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STABILIZATION OF THE MOVING SANDS OF THE DRAINED AND DRIED ARAL SEA BED

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ABSTRACT

The paper shows the possibility for formation of water-stable structures in dispersions of salted sand on the dried bottom of the Aral Sea with composition fixers - water soluble polymer MPK-1 with sawdust. This creates a surface crust of sand, which has a sufficiently high value of (about 2.59 MPa) strength and a significant amount of water-resistant aggregates (> 0.25 mm) in a structure equal to 70.65 % against 6.28 % brfore its creation. The processes of phytomelioration on fixed sands by planting seeds and seedlings salt resistant plants have been studied. Research and field trials to consolidate salted sand Kazakhdarya on the dried bottom of the Aral Sea were conducted. Complex fixer - MPK-1 with sawdust, in combination with phytomelioration are recommended for practical implementation.
Keywords: stabilization of mobile sand, water-stable aggregates, water-soluble polymer (MPK-1), sawdust, movable barkhan sands, grain size, mineralogical composition.

INTRODUCTION

It is known that one of the serious factors for environmental deterioration in Central Asia is the moving as a result of wind erosion of dust salts (annually more than 100 million tons) from a drainage area of the Aral Sea. The reason for this catastrophe - irrevocable loss of water from main local rivers - the Amu Darya and Syr Darya, to develop irrigated agriculture. At present the fall of the water level of 22.5 m, a decrease in the area from 66,000 to 15,000 km2, of the volume from 1060 to 100 km3. The residual depth does not exceed 3.4 m. All this together will inevitably lead to the disappearance of the sea. Billions of tons of salt and hundreds of cubic kilometers of loose deposits will fall on settlements, pastures and fertile land, destroying all ecosystems of the region as a whole. This process will have a planetary impact [1- 4].

In the present paper, we develop ways to improve the environmental situation by selecting effective reagents for fixing salted sand and the dried bottom of the Aral Sea, while sowing the seeds of plants. We present the results of research to obtain a solid water resistant structure (crusts) surface of the salted sand using complex fixers (water-soluble polymer with a production waste - sawdust) in combination with phytomelioration. Research in this area requires finding of cheap, non-toxic and available reagents-fixers.

Earlier, some types of reagents, that can create artificial structures in saline soils and sands were suggested [5 - 9]. As reagent-fixers were tested cheap industrial polymers and production wastes. Securing the salted sand coast of the Kazakhdarya Aral region using complex additives reagents and industrial waste will contribute to the creation of small thickness of sand on a solid waterproof structure (crust able to keep the root system of plants) in combination with phytomelioration. This will allow the use of these areas, as well as dramatically reduce salinization of neighboring fertile land, due to wind erosion.

RESEARCH METHODOLOGY

The used research methods were selected in line with the objectives of the work. These are needed to investigate the physical and chemical properties of moving sands; the formation of structures by water dispersions fixers; interaction far of sand; changing contact resistance between the sand particles; mechanical, thermal, physical water, wind erosion and other properties of the obtained protective coatings.

Gross chemical and salt composition of the objects of research have been identified by the methods described in [10], and particle size distribution of sand samples – with a combined method: sieving to determine particles larger than 0.1 mm, and elutriation – for particles less than 0.1 mm.

The mineralogical composition of raw and fixed complex additive samples of soil and sand were captured on X-ray diffractometry DRON - 2.0 with a copper anti-cathode at a voltage of 30 kV; anode current 3 mA at a rotation speed of the counter - 2°/min and nickel filter [11]. The water resistant structure was characterized by the content of water-aggregates (larger than 0.25 mm) by the method Pavlova [12]. The raw material powder of air-dried ground soil (fraction ≤ 1 mm) were placed in a petri dish, treated with water or an aqueous solution, addition of the additive in water-solid ratio of 1:2, and after two hour soaking the sample was dried at room temperature to air-dry state. Aggregate composition was characterized by the quantitative content in the soil water-stable aggregates (WSA).

EXPERIMENTAL

As objects of study, samples were taken from the moving sands from the coast of the dried bottom of the Aral Sea Kazakhdarya (station number 2 - 15 km from the village Kazakhdarya). The crusts samples were taken from these sites at a depth of 0 - 5 cm. The results for particle size and general chemical analyzes of the samples are given in Tables 1 and 2.

As can be seen from the data in Tables 1 and 2, the samples from the moving sands of the coast of Kazakhdarya are more mineralized. The prevailing water-soluble salts include sodium chloride and sulfates. The content of SiO_2 in the sand sample is 89.24 % and the CaO, MgO, K_2O and Na_2O are 1.11; 0.95; 1.85 and 1.35 %, respectively. The granulometric composition (Table 2) of a sample of the movable sand coast Kazakhdarya is predominantly of particles 0,10 - 0,05 mm.

In this paper, chemically modifying the surface

Table 1. Data for the general chemical analysis of the samples from the mobile sands of Kazakhdarya.

SiO_2	Al_2O_3	Fe_2O_3	SO_3	CaO	MgO	K_2O	Na_2O	l.u.c*	Σ
89,24	2,36	1,89	0,11	1,11	0,95	1,85	1,30	1,20	100,1

* loss upon calcination (950-1000^{0}C).

Table 2. Granulometric composition of the movable sand of Kazakhdarya.

Hygroscopic moisture	Particle content (%) on sieves of fractions (mm)								
	More 0,50	0,50-0,25	0,25-0,10	0,1-0,05	0,05-0,01	0,01-0,005	0,005-0,002	Less 0,002	sum fractions
1,2	tracks	0,8	3,1	90,1	2,2	-	0,9	2,9	100

of the particles of the solid phase with additives a mechanical and water-resistant structure in the sand dispersion was obtained [13 - 16]. In the selection of the reagents – structurants, a fundamentally new approach, was applied. First of all, we abandoned the use of individual polymeric preparations and moved to their combining with sawdust, able to interact with both the polymer and the particles of sand and a salt-containing compound. During this interaction a strong surface (wireframe) crust forms. As a fixative water-soluble polymer MPK-1, which is a modified product obtained by hydrolysis of production waste fiber "Nitron" at 105 - 110^{0}C, for 24 - 48 h, was used. Concentration of polymer in water solution of a product makes 15 - 17%, pH a preparation 7-8.

RESULTS AND DISCUSSION

The experimental results on fixing the salted sand of Kazakhdarya with complex additives, using sand-water soluble polymer binder MPK^{-1}, were carried out at concentrations of polymer solutions 0.1; 0.3; 0.5 and 0.7 % and compositions with sawdust. Fixing of the salted sand Kazakhdarya was performed by treating them with an aqueous solution of the polymer MPK-1, after the sand was crushed and sieved through 0.5 mm sawdust in the amount of 0,26 kg/m^2 with vigorous stirring of the mixture. Surface treatment of the sand was carried out by spray with the polymer solution. In the case of seed and seedling plants salt resistance - spraying was done after sowing. The results for the effect of the compositions on the formation of water-fixer aggregates (WSA) and the mechanical strength of the surface crust are shown in Table 3.

As can be seen from Table 3, the contents of the initial WSA and the sand are low - 6.28 %. Sprinkling the sand surface with water solution of the polymer MPK-1 at concentrations of 0.1 and 0.3% and mixing with sawdust significantly contributes to the strength of the structure and WSA. Thus, the strength of the created structure and WSA sand fixed with 0.1 % polymer solution is 0,62 - 0,79 WSA and 28,38 - 29,39 MPa, respectively, and fixed to sand 0.3 % solution of polymer - 1,30 - 1,46 WSA and 45,00 - 48,44 MPa, respectively. When fixing sand with aqueous solution of the polymer MPK-1 at concentrations of 0.5 and 0.7 % and their compositions with sawdust structure, the strength was increased up to 2,16 - 2,59 MPa for polymer concentration of 0.5 % and up to 2,98 - 3,19 MPa for 0.7 % polymer concentration, and up to 64,24 - 70,65 % WSA and 71,41 - 78,03 %, respectively. We can explain the fixing mechanism of action of complex additives [17]. MPK-1 polymer reacts with the sand particles and in the presence of salts (anions chloride,

Table 3. Influence of the concentration of the MPK-1 polymer solution and its composition with saw-dust (SD) on rate of WSA and the mechanical stability* of the surface crust of the saline sand of Kazakhdarya shore.

№	Concentration of MPK-1 solution	extent of WSA (%) by fractions, mm				Total WSA, %	Strength of crust, MPa
		> 2,0	2,0-1,0	1,0-0,5	0,5-0,25		
1	Untreated	-	-	1,14	5,14	6,28	-
2	MPK-1 0,1 %	0,82	0,85	3,13	23,59	28,38	0,62
3	MPK-1 0,3 %	13,98	8,01	6,95	15,80	45,00	1,30
4	MPK-1 0,5 %	35,05	10,06	10,00	9,16	64,24	2,16
5	MPK-1 0,7 %	42,13	11,92	10,96	7,08	71,41	2,98
6	MPK-1 0,1 % + SD	0,95	1,01	3,24	24,16	29,36	0,79
7	MPK-1 0,3 % + SD	15,75	8,67	7,17	16,87	48,46	1,46
8	MPK-1 0,5 % + SD	38,50	11,21	10,46	10,31	70,65	2,59
9	MPK-1 0,7 % + SD	45,95	14,32	10,66	7,10	78,03	3,19

*Average values of WSA and values of mechanical strength, found from 3 determinations, are listed.

sulfate, etc.) forms gelled products which create a neoplasm in the interphase with allocated spaces in the contact area of particles and adhering to the exposed surface. The role of the adhesive agent is to give strength and water resistance of the formed structure. Relative strength of the structure increases with sawdust polymer, because of dust particles that would play the role of a “reinforcement” in the precipitated polymer phase, not being included in it as a simple mechanical suspension and adhesively interacting with the polymer. This is evidenced by the IR spectra of the created structure. The IR absorption spectra of the treated sand shows an absorption band at 1660 cm^{-1} attributable to an amide carbonyl group, which indicates adsorption of the polymer on the surface of the sand particles.

Thus, the optimal method for fixing saline sands comprises treating of the surface of the sand with a solution of a water soluble polymer MPK-1, while in the sand beforehand are introduced 0.26 kg m^{-2} crushed sawdust (sieved through a 0.5 mm sieve) and mixed. The processing solution of the MPK-polymer is with a concentration of 0.5 - 1%.

Based on the above results on the dried bottom of the Aral Sea a sandy area for conducting field experiments and selecting the most promising for these conditions, plant species typical of Central Asian flora was chosen. The experimental site is located east of the village Kazakhdarya (66 km) from the lake Zhiltirbas (former Bay Aral Sea). Here, moving sand dunes formed by the wind Northeastern rumba have a direction from north-east to south-west. These moving sand dunes are dry, granular, free-flowing and saline. The survey area recorded the following floristic composition: *Tamarix hispida, Heliotropium sp, Calligonum sp, Stipagrostis karelinii, Salsola paulseni, Horaninovia ulicina, Atriplex fominii, Tamarix hispida* which form high hills.

In winter, in special plastic bags under greenhouse conditions 7 species of seedlings with high economic values were prepared [18-19]: *Ammodendron conollyi (Stern, peskzakrepitel), Salsola richteri (medicinal, fodder, peskozakrepitel), Astragalus villosissimus (fodder, medicinal), A. unifoliolatus (stern, peskozakrepitel), A. turbinatus (aft), Pistacea vera (food), Amygdalis bucharica (food)* (Fig. 1). Transplant seedling to the experimental site was carried out in early spring.

The scheme of the experimental field for trees and shrubs was 2x2 m (distance between rows and plant density 2 m). For suffrutescent 1×1m, between trees and shrubs were planted the seeds of herbaceous plants. The windward side surface of the substrate and the experimental plot was pre-treated with sawdust at the rate of 0.26 kg m^{-2}, and was then sprinkled with a solution of 0.5 % polymer MPK-1 0.75 liters of polymer solution per 1 m^2, in order to consolidate the surface of the sand.

During the year, phenomenological observations for the survival and growth of vegetative plants in the experimental plot were carried out. They revealed that the survival of plants at the end of the first year of vegetation was: *Salsola richteri* - 64 %, *Ammodendron conollyi* - 73 %, *Astragalus villosissimus* - 52 %, *A. unifoliolatus* - 48 %, *A. turbinatus* - 46 %, *Amygdalus bucharica* - 76 %, *Pistacea vera* - 44 %. The median

(A)

(B)

Fig. 1. Seedlings of *Artemisia ferganensis* (A) and *Salsola richteri* (B) in conditions of greenhouse.

survival of seedlings and sprouts, despite the high temperature of the surface of the sand dunes (45 - 55°C) amounted to - 57.6 % (Table 4).

Plants developed normally, reach a height of 20 - 25 cm (*Salsola richteri, Amygdalus bucharica*). Phenomenological observations in subsequent years showed that the fruit crops, which have been used by us, were not frost. During the winter in the experimental plot both fruit crops fell. It is established that the pilot area, fenced off from the shield Pragmites australis height of 1.5 m, observed the process of deflation and accumulation of a sand layer 10 - 15 cm thick.

On the experimental plot Kazakhdarya, in addition to these plants, the following species collected from the sandy deserts of Kyzyl Kum and the Ferghana Valley, were planted: *Salsola poletzkiana, Artemisia ferganensis, Ceratoides eversmanniana, Eremosporton aphylum, Elaeagnus angustifolus, Nitraria schoberi, Licium rutenicum, Rosa sp, Alhagi pseudalhagi.*

Most saplings of *Eremosporton aphylum, Elaeagnus angustifolus, Nitraria schoberi, Licium rutenicum, Rosa sp, Alhagi pseudalhagi* by mid-July were killed, and by the end of the vegetation only a few individuals have been preserved.

Of the tested plants 5 shrubs can be identified as promising - *Salsola richterii, Ammodendron conollyi, shrubs - Astragalus villosissimus, Ceratoides eversmanniana, Artemisia ferganensis.* All of these species in the experimental plot showed a high survival rate, good growth and development. Salsola richterii and Artemisia ferganensis by the end of the first year of vegetation, include the generative phase of development. At the end of the third year Artemisia ferganensis height reached 60 cm (Fig. 2), and Salsola richterii up to 300 cm, taking the form of a dense forest (Fig. 3). It should be noted that the height of the three-year vivo specimens Ammodendron conollyi did not exceed 10.8 cm. At the end of experimental plot 3, the vegetation is 60 cm. (Fig. 4).

Thus, the experimental plot in Kazakhdarya revealed a relatively high survival rate of planted seedlings and sprouts. Marked by the highest degree of adaptability to the extreme conditions of the Aral Sea are *Salsola richteri, Ammodendron conollyi, Astragalus villosissimus, Artemisia ferganensis, Ceratoides eversmanniana,* due to their high drought and salt tolerance.

CONCLUSIONS

• It has been shown that the basis of the proposed method for fixing saline sands by a fixer complex is the process of transferring of their surface layers (up to 5 cm) from the free-dispersed state in connected-dispersed by forming a structure (crust), consisting of water-stable macroaggregates – particles > 1.0 mm, having mechanical strength (up to 3.0 MPa) and providing conditions for the cultivation of salt-tolerant plants on

Table 4. Quantity of vegetating plants of Kazakhdarya experimental area for 20.06.2007.

№	Name of plants	Quantity of locules with plants, pcs	Quantity of plants, pcs	Quantity of vegetating plants, pcs	Survival rate, %	Height of plants, cm
1.	*Salsola richteri*	41	233	149	64	10-15 (20-25)
2.	*Ammodendron conollyi*	130	403	296	73	5-10 (15)
3.	*Astragalus villosissimus*	57	228	119	52	5-10 (12)
4.	*A. unifoliolatus*	32	146	76	48	5 (10)
5.	*A. turbinatus*	20	68	31	46	5 (10)
6.	*Amygdalus bucharica*	20	32	25	76	15-25 (30)
7.	*Pistacea vera*	20	75	35	44	15 (20)

Fig. 2. *Salsola richteri* at the dried bottom of Aral Sea.

Fig. 3. *Artemisia ferganensis* at the dried bottom of Aral Sea.

Fig. 4. *Ammodendron conollyi* at the dried Bottom of Aral Sea.

fixed sands.

• The optimal conditions under which the composition fixers exhibit maximum effects of action, as well as the procedure for their introduction into the sand. It has been shown that a composition consisting of 0.26 kg m^{-2} sawdust and 0,008 kg m^{-2} MPK-1 polymer (calculated as dry product that provided using a 0.5 % polymer solution) can be considered the optimum. It promotes a cake having a sufficient high strength of the order of 2.59 MPa, and amount of water-aggregates (> 0.25 mm) in the structure equal 70.65 % vs. 6.28 % in the original.

• Developing comprehensive fixers for chemical reclamation of saline sands combined with phytomelioration with positive results have been proved in the experimental field tests on the coasts of Kazakhdarya dried bottom of the Aral Sea. On the experimental plot in Kazakhdarya a relatively high survival rate of planted seedlings and sprouts was obtained. Marked by the highest degree of adaptability to extreme conditions of the Aral Sea are *Salsola richteri, Ammodendron conollyi, Astragalus villosissimus, Artemisia ferganensis, Ceratoides eversmanniana,* due to their high drought and salt tolerance. Based on the positive results, the complex fixer MPK-1 with sawdust, in combination with phytomelioration, are recommended for implementation.

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