

Research Article

<https://doi.org/10.31489/2026FEB3/56-65>

UDC 58.02

Received: 18.03.2026 | Accepted: 8.06.2026 | Published online: 30.09.2026

T.A. Vdovina, O.A. Anufrieva, A.A. Vinokurov, A.N. Danilova,
A.A. Sumbembaev, A.A. Chernakova*

Altai Botanical Garden, Ridder, Kazakhstan

*Corresponding author: dolmatova-1986@bk.ru

Flora of anthropogenically disturbed territories of the Ridder Metallurgical Complex

The aim of this study is to provide a comprehensive ecological assessment of the vegetation cover of technogenically disturbed territories of the Ridder Metallurgical Complex based on an analysis of floristic composition, life forms, and ecological plant groups, in order to determine succession pathways and substantiate biological reclamation measures. As part of the study, a comprehensive research program was implemented jointly with the “Institute of Plant Biology and Biotechnology” to investigate the phytocenoses of technogenic landscapes and the composition of their soils. The studied territory is characterized by a high degree of anthropogenic disturbance. The floristic composition was analyzed, comprising 126 species belonging to 38 families and 93 genera. The families Rosaceae (11 genera), Cyperaceae and Asteraceae (9 genera each), and Poaceae (7 genera) were the most prominent in the taxonomic spectrum. The spatial distribution, abundance, life forms, and condition of the plants were determined. A bioecological characterization of the species and their life forms (ecomorphs) was provided, and ecological groups of plants with respect to moisture requirements were identified. The results made it possible to assess the degree of disturbance of the territory and predict the direction of vegetation succession. The vegetation cover is predominantly composed of native, ecologically stable species, reflecting their adaptation to anthropogenic habitats. The findings contribute to the restoration of technogenically disturbed lands and their rehabilitation for integration into the biosphere.

Keywords: flora, species, technogenically disturbed territories, enterprises of the Ridder Metallurgical Complex, life form, plant condition, ecomorph, ecosystem.

Introduction

East Kazakhstan Region is one of the most anthropogenically transformed regions of Kazakhstan, where rich metal deposits, developed industry, mountainous relief, steppe and forest ecosystems are combined. This leads to a sharp contrast between natural and disturbed landscapes. The city of Ridder is located in the East Kazakhstan Region, within the Rudny Altai—a region rich in polymetallic ores (zinc, lead, copper, silver, gold). The presence of these deposits predetermined the industrial specialization of the territory, including ore mining, its beneficiation, and preparation of concentrates for metallurgical plants. The Ridder Metallurgical Complex (RMC) is one of the largest polymetallic enterprises in Kazakhstan, the intensive development of which has led to the accumulation of tailings storage facilities, soil and water pollution, and the formation of technogenic landscapes. With the growth of environmental problems, it became clear that without land restoration ecological balance is disrupted, fertile territories are lost, and the living conditions of the population deteriorate.

Land reclamation (industrial sites) of the Ridder Metallurgical Complex was actively carried out in the 1980s by employees of the Main Botanical Garden (Almaty) and the Altai Botanical Garden (Ridder). The work carried out was aimed at restoring the biological productivity and economic value of disturbed lands, as well as improving the conditions of the surrounding natural environment.

Studies on the flora of disturbed territories are presented in extensive literature [1–3]. One of the significant technogenic factors affecting the state of ecosystems and biodiversity is the high susceptibility of the soil and vegetation cover to the influence of heavy metals that accumulate in the soil. The results of studies conducted by domestic and foreign scientists show that these issues remain relevant to this day and acquire particular importance [4–8].

These studies directly contribute to the restoration of technogenically disturbed lands and their return to the biosphere fund. In order to restore disturbed areas and prevent their harmful impact on the natural environment, further reclamation is required, in the process of which the motivated formation of landscapes and the creation of a certain natural environment are always taken into account, as well as the study of mechanisms of natural restoration of ecosystems and the investigation of flora [9].

Plant communities (phytocenosis) are a set of plants growing together in the same territory, interconnected with each other and with the environment, performing ecosystem functions: soil-protective, water-regulating, environment-forming, and sanitary-hygienic. On anthropogenically disturbed lands, the structure of plant communities differs significantly from natural ones due to changes in soil, microclimate, and the level of anthropogenic impact.

Experimental

The names of accepted genera and species of vascular plants forming plant communities were verified with the online World Plants catalog of the website Plants of the World Online (POWO, 2025) [10]. The studies were carried out from May to October during the vegetation periods of 2023–2025, when active plant growth and vegetation occur. The Ridder Metallurgical Complex (RMC) belongs to the mountain-taiga zone. As a result of the research, 23 sample plots (loci) were established using random and regular methods in the zone of influence of harmful emissions (tailings of the Concentration Plant, the Zinc Plant, the Ridder and Sokolny mines). The size of the sampling plots ranged from 150 m² to 200 m² in the form of a square or rectangle. The coordinates of the plot locations were determined using a GPS navigator “Garmin”. To assess the abundance–cover of species in phytocenoses of technogenic landscapes, the Braun-Blanquet method with the r–5 scale was used, which allows comparison of vegetation on experimental plots.

The vitality of species was determined using a 3-point scale: 3a—the species in a given phytocenosis completes the full development cycle and develops normally, including fruiting; 3b—the species passes through all stages of development but does not reach its usual size; 2—the species is vegetatively developed fairly well but does not bear fruit; 1—the species does not bear fruit and is strongly suppressed, with weak vegetation.

At each sample plot, the vital condition of all present trees, shrubs, and perennial herbs was assessed. The condition of woody plants was evaluated using a 5-point scale: 5—healthy trees without external signs of damage; 4—weakened trees with isolated damaged or drying leaves and branches; 3—strongly weakened trees with drying of branches up to 1/3; 2—drying trees with branch dieback up to 2/3; 1—with more than 2/3 of branches dried.

The distribution of plants according to the water regime was determined by plant moisture requirements: mesophytes, xeromesophytes, hygromesophytes, xerophytes, and hygrophytes. The biomorphological composition of the flora was determined according to the classical system of life-form classification (tree, shrub, semi-shrub, perennial herbaceous, biennial, annual—Raunkiaer C. “The Life Forms of Plants and Statistical Plant Geography” (1907) [11].

Results and Discussion

The study of the flora of anthropogenically disturbed territories of the RMC was carried out on 23 plots, where the natural vegetation has been destroyed and significantly altered as a result of its activities (quarries, mines, dumps, tailings storage facilities) (Fig. 1).

Anthropogenic phytocenoses are plant communities that have formed or been significantly altered as a result of human activity. They differ from natural phytocenoses by their simplified structure, instability, and specific species composition, but they play an important role in landscape dynamics and the restoration of disturbed territories.

The formation of vegetation cover occurs in several stages (successions). Succession is a regular process of sequential replacement of plant communities in the same area over time. It occurs under the influence of changing environmental conditions, including those caused by human activity. For anthropogenically disturbed territories, succession is the main mechanism of natural ecosystem restoration [12–14].

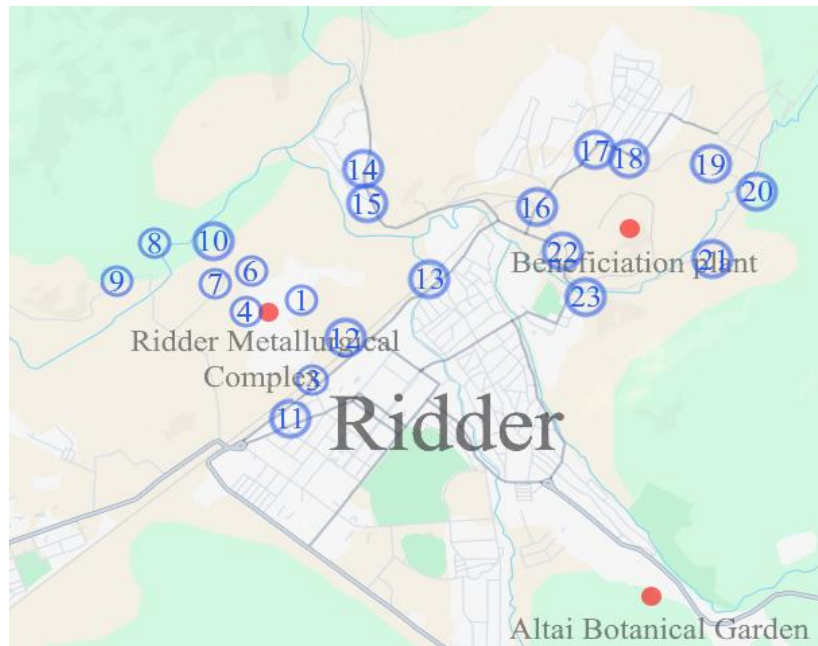


Figure 1. Location of the RMC experimental plots

The main stages of succession in anthropogenic territories include the herbaceous stage, an increase in species diversity, and the formation of a stable herbaceous cover composed of perennial herbaceous plants, mixed herbs, grasses, and legumes. This stage has ecological significance in active soil formation, accumulation of organic matter, and improvement of the microclimate. Soil is one of the most important components of the ecosystem and plays a crucial role in the formation and restoration of vegetation, especially on anthropogenically disturbed lands. The condition of the soil largely determines the possibility, speed, and direction of vegetation recovery.

The next shrub stage involves the appearance of woody-shrub forms, with increased competition for light and moisture. The tree stage forms a relatively stable plant community, with a structure approaching that of the natural vegetation of the zone. This is the final stage of succession under stable conditions.

When studying the spatial distribution of trees and shrubs on the plots, either even or grouped distribution patterns were observed.

During the study of the flora on the plots of the Ridder Metallurgical Complex, a species list was compiled. In the taxonomic list of 38 families, the leading families are Rosaceae — 11 genera, Cyperaceae and Asteraceae — 9 genera each, Poaceae — 7 genera, Fabaceae, Apiaceae, Plantaginaceae — 4 genera each, Brassicaceae, Caryophyllaceae, Malvaceae — 3 genera each. The remaining families include 1 to 2 genera (Tab. 1).

Table 1

Floristic composition of the plant cover of disturbed territories of the RMC

Family	Genus	Species
Sapindaceae	Acer L.	<i>Acer ginnala</i> Maxim., <i>Acer negundo</i> L., <i>Acer tataricum</i> L.
Salicaceae	Populus L.	<i>Populus laurifolia</i> Ledeb., <i>Populus tremula</i> L., <i>Populus nigra</i> L.
	Salix L.	<i>Salix acutifolia</i> Willd., <i>Salix alba</i> L., <i>Salix cinerea</i> L., <i>Salix integra</i> Thunb., <i>Salix rorida</i> Laksch., <i>Salix daphnoides</i> Vill., <i>Salix pentandra</i> L., <i>Salix viminalis</i> L.
Betulaceae	Betula L.	<i>Betula pendula</i> Roth, <i>Betula pubescens</i> Ehrh
Rosaceae	Malus Mill.	<i>Malus baccata</i> (L.) Borkh.
	Prunus L.	<i>Prunus padus</i> L.
	Sorbus L.	<i>Sorbus sibirica</i> Hedl
	Amelanchier Medik.	<i>Amelanchier alnifolia</i> (Nutt.) Nutt. ex M.Roem
	Spiraea L.	<i>Spiraea chamaedryfolia</i> L.

Continuation of Table 1

Family	Genus	Species
Rosaceae	<i>Rosa</i> L.	<i>Rosa acicularis</i> Lindl
	<i>Rubus</i> L.	<i>Rubus saxatilis</i> L., <i>Rubus sachalinensis</i> Lévl
	<i>Fragaria</i> L.	<i>Fragaria viridis</i> (Duchesne) Weston
	<i>Geum</i> L.	<i>Geum urbanum</i> L.
	<i>Agrimonia</i> L.	<i>Agrimonia pilosa</i> Ledeb.
	<i>Sorbaria</i> (Ser.) A.Braun	<i>Sorbaria sorbifolia</i> (L.) A. Braun
Pinaceae	<i>Larix</i> Mill.	<i>Larix sibirica</i> Ledeb.
	<i>Pinus</i> L.	<i>Pinus sylvestris</i> L.
Oleaceae	<i>Fraxinus</i> L.	<i>Fraxinus pennsylvanica</i> Marshall
Adoxaceae	<i>Viburnum</i> L.	<i>Viburnum opulus</i> L.
Caprifoliaceae	<i>Lonicera</i> L.	<i>Lonicera tatarica</i> L.
Poaceae	<i>Calamagrostis</i> Adans.	<i>Calamagrostis epigeios</i> (L.) Roth, <i>Calamagrostis purpurea</i> (Trin.) Trin.
	<i>Poa</i> L.	<i>Poa pratensis</i> L., <i>Poa attenuata</i> Trin.
	<i>Festuca</i> L.	<i>Festuca pratensis</i> Huds., <i>Festuca rubra</i> L., <i>Festuca valesiaca</i> Schleich. ex Gaudin
	<i>Phleum</i> L.	<i>Phleum pratense</i> L., <i>Phleum phleoides</i> (L.) H. Karst.
	<i>Phragmites</i> Adans.	<i>Phragmites australis</i> (Cav.) Trin. ex Steud.
	<i>Dactylis</i> L.	<i>Dactylis glomerata</i> L.
	<i>Bromopsis</i> Fourr.	<i>Bromopsis inermis</i> (Leyss.) Lindm.
	<i>Leymus</i> Hochst.	<i>Leymus angustus</i> (Trin.) Pilg
	<i>Elymus</i> L.	<i>Elymus repens</i> (L.) Gould, <i>Elymus geniculatus</i> (Trin.)
	<i>Agrostis</i> L.	<i>Agrostis stolonifera</i> L.
Cyperaceae	<i>Carex</i> L.	<i>Carex pediformis</i> var. <i>macroura</i> (Meinsh.) Kük
Asteraceae	<i>Artemisia</i> L.	<i>Artemisia absinthium</i> L., <i>Artemisia vulgaris</i> L.
	<i>Arctium</i> L.	<i>Arctium tomentosum</i> Mill.
	<i>Tanacetum</i> L.	<i>Tanacetum vulgare</i> L.
	<i>Achillea</i> L.	<i>Achillea millefolium</i> L.
	<i>Carduus</i> L.	<i>Carduus crispus</i> L., <i>Carduus nutans</i> L.
	<i>Cirsium</i> Mill.	<i>Cirsium vulgare</i> (Savi) Ten.
	<i>Tussilago</i> L.	<i>Tussilago farfara</i> L.
	<i>Tripleurospermum</i> Sch.Bip.	<i>Tripleurospermum perforatum</i> (Mérat) M. Lainz
	<i>Galatella</i> Cass.	<i>Galatella hauptii</i> (Ledeb.) Lindl., <i>Galatella punctata</i> (Waldst. & Kit.) Nees
	<i>Inula</i> L.	<i>Inula britannica</i> L., <i>Inula helenium</i> L.
	<i>Echinops</i> L.	<i>Echinops tricholepis</i> Trautv.
	<i>Serratula</i> L.	<i>Serratula coronata</i> L.
	<i>Taraxacum</i> F.H. Wigg.	<i>Taraxacum officinale</i> F.H. Wigg.
	<i>Hieracium</i> L.	<i>Hieracium umbellatum</i> L.
Fabaceae	<i>Vicia</i> L.	<i>Vicia sepium</i> L., <i>Vicia cracca</i> L., <i>Vicia silvatica</i> L.
	<i>Trifolium</i> L.	<i>Trifolium hybridum</i> L., <i>Trifolium lupinaster</i> L., <i>Trifolium repens</i> L., <i>Trifolium pratense</i> L.
	<i>Medicago</i> L.	<i>Medicago falcata</i> L.
	<i>Melilotus</i> Mill.	<i>Melilotus albus</i> Medik.
Brassicaceae	<i>Armoracia</i> Gaertn.	<i>Armoracia rusticana</i> P. Gaertn., B. Mey. & Scherb.
	<i>Bunias</i> L.	<i>Bunias orientalis</i> L.
	<i>Berteroa</i> DC.	<i>Berteroa incana</i> (L.) DC.
Apiaceae	<i>Angelica</i> L.	<i>Angelica decurrens</i> (Ledeb.) B. Fedtsch., <i>Angelica sylvestris</i> L.
	<i>Heracleum</i> L.	<i>Heracleum dissectum</i> Ledeb.
	<i>Carum</i> L.	<i>Carum carvi</i> L.
	<i>Bupleurum</i> L.	<i>Bupleurum longifolium</i> subsp. <i>aureum</i> (Fisch. ex Hoffm.) Soo
Lamiaceae	<i>Origanum</i> L.	<i>Origanum vulgare</i> L.
	<i>Stachys</i> L.	<i>Stachys silvatica</i> L.
Polygonaceae	<i>Aconogonon</i> Schrank.	<i>Aconogonon alpinum</i> (All.) Schur
Urticaceae	<i>Urtica</i> L.	<i>Urtica dioica</i> L.

Continuation of Table 1

Family	Genus	Species
Chenopodiaceae	<i>Chenopodium</i> L.	<i>Chenopodium album</i> L.
	<i>Kochia</i> Scop.	<i>Kochia prostrata</i> (L.) Schrad.
Typhaceae	<i>Typha</i> L.	<i>Typha angustifolia</i> L.
Valerianaceae	<i>Valeriana</i> L.	<i>Valeriana officinalis</i> L.
Caryophyllaceae	<i>Silene</i> L.	<i>Silene repens</i> Patrín ex Pers., <i>Silene vulgaris</i> (Moench) Garcke
	<i>Gypsophila</i> L.	<i>Gypsophila altissima</i> L.
	<i>Dianthus</i> L.	<i>Dianthus superbus</i> L.
Iridaceae	<i>Iris</i> L.	<i>Iris ruthenica</i> Ker Gawl.
Campanulaceae	<i>Campanula</i> L.	<i>Campanula rapunculoides</i> L.
Malvaceae	<i>Lavatera</i> L.	<i>Lavatera thuringiaca</i> L.
	<i>Alcea</i> Mill.	<i>Alcea nudiflora</i> (Lindl.) Boiss., <i>Alcea rosea</i> L.
	<i>Malva</i> L.	<i>Malva pusilla</i> Sm.
Boraginaceae	<i>Pulmonaria</i> L.	<i>Pulmonaria mollis</i> Wulfen ex Hornem.
Plantaginaceae	<i>Plantago</i> L.	<i>Plantago major</i> L.
	<i>Linaria</i> L.	<i>Linaria vulgaris</i> Mill.
	<i>Veronica</i> L.	<i>Veronica krylovii</i> Schichk.
	<i>Dodartia</i> L.	<i>Dodartia orientalis</i> L.
Euphorbiaceae	<i>Euphorbia</i> L.	<i>Euphorbia latifolia</i> C.A. Mey.
Hypericaceae	<i>Hypericum</i> L.	<i>Hypericum perforatum</i> L.
Papaveraceae	<i>Chelidonium</i> L.	<i>Chelidonium majus</i> L.
Equisetaceae	<i>Equisetum</i> L.	<i>Equisetum sylvaticum</i> L., <i>Equisetum arvense</i> L., <i>Equisetum hyemale</i> L., <i>Equisetum palustre</i> L.
Asparagaceae	<i>Allium</i> L.	<i>Allium rubens</i> Schrad. ex Willd.
Geraniaceae	<i>Geranium</i> L.	<i>Geranium pratense</i> L.
Convolvulaceae	<i>Convolvulus</i> L.	<i>Convolvulus arvensis</i> L.
Grossulariaceae	<i>Ribes</i> L.	<i>Ribes aureum</i> Pursh
Scrophulariaceae	<i>Verbascum</i> L.	<i>Verbascum thapsus</i> L.
Rubiaceae	<i>Galium</i> L.	<i>Galium boreale</i> L.
		<i>Galium verum</i> L.
Crassulaceae	<i>Sedum</i> L.	<i>Sedum purpureum</i> (L.) Schult.
Onagraceae	<i>Epilobium</i> L.	<i>Epilobium angustifolium</i> L.

The most species-rich and dominant genera in the flora of the disturbed territories of the Ridder Metallurgical Complex are: *Trifolium* — 9 species (7.3 %), *Salix* — 8 species (6.5 %), *Equisetum* — 4 species (3.1 %), *Acer* and *Populus* — 3 species each (4.8 %). 11 genera have two species each, accounting for 11.4 %, while the remaining genera (66.9 %) have only 1 species.

The number of species per plot ranges from 14 to 23. Species abundance is as follows: 104 species (82.5 %) are represented on only some plots — from 1 to 7, and 12 species (9.6 %) are represented on 8 to 13 plots (Fig. 2).

They include: *Betula pendula*, *Betula pubescens*, *Malus baccata*, *Elymus repens*, *Phleum phleoides*, *Vicia sepium*, *Vicia cracca*, *Armoracia rusticana*, *Trifolium pratense*, *Trifolium hybridum*, *Tussilago farfara*, *Hypericum perforatum*

Species such as *Acer negundo*, *Populus laurifolia*, *Calamagrostis epigeios*, *Dactylis glomerata*, *Artemisia vulgaris*, *Arctium tomentosum*, *Cirsium vulgare*, *Echium vulgare*, *Convolvulus arvensis*, *Bunias orientalis*, and *Urtica dioica* are widely distributed on nearly all industrial plots, ranging from 14 to 22 sites, which corresponds to 7.9 % in percentage terms. Compared to 7 other industrial enterprises in the East Kazakhstan Region, the RMC exhibits the highest species diversity with 126 species — 157.5 %, which is associated with a richer natural flora. This accounts for almost half of the species (49.1 %) of the total number of species (255) across all surveyed industrial plots of the enterprises.

The ecological plasticity of plants plays a crucial role in the formation of vegetation cover on disturbed lands. This characteristic enables species to adapt to changing environmental conditions while maintaining viability, growth, and reproduction. For anthropogenically disturbed territories, ecological plasticity is one of the key factors for plant survival and successful colonization. On disturbed lands, the advantage is given to

plants that are resistant to soil compaction, tolerant to pollution, capable of rapid recovery after damage, and able to grow and disperse quickly. Typical plant groups include ruderal species, pioneer plants, weed herbs, and certain shrubs.

Species	Number of plots																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
<i>Acer negundo</i> L.			+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
<i>Acer tataricum</i> L.			+								+						+						
<i>Populus nigifolia</i> Ledeb.	+		+	+			+																+
<i>Populus tremula</i> L.		+	+			+									+								
<i>Populus balsamifera</i>	+		+					+	+	+	+		+		+	+	+	+			+		
<i>Betula pendula</i> Roth		+	+	+			+	+	+	+			+	+	+							+	
<i>Betula pubescens</i> Ehrh.	+			+	+					+		+		+	+					+	+		
<i>Malus baccata</i> (L.) Borkh.	+				+							+	+		+		+						
<i>Pinus sylvestris</i> L.	+		+	+			+	+	+														
<i>Viburnum opulus</i> L.											+											+	
<i>Padus avium</i> Mill.										+	+	+						+					
<i>Salix alba</i> L.									+			+											
<i>Salix cinerea</i> L.			+	+		+				+	+										+		
<i>Salix pentandra</i> L.							+	+	+	+		+							+				
<i>Salix daphnoides</i> Vill.							+							+									
<i>Salix viminalis</i> L.		+					+				+							+	+				
<i>Calamagrostis arundinacea</i> (L.) Roth	+	+	+	+	+	+		+	+		+		+	+	+		+			+			
<i>Elymus repens</i> (L.) Nevski	+	+	+			+	+				+	+							+			+	+
<i>Filipendula ulmaria</i>																	+						
<i>Dactylis glomerata</i> L.	+	+			+	+	+	+	+	+	+	+	+		+		+	+	+	+	+	+	+
<i>Phleum pratense</i> L.		+						+	+						+				+				+
<i>Phleum phleoides</i> (L.) H. Karst.								+			+	+	+	+				+				+	
<i>Artemisia vulgaris</i> L.	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+
<i>Artemisia absinthium</i> L.								+						+	+								
<i>Artemisia commutata</i> Mill.		+	+		+			+		+	+				+	+		+	+	+	+	+	+
<i>Armerasia maritima</i> Gaertn. Mey.			+							+	+		+					+	+				+
<i>Vicia sepium</i> L.	+		+		+					+			+					+	+				
<i>Vicia cracca</i> L.	+	+		+														+	+				+
<i>Vicia</i> sp.			+			+																+	
<i>Coriaria myrtiflora</i> Bess.		+					+									+	+	+	+			+	+
<i>Bunias orientalis</i> L.	+	+			+				+	+					+	+		+				+	+
<i>Achillea millefolium</i> L.		+					+									+						+	
<i>Rumex confertus</i> Willd.	+									+					+						+		
<i>Trifolium hybridum</i> L.	+							+	+					+		+	+				+		
<i>Trifolium pratense</i> L.																							
<i>Trifolium repens</i> L.			+		+						+				+	+						+	
<i>Cynanchum vulgare</i> (Savi) Tetz.	+	+	+	+	+	+		+	+	+			+	+	+	+	+	+	+		+	+	+
<i>Echium vulgare</i> L.	+	+		+	+			+	+	+	+	+	+		+	+	+	+	+	+	+	+	+
<i>Convolvulus arvensis</i>	+		+		+					+		+	+		+			+	+				+
<i>Linaria vulgaris</i> Mill.		+			+	+			+			+	+	+	+	+		+					

Figure 2. Occurrence of certain species on the RMC experimental plots

The vitality of most species (52.0 %) growing on the plots was rated as 3a. These species complete the full development cycle and develop normally, including fruiting. They include: *Acer negundo*, *Malus baccata*, *Populus laurifolia*, *Elymus repens*, *Phleum phleoides*, *Trifolium pratense*, *Trifolium hybridum*, *Tussilago farfara*, *Hypericum perforatum*. About one-third of the species (30.0 %) received a 3b rating; they go through all developmental stages but do not reach their usual size. 16.6 % of species grow reasonably well but do not fruit, and 1.4 % of species are severely suppressed and do not fruit.

Under conditions of prolonged anthropogenic impact, it is important to provide an ecological-geographical analysis of the flora, reflecting their origin and connection with anthropogenic habitats. To assess the stability of plant communities and biodiversity on the RMC plots, biological groups of plants were identified: apophytes (native species), adventives, ruderal species, and synanthropic species. Considering that some species belong not only to one group but to two or three different groups—a phenomenon more common in species of the families Rosaceae, Asteraceae, Poaceae, Fabaceae, Plantaginaceae, Brassicaceae—the following distribution was observed. Native species occupy a special position, forming the basis (72.6 %) for

stabilizing the spatial structure; synanthropic species account for 10.0 %; ruderal plants of disturbed habitats make up 11.7 %; and adventive, invasive species make up 5.7 %, some of which exhibit aggressive behavior throughout the area, for example, *Acer negundo*.

The condition of woody plants is reflected in their morphological plasticity—the ability of a plant to change its external structure, in particular leaf size, plant height variation, development of a more robust root system, and modification of shoot form. Morphological plasticity helps plants adapt to deficits of moisture, light, and nutrients. Assessment of the vital condition of woody plants growing on the experimental plots showed that on the industrial sites near the Concentration Plant (tailings storage facilities), species such as *Betula pendula*, *Betula pubescens*, and *Populus laurifolia* exhibited a decrease in plant height by 15–18 %, reduction in growth by 14–16 %, and a 9 % reduction in leaf area compared to the control. Among the dominant grass species in the communities, *Dactylis glomerata* and *Phleum pratense*, most morphometric traits decreased, including plant height, stem thickness, and leaf blade area.

The life forms of the described species are classified according to the classical system of life-form classification (tree, shrub, semi-shrub, perennial herbaceous, biennial, annual). This classification is based on the method of overwintering and the position of generative buds relative to the soil surface. It is a simplified scheme often used in geobotany and vegetation ecology: 3 — woody plants over 5 m tall with a single stem; shrub—woody plants under 5 m, multi-stemmed; semi-shrub—semi-evergreen or low-growing subshrubs; perennial herbaceous—perennial herbs, including rhizomatous and tuberous forms; biennial—annual herbs—classified by lifespan. In these plants, aboveground parts die completely in winter but regenerate quickly.

According to this classification, on the disturbed territories of the RMC, perennial herbaceous plants dominate — 79 species (62.8 %), including rhizomatous species such as *Calamagrostis epigeios*, *Calamagrostis purpurea*, *Poa pratensis*, *Elymus repens*, *Agrostis stolonifera*, *Bromus inermis*, *Phragmites australis*, *Dactylis glomerata*, *Alopecurus pratensis*. These species have a high capacity to occupy open spaces, ensuring the stability of the vegetation cover and turf formation. Woody plants comprise 34 species, including 18 tree species (14.2 %) and 16 shrub species (13.4 %); semi-shrubs account for 7 species (5.5 %); annual herbs are represented by 5 species (3.9 %). Such biomorphological diversity demonstrates the resilience of plant communities on the RMC plots and their high capacity for self-restoration.

Grouping species by water regime shows that mesophytic species dominate the studied territory—38 species, accounting for 30.3 % of the total number of species. These are moderately moisture-loving plants, many of which have well-developed root systems. Xeromesophytes—34 species, make up 26.9 %. They are adapted to moisture deficiency through small or modified leaves, thick cuticles, and deep root systems, making them drought-resistant. Hygromesophytes include 24 species, accounting for 19.1 %. Xerophytes comprise 18 species (14.2 %), and 12 species are hydrophytes, representing only 9.5 % of the total species present. The identified groups reflect the morphological manifestation of colloidal-chemical issues in plants (Fig. 3).

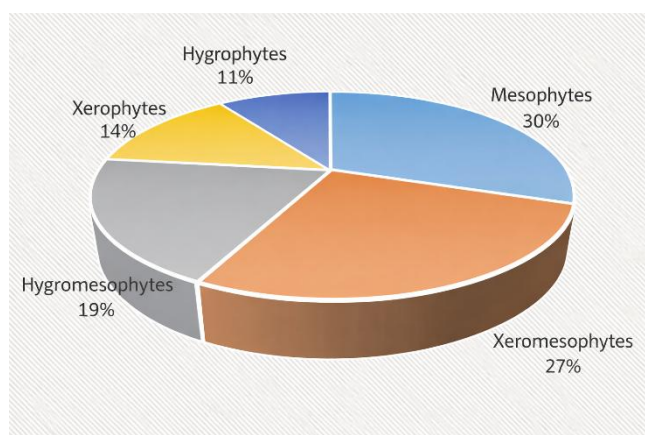


Figure 3. Distribution of species by water regime on RMC plots, methodology — (Raunkiær C., 1907)

Conclusion

The review of the flora includes ecological and geographical aspects. The conducted studies made it possible to assess the degree of disturbance of the territory and to predict the direction of succession. In the

vegetation cover, preference is given to local, ecologically stable species. The restoration of native vegetation can play a crucial role in forming resilient plant communities on the disturbed territories of the RMC.

The research concluded that a number of indicators (soil composition, ecological and biological characteristics of species) can be used to characterize vegetation condition as criteria for assessing environmental contamination with heavy metals. The biomorphological composition of the flora reflects the distribution of plants by life forms (biomorphs), which have evolved as adaptations to environmental conditions. Analysis of the biomorphological composition allowed for the assessment of the ecological state of the territory, the degree of anthropogenic disturbance, and the direction of succession. Ecological groups of plants were identified according to their moisture requirements.

The floristic composition studied includes 126 species from 38 families and 93 genera. The leading families are Rosaceae — 11 genera, Cyperaceae and Asteraceae — 9 genera each, Poaceae — 7 genera, Fabaceae, Apiaceae, Plantaginaceae — 4 genera each, Brassicaceae, Caryophyllaceae, Malvaceae — 3 genera each. The remaining families include 1 to 2 genera.

Within the phytocenoses, the spatial distribution, abundance, life form, and condition of the plants were determined. These studies contribute to the restoration of technogenically disturbed lands and their return to the biosphere fund. The study results allowed the identification of native and adventive species that predominate in plant communities.

Funding

The Committee of Science and Higher Education of the Republic of Kazakhstan, within the framework of project BR24992837 “Comprehensive Ecological Monitoring of the East Kazakhstan Region for Sustainable Development of the Agricultural Sector and Improvement of Environmental Quality”, 2024–2026.

Conflict of Interest

The authors declare no conflict of interest.

Authors' contributions

The manuscript was prepared with the participation of all authors. All authors approved the final version of the manuscript. **Vdovina T.A.** — data analysis, manuscript writing; **Anufrieva O.A.** — floristic research; **Vinokurov A.A.** — floristic research; **Danilova A.N.** — manuscript discussion and editing; **Sumbembaev A.A.** — floristic research, data analysis; **Chernakova A.A.** — data digitization and analysis.

References

- 1 Hajiyeva, G. N., & Ibrahimova, L. P. (2024). Ecological problems of technogenically disturbed lands on the Absheron Peninsula. *Journal of Geology, Geography and Geoecology*, 33(1), 70–76. <https://doi.org/10.15421/112408>
- 2 Stepanova, L. P., Pisareva, A. V., Bolmat, T. N., & Yelissarov, N. A. (2022). Ecological assessment of disturbances in the landscape structure of alluvial soils of floodplains under technogenesis influences. *IOP Conference Series: Earth and Environmental Science*, 988(4), Article 042024. <https://doi.org/10.1088/1755-1315/988/4/042024>
- 3 Kopach, P. I., Yakubenko, L. V., Mormul, T. M., Danko, T. T., Gorobets, N. V., & Halchenko, Z. S. (2022). Assessment of natural resource potential of territories disturbed by mining works in the context of effective use of post-technogenic landscape. *Geo-Technical Mechanics*, 162, 38–47. <https://doi.org/10.15407/geotm2022.162.038>
- 4 Osintseva, M. (2023). Assessment of soil properties in technogenically disturbed lands of Kemerovo Oblast — Kuzbass. *Qubahan Academic Journal*, 3(4), 77–92. <https://doi.org/10.48161/qaj.v3n4a164>
- 5 Ivakina, E. V. (2022). Habitat formation in technogenic landscapes. *IOP Conference Series: Earth and Environmental Science*, 1045(1), Article 012133. <https://doi.org/10.1088/1755-1315/1045/1/012133>
- 6 Shergina, O. V., Mironova, A. S., Mikhailova, T. A., & Badryanova, V. V. (2022). Assessment of effects of anthropogenic disturbance on plant communities and soils in urbanized territories. *IOP Conference Series: Earth and Environmental Science*, 979(1), Article 012162. <https://doi.org/10.1088/1755-1315/979/1/012162>
- 7 Ivanova, S., Vesnina, A., Fotina, N., & Prosekov, A. (2024). Technogenically disturbed lands of coal mines: Restoration methods. *Nature Environment and Pollution Technology*, 23(4), 2447–2452. <https://doi.org/10.46488/NEPT.2024.v23i04.050>
- 8 Dudnikova, T., Sushkova, S., Minkina, T., Barbashev, A., Ferreira, C. S. S., Antonenko, E., Shuvaev, E., & Bakoeva, G. (2023). Main factors in polycyclic aromatic hydrocarbons accumulations in the long-term technogenic contaminated soil. *Eurasian Journal of Soil Science*, 12(3), 282–289. <https://doi.org/10.18393/ejss.1291033>

- 9 Chaplygina, A. B., Filatova, O. V., Litvin, L. M., & Nykyforov, V. V. (2023). The main factors and prospects for the restoration of biodiversity in technogenic territories: On the example of the Poltava Mining and Processing Plant. *Biosystems Diversity*, 31(1), 100–112. <https://doi.org/10.15421/012311>
- 10 (2024). Royal Botanic Gardens, Kew. www.plantsoftheworldonline.org. Retrieved from <http://www.plantsoftheworldonline.org/>
- 11 Raunkiaer, C. (1905). Types biologiques pour la géographie botanique. *Oversigt over Det Kongelige Danske Videnskabernes Selskabs Forhandling*, 347–437.
- 12 Litvinskaya, S. A. (2023). Transformation and features of plant successions of the Taman Peninsula in case of technogenic impact. *Russian Journal of Earth Sciences*, 23(5), 1–6. <https://doi.org/10.2205/2023ES02SI18>
- 13 Watkinson, A. D., Juckers, M., D'Andrea, L., Beckett, P., & Spiers, G. (2022). Ecosystem recovery of the Sudbury technogenic barrens 30 years post-restoration. *Eurasian Soil Science*, 55(5), 663–672. <https://doi.org/10.1134/S106422932205012X>
- 14 Faleyev, D., Ivanov, A., Petrov, S., & Smirnov, V. (2024). Changes in vegetation cover as a result of anthropogenic and technogenic impact on arid ecosystems of the Ashchykol depression (Betpak-Dala): Problems and prospects for the recultivation of uranium mines. *BIO Web of Conferences*, 128, Article 00006. <https://doi.org/10.1051/bioconf/202412800006>

Т.А. Вдовина, О.А. Ануфриева, А.А. Винокуров, А.Н. Данилова,
А.А. Сумбембаев, А.А. Чернакова

Риддер металлургиялық кешенінің антропогендік бұзылған аумақтарының флорасы

Жұмыстың мақсаты — Риддер металлургиялық кешені аумағындағы өнеркәсіптік бұзылған жерлерде қалыптасатын өсімдіктердің флоралық құрамын зерттеу арқылы оларды биологиялық рекультивациялау мәселесін шешу. Риддер металлургиялық кешенінің өнеркәсіптік бұзылған жерлеріндегі флораны зерттеу барысында Өсімдіктер биологиясы және биотехнологиясы институтымен бірлесіп техногендік ландшафттардың фитоценоздары мен топырақ құрамын зерттеуге бағытталған кешенді бағдарлама жүзеге асырылды. Бұл аумақ антропогендік әсердің жоғары деңгейімен сипатталады. Зерттеу нәтижесінде 38 тұқымдасқа, 93 туысқа жататын 126 түрден тұратын флоралық құрам анықталды. Таксономиялық тізімде жетекші орын алатын тұқымдастар: Rosaceae — 11 туыстан, Cyperaceae және Asteraceae — 9 туыстан, Poaceae — 7 туыстан тұрады. Өсімдіктердің кеңістікте таралуы, саны, тіршілік формалары мен жағдайы айқындалды. Түрлердің биоэкологиялық сипаттамасы беріліп, тіршілік формалары (экоморфалары) анықталды, сондай-ақ өсімдіктердің ылғалға қатынасы бойынша экологиялық топтары ажыратылды. Жүргізілген зерттеулер аумақтың бұзылу дәрежесін бағалауға және сукцессия бағытын болжауға мүмкіндік берді. Өсімдік жамылғысының негізін антропогендік ортаға бейімделген жергілікті, экологиялық тұрғыдан тұрақты түрлер құрайды. Бұл зерттеулер техногендік бұзылған жерлерді қалпына келтіруге және оларды биосфералық қорға қайтаруға ықпал етеді.

Кілт сөздер: флора, түр, техногендік бұзылған аумақтар, Риддер металлургиялық кешенінің кәсіпорындары, тіршілік формасы, өсімдіктердің жағдайы, экоморфа, экожүйе.

Т.А. Вдовина, О.А. Ануфриева, А.А. Винокуров, А.Н. Данилова,
А.А. Сумбембаев, А.А. Чернакова

Флора антропогенно нарушенных территорий Риддерского металлургического комплекса

Цель работы — исследование флористического состава растений, формирующегося на нарушенных промышленностью землях в районе Риддерского металлургического комплекса для решения проблемы их биологической рекультивации. При проведении исследований на нарушенных промышленностью землях Риддерского металлургического комплекса совместно с «Институт биологии и биотехнологии растений» была реализована комплексная программа по изучению фитоценозов техногенных ландшафтов, почвенного состава. Данная территория характеризуется высокой степенью антропогенного воздействия. В результате исследований изучен флористический состав, насчитывающий 126 видов из 38 семейств, 93 родов. На лидирующих позициях в таксономическом списке такие семейства, как Rosaceae (одиннадцать родов), Cyperaceae и Asteraceae (девять родов), Poaceae (семь родов). Определено их пространственное размещение, численность, жизненная форма, состояние растений. Приведена биоэкологическая характеристика видов, жизненная форма (экоморфа), выделены экологические группы растений по отношению к влаге. Проведенные исследования позволили оценить степень нарушенности территории, спрогнозировать направление сукцессии. В растительном покрове основу

составляют местные, экологически устойчивые виды, отражающие связь с антропогенным местообитанием. Данные исследования способствуют восстановлению техногенно нарушенных земель, возвращению их в биосферный фонд.

Ключевые слова: флора, вид, техногенно нарушенные территории, предприятия Риддерского металлургического комплекса, жизненная форма, состояние растений, экоморфа, экосистема.

Information about the authors

Vdovina Tatyana Afanasyevna — Candidate of Biological Sciences, Altai Botanical Garden, Ridder, Kazakhstan; e-mail: tvdovina2017@mail.ru; ORCID: <https://orcid.org/0000-0002-1767-3047>

Anufrieva Olga Alexandrovna — Senior Researcher, Altai Botanical Garden, Ridder, Kazakhstan; e-mail: anufrievaolgaalex59@yandex.kz; ORCID: <https://orcid.org/0000-0001-9675-7654>

Vinokurov Andrey Andreevich — Senior Researcher, Altai Botanical Garden, Ridder, Kazakhstan; e-mail: anvin64@mail.ru; ORCID: <https://orcid.org/0000-0003-0154-8943>

Danilova Alevtina Nikolaevna — Candidate of Biological Sciences, Altai Botanical Garden, Ridder, Kazakhstan; e-mail: a-n-danilova@yandex.ru; ORCID: <https://orcid.org/0000-0002-1096-9339>

Sumbembaev Aidar Aitkazyevich — PhD, General director, Altai Botanical Garden, Ridder, Kazakhstan; e-mail: aydars@list.ru; ORCID: <https://orcid.org/0000-0003-0682-9162>

Chernakova Anzhelika Alexandrovna (contact person) — Junior Researcher, Altai Botanical Garden, Ridder, Kazakhstan; e-mail: dolmatova-1986@bk.ru; ORCID: <https://orcid.org/0009-0007-6481-5611>