Biodiversity, Ecology, and Microelement Composition of Kyzylkum Desert Shrubs (Uzbekistan)

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Abstract—Geobotanic research and large-scale mapping with the help of Geographical Information System (GIS) permit us to find out the present state of Kyzylkum Desert shrublands, regularities of plant communities distribution, and chemical composition of the main dominant shrubs. Zonal vegetation types were formed on the basis of Old Xerophilous and Old Mediterranean floras in the Paleogene and Neogene periods. Composition of plant associations and their anthropogenic modification largely depends on physical and chemical properties of the soils. Climax associations of *Artemisia diffusa, Astragalus villosissimus, Convolvulus hamadae,* and *Ceratoides latens* are connected with almost saline-free soils. Communities of *Artemisia turanica, Salsola arbuscula,* and *S. arbusculiformis* are found on soils with the lowest salt content, and *Haloxylon aphyllum, Nanophyton erinaceum,* and *Salsola orientalis* communities prefer average and very saline soils. Microelement concentration of the shrubs depends on chemical composition of their habitats.

Introduction

The region of our investigation belongs to the Turanian Province of the Irano-Turanian subdistrict of the Sahara-Gobi Desert zone (Lavrenko 1962). Mean annual temperature is +14 °C. Rainfall in the region amounts to less than 150 millimeters per year. The annual sunshine period is about 3,000 hours.

Gypsum Desert and Saline Desert

All these types are located from 100 m to 300 m above sea level under rather similar climatic conditions. The desert ecosystems, by virtue of natural peculiarities, are distinguished by a rich variety of flora and fauna. There are more than 5,000 species of vascular plants in Uzbekistan (Red data book 1999). Among these many are rare, endemic and relict plants, which need protection by efficient measures. The flora of the Kyzylkum Desert contains about 937 vascular plants, and the fauna consists of over 500 species and sub-species of vertebrates and about 950 species of non-vertebrates. The following main categories of desert ecosystems can be found in Uzbekistan: Sand Desert; Clay (or Gypsum) Desert and Saline Desert. All these types are located from 100 to 300 m above sea level under similar climatic conditions. The desert ecosystems, by virtue of natural peculiarities, are distinguished by a rich variety of flora and fauna.

The development of industrial enterprises and agriculture are the main reasons for changes of ecological conditions, for impoverishment of biodiversity, and for genetic resources. Grazing has multiple effects on natural ecosystems. Animals defoliate vegetation and, consequently, affect plant growth, vigor, reproduction, species composition, plant cover, and biomass. At the same time animals trample the soil thus reducing bulk density and infiltration rates and increasing overland flow. On the other hand, as they move around the grazing land they redistribute nutrients in the ecosystem. All these effects, however, are minor and therefore reversible if grazing intensity is light to moderate. On the contrary, they become severe and irreversible by heavy grazing. Grazing intensity, therefore, is a crucial factor affecting the Kyzylkum Desert ecosystems. Intensive pastoralism combined with overhunting has reduced wildlife and has influenced the number and diversity of rare animal species such as *Gazella subgutturosa, Ovis polii severtzovi, Felix margarita*, *Felix manul*, *Felix ocreata caudata*, *Falco cherrug coasti*, *Otis undulata macqueenii,* and so forth.

Material and Methods

Results of long-term paleobotanical, floristic and ecological researches are used in this work (Popov 1927; Iljin 1946; Kamelin 1979; Kapustina and others 1996). Investigation of the present state of vegetation was carried out according to the traditional geobotanical and GIS methods (Aleksandrova 1964; Hill and others 1996). Modifications of the vegetation are compared with relief changes, salinization and mechanical composition of the soils. The vegetation has been classified according to Kamelin (1979). During the geobotanical investigations in the field, ecological profiles were plotted crossing mountain slopes and plains. Plant and soil samples were taken along these profiles. The chemical compositions of plants and soils were determined by spectral analysis. Degree and type of the most saline soils were classified according to Kovda and Egorova (Pankov 1974; Alekcandrova and Naidenov 1976).

Results and Discussion

Arid territories are present in Uzbekistan since the beginning of the Jurassic. Similar xerophytic flora with representatives of *Rutaceae, Capparidaceae, Geraniaceae,*

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Frankeniaceae, and *Chenopodiaceae* emerged in the Southern Hemisphere in the Upper Cretaceous and Tertiary. The formation of saline and sandy deserts began in the Paleogene. At that time savanna vegetation types were dominant. The main savanna types were destroyed by the arctic climate in the Pliocene. An exchange of xerophytic flora (Popov 1927; Iljin 1946; Bobrov 1965) was distributed on the Old lands of the Northern species between the West and East of the Old Mediterranean region at the end of the Neogene. Many of the Old Mediterranean genera were formed at the same time and are the basis of the modern composition of the xerophytic desert vegetation (Iljin 1946; Kamelin 1979). In recent times two types, extremely arid and semiarid, of the Temperate Floracenotype can be distinguished in the desert vegetation of Uzbekistan (Kamelin 1979). The first group of extremely arid types includes: Turanian Shrub-Desert type, Turanian Psammophyton type, Irano-Turanian Psammosavanna type, Halophyton Turanicum type and Desert Forest on humid soils. Shrubs are a very important part of the vegetation in the arid zone.

Types of Habitats in the Kyzylkum Desert

Gypsum Desert occupies about 29 percent of Uzbekistan and is represented by Turanian Shrub Desert type on gray-brown soils. This type was formed on the bases of Old Mediterranean and Old Xerophilous floras in the Neogene period. Groups of oligothermal and mesothermal euxerophilous shrubs are prevailing (Kamelin 1979). Gray-brown soils flora consists of more than 400 species and includes species that occur on shallow soils of residual mountains and mixed rock; 25 percent are endemics of Middle Asia, and 3.5 percent are endemics of the Kyzylkum Desert. Forty one species depend on soil gypsum horizons for water and mineral nutrition. Forty-seven species are shrubs. Climax associations are formed by *Artemisia diffusa, A. turanica, Salsola orientalis, S. arbuscula* with *Carex pachystylis* and *Poa bulbosa* (grasses of the semisavanna group). Xeric semishrubland on loam gray-brown soils (*Artemisia diffusa* communities including *Artemisia turanica, Salsola orientalis, S. arbuscula* and *Aellenia subaphylla*) and xeric pelitic semishrubland on clay gray-brown soils (*Artemisia turanica* communities with *Salsola orientalis, S. arbuscula, Artemisia diffusa, Carex pachystylis* and *Poa bulbosa*) are predominant on the Southern mountain plains. Xeric psammophytic semishrubland on sandiest gray-brown soils (*Artemisia diffusa* communities with *Salsola arbuscula, Ferula foetida, Calligonum leucocladum, Ceratoides latens, Haloxylon aphyllum*) and xeric shrubland on the loam gray-brown soils (*Salsola arbuscula* communities with *Artemisia diffusa, A. turanica, Carex pachystylis* and *Salsola orietalis*) are spread on the Northern and Western mountain plains. *Artemisia diffusa* and *Salsola arbusculiformis* communities with *Artemisia terrae-albae, Rhamnus sintenisii, Convolvulus fruticosus* and *Atraphaxis spinosa* are predominant on the calcareous low desert mountain slopes. *Salsola orientalis* communities with *Anabasis brachiata, A. truncata, Nanophyton erinaceum* and *Artemisia turanica* are spread on the saline soils of the mountain plains and rocks (table 1).

Formations of *Anabasis salsa, A. brachiata, A. eriopoda, A. truncata* and *Artrophytum lehmannianum* can be considered as Old Euxerophilous Paleofloracenotype in the Turanian desert flora, and *Atraphaxis spinosa* and *Calligonum junceum* as Old Mediterranean species emerging in the Paleogene. At present these are spread on paleogenic slopes of low desert mountains.

Sandy Desert is formed on sandy desert soils and loose sands. The area of the sandy desert in Uzbekistan makes up 27 percent of the Republic. Within the sandy desert there are about 320 vascular plants from 31 families and 134 genera. Of these 53 percent are endemics of Middle Asia; the rest is represented by Irano-Turanian, Turanian-Caucasian and Turanian-European elements. Between them are 62 endemic shrubs on sandy desert soils: representatives are *Calligonum* spp., *Ammodendron conollyi, A. karelinii, Salsola paletzkiana, Eremosparton flaccidum, Smirnovia turkestana, Dendrostella arenaria, Tamarix androssovii, Astragalus* from sections, *Ammodendron* and *Eremophysa, Convolvulus divaricatus, C. erinaceus, Acanthophyllum borszczowii, A. korolkovii, Ammothamnus lehmanii,* and *Artemisia diffusa* (Melnikova 1973). Real psammophytes comprise 174 species; of these, 40 species are also common in the gypsum desert and 60 in the mountain foothills. The

Table 1—Biodiversity of the shrubland in the Kyzylkum Desert.

Shrubland	Area (km^2)
Haloxylon persicum	58,714
H. aphyllum	6,720
Ammodendron conollyi	17,678
Salsola richteri and *S. paletskiana*	392
Salsola arbuscula	2,339
Low desert mountain shrubland (*Rhamnus sintenisii, Convolvulus fruticosus* and *Atraphaxis spinosa*)	1,650
Nanophyton erinaceum	1,224
Anabasis salsa, A. eriopoda and *A. brachiata*	267
Astragallus villosissimus	223
Convolvulus hamadae	70
Ceratoides latens	1,064
Artemisia diffusa and *A. turanica*	22,229
Salsola gemmascens	22
Salsola orientalis	1,629

ecological and biological peculiarities of sandy habitats cause the occurrence of diverse forms. Trees and shrubs form a characteristic part of the "psammophyte vegetation" and make up to 30 percent of the flora composition. Twenty shrub species are edificators and subedificators of plant communities. Climax and subclimax stages are presented by communities of the Turanian Psammophytic type that was formed on the basis of the Old Mediterranean flora in the Neogene. There are groups of oligothermal, and not so often mesothermal euxerophilous psammophilous trees and shrubs (Kamelin 1979). *Salsola arbuscula, Calligonum microcarpum*, *C. leucocladum, C. setosum, Haloxylon aphyllum* and *Haloxylon persicum* form climax and serial associations on the sandiest gray-brown and sandy desert soils. Syngenetic stages are presented by sparse communities of Psammodendron Irano-Turanian type on loosely fixed sandy soils. Eroded xeric and psammophytic vegetation is wide spread in the region of study. This type was formed from the Old Xerophilous flora in the Paleogene and Neogene. Later on, some communities became relict and were enriched by Turanian Psammophytic species. There are groups of mesothermal xerophilous and psammophilous trees, shrubs and herbs (Kamelin 1979) on eroded sandy desert soils. In places with strong desertification on less hardened, furrowed sands and dunes as well as on sand plains are communities of *Ammodendron conollyi*, *Convolvulus korolkovii, Salsola richteri*, *Calligonum setosum, Acanthophyllum borszczowii,* and *Salsola richteri*. The perennials *Peganum harmala* and *Stipagrostis pennata* are dominant.

Saline Desert occupies about 3 percent of Uzbekistan. It developed on the saltiest plains and closed depressions (such as Mingbulak, Auminzatay, and Karakata). Characteristic features of saline areas are constant humidity of superficial soil horizons and occurrence of temporary reservoirs. There are 304 species on these soil types; 30 percent of the species are the real halophytes. Fifty two species are shrubs; some of these form the communities of the Halophyton Turanicum type that are widely spread on the saltiest habitats. This type was formed on the basis of Old Xerophilous and Old Mediterranean floras in the Paleogene and Neogene. There are groups of mesothermal euxerophilous halophilous trees, shrubs, perennials and rare succulent shrubs (Kamelin 1979). *Haloxylon aphyllum* communities with *Girgensohnia oppositiflora, Salsola praecox, Artemisia diffusa, Calligonum erinaceum* are spread on saline sandy desert soils. Salty pelitic shrubland communities of *Anabasis salsa, A. aphylla, Halocnemum strobilaceum, Halostachys caspica, Limonium suffruticosum, Kalidium caspicum, Frankenia bucharica, Atriplex cana* and *Suaeda microphylla* are spread on saline gray-brown soils and solonchaks.

Desert Forest on humid soils covers about 3 percent of the territory and was formed on the basis of Old Xerophilous and Arctic Tertiary Floras in the Pliocene (Kamelin 1979). The area of this type has been reduced in the Pleistocene and Anthropogene. There are mesothermal or rarely oligothermal hydrophilous trees and shrubs. *Tamarix ramosissima, T. elongata, T. hispida, T.laxa, T. florida, Ulmus pumila, Populus diversifolia, Halimodendron halodendron, Lycium turcomanicum* and *L. ruthenicum* form communities on humid soils near the Amudaria and Syrdarya rivers, artificial lakes and canals. *Nitraria schoberi* shrub communities are a relict part of this florocenotype. The flora consists of 285 species; about 190 species are typical for these habitats only. Of these, 28 species are endemic in Middle Asia and four in Uzbekistan. Thirty-five species are widely distributed in the river valleys of Central Asia, Dsungaria and Iran; some of them (*Populus* spp., *Tamarix* spp. and *Salix songarica*) are edificators of this vegetation.

Xerophilous Shrubs of the **Semiarid Type** formed the main zonal type of the Turanian up to the Ice Age. At present the shrub formations of this type (*Artemisia juncea, Astragalus scleroxylon, Convolvulus fruticosus, Salsola arbusculiformis*, and *Nanophyton erinaceun*) are found only on the paleogene slopes of the low desert mountains (such as, Kuldzuktay, Bukantay, Tamdutay, and Kokchatay).

Ecological Types of Desert Shrubs and Their Adaptive Strategy

Desert shrubs can be divided into three groups according to their biological structures and ecological peculiarities (Butnik 1991; Alimuchamedova 1979; Rachimova 1991): hyper-xerophytes, eu-xerophytes and meso-xerophytes (table 2).

Hyper-xerophytes have succulent assimilative organs and are microphyllous or aphyllous. Their above ground organs develop slowly, but root development is quick. Stability of water balance and photosynthesis, sclerotization of axial organs and a vegetative period from spring up to late autumn characterize this group. They have two types of adaptive strategy. The first one, aphylly, is the strategy of substitution and reduction of leaves by an assimilating shoot cortex as a result of cell-division change in the growing point. The second one, sclerophylly, consists of deep embedded stomatas, thick and complicated structure of outer epidermis walls and fiber-cell sheath bundles to prevent loss of water through evaporation (Butnik,1991). Transpiration rate varies from 123 to 660 mm^3 of O_2—fresh weight per hour (Nigmatov and Alekseeva 1998); osmotic pressure is 5–10 atm in spring and 44 atm in autumn. Growth occurs in the very hot summer time, when temperatures are about 60–63 °C and have a low index of potential photosynthesis: 21–31 mg CO_2/g^2 per hour (Zakharianc 1971). The greater part of the representatives of this group belong to the *Chenopodiaceae* family (*Haloxylon aphyllum, Halothamnus subaphyllus, Salsola orientalis, Nanophyton erinaceum, Anabasis eriopoda, Salsola arbuscula, S. arbusculiformis* and *S. paletzkiana*).

Eu-xerophytes solve the problem of evaporation decrease in the xerothermic period by dropping 70 percent of their leaves, and have more xeromorphous than succulent structure. Additional adaptive strategies to desert conditions without high specialization are pubescence, thickening of outer epidermis walls and sclereids (Butnik 1991). The vegetative growth period of this group of plants continues from spring to late autumn. Intensity of transpiration varies from 1,170 mm^3 of O_2 of fresh weight per hour (spring) up to 180 (summer); osmotic pressure is 6–9 atmospheres in spring and 67 in summer (Rachimova 1991); index of potential photosynthesis is higher than in the first group

Table 2—Ecological types of desert shrubs.

Type of desert shrubs	Species	Adaptive strategy	Intensity of transpiration (mm^3 of 02 for the gram of fresh weight per hour)	Osmotic pressure (atm)	Index of potential photosynthesis (mg CO_2/g^2 per hour)	Vegetative growth period
Hyper-xerophytes	*Haloxylon aphyllum, Halothamnus subaphyllus, Salsola orientalis, Nanophyton erinaceum* and *Anabasis eriopoda, Salsola arbuscula, S. arbusculiformis* and *S. paletzkiana*	Aphylly and sclerophylly	123–660	5–44	21–31	From spring up to late autumn
Eu-xerophytes	*Ceratoides latens, Ammodendron conollyi, Astragalus villosissimus* and *Kochia prostrata*	Defoliation (70 percent), pubescence, thicknening of epidermis walls	1,170–180	16–9–67	31–50	From spring time to late autumn
Meso–xerophytes	*Artemisia diffusa, A. turanica* and *A. ferganensis*	Defoliation (100 percent), thin leaves, pubescence, biological rest in summer time	1,704–30 (80)–410	12–32	44–55	Three vegetative phases

–31 to 50 mg CO_2/g^2 per hour. Eu-xerophytes can stand +59 °C; their root systems go 4 to 5 m deep. Desert shrubs *Ceratoides latens, Ammodendron conollyi, Astragalus villosissimus,* and *Kochia prostrata* belong to this group.

Meso-xerophytes drop 80 to 100 percent of their leaves in the hottest period of summer. They are not as adapted to the xerothermic period like hyper-xerophytes and eu-xerophytes and have some elements of xeric structure: thin leaves, covered with hairs, biological repose in summer time and the possibility to use essential oils in the hot time for protecting the plant from excessive heating due to very high temperatures. *Artemisia* shrubs of the subgenus *Seriphidium* belong to this group. Species of this subgenus have three vegetative phases: first is mesothermic (in the spring)—for growing and development, second is xerothermic (in the summer) for biological rest, and third is microthermic (in the autumn and winter) for seed production and dying of the inflorescences. The root system of these shrubs goes about 2 to 2.5 m deep. Intensity of transpiration of this group varies from 1,704 to a maximum of 2,388 mm^3 O_2 for 1 g of fresh weight per hour (spring) up to 30–80 (summer) and 410 (autumn); osmotic pressure is 12 atm in spring time, 28 in summer and 32 in autumn; index of potential photosynthesis is 44 to 55 mg CO_2/g^2 per hour (Rachimova 1991).

Adaptation to Saline Soils

The distribution of vegetation in the Uzbekistan Desert zone depends on the adaptation to the moist saline soils. Analysis of the desert shrub communities distribution and chemical composition of soils have shown that three edaphotypes (Bikov 1981; Freitag 1991; Akjigitova 1996) can be distinguished in the Kyzylkum Desert: euhalophytes, hemihalophytes and halo-glycophytes.

Euhalophytes have a wide tolerance range and are very well adapted to the average and high saline soils containing magnesium-calcium sulphate. Dry residue of the complete water extract from these soils is about 1.8 to 2.5 percent (table 3). Due to their adaptation they belong to salt accumulating- and salt-excreting halophytes. *Haloxylon aphyllum,*

Table 3—Chemical composition of soils in the zone of maximum root distribution of dominant shrubs (percent).

Species	Dry residue	HCO3	Cl	SO4	NO3	Ca	Mg	K	Na
Haloxylon aphyllum	2.58	0.6	2.45	32.9	0.16	27.4	1.6	0.08	6.81
Salsola orientalis	2.39	0.6	2.4	32.1	0.65	29.0	3.3	0.08	3.45
Salsola arbusculiformis	0.37	0.6	0.1	4.46	0.02	4.2	0.75	0.36	0.16
Salsola arbuscula	0.1	0.9	0.1	0.6	0.03	0.5	0.2	0.2	0.73
Artemisia diffusa	0.08	0.8	0.1	0.5	0.03	0.5	0.55	0.18	0.13
Artemisia turanica	0.13	0.8	0.05	1.1	0.03	1.25	0.2	0.34	0.19

Salsola orientalis, S. gemmascens, Anabasis salsa, A. brachiata and *Nanophyton erinaceum* are Chenopodiace shrubs and they are predominant in this group.

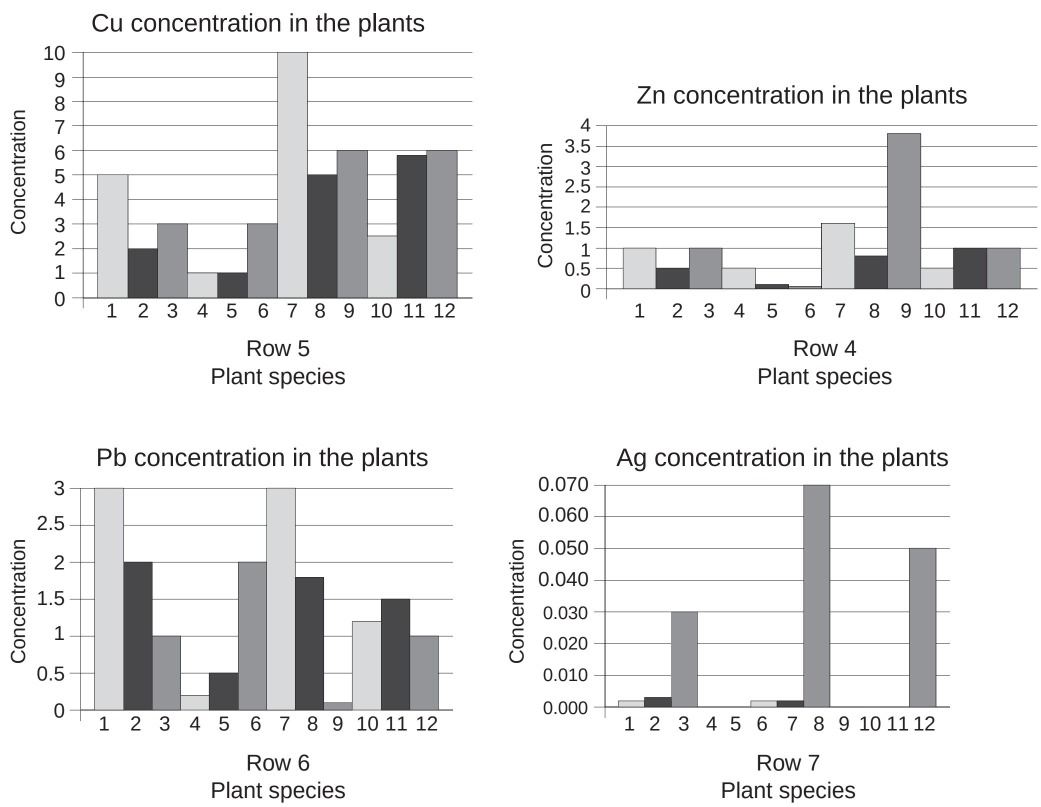
Hemihalophytes are shrubs of average saline soils containing magnesium-calcium sulphate. Dry residum of the complete water extract from these soils varies from 0.9 to 1.7 percent (table 3). Species of this group are *Salsola arbuscula, Arthrophytum lehmannianum, Nitraria schoberi, Artemisia turanica, A. ferganensis,* and *A. santolina;* they are sometimes spread on lower or high saline soils, too, but do not form communities in this habitat.

Haloglycophytes are shrubs with weak tolerance to very saline soils. Dry residue of the complete water extract from these soils is not more than 0.3 percent (table 3). *Artemisia diffusa, Astragalus villosissimus, Convolvulus hamadae, S. arbusculiformis* and *Ceratoides latens* belong to this group. Sometimes communities of these species are found on almost saline-free soils (the dry residue of the complete water extract from these soils is about 0.08 percent).

The chemical composition of plants growing in the same habitats, but belonging to different life-forms, is various and depends on physiological and ecological factors (Biogeochemical and Geobotanical Investigations 1972). According to chemical composition of desert shrubs in the Kyzylkum Desert we could establish that the following species accumulate elements most actively: *Artemisia diffusa* and *A. turanica*—Cu, W, V, Cr, Pb, Zn, Ni, Mo, Co, Bi,P and Sn; *Artemisia sogdiana*—U, Pb, Cd, Zn and Mo; *Astragalus villosissimus*—Ni, Ag, Pb, Sr, Zn, P and Cu; *Salsola arbuscula*—Mn, Sr, Ba, Pb, U and Ni; *Salsola orientalis*—Sr, Ba; *Calligonum microcarpum*—P, Pb and Ni; *Ceratoides latens*—Mo, Zn, Cu; and *Nanophyton erinaceun*—Ag,Cu and Pb (fig. 1). Pb was best accumulated *Artemisia diffusa* and *Calligonum microcarpum*; Zn and Cu—*Artemisia diffusa* and *Halocnemum strobilaceum*; V and Cr—*Artemisia diffusa.*

Conclusion

Shrublands are predominant in the Kyzylkumm Desert. Three ecological types of desert shrubs widely spread on different soils. The greater part of the representatives of hyper-xerophytes are adapted to average and very saline soils and belong to euhalophytes. Chemical compositions of desert shrubs (*Artemisia diffusa, Calligonum microcarpum, Ceratoides latens and Salsola arbuscula*) can be used us indicators of the polluted zones and deposits.



1. *Calligonum microcarpum*
2. *Salsola arbuscula*
3. *Astragalus villosissimus*
4. *Aellenia subaphylla*
5. *Haloxylon aphyllum*
6. *Salsola orientalis*
7. *Artemisia diffusa*
8. *Nanophyton erinaceum*
9. *Ceratoides larens*
10. *Anabasis salsa*
11. *Kochia prostrata*
12. *Halocnemum strobilaceum*

Figure 1—Microelement composition of shrubs in the Kyzylkum Desert (percent concentration: n x 0.001).

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