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Natural vegetation communities on the iron ore dumpsites in Northern Kazakhstan

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Abstract. *Simanchuk Y, Sultangazina G. 2023. Natural vegetation communities on the iron ore dumpsites in Northern Kazakhstan. Biodiversitas 24: 3414-3423.* Mining can significantly impact the landscape, clearing vegetation and causing other environmental damage. Reclamation and revegetation are often used to restore degraded land after mining. One reclamation method is passive restoration, which allows vegetation to regenerate naturally. In this study, we investigated the primary stages of syngenesis at the dumpsites of the Sokolov Sarbai Mining Production Association (SSGPO JSC), including the Sokolov and Sarbai deposits and the Kachary Ruda JSC. The age of the dumps studied ranged from two to forty years. According to the degree of syngenesis, the vegetation cover of the dumps was divided into three groups: pioneer groups, group-thicket communities, and diffuse communities. A total of sixty-three standard geobotanical descriptions were made. The composition of plant cenopopulations for saline and non-saline soils was analyzed. A comprehensive floristic analysis of the list of plants, as well as the activity of species in terms of their importance, was carried out. Dominant plants with a high class of consistency were highlighted. The study of syngenesis stages showed that, despite the long period of existence of the dumps, the formation of zonal or intrazonal communities did not occur. The initial stages of syngenesis were characterized by a random and unstable floristic composition of plant communities. The ecological species heterogeneity of the first stages of syngenesis was documented in the spread of species of different coenotic groups. It was determined that salinity slowed down the rate of syngenesis stage change, reduced the number of species, and altered floral composition in saline soils compared to non-saline ones. Even at old dump sites, the floristic composition was incomplete compared to natural phytocenoses.

Keywords: Diffuse community, group-thicket community, iron ore deposit dump, pioneer group, technogenic landscape

Abbreviations: CC: Constancy Class, CP: Cenopopulation, GOST: State standard (Gosudarstvennyi Standart), MVI: Measurement technique (Metodika Vypolneniya Izmerenii), PND F: Environmental regulatory documents federal (Prirodoohrannye Normativnye Dokumenty Federativnye), SSGPO JSC: Sokolov Sarbai Mining Production Association Joint-Stock Company, TMF: Technogenic Mineral Formations

INTRODUCTION

Mining has a significant impact on the environment, leading to changes in natural landscapes, dust pollution, water and wind erosion, subsidence, landslides, and endogenous fires (Koščová et al. 2018; Feng et al. 2019; Brand et al. 2021; Klimova et al. 2021). Understanding the environmental impacts of mining is essential for finding ways to preserve biodiversity and restore disturbed territories. Vegetation is a key factor in the reclamation of open-pit dumps, and research is ongoing to develop effective vegetation restoration techniques (Peltz et al. 2016; Noviyanto et al. 2017; Swab et al. 2017; Koščová et al. 2018; Feng et al. 2019; Hendrychová et al. 2020; Fernández-Caliani et al. 2021; Klimova et al. 2021; Peco et al. 2021; Pratiwi et al. 2021).

When revegetating post-mined land, it is important to carefully select local zonal species that are adapted to the specific environment. This should take into account the species composition of adjacent territories, the types of local species and habitats that have been lost, and the level of ecosystem degradation (Swab et al. 2017; Feng et al. 2019; Hendrychová et al. 2020; Fernández-Caliani et al. 2021; Peco et al. 2021). Scientific evidence has shown that revegetation can protect soil from erosion and improve soil quality. As trees and shrubs grow, microclimatic conditions improve, with reduced light intensity and temperature, and increased air humidity (Pratiwi et al. 2021).

Due to the high cost and resource-intensiveness of active restoration, some mining companies choose to use passive restoration, which allows the ex-mined land to undergo natural regeneration. Various studies of natural regeneration have identified plant species that can survive in the harsh conditions of these sites (Konysbaeva 2016; Peltz et al. 2016; Noviyanto et al. 2017; Swab et al. 2017; Koščová et al. 2018; Feng et al. 2019; Hendrychová et al. 2020; Fernández-Caliani et al. 2021; Klimova et al. 2021; Peco et al. 2021; Pratiwi et al. 2021). This knowledge can be used to accelerate restoration by planting these species in the appropriate locations.

Studies in Kazakhstan's neighboring countries have found that vegetation on dumps naturally regenerates in a pattern similar to primary succession, which is the process of plant colonization on a previously unvegetated area. These studies provide valuable insights for post-mined reclamation in Kazakhstan (Shandala et al. 2016; Belov et al. 2020; Korniyenko et al. 2020; Khismatullin et al. 2021; Klimova et al. 2021; Tchoroev 2021; Treschevskaya et al. 2021; Edelev et al. 2022; Henyk et al. 2022; Chaplygina et al. 2023).

Most disturbed lands undergo succession, a process that leads to the development a vegetation community with a changing species composition. As succession progresses, different biocenoses replace each other, closing the biochemical circulation of substances (Buma et al. 2017; Chang and Turner 2019). A Shennikov classified vegetation communities in primary successions on mining dumps into several groups, namely: (i) pioneer group, which shows no significant relationships between plants; (ii) group-thicket community, which shows more definite relationships between plants and fragmentary distribution of communities; and (iii) diffuse community, which shows a mixed relationship between plants and patterns of distribution of individual species corresponding to the level of competition (Shennikov 1964; Simanchuk et al. 2023).

The problem of overgrowing of technogenic landscapes formed by industrial facilities is relevant for Kazakhstan, which has a considerable extent of lands for mineral extraction. One region which intensively extracts mineral is Kostanay region which ranks third in terms of the disturbed lands extent in Kazakhstan . The growing volumes of metal ores extracted in open-pit mines are leading to an increase in the formation of waste rock dumps. These dumps disturb and transform the surrounding natural ecosystem.

In this study, we investigated the spontaneous formation of vegetation cover at different ages of dumps with limiting factors identified. We studied the flora of SSGPO JSC, and Kachary Ruda JSC dumps in the Kostanay region (North Kazakhstan), where the first dumps dated back to the mid-60s. The disturbed territories of these enterprises cover a total of 20,000 hectares, including 7,000 hectares of dumps with varying rock compositions. The rock consisted of sands, clays, gaizes, andesitic and basalt porphyrites, limestones, tuffs, diorites, porphyrites, etc (Terekhova 1976). In the surface, two groups of technogenic soil types are distinguished, namely eluvium, non-saline with a neutral reaction of the environment (quaternary loams and sandy loams, limestones, tuffs, porphyrites, etc.) and highly saline (gaizes, Cretaceous age Chegan, and lignite clays, clays of ancient weathering crust) in which natural overgrowth occurring faster on the former ones (Terekhova 1976, 1977; Rysbekov et al. 2019). We believe that a systematic, multidimensional study of the self-overgrowth of iron ore industry dumps will allow us to develop optimal, advanced methods for the reclamation degrading lands and restore biological diversity. These methods could be used by the companies involved.

MATERIALS AND METHODS

Study area

This study was conducted during the vegetation period of 2022 in the northwestern part of Kazakhstan in the Turgai belt (Figure 1). Kazakhstan is a transcontinental country located in the center of Eurasia. It is bordered by the Caspian Sea to the west, the Ural Mountains to the north, the Lower Volga region to the northeast, Siberia to the east, Central Asia to the south, and China to the south-east. The country is the world's largest landlocked country, with a vast desert landscape that covers over half of its territory. Kazakhstan’s steppes, or grasslands, comprise another quarter of the land, while forests cover only a small percentage. The republic is home to an enormous mineral resource base, with over 5,000 deposits estimated to be worth tens of trillions of dollars. Despite the Minister for Investment and Development's Order No. 386, which sets out the rules for drawing up a plan for the elimination of the consequences of subsoil use, Kazakhstan is still facing the problem of unliquidated open pits and mines. The Order contains requirements for the area's state after liquidation, including restoring of the natural ecosystem to the maximum similarity with the ecosystem before the subsoil use activities (Order No. 386).

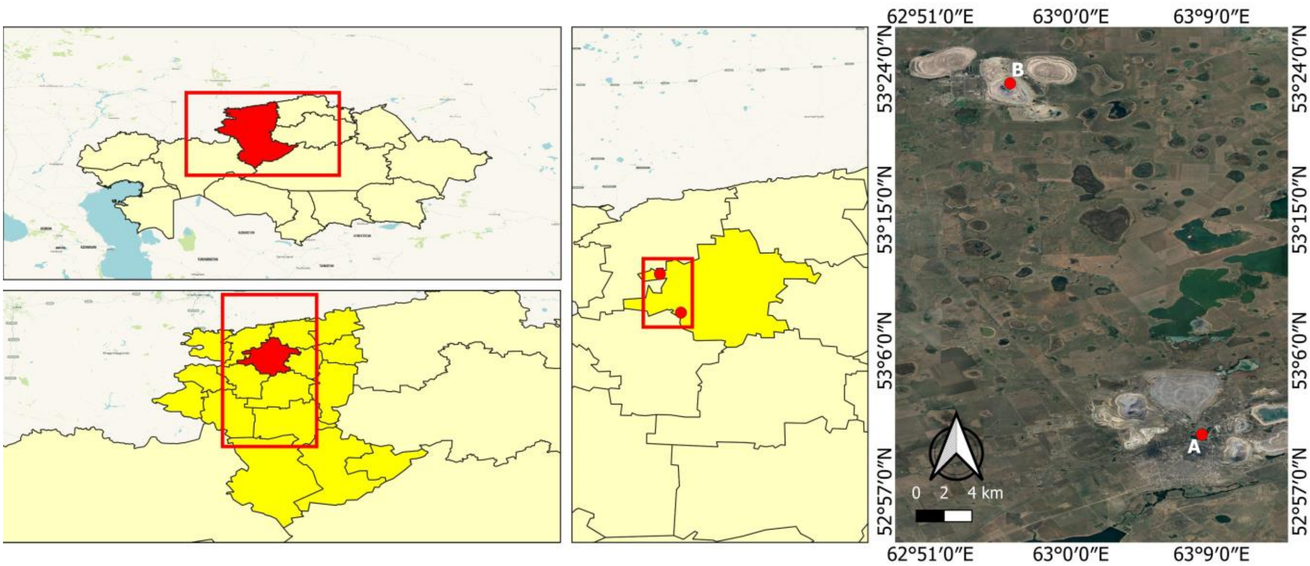

Figure 1. Map of study locations in the Turgai belt in the northwestern part of Kazakhstan and the dump sites (in red). A. SSGPO JSC, B. Kachary Ruda JSC

The objects of the current study were dumps of different ages of SSGPO JSC and Kachary Ruda JSC, including the Sokolov (south-east dump), sarbai (south-west and south-west of the south Sarbai part), Kachar (railway dump No. 7) deposits (Figure 1). All dumps were divided into non-saline and highly saline. The age of the studied dumps ranged from two to forty years. The deposits of magnetite ores in the studied area are associated with volcanic-sedimentary rocks of the Trans-Ural zone. These deposits, together with other satellite deposits and manifestations, form an extended magnetite-bearing belt extending in the NNE-SSW directions-the Turgai belt, which extends from the Sarbai deposit in the south to the Glubochensky deposit in the north (Hawkins et al. 2017; Ayupova et al. 2020).

The quarry rocks are dated to the Carboniferous, Cretaceous, Tertiary, and Quaternary periods. The rocks formed in the tertiary age predominate, while Carboniferous rocks almost do not appear in the composition of the latter, Cretaceous rocks occupy relatively small spaces, and Quaternary rocks are present as an insignificant admixture to the rest. Technogenic mineral formations in the form of loose sandy-argillaceous overburden rocks of the platform cover, formed from gaize, sands, and clays, were transported to the studied dumps by road and rail transport. The general type of deposit source of TMF is contact-metasomatic. Due to the unsystematic storage of overburdened rocks in dumps, complex soil mixtures turned out to be on the surface of the latter, formed mainly by Tertiary and partly Cretaceous rocks, extremely mosaically mixed and irregularly changing in space (Terekhova 1976, 1977; Hawkins et al. 2017).

The flora in the studied region refers mainly to arid steppes and forest steppes with rare occurrences of forest belts and meadows in a sharply continental climate. The highest average temperature is 21°C which occurs in July, while the lowest average annual temperature is -15,4°C which usually occurs in January. In some years, the temperature can extremely decrease to -40°C and extremely increase to 45°C. The annual precipitation is up to 390 mm. The average annual wind speed is 3.2 to 5.7 m/s. The annual maximum wind in the region is within 24-35 m/s. The prevailing wind direction is southwest (Baysholanov 2017; Deák et al. 2017; Bragina and Khisametdinova 2018; Dryuk and Simanchuk 2018; Tölgyesi et al. 2018).

It should be noted that in the steppe zone of Northern Kazakhstan, specific environmental conditions are created on the surface of the dump sites (a small amount of precipitation during the growing season, sharp fluctuations in daily and annual temperatures, strong winds and dry winds, increased moisture runoff from the surface of the substrate and its accumulation in small depressions, etc.) (Baysholanov 2017; Dryuk and Simanchuk 2018). All these cause a tight ecotopic selection of plants that settle on a bare substrate. Plants should not only be resistant to dry, frost, and heat, but also resistant to soil erosion, root exposure and cover with erosive material, salt-resistant. This determines the limited species composition and the mosaic nature of the vegetation cover, which naturally develops on dumps in the process of syngenetic successions.

Vegetation analysis

According to Shennikov's classification mentioned earlier, the descriptions of the vegetation cover of the dumps studied were divided into three groups: pioneer groups, group-thicket communities, and diffuse communities (Shennikov 1964; Simanchuk et al. 2023). Botanical surveys using the Braun-Blanquet method were conducted at each site to study the flora of technogenic ecotopes. At each 100-square-meter observation plot, standard geobotanical descriptions were made, and GPS data (longitude, latitude, and altitude) were recorded. A total of 63 descriptions were made during the field study (Table 1).

All the dumps were subdivided into non-saline and highly saline. The distribution into groups was carried out according to state standards for determining salt anions' quantitative and qualitative content in soil samples.

Qualitative and quantitative vegetation analysis was carried out according to accepted methods (Kopytov et al. 2021; Aidarkhanova et al. 2022). The number of species (pcs), occurrence (%), and partial projective coverage (%) were determined. A species's Constancy Class (CC) was categorized into five: I: 0-20%, II: 21-40%, III: 41-60%, IV: 61-80%, and V: 81-100%.

The assessment of the quantitative participation of species in the community was carried out according to the J. Braun-Blanquet scale: "r": very rare (1-4 plants); "+": sparse and covers less than 1% of the area; "1": plants are numerous, but cover no more than 5% of the area or rather sparse, but with the same amount of coverage; "2": from 6 to 25%; "3": from 26 to 50%; "4": from 50 to 75%; "5": more than 75% (Braun-Blanquet 1964).

For a total assessment of the coenotic position of a species, a complex indicator of species activity, which shows a measure of the life prosperity of a species in a given territory, one of the expressions for the "species weight" in a given flora, was used (Kopytov et al. 2021).

The species activity was calculated in the IBIS v. 7.2 system using formula (1):

$$Act = \sqrt{\frac{C \times 100\,\%}{N} \times \frac{\sum_{i=1}^{N} A_i}{N}} = 10 \times \frac{\sqrt{C \times A_{\Sigma}}}{N}\,\% \quad \ldots (1)$$

Where:

Act : Calculated activity of the taxon for the monitoring area in percent (0÷100%)

N : The number of sample plots (elementary one-meter samples)

C : Taxon constancy (the absolute number of sample plots where the taxon is registered)

Ai : The projective cover of the taxon on the i-th sample plot

A_{Σ} : The sum of projective covers of the taxon on all sample plots

Table 1. Characteristics of the studied cenopopulations (CP) in the observation plots

Dumps	CP	Coordinates	Age, years	Technogenic eluvium features	Syngenesis stage
Non-saline soils					
South-western, Sarbaysky quarry	1-5	53°03′74.1″N, 63°03′85.8″W	2	Non-saline ferruginous limestones	Pioneer group
South-eastern, Sokolovsky quarry	6-10	52°97′57.1″N, 63°17′02.1″W	17-20	Sandy loamy embryozem with limestones	Group-thicket community
South-western, Sarbaysky quarry	11-15	53°03′74.2″N, 63°03′89.0″W	5-7	Limestones	roup-thicket community
South-eastern, Sokolovsky quarry	16-20	52°97′55.0″N, 63°17′11.0″W	40	Sandy loamy embryozem with limestones	Diffuse community
South-western, Sarbaysky quarry	21-26	53°03′00.7″N, 63°04′79.2″W	40	Rocky limestones, sandstones	Diffuse community
Highly saline soils					
7th, Kacharsky quarry	43-47	53°39′78.5″N, 62°83′21.8″W	5	Saline sandy loams and loams	Pioneer group
7th, Kacharsky quarry	48-52	53°39′18.9″N, 62°84′62.1″W	5	Saline sandy loams and loams	Pioneer group
South-western, South-Sarbaysky area	27-32	53°00′68.4″N, 63°08′17.5″W	12-14	Highly saline sandy loam and light loam	Group-thicket community
7th, Kacharsky quarry	33-37	53°41′05.2″N, 62°89′14.7″W	20	Saline sandy loam and light loam	Group-thicket community
7th, Kacharsky quarry	38-42	53°40′95.3″N, 62°88′78.3″W	20	Average salinity, light loams	roup-thicket community
7th, Kacharsky quarry	53-57	53°39′87.7″N, 62°87′38.2″W	36	Highly saline soil, loose sandstone	Diffuse community
7th, Kacharsky quarry	58-63	53°41′43.3″N, 62°85′25.5″W	14	Saline soil, loose sandstone	Diffuse community

Soil chemical analysis

Multiple soil sampling was carried out at 11 points according to state standard GOST 17.4.3.01-2017. The representative samples were sent to the accredited laboratory Darkan Dala (Kostanay, Kazakhstan). A dense residue (GOST 26423-85); pH indicator (GOST 26423-85); salt anions: CO_4^{2-} (GOST 26426-85), CO_3^{2-}, HCO^{3-}, Cl^- (GOST R 59540-2021); calcium and magnesium (GOST 26428-85) sodium and potassium (GOST 26427-85) in water extract; mobile forms of phosphorus (GOST 26207-91), total nitrogen (GOST 26107-84), organic matter (MVI 66373620-005-2015), mobile forms of copper, iron, lead, and zinc (PND F 16.2.2:2.3.71-2011) were determined.

RESULTS AND DISCUSSION

Soil chemical analysis

The soil chemical parameters of the newly formed soils of the dumps of the Sokolov Sarbai and Kachar deposits, which we took on the dumps during the growing season, varied widely. Geobotanical studies have shown significant differences in the floristic composition of various CPs. To assess the influence of edaphic factors, soil chemical parameters (organic matter, K, N, P, pH) and the main trace elements in a mobile form were determined as presented in Table 2.

The content of organic matter in samples ranged from 0.3 to 2.8%. The nitrogen content is from 0 to 0.034%. Mobile phosphorus and potassium are determined in concentrations: P - from 1.3 to 28.2 mg/100 g of soil; K - from 0.2 to 19 mg/100 g of soil. The processes of soil formation of deep sterile rocks proceed slowly.

The reaction soil pH varied from 2.7 to 8.6. The value of the dense residue ranged from 0.04% (non-saline soils) to 0.36% (saline soils). The analysis of salt content in the samples showed a high content of sulfates - up to 483.30 mmol/100 g in areas with a dry residue content of 0.3% or more, which indicates predominantly sulfate salinization of soils. The values of the carbonate ion index in all samples showed low values (<0.01) and were not taken into account in this study.

To determine potential direct influences, a correlation analysis of the data was carried out using the r-Pearson correlation coefficient, the strength of the relationship between all indicators and the number of species (SN), Projective Coverage (PC) was determined (Table 2).

Based on our data, it can be assumed that a significant increase in the concentration of sulfate ions led to a decrease in the number of species in iron ore dumps. An increase in the magnesium content and mobile forms of copper and iron led to a depletion of the floristic composition. Approximation of the pH value to neutral ones led to an increase in the number of species. A moderate positive role of organic matter content is noted both for the quantitative composition of phytocenoses and for the projective cover.

An increase in the concentration of sulfate ions, magnesium and mobile forms of copper and iron significantly negatively affected the overall projective cover. An increase in calcium concentration negatively affected both the number of species and the total projective cover. No direct relationship was found between botanical indicators and nitrogen, phosphorus, potassium, and zinc content.

The soil chemical properties listed above largely determined, along with climatic factors, the mosaic distribution of natural vegetation in iron ore dumps. In general, the soils of the SSGPO JSC and Kachary Ruda JSC dumps are infertile and unsuitable for plant growth without reclamation work.

Vegetation analysis

In the study area, 103 species of spermatophytes were identified, belonging to 79 genera and 31 families. The dump flora is dominated by angiosperms, with 102 species (99.1%). Monocots account for 16 species (15.5%), while dicots comprise 86 species (83.5%). Gymnosperms are represented by a single species (0.9%).

Table 2. Results of soil chemical analysis

Sample	Indicator																
	Dense residue (%)	**HCO_3^- (mg-eq/ 100 g)**	**Cl^- (mg-eq/100 g)**	**SO_4^{2-} (mmol/100 g)**	**Ca (mmol/100 g)**	**Mg (mmol/100 g)**	**pH (water units)**	**Na (mmol/100 g)**	**organic matter (%)**	**Cu mobile form (mg/kg)**	**Fe mob. form, (mg/kg)**	**Pb mob. form (mg/kg)**	**Zn mob. form (mg/kg)**	**P mob. form (mg/100g)**	**K mob. form (mg/100 g)**	**N (%)**
S1	0.04	0.37	1.45	6.60	0.05	0.01	4.2	0.01	0.30	0.85	235.0	0.01	1.41	7.2	0.2	0.03
S2	0.06	0	0.40	5.30	0.48	0.10	8.6	0.07	1.50	0.69	10.20	0.46	1.78	5.3	19.0	0.01
S3	0.24	0.62	0.50	233.9	4.62	0.30	7.9	0.07	2.80	10.70	324.0	3.75	27.1	9.1	5.7	0.01
S4	0.12	0.25	10.00	145.8	1.59	0.87	2.7	0.41	0.40	1.56	350.0	0.23	4.20	8.0	4.4	0
S5	0.04	0.30	3.01	97.00	0.40	0.31	5.8	0.20	1.20	3.40	228.0	1.12	8.60	4.2	4.4	0.01
K1	0.04	0.50	1.70	17.40	0.45	0.14	4.8	0.11	1.30	6.01	274.0	0.11	4.73	20.0	8.3	0
K2	0.06	0.50	0.70	12.60	0.08	0.05	7.2	0.16	0.40	0.82	35.40	0.01	0.91	1.3	12.1	0.01
K3	0.36	0.50	1.35	483.3	3.36	2.65	4.6	2.48	1.60	19.30	307.0	2.15	7.62	2.3	4.4	0.03
K4	0.04	0.20	1.20	8.00	0.22	0.09	4.6	0.25	0.90	1.37	411.0	0.16	2.83	3.0	0.2	0.01
K5	0.04	0.40	1.23	130.0	3.00	0.72	5.2	0.16	1.00	6.60	256.7	2.00	4.10	28.2	10.9	0.01
Ctr	0.22	0.37	8.00	50.90	0.19	0.12	6.4	1.98	4.10	0.22	9.09	0.59	4.09	30.1	8.1	0.04
r (SN)	-0.19	-0.14	0.18	-0.54	-0.38	-0.68	0.42	-0.20	0.44	-0.56	-0.58	-0.16	-0.07	0.07	0.02	N/A
r (PC)	-0.21	0.15	0.26	-0.58	-0.43	-0.66	0.36	-0.05	0.52	-0.54	-0.57	-0.24	-0.07	0.05	0.03	N/A

Note: S1-S5: Samples taken at the dumps of SSGPO JSC, K1-K5: Kachary Ruda JSC, Ctr: Control, r: The Pearson correlation coefficient, SN: Species Number, PC: Projective Coverage

The pioneer group stage

The colonization of the substrate occurred spontaneously through the introduction of ovules from the surrounding phytocenoses. The distribution of plants was scattered and singly, depending on environmental conditions. Difficult relief was a favorable factor, as conditions were created for the retention and germination of seeds. SSGPO JSC and Kachary Ruda JSC dumps are flat and multi-tiered with steep slopes (30° and more), and the main part of the vegetation inhabited bare flat areas.

The pioneer group on saline soils was extremely small and consisted 7 species (Table 3) with average projective cover of 16%. Two species, *Isatis costata* and *Chenopodium album* were found with Constancy Class (CC) of V. *Polygonum salsugineum* was found with CC III. It is worth mentioning that the latter species is not typical for Northern Kazakhstan; it usually occurs on the alkali and alkaline soil of the Betpakdala desert and on the sodden sands of Bolshie Barsuki (Chukavina 1971). All species are classified as adventitious or weed plants. Only two species of the steppe zonal flora (*Achillea nobilis* and *Poa angustifolia*) with minimal occurrence and activity were noted.

The pioneer group on non-saline soils appeared 2-3 years after filling with 7 species were noted (Table 4). Since the growing conditions of plants were extremely difficult (failure moisture permeability, high temperature on the surface of the dump), the colonizing plants were extremely thin, which was reflected by the projective cover, which is 1-2%. Steppe species of *Artemisia dracunculus* (CC V), *A. marschalliana* (CC IV) and that of *A. sieversiana* weed species (CC IV) had the highest class of constancy.

The group-thicket community stage

At this stage of syngenesis, plant groups became more complex due to the spread of species with active seed and vegetative reproduction, capable of capturing large areas in a short time. A typical characteristic of communities at the second stage is pronounced spotting when 3-5 species were actively develop the same ecotope. In total, 65 species of plants were identified on the waste dumps of SSGPO JSC and Kachary Ruda JSC at the group-thicket community stage: 42 species settled on saline soils, and 44 species settled on non-saline soils.

Polygonum salsugineum and *Artemisia dracunculus* had the highest class of constancy (IV), while *Gypsophila perfoliata* and *Calamagrostis epigeios* had CC III (Table 5). At this stage, widely distributed plants were those of long-rhizome and rhizomatous ones, such as *Artemisia nitrosa, Bromopsis inermis, Calamagrostis epigeios, Cirsium setosum, Convolvulus arvensis, Elytrigia repens* and *Phragmites australis*. At this stage, woody plants such as *Acer negundo, Populus × sibirica, Populus tremula* were documented, but they were small-sized, reaching no more than 1.5 m in height. *Calamagrostis epigeios* and *Artemisia dracunculus* were the most active.

Forty-four species were found on non-saline soils. *Calamagrostis epigeios, Artemisia austriaca*, long-rhizomatous plant species with a wide distribution in the steppe zone of Kazakhstan, showed the highest class of consistency of V. *Artemisia dracunculus*, *Artemisia dracunculus, Achillea nobilis*, and *Medicago sativa* have class of consistency IV (Table 6). The first woody plants to appear at this stage were *Acer negundo*, *Betula pendula*, *Elaeagnus oxycarpa*, *Malus domestica*, *Populus × sibirica*, *P. tremula*, and *Ulmus pumila*. Occurrence of steppe plants of zonal flora such as *Artemisia marschalliana*, *Festuca valesiaca*, *Poa angustifolia*, *Stipa pennata* and others was noted.

The diffuse community stage

At the stage of a diffuse community, well-formed layers with predominant participation of species of zonal phytocenoses appeared. The characteristics of this stage are: the formation of a closed vegetation cover, the capacity of phytocenoses from 20 to 40 species, and the predominance of species of zonal flora in the vegetation cover.

The age of dumps where the diffuse community stage is present ranged from 14 to 40 years, depending on the prevailing environmental conditions. Twenty-nine species were recorded on saline soils, with the total projective cover being 47%. *Calamagrostis epigeios* had the fifth class of constancy with an activity of 48.8. Five species with constancy class III were found: *Achillea nobilis, Betula pendula, Phragmites australis, Artemisia dracunculus,* and *Polygonum salsugineum* (Table 7). On saline soils, mosaic communities were formed with the inclusion of single pines (*Pinus sylvestris*) and birches (*Betula pendula*). Since saline soils are often associated with the release of groundwater, numerous self-seeding of birch were noted. Despite the significant age of the dumps, the presence of weed plants such as *Artemisia sieversiana, Chenopodium album, Conyza Canadensis, Lactuca serriola, Melilotus officinalis, Taraxacum officinale* was recorded at this stage as well.

Table 3. Characteristics of pioneer stage communities on saline soils

Plant species	V	P	A	CC
Chenopodium album L.	90	6.6	24.4	V
Isatis costata C.A.Mey.	90	4.9	21	V
Polygonum salsugineum Bieb.	50	3.3	12.8	III
Achillea nobilis L.	10	0.05	0.7	I
Lactuca tatarica (L.) C.A.Mey.	10	0.05	0.7	I
Poa angustifolia L.	10	0.05	0.7	I
Tripleurospermum inodorum (L.) Sch. Bip.	10	0.05	0.7	I

Note: V: Occurrence (%), P: Partial projective cover (%), A: Activity (score), CC: Constancy Class

Table 4. Characteristics of pioneer stage communities on non-saline soils

Plant species	V	P	A	CC
Artemisia dracunculus L.	80	0.4	5.6	V
Artemisia marschalliana Spreng.	60	0.3	2	IV
Artemisia sieversiana Willd.	60	0.4	4.9	IV
Achillea nobilis L.	20	0.1	1.4	I
Conyza canadensis (L.) Cronqist	20	0.1	1.4	I
Koeleria cristata (L.) Pers.	20	0.1	1.4	I
Tragopogon orientalis L.	20	0.1	1.4	I

Note: V: Occurrence (%), P: Partial projective cover (%), A: Activity (score), CC: Constancy Class

Table 5. Characteristics of the group-thicket community stage on saline soils

Plant species	V	P	A	CC
Artemisia dracunculus L.	68.8	9.25	25.22	IV
Polygonum gracilius (Ledeb.) Klok.	75	5.7	20.7	IV
Calamagrostis epigeios (L.) Roth	43.8	15.34	25.91	III
Gypsophila perfoliata L.	43.8	0.5	4.68	III
Artemisia nitrosa Weber	31.3	0.31	3.13	II
Artemisia sieversiana Willd.	31.3	0.16	2.24	II
Carduus nutans L.	25	0.125	1.77	II
Chamaenerion angustifolium (L.) Scop.	37.5	0.19	2.67	II
Isatis costata C.A.Mey.	25	0.125	1.77	II
Lactuca tatarica (L.) C.A.Mey.	25	0.69	4.15	II
Phragmites australis (Cav.) Trin. ex Steud.	25	4.44	10.54	II
Acer negundo L.	6.3	0.03	0.43	I
Achillea millefolium L.	12.5	0.06	0.87	I
Achillea nobilis L.	6.3	0.03	0.43	I
Agrostis gigantea Roth	6.3	0.31	1.39	I
Artemisia commutata Besser	6.3	0.03	0.43	I
Artemisia marschalliana Spreng.	6.3	0.03	0.43	I
Artemisia proceriformis Krasch.	6.3	0.03	0.43	I
Artemisia schrenkiana Ledeb.	6.3	0.03	0.43	I
Artemisia vulgaris L.	18.8	0.09	1.3	I
Bromopsis inermis (Leyss.) Holub.	12.5	0.06	0.87	I
Chenopodium album L.	6.3	0.19	1.09	I
Cirsium setosum (Willd.) Besser	18.8	0.84	3.97	I
Convolvulus arvensis L.	12.5	0.22	1.66	I
Conyza canadensis (L.) Cronquist	6.3	0.03	0.43	I
Dracocephalum thymiflorum L.	12.5	0.06	0.87	I
Elaeagnus oxycarpa Schltdl.	12.5	0.06	0.87	I
Elytrigia repens (L.) Nevski	6.3	0.03	0.43	I
Eryngium planum L.	6.3	0.03	0.43	I
Festuca valesiaca Gaudin	6.3	0.03	0.43	I
Gypsophila paniculata L.	18.8	0.09	1.3	I
Lactuca tatarica (L.) C.A.Mey.	6.3	0.03	0.43	I
Limonium gmelinii (Willd.) Kuntze	6.3	0.03	0.43	I
Melilotus albus Medikus	12.5	0.06	0.87	I
Phleum phleoides (L.) H.Karst.	6.3	0.19	1.09	I
Populus × sibirica G. Kryl. et Grig. ex A. Skvortsov	6.3	0.03	0.43	I
Populus tremula L.	6.3	0.03	0.43	I
Senecio jacobaea L.	6.3	0.03	0.43	I
Solanum kitagawae Schonb.-Tem.	6.3	0.03	0.43	I
Stipa lessingiana Trin. & Rupr.	6.3	0.03	0.43	I
Taraxacum officinale F.H.Wigg.	18.8	0.09	1.3	I
Tragopogon orientalis L.	18.8	0.09	1.3	I

Note: V: Occurrence (%), P: Partial projective cover (%), A: Activity (score), CC: Constancy Class

Table 6. Characteristics of the group-thicket community stage on non-saline soils

Plant species	V	P	A	CC
Artemisia austriaca Jacq.	80	2.95	15.36	V
Calamagrostis epigeios (L.) Roth	90	11.55	32.24	V
Achillea nobilis L.	70	1.75	11.07	IV
Artemisia dracunculus L.	70	3.6	15.87	IV
Medicago sativa L.	70	2.25	12.55	IV
Achillea millefolium L.	50	0.25	3.54	III
Artemisia marschalliana Spreng.	60	1.25	8.66	III
Bromopsis inermis (Leyss.) Holub.	50	0.95	6.89	III
Festuca valesiaca Gaudin	50	6.5	18.03	III
Hieracium virosum Pall.	50	0.25	3.54	III
Poa angustifolia L.	50	1.9	9.75	III
Tanacetum vulgare L.	50	1.2	7.75	III
Artemisia commutata Besser	30	0.15	2.12	II
Centaurea scabiosa L.	40	0.2	2.83	II
Chamaenerion angustifolium (L.) Scop.	30	0.65	4.42	II
Dracocephalum thymiflorum L.	30	0.15	2.12	II
Elaeagnus oxycarpa Schltdl.	30	0.15	2.12	II
Hieracium umbellatum L.	30	0.15	2.12	II
Linaria genistifolia (L.) Mill.	30	0.15	2.12	II
Malus domestica Borkh.	30	1.55	6.82	II
Stipa pennata L.	30	0.65	4.42	II
Taraxacum officinale F.H.Wigg.	30	0.15	2.12	II
Acer negundo L.	10	0.05	0.71	I
Artemisia proceriformis Krasch.	20	0.1	1.41	I
Artemisia vulgaris L.	10	0.1	1	I
Betula pendula Roth	10	0.05	0.71	I
Chamaenerion angustifolium (L.) Scop.	10	0.05	0.71	I
Cirsium setosum (Willd.) Besser	10	0.05	0.71	I
Gypsophila paniculata L.	20	0.35	2.65	I
Lactuca serriola L.	10	0.05	0.71	I
Lappula stricta (Ledeb.) Guerke	10	0.05	0.71	I
Lonicera tatarica L.	20	0.1	1.41	I
Medicago falcata L.	10	0.05	0.71	I
Nonea pulla DC.	10	0.05	0.71	I
Poa palustris L.	10	0.1	1	I
Poa urssulensis Trin.	10	0.05	0.71	I
Polygonum salsugineum Bieb.	10	0.05	0.71	I
Populus × sibirica G. Kryl. et Grig. ex A. Skvortsov	10	0.05	0.71	I
Populus tremula L.	10	0.05	0.71	I
Potentilla argentea L.	10	0.05	0.71	I
Trifolium pratense L.	10	0.05	0.71	I
Trigonella arcuata C.A.Mey.	10	0.05	0.71	I
Trommsdorffia maculata (L.) Bernh.	10	0.05	0.71	I
Ulmus pumila L.	10	0.05	0.71	I

Note: V: Occurrence (%), P: Partial projective cover (%), A: Activity (score), CC: Constancy Class

On non-saline soils at the stage of a diffuse community, 58 species appeared with the total projective cover being 36%. On the oldest dumps (40 years), birch-aspen tree stands were formed with a density of 0.5 and composition of 80% birch and 20% aspen). *Salix caprea, Rosa majalis, Lonicera tatarica* were found in the undergrowth (Table 8). In addition to woody plants with CC V, there were steppe flora such as *Artemisia austriaca*, *Festuca valesiaca*, and *Tanacetum vulgare*.

At this stage, typical plants of the zonal steppe occurred on soils with a light mechanical composition with the participation of *Achillea nobilis, Astragalus buchtormensis, A. testiculatus, Galium verum, Helichrysum arenarium, Hieracium umbellatum*, and *Medicago falcata*. It is important to note that *Stipa pennata* was found at the dumps on the non-saline soil at the group-thicket community and the diffuse community stages. This species is identified as an endangered species (III category) in the Red Book of Kazakhstan (Plants). This only confirms the need for further research and search for ways to preserve the region's biodiversity.

Table 7. Characteristics of the diffuse community stage on saline soils

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

Note: V: Occurrence (%), P: Partial projective cover (%), A: Activity (score), CC: Constancy Class

It is important to note that *Stipa pennata* was found at the dumps on the non-saline soil at the group-thicket community and the diffuse community stages. This species is identified as an endangered species (III category) in the Red Book of Kazakhstan (Plants). This only confirms the need for further research and search for ways to preserve the biodiversity of the region.

There are large differences in the overgrowth of saline and non-saline soils. Usually, the pioneer group is formed by annual weeds (Chukavina 1971; Klimova et al. 2021; Kopytov et al. 2021). Halophytes predominated on the saline soils of the dumps of the Sokolov Sarbai and Kachar deposits. 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 Betpakdala desert (Kubanskaya 1956). On the other hand, wide-range meadow-steppe species settled on non-saline soils.

Table 8. Characteristics of the diffuse community stage on non-saline soils

Plant species	V	P	A	CC
Artemisia austriaca Jacq.	81.8	1.73	11.9	V
Betula pendula Roth	81.8	0.37	5.5	V
Festuca valesiaca Gaudin	90.9	6.6	24.49	V
Populus tremula L	81.8	0.37	5.5	V
Tanacetum vulgare L.	90.9	1.14	10.18	V
Artemisia dracunculus L.	63.6	0.55	5.92	IV
Calamagrostis epigeios (L.) Roth	63.6	3.14	14.13	IV
Achillea millefolium L.	54.5	0.95	7.2	III
Achillea nobilis L.	54.5	0.5	5.22	III
Chamaenerion angustifolium (L.) Scop.	54.5	0.27	3.84	III
Hieracium virosum Pall.	54.5	0.73	6.27	III
Medicago falcata L.	45.5	0.23	3.23	III
Astragalus buchtormensis Pall.	36.4	1.27	6.8	II
Bromopsis inermis (Leyss.) Holub.	27.3	1	5.22	II
Centaurea scabiosa L.	36.4	0.18	2.56	II
Hieracium umbellatum L.	36.4	1.55	7.51	II
Lonicera tatarica L.	27.3	0.14	1.95	II
Phragmites australis (Cav.) Trin. ex Steud.	27.3	4.82	11.46	II
Poa pratensis L.	27.3	0.36	3.13	II
Potentilla chrysantha Trevir.	27.3	0.36	3.13	II
Stellaria graminea L.	36.4	0.18	2.56	II
Acer negundo L.	9.1	0.05	0.67	I
Agrostis gigantea Roth	9.1	0.05	0.67	I
Alyssum turkestanicum var. desertorum (Stapf) Botsch.	9.1	0.05	0.67	I
Artemisia marschalliana Spreng.	9.1	0.05	0.67	I
Asparagus officinalis L.	18.2	0.09	1.28	I
Astragalus testiculatus Pall.	18.2	0.09	1.28	I
Cerasus fruticosa Pall.	9.1	0.05	0.67	I
Elytrigia repens (L.) Nevski	9.1	0.05	0.67	I
Erigeron acris L.	9.1	0.05	0.67	I
Eryngium planum L.	9.1	0.05	0.67	I
Euphorbia virgata Waldst. & Kit.	9.1	0.05	0.67	I
Falcaria vulgaris Bernh.	9.1	0.05	0.67	I
Galium verum L.	18.2	0.32	2.42	I
Gypsophila perfoliata L.	9.1	0.05	0.67	I
Helichrysum arenarium (L.) Moench	9.1	0.05	0.67	I
Hippophae rhamnoides L.	18.2	0.09	1.28	I
Lactuca tatarica (L.) C.A.Mey.	18.2	0.09	1.28	I
Linaria genistifolia (L.) Mill.	9.1	0.05	0.67	I
Nonea pulla DC.	9.1	0.05	0.67	I
Oxytropis pilosa (L.) DC.	9.1	0.05	0.67	I
Pilosella echioides (Lumn.) F. Schulz et Sch. Bip.	9.1	0.05	0.67	I
Plantago media L.	9.1	0.27	1.57	I
Poa angustifolia L.	18.2	0.95	4.16	I
Poa palustris L.	9.1	0.27	1.57	I
Ribes aureum Purch	9.1	0.05	0.67	I
Rosa majalis Herrm.	9.1	0.91	2.88	I
Salix caprea L.	9.1	0.05	0.67	I
Sedum telephium L.	18.2	0.09	1.28	I
Sisymbrium loeselii L.	9.1	0.05	0.67	I
Stipa lessingiana Trin. et Rupr.	18.2	0.32	2.41	I
Stipa pennata L.	9.1	0.05	0.67	I
Taraxacum officinale F.H.Wigg.	18.2	0.09	1.28	I
Valeriana tuberosa L.	9.1	0.05	0.67	I
Veronica incana L.	18.2	0.09	1.28	I
Veronica spicata L.	18.2	0.09	1.28	I

Note: V: Occurrence (%), P: Partial projective cover (%), A: Activity (score), CC: Constancy Class

In conclusion, the study of the stages of syngenesis on iron ore dump enterprises sites of the Kostanay region showed that, despite the long period of existence of dumps, the formation of zonal or intrazonal communities did not occur. The initial stages of syngenesis were characterized by a random and unstable floristic composition of plant communities. The ecological heterogeneity of the species of the first stages of syngenesis was noted, which was expressed in the spread of species of different coenotic groups. Even on old dumps, an incomplete floristic composition was discovered in comparison with natural phytocenoses. There were significant differences in the floristic composition of different cenopopulations. One of the main reasons for this phenomenon was the focal sulfate salinization of soils formed from initially sterile quarry rocks. The data obtained in the course of the current study allow us to draw some conclusions about the rate of natural regeneration of vegetation community on dump landscapes, which is a promising direction in studying the processes of restoring the biodiversity on degraded lands. To consider these processes in more detail, it is planned to further study the flora of the dumps, herbarize previously unidentified species, analyze of changes in the floristic composition at the same geographical points.

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