	0.05	0.67	I
Hieracium virosum Pall.	54.5	0.73	6.27	**III**	*Falcaria vulgaris* Bernh.	9.1	0.05	0.67	I
Achillea nobilis L.	54.5	0.5	5.22	**III**	*Artemisia marschalliana* Spreng.	9.1	0.05	0.67	I
Achillea millefolium L.	54.5	0.95	7.2	**III**	*Pilosella echioides* (Lumn.) F. Schulz et Sch. Bip.	9.1	0.05	0.67	I
Chamaenerion angustifolium (L.) Scop.	54.5	0.27	3.84	**III**	*Erigeron acris* L.	9.1	0.05	0.67	I
Medicago falcata L.	45.5	0.23	3.23	**III**	*Helichrysum arenarium* (L.) Moench	9.1	0.05	0.67	I
Phlomis tuberosa L.	36.4	1.55	7.51	II	*Nonea pulla* DC.	9.1	0.05	0.67	I
Hieracium umbellatum L.	36.4	1.55	7.51	II	*Sisymbrium loeselii* L.	9.1	0.05	0.67	I

Table continuation

Plant species	V*	PPC	A	CC	Plant species	V*	PPC	A	CC
Centaurea scabiosa L.	36.4	0.18	2.56	II	*Alyssum turkestanicum var. desertorum* (Stapf) Botsch.	9.1	0.05	0.67	I
Stellaria graminea L.	36.4	0.18	2.56	II	*Gypsophila perfoliata* L.	9.1	0.05	0.67	I
Astragalus buchtormensis Pall.	36.4	1.27	6.8	II	*Euphorbia virgata* Waldst. & Kit.	9.1	0.05	0.67	I
Lonicera tatarica L.	27.3	0.14	1.95	II	*Oxytropis pilosa* (L.) DC.	9.1	0.05	0.67	I
Bromopsis inermis (Leyss.) Holub.	27.3	1	5.22	II	*Ribes aureum* Purch	9.1	0.05	0.67	I
Poa pratensis L.	27.3	0.36	3.13	II	*Plantago media* L.	9.1	0.27	1.57	I
Phragmites australis (Cav.) Trin. ex Steud.	27.3	4.82	11.46	II	*Stipa pennata* L.	9.1	0.05	0.67	I
Polygonum aviculare L.	27.3	0.36	3.13	II	*Elytrigia repens* (L.) Nevski	9.1	0.05	0.67	I
Potentilla chrysantha Trevir.	27.3	0.36	3.13	II	*Poa palustris* L.	9.1	0.27	1.57	I
Asparagus officinalis L.	18.2	0.09	1.28	I	*Agrostis gigantea* Roth	9.1	0.05	0.67	I
Lactuca tatarica (L.) C.A.Mey.	18.2	0.09	1.28	I	*Rosa majalis* Herrm.	9.1	0.91	2.88	I
Taraxacum officinale F.H.Wigg.	18.2	0.09	1.28	I	*Cerasus fruticosa* Pall.	9.1	0.05	0.67	I
Hylotelephium triphyllum (Haw.) Holub	18.2	0.09	1.28	I	*Salix caprea* L.	9.1	0.05	0.67	I
Hippophae rhamnoides L.	18.2	0.09	1.28	I	*Linaria genistifolia* (L.) Mill.	9.1	0.05	0.67	I
Astragalus testiculatus Pall.	18.2	0.09	1.28	I	*Valeriana tuberosa* L.	9.1	0.05	0.67	I
Poa angustifolia L.	18.2	0.95	4.16	I	*Populus tremula* L.	9.1	0.05	0.67	I

*V – occurrence, %; PPC – partial projective cover, %; A – activity, points; CC – class of constancy

The most numerous in terms of the number of species and genera – *Asteraceae* (17 genera, 24 species) – 30% of all species, then *Poaceae* (9 genera, 12 species) – 15%, and *Fabaceae* (5 genera, 7 species) – 9%.

The genus with the largest number of species is *Artemisia* (5), followed by *Poa* (3), then *Achillea, Astragalus, Hieracium, Lactuca, Melilotus, Polygonum, Stipa,* and *Veronica* – 2 species each. Most genera contain only 1 species.

In total, there were 11 species found both on saline and non-saline soils: *Achillea nobilis, Artemisia dracunculus, Betula pendula, Calamagrostis epigeios, Chamaenerion angustifolium, Erigeron acris, Hieracium umbellatum, Lactuca tatarica, Phragmites australis, Populus tremula* and *Taraxacum officinale*.

The dominance of the families *Asteraceae, Poaceae, Fabaceae*, noted by us at the stage of a complex phytocenosis on dumps, is characteristic of the taxonomic structure of the region as a whole [34-37].

Table 4 – Taxonomic structure of complex phytocenoses of dumps of SSGPO JSC and Kachary Ruda JSC

Taxonomic indicators	Values
Total number of species	79
Total number of genera	65
Total number of families	28
Number of single-species genera	55
Number of single-species families	17
Number of homogeneous families	18
Share of species in 5 leading families, %	62
Share of species in 10 leading families, %	72

We also analyzed previous works related to the dumps of SSGPO JSC.

In the previously mentioned 1974 study by Terekhova E.B. et al indicated that already by the beginning of the second decade, complex multispecies communities were formed on non-saline soils, similar in characteristics to the stage of a complex phytocenosis. *Artemisia marschalliana, Melilotus spp.* predominate here. Significant participation of steppe grasses and forbs was also noted. Contrary, in the communities studied by us, the role of *Artemisia marschalliana* is much lower, this species did not act as a dominant or codominant in any CP, and was noted by us only in non-saline areas. The total number of species at the third stage of syngenesis was 33 [16].

In the study of Konysbayeva D.T. 2003 on a conditionally favorable substrate, the number of species was 67, triad of dominant families: *Asteraceae, Poaceae, Fabaceae*. The author also notes the emergence of new forest, forest-meadow and swamp-meadow species; at the previous stage, steppe, meadow-steppe and steppe-meadow coenotic groups predominated. On an unfavorable substrate, the total number of species was 33; the dominant families remained the same. There was no significant change in the ratio of coenotic and ecological groups in comparison with the previous stages [3].

As can be seen, fluctuations in the floristic composition of the dumps have occurred over half a century. There was a change not only in the dominant species on certain types of soils, but also in entire coenotic groups.

In the course of our study, we analyzed the ecological and coenotic structure of the dump flora at the stage of a complex phytocenosis. We identified 5 ecological-coenotic groups in the dump flora: meadow, forest, steppe, coastal-aquatic, weedy.

As can be seen from Figure 3, there are striking differences in the distribution of species by coenotic groups with respect to soil salinity:

- most types of saline soils are weedy species,
- meadow and steppe species predominate on non-saline soils.

The coastal aquatic group is the least numerous for both types of soils.

In the course of a systematic analysis, the taxonomic structure of the flora, the composition and ratio of the leading families (floristic spectrum) were revealed, characterizing the belonging of the floras to a certain botanical and geographical area. The composition and correlation of geographical elements reveal the features and specifics of the studied flora. Five main groups of geographical areas have been identified:

- *Cosmopolitan* – species that live in different (sometimes all) regions of the globe,
- *Holarctic* – plants growing in most of the Northern Hemisphere, from the high-latitude Arctic to the subtropical zone inclusive,
- *Eurasian* – a group of species distributed in Europe, Western Siberia and the western part of the Ancient Middle-earth (Pan-Eurasian, Mediterranean-Asian, East European-Asian, European-North Asian, Eurosiberian),
- *Asian* – plants of Siberia, Central and North Asia (Asiatic, Central Asian, Siberian),
- *American-Asian* – the group is represented by plants associated with the flora of North America [1].

In the context of geographical elements, the predominance of the pan-Eurasian faction is noticeable (13, 22) – 44% of all species in the dump flora on this stage. Further in descending order for saline soils: Cosmopolitan (6), Holarctic (5); for unsalted – Mediterranean-Asian and Holarctic – 8 each, Cosmopolitan – 4. No species belonging to the American-Asian range has been found.

As a result of studying the patterns of natural overgrowth of dumps of mining enterprises in the Kostanay region of SSGPO JSC and Kachary Ruda JSC at the stage of a complex phytocenosis, it was established:

1) on non-saline soils, a parazonal meadow-steppe community with a high class of constancy is formed: *Tanacetum vulgare*, *Festuca valesiaca, Artemisia austriaca, Betula pendula*. Here, birch-aspen plantations (*Betula pendula* + *Populus tremula*) are formed with a small admixture of *Pinus sylvestris*.

2) on saline soils, communities form species with a wide ecological range: *Calamagrostis epigeios, Phragmites australis, Artemisia dracunculus*, and others.

3) taxonomic analysis showed that the head parts of the flora spectra iron ore dumps and flora of Kostanay region coincide.

4) the flora of the dumps is dominated by species with wide ranges – pan-Eurasian and Holarctic.

5) the representation of geographical groups in the ecological-coenotic spectrum of the flora and life forms distribution of dumps differs depending on the degree of soil salinity.

The study of life forms (LF) makes it possible from an ecological point of view to assess the characteristics of the dump flora, as well as to find some correlative relationships between the LF and confinement to a certain type of community. The classification we used is based on the structure and lifespan of the aboveground skeletal axes of plants.

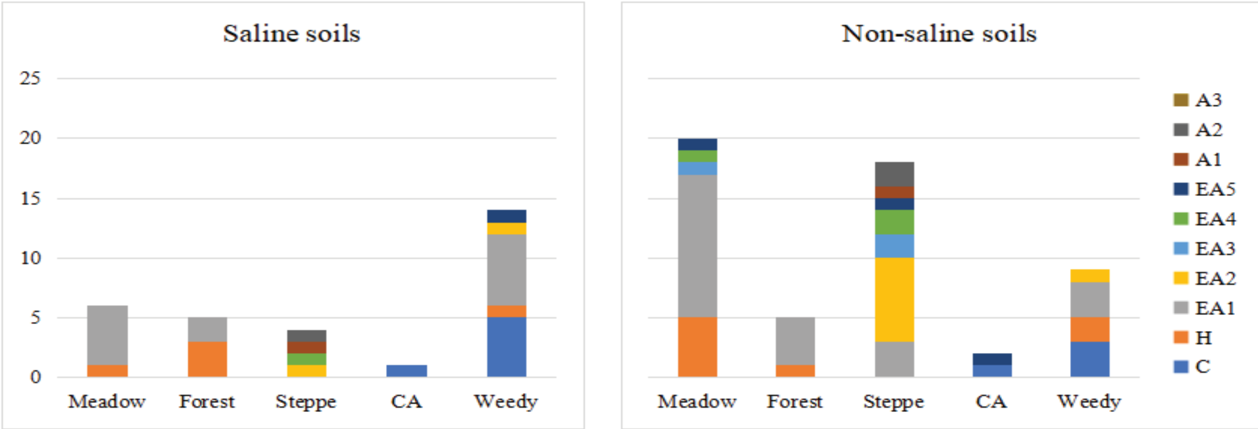


Figure 3 – Characteristics of the flora on different soils

Note: geographical groups: C – Cosmopolitan, H – Holarctic, EA1 – Pan-Eurasian,
EA2 – Mediterranean-Asian, EA3 – East European-Asian, EA4 – European-North Asian,
EA5 – Eurosiberian, A1 – Asiatic, A2 – Central Asian, A3 – Siberian. CA – coastal aquatic plants

At the third stage of syngenesis, we identified the dominant LFs: for saline soils: long-rhizomatous (8), annuals (6) and taproot (5); for non-saline – short-rhizomatous (15), long-rhizomatous (14), and taproot (12) (Figure 4).

On saline soils in the steppe coenotic groups, long-rhizomatous (50%) prevail; in weedy – annual herbaceous (33%) and taproot (27%) groups; in forest – trees (80%), in coastal aquatic – long-rhizomatous (100%).

Taproot (33%) and short-rhizomatous (28%) dominate on non-saline soils in the steppe groups, long-rhizomatous (30%) dominate in weedy group, and short-rhizomatous (45%) and long-rhizomatous (30%) plants dominate in meadow type.

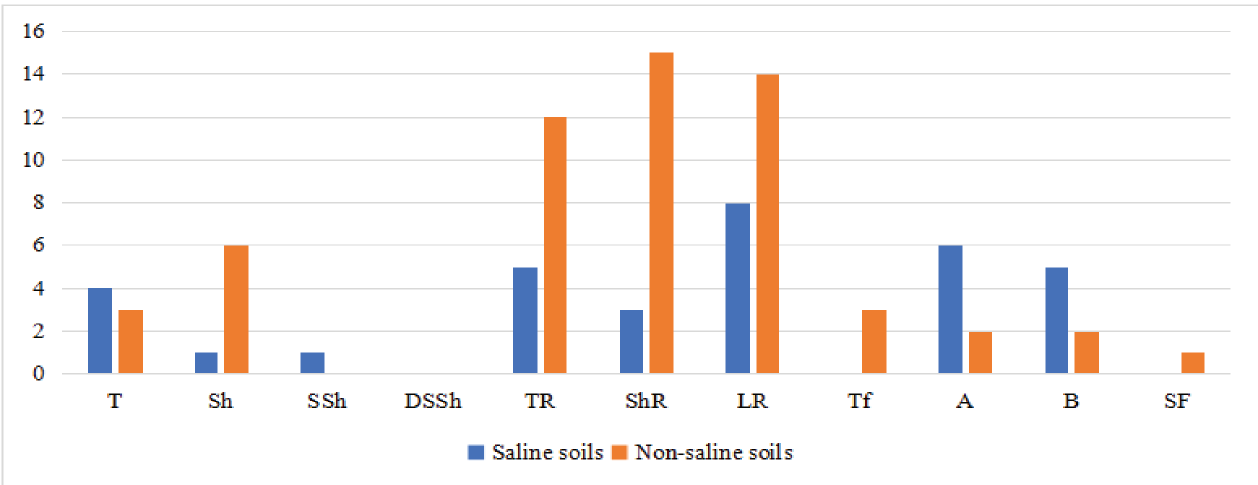


Figure 4 – Characteristics of life forms of plants growing at the stage of CPh

Note: life form according to the classification of I.G. Serebryakov (1962): T – trees, Sh – shrubs,
SSh – semishrubs, DSSh – dwarfs semishrubs, TR – taproot, ShR – short-rhizomatous,
LR – long-rhizomatous, Tf – turf, A – annuals, B – biennials, SF – stolon-forming.

Conclusion

As a continuation of our study, it is planned to resume work on the dump sites, compiling geobotanical descriptions on the same geo coordinates to compare the results, herbarization of previously unidentified species.

Further, after analyzing the patterns of formation of the vegetation cover of dumps at different stages of syngenesis, recommendations will be drawn up for the restoration of biodiversity by effective scientifically based methods for the mining enterprises of the Kostanay region, on the territory of which the research was carried out.

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All authors declare that they have no conflicts of interest.

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