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Analysis of the syngenesis pioneer stage on the iron ore enterprises dump sites in the Kostanay region

Study of primary stages of syngenesis at the dumps of the Sokolovsko-Sarbai Mining and Processing Production Association, including Sokolovsky, Sarbaisky, Kacharsky deposits was carried out. In total, during the study, 63 geobotanical descriptions were compiled; pioneer grouping being found in 15 of them. Waste and poor rocks of iron ore open pits dumps are difficult to demutate during first few years after backfilling completion, therefore, succession initial stage here proceeds extremely slowly. However, succession rate gradually increases as the edaphic conditions of the ecotype improve and phyto-environment develops. Moreover, during the study, division of soils into saline and non-saline ones was discovered, establishing that this factor greatly influenced projective cover and species composition of the pioneer plants discovered. Floristic data were processed using IBIS 7.2 program developed by Zverev. Qualitative and quantitative accounting of plants was carried out in accordance with generally accepted botanical methods, during the application of which such parameters as occurrence, general and partial projective cover were noted. It was ascertained that on saline soils halophytes and weedy species with wide ecological amplitude predominate, while on non-saline ones different types of wormwood are most stable. All species on the dumps with non-saline substrates show wide ecological amplitude.

Keywords: pioneer group, iron ore industry dumps, biodiversity, technogenic landscape, succession, syngenesis, pioneer plants, flora, dump overgrowth.

Introduction

Modern society faced many challenges that threaten both health and, in general, the existence of the human population. In order to preserve and develop their species, humans resort to intensive and extensive nature use, bringing the global ecological crisis and the Earth's ecosystem destruction closer [1-3].

Products of processing of minerals, such as iron, oil, coal and others, have become an inevitable consequence of ensuring comfortable life of people. However, the extraction of these resources often leads to irreversible harm for the environment. So, there is a complete (rarely partial) destruction of soil and vegetation cover as significant changes occur in the lithogenic basis, and hydrological regime of the area. These lead to the substitution of natural landscapes by natural-technogenic or absolutely technogenic ones, in both cases, the restoration of disturbed ecosystems taking lengthy periods of time. But, regretfully, even in centuries, the original natural communities will not be formed. Late 20th century witnessed the largest anthropogenic impact in the history of mankind. On a planetary scale, the anthropogenic transformation of terrestrial landscapes has led to the replacement of forests by forest and forest-meadow landscapes; those of steppe and forest-steppe complexes by field and agricultural landscapes [4-6].

Restoration of some technogenic landscapes may proceed through reclamation and self-overgrowing. In other words, the relative laboriousness and high cost of reclamation, as well as gaps in the legislation, allow users of natural resources resorting to a wait-and-see tactics that is to self-overgrowth. The Republic of Kazakhstan has to face the problem of unliquidated open pits and mines handling, despite No. 386 Order of the Minister for Investment and Development dated May 24, 2018, which postulates the rules for drawing up a plan for the elimination of the consequences of subsoil use for each object of the subsoil plot, including open pits and dumps of overburden and waste rocks, and poor ores. The Order contains requirements for the state of the area after liquidation. It should be noted that one of the most important results of the final liquidation is *"the restoration of the natural ecosystem to the maximum similarity with the ecosystem that existed before the subsoil use activities"* [7-9].

In the course of this study, we studied the degree of natural overgrowing of dumps of the iron ore industry in the Kostanay region. All dumps are on the balance sheet of the enterprises, passports and EIA projects, which indicate the stage of reclamation and subsequent monitoring, having being supplied for each of them.

However, not all dumps need reclamation, for example, there is no indication of such in the EIA Project for a local project for filling an external bulldozer dump on the eastern and southeastern sides of the Sokolovsky open pit for 2021, because in the course of work within the framework of this project, it is not planned to disturb the vegetation cover, since dumping will take place on the already changed area. Consequently, long-term prospects are not considered in this document [10]. Thus, self-overgrowing is an important factor in the formation of vegetation cover on dumps.

Self-overgrowing of industrial dumps occurs in three stages of syngenesis:

- pioneer group (low projective cover (PC) 10-15 %, 13-25 species),
- group-thicket community (PC — more than 15 %, 20-50 species),
- complex phytocenosis (diffuse community) (PC more than 30 %, 20-50 species).

The rate of natural overgrowth depends on many factors. Selectivity is determined by the probability of the introduction of ovules from neighboring phytocenoses and is strictly determined by the biological characteristics and ecological conditions of dumps. Often, favorable conditions in the first years after dumping favor the overgrowth of rocks by a small number of species, seeds of which get to dumps faster, gaining an advantage. The edaphic factors of each ecotope influence the selectivity of seed germination, and as well as establish the course of development of the vegetation cover of technogenic landscapes. Pioneer species usually have high germination energy [11-17].

In the current article, we analyze the pioneer stage of syngenesis in the dumps of iron ore enterprises in the Kostanay region.

Experimental

There are two large enterprises processing iron ore on the territory of the Kostanay region: “SSGPO” JSC and “Kachary Ruda” JSC, which were one legal entity until 2020; and currently they are part of the ERG group. “SSGPO” is engaged in the development of the Sokolovsky, Sarbaisky and Kurzhunkulsky open pits; whereas “Kachary Ruda” that of the Kacharsky open pit [18].

The Sokolovsky, Sarbaysky and Kacharsky deposits of magnetite ores are located in the northwestern part of Kazakhstan in the Turgai belt, which also extends into Russia. The Turgai deposits are associated with volcanic-sedimentary rocks of the Trans-Ural zone. These deposits, together with other smaller satellite deposits and the likes, form an extended magnetite-bearing belt extending in the NNE-SW directions — the Turgai belt, which extends from the Sarbaisky deposit in the south to the Glubochensky deposit in the north [19, 20].

In the course of this study, the waste dumps of SSGPO JSC were studied: the South-East one of the Sokolovsky open pit, South-West — of the Sarbaisky and South-West — of the South-Sarbi area; as well as № 7 railway dump of “Kachary Ruda” JSC. Technogenic mineral formations in the form of loose sandy-argillaceous overburden rocks of the platform cover were transported to these dumps by road and rail transport, the raw material for which were flasks, sands, and clays [21-24].

The study was carried out in the spring-summer period of 2022. The objects of study are situated in the Kostanay region, located in the northwestern part of the Republic. This territory is characterized by sharp continental climate with a wide range of temperatures in winter and summer, day and night. The highest average temperature of $+21^0$C on the location of Rudny is characteristic for July, while the lowest average annual temperature of $-15,4^0$C is typical for the same territory for January. In some years, a more significant short-term extreme decrease in temperature to -40^0C was also observed. The northern and central part of the Kostanay region, the territory of Rudny belong to a slightly humidified moderately warm agro-climatic zone, which is characterized by moisture coefficient values in the range of 0.8-1.0 during the vegetative active period from May to August and the sum of temperatures of above 10 °C in the range of 2200-2500 °C, which in general can be considered as favorable conditions for plant growth [25].

In the studied territories, there are ordinary and southern chernozems, dark and medium chestnut soils, complexes of these soils with salty soils, and others. The mechanical composition is dominated by heavy loamy and clayey soils, a large proportion of soils being those of sandy loam [25].

To study the flora of technogenic ecotopes, a route-expeditionary research method was used. A total of 63 geo botanical descriptions were compiled. Floristic data were processed using the IBIS 7.2 program developed by A.A. Zverev [26]. Qualitative and quantitative accounting of plants was carried out in accordance with accepted methods; occurrence (%), total and partial projective cover (PPC, %) were noted [14, 27].

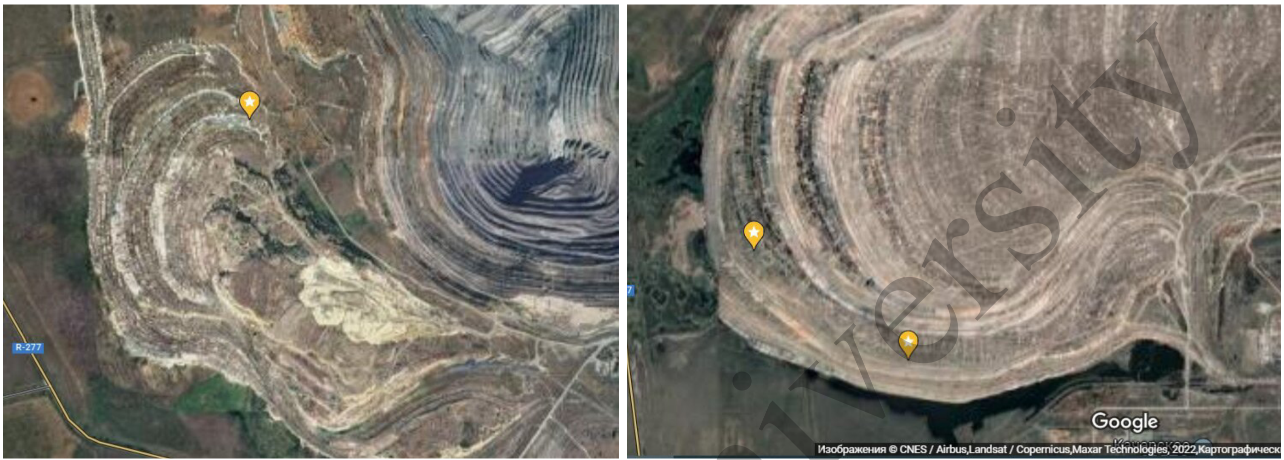
Calculation of numerical data, such as herbage density (pcs/m^2), number of species (pcs), occurrence (%), and partial projective cover (%) was carried out according to the indicators previously referred to.

The frequency of occurrence made it possible to distinguish classes of constancy (hereinafter CC) in the descriptions: in total, five CCs were identified, with a step of 20 %: I — 20 %; II — 40 %; III — 60 %; IV — 80 %; V — 100 % [12].

Results and Discussion

The rock dumps of the iron ore quarries of the Sokolovsky, Sarbaisky and Kacharsky deposits are newly formed geomorphological objects devoid of plants. Freshly dumped rock heaps are initially devoid of vegetation and are therefore ideal models for studying the stages of ecosystem formation.

Fifteen geo botanical descriptions were analyzed: CP 1-5, CP 43-47, CP 48-52, made on non-saline and saline dumps, having a backfill age of 2-5 years and falling under the definition of a pioneer group (Fig. 1).



A B

Figure 1. Location of the studied ecotopes of the pioneer plant group: A — South-West open pit of the Sarbaisky deposit, B — № 7 dump of the Kacharsky open pit

In the course of the study, it was noted that saline soils are characterized by an extremely low number of species in the pioneer group — no more than 7 species (Table 1, Fig. 2), while the total projective cover (hereinafter TPC) is 16 % on average. Two species *Isatis costata* and *Chenopodium album* are characterized by the V class of constancy and are absolute dominants in this community. It is also worth noting that on highly saline soils, *Polygonum salsugineum* is distinguished by a high class of constancy (Table 2). All species are either adventitious or weedy. Two species of steppe zonal flora, *Achillea nobilis* and *Poa angustifolia*, with low occurrence and activity were found.

Table 1

Characteristics of then Pioneer Stage Cenopopulations

Cenopopulation	Date	Dominants	TPC %	Species number
CP-1	18 V 2022	*Artemisia dracunculus* L.	<1	3
CP-2	18 V 2022	*Koeleria cristata* (L.) Pers.	<1	2
CP-3	18 V 2022	*Artemisia marschalliana* Spreng.	<1	4
CP-4	18 V 2022	*Koeleria cristata* (L.) Pers.	<1	3
CP-5	18 V 2022	*Conyza canadensis* (L.) Cronqist	1	1
CP-43	19 V 2022	*Isatis costata, Chenopodium album, Polygonum salsugineum*	30	4
CP-44	19 V 2022	*Isatis costata, Chenopodium album, Polygonum salsugineum*	20	5
CP-45	19 V 2022	*Isatis costata, Chenopodium album, Polygonum salsugineum*	40	4
CP-46	19 V 2022	*Lactuca tatarica, Polygonum salsugineum*	30	3
CP-47	19 V 2022	*Isatis costata*	40	3
CP-48	19 V 2022	*Isatis costata, Chenopodium album*	<1	2
CP-49	19 V 2022	*Isatis costata, Chenopodium album*	<1	3
CP-50	19 V 2022	*Isatis costata, Chenopodium album*	<1	4
CP-51	19 V 2022	*Isatis costata, Chenopodium album*	<1	4
CP-52	19 V 2022	0	0	0

A B

Figure 2. Pioneer stage on saline (A) and non-saline (B) dumps

Table 2

List of pioneer plants and their occurrence (in %), settling on saline soils of dumps

Plant species	Occurrence (in %)
Isatis costata **C.A. Mey.**	**90**
Chenopodium album **L.**	**90**
Polygonum salsugineum M. Bieb.	50
Achillea nobilis **L.**	10
Lactuca tatarica **(L.) C.A. Mey.**	10
Poa angustifolia **L.**	10
Tripleurospermum inodorum **(L.) Sch. Bip.**	10

Two years after the completion of backfilling, 7 species also settled on the dump of ferruginous limestone (Table 3). The pioneer group on these dumps consists of thin plants, the projective cover reaching 1-2 %. (Fig. 2). The steppe species *Artemisia dracunculus, A. marschalliana* and the weed species *Artemisia sieversiana* form groups with the highest class of consistency. More than 70 % of pioneer plants in these cenopopulations are steppe plants.

Table 3

List of pioneer plants and their occurrence (in %), settling on non-saline soils of dumps

Plant species	Occurrence (in %)
Artemisia dracunculus L.	**80**
Artemisia marschalliana Spreng.	**60**
Artemisia sieversiana Willd.	**60**
Achillea nobilis L.	20
Conyza canadensis (L.) Cronqist	20
Koeleria cristata (L.) Pers.	20
Tragopogon orientalis L.	20

Table 4 shows the taxonomic structure of the general floristic list of the pioneer group on the dumps of “SSGPO” JSC and “Kachary Ruda” JSC. The total number of families represented in the pioneer grouping on saline and non-saline dumps is 5. The largest one in terms of the number of species and genera are Asteraceae (6 genera, 8 species), then Poaceae (2 genera, 2 species), Brassicaceae, Chenopodiaceae and Polygonaceae -1 genus and 1 species each. The only species found on both saline and non-saline soils is *Achillea nobilis L.*

T a b l e 4

Taxonomic structure of the pioneer grouping of dumps

Taxonomic indicators	Value
Total number of species	13
Total number of genera	11
Total number of families	5
Number of single-species genera	10
Number of single-species families	3
Number of homogeneous families	3
Share of species in 5 leading families, %	100

It should be noted that, according to the data of 2008 obtained by Yu.V. Perezhogin the largest families on the territory of the Kostanay region are: *Asteraceae* (201 species), *Poaceae* (105), *Fabaceae* (80), *Chenopodiacceae* (67), *Brassicaceae* (66), *Caryophyllaceae* (53), *Cyperaceae* (49), *Rosaceae* (49), *Ranunculaceae* (38), *Scrophulariaceae* (36), *Lamiaceae* (33), *Apiaceae* (32), *Boraginaceae* (29), and *Polygonaceae* (26) [28].

Various studies of individual territories of the Kostanay region also show the predominance of the families *Asteraceae, Rosaceae, Polygonaceae* [29, 30], *Poaceae* and *Fabaceae* [31]. The plants found by us in pioneer communities on dumps are also the representatives of the most common families in the region.

In the course of the study of overgrowing of iron ore dumps of the Sokolovsky iron ore open pit, carried out in 1974, 16 species of overgrowing pioneers were identified, the most common of which were *Atriplex nitens Borkh., Polygonum aviculare,* and *Kochia prostrata (L.) Beck*. The authors of the report also point to the presence of groups of fireweed (*Chamerion angustifolium* (L.) Holub etc.) and melilot (Mel*ilotus officinalis* (L.) Pall.) in the pioneer groups [32].

Studies conducted in 2003 [11] showed that the total number of species with projective cover of 10–25 % on favorable soils (Quaternary loams, Neogene sands and sandy loams) reached 55 species, while 23 species with a coverage of 5-15 % were found under unfavorable conditions on saline flasks and Chegan loams. Dominant families: *Asteraceae, Poaceae* and *Chenopodiaceae*. This quantity noticeably exceeds that obtained during our studies, but, as far as we can judge by the lists given, the author for some reason included species of the group-thicket community in the composition of the pioneer species.

The results of studies of self-overgrowing of dumps of various industries, carried out on the dumps of the Kempirsai nickel deposit (Aktobe region, Kazakhstan, South Urals), carried out by specialists from the Ural Federal University, showed that the pioneer group on the dumps of 1-4 years is characterized by a low projective cover — 10-20 %, and the number of species also turned out to be similar to our study — from 6 species. However, the species composition differs sharply: the highest occurrence on dumps 1-4 years old is characterized by the species *Bassia prostrata, Polygonum aviculare*. Species such as *Achillea nobilis, Lactuca tatarica,* and *Poa angustifolia* noted in our study were found on a 6-year-old dump [33].

The study of self-overgrowing of dumps of the Korfovsky granodiorite deposit (Khabarovsk Territory, Russia) showed at the pioneer stage — 1-2 years after the end of the dumping — 2-3 plant species, after 5 years — 4 species, dominant species being *Artemisia vulgaris L.* and *Trifolium hybridum L.*

While the number of pioneer species in the nickel and iron ore dumps barely reaches 55, a completely different picture is presented in the coal mining dumps of Kuzbass (Russia), where the composition of the rocks is strikingly different from those studied in our study. For example, in the course of research, 131 species of pioneer plants were discovered in the sandstone dumps of the Kedrovsky open pit. The most active species are *Artemisia sieversiana, Salsola collina, Sonchus arvensis, Taraxacum officinale* and *Tussilago farfara,* dominant families being *Asteraceae, Poaceae, Fabaceae, Brassicaceae, Rosaceae, Chenopodiaceae, Salicaceae, Onagraceae, Polygonaceae, Lamiaceae* [11, 15].

As for the dominant families, it should be noted that in all studies at the stage of pioneer groupings, species from *Asteraceae, Chenopodiaceae*, and *Polygonaceae* prevail.

Conclusion

On conducting a study of the patterns of natural overgrowing of dumps of mining enterprises in the Kostanay region on the example of the dumps of "SSGPO" JSC and "Kachary Ruda" JSC, we came to the following conclusions:

1) the dumps of iron ore open pits during the first few years after backfilling are difficult to demutate and the initial stage of succession proceeds here very slowly;

2) the rate of succession gradually increases with the improvement of the edaphic conditions of the ecotope and the formation of a phyto-environment;

3) pioneer groups are formed on dumps with the participation of both ruderal species and species of zonal phytocenoses, although quantitatively the former predominate;

4) *Isatis costata* and *Chenopodium album* have the highest class of constancy (V) on saline soils at the pioneer stage, *Polygonum salsugineum* has a fairly high class of constancy (III) as well; mainly these are halophytes and a weedy species with a wide ecological amplitude;

5) *Artemisia dracunculus* (V), *A. marschalliana* (IV), *A. sieversiana* (IV) show the greatest constancy on non-saline soils, all the species having wide ecological amplitude.

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Қостанай облысының темір рудасы кәсіпорындарының үйінділеріндегі сингенездің пионерлік кезеңін талдау

Соколов, Сарыбай, Қашар кен орындарын қоса алғанда, «Соколов-Сарыбай тау-кен байыту өндірістік бірлестігінің» («ССКӨБ» АҚ) үйінділеріндегі сингенездің бастапқы кезеңдеріне зерттеу жүргізілді. Мақалада пионерлік топтастыру сатысында Қостанай облысының темір кені өнеркәсібі үйінділерінің өздігінен өсу дәрежесін зерттеу нәтижелері сипатталған. Зерттеуде барлығы алпыс үш геоботаникалық сипаттама жасалды, олардың он бесеуінен пионерлік топтастыру табылды. Темір рудасы кен орындарында бос және байытылмаған жыныстарының үйінділері құю аяқталғаннан кейінгі алғашқы бірнеше жыл ішінде демутациялық процестері қиын, сондықтан бұл жерде сукцессияның бастапқы кезеңі өте баяу жүреді. Алайда, экотоптың эдафиялық жағдайлары мен фитоортаның пайда болуы жақсарған сайын сукцессия жылдамдығы біртіндеп артады. Сондай-ақ, зерттеу барысында топырақтың тұзды және тұзсыз болып нақты бөлінуі және бұл фактор табылған пионерлік өсімдіктердің проекциялық жабыны мен түрлік құрамына үлкен әсер ететіні анықталған. Флористикалық деректер А.А. Зверев әзірлеген IBIS 7.2 бағдарламасы арқылы өңделді. Өсімдіктердің сапалық және сандық есебі жалпы қабылданған ботаникалық әдістерге сәйкес жүзеге асырылады, оларды қолдану барысында пайда болу, жалпы және жеке проекциялық қамту сияқты параметрлер атап өтілді. Пионерлік сатысында тұзды топырақтарда негізінен галофиттер мен кең экологиялық амплитудасы бар арамшөптер басым екендігі анықталды, ал тұзсыз топырақтарда жусанның түрлері ең тұрақты болып табылады. Тұздалмаған субстраты бар үйінділер барлық экологиялық амплитудаға ие.

Кілт сөздер: пионерлік топтастыру, темір рудасының үйінділері, биоәртүрлілік, техногендік ландшафт, сукцессия, сингенез, пионерлік-өсімдіктер, флорасы, үйінділердің өздігінен өсуі.

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Анализ пионерной стадии сингенеза на отвалах железорудных предприятий Костанайской области

Проводилось изучение первичных стадий сингенеза на отвалах «Соколовско-Сарыбайского горно-обогатительного производственного объединения» (АО «ССГПО»), включая Соколовское, Сарыбайское, Качарское месторождения. Всего в ходе нашего исследования было составлено шестьдесят три геоботанических описания, причем пионерная группировка обнаружена в пятнадцати из них. Отвалы пустых и бедных пород железорудных карьеров первые несколько лет после завершения отсыпки трудно поддаются демутационным процессам, и, следовательно, начальная стадия сукцессии здесь протекает крайне медленно. Однако скорость сукцессии постепенно возрастает по мере улучшения эдафических условий экотопа и образования фитосреды. Также в ходе исследования мы обнаружили четкое разделение грунтов на засоленные и незасоленные и установили, что данный фактор оказал большое влияние на проективное покрытие и видовой состав обнаруженных нами растений-пионеров. Флористические данные были обработаны с помощью программы IBIS 7.2, разработанной А.А. Зверевым. Качественный и количественный учет растений осуществлен в соответствии с общепринятыми ботаническими методами, в ходе применения которых отмечались такие параметры, как встречаемость, общее и частное проективное покрытие. Обнаружено, что на засоленных грунтах на пионерной стадии в основном преобладают галофиты и сорные виды с широкой экологической амплитудой, в то время как на незасоленных грунтах наибольшим постоянством отличаются разные виды полыни. Все виды на данных отвалах с незасоленным субстратом обладают широкой экологической амплитудой.

Ключевые слова: пионерная группировка, отвалы железорудной промышленности, биоразнообразие, техногенный ландшафт, сукцессия, сингенез, растения-пионеры, флора, самозарастание отвалов.

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