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# Structurants Based on Water-Soluble Surfactants for Fixing Mobile Sands and Soils of the Drained Bottom of the Aral Sea

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**ABSTRACT:** Thus, summarizing, we can conclude that the soils and sands of the Aral Sea are poly mineral and salt-containing, which, depending on climatic conditions and others, have different adsorption characteristics. Accounting for these features when they are fixed is necessary because they determine the duration of the forming crusts. An experimental study of the effect of wind airflow on the mechanical strength of fixed soil and sands of the Aral has been established. Based on the proposed methods for fixing mobile saline sands, optimal conditions for phytomelioration have been established: the mechanical strength of the crust is 2.6-3.0 MPa, the number of water-resistant aggregates is 70-80%.

**KEYWORDS:** Aral Sea, mobile soils and sands, water-soluble surfactant, phytomelioration, Muynak, Kok-Darya, strength of the crusts, water-resistant aggregates.

## I, INTRODUCTION

Arid Central Asia is facing many environmental problems related to water resources, desertification, and salinization. One of the main factors contributing to environmental deterioration is the aeolian distribution of mineral salts and sand from the dried-up lake-bed of the Aral Sea. The transported salt greatly contributes to crop failures, soil and water salinization in the arable lands surrounding the Aral Sea, as well as to impairing human and livestock health. Reducing the amount of mobilized sand and salt is therefore highly relevant and fixating the lake-bed sediments by creating strong surface crusts is an efficient way to minimize deflation and support the stabilization and reclamation of the former Aral Sea [1].

Today, chemical fixing of moving soils and sands is part of the environmental protection problem and applied colloid chemistry, which, among others, is studying the regulation of soil structure, soil stabilization, and obtaining materials with specified colloidal structural characteristics and strength properties [2]. It is known that chemical fixing of moving soils and sands is carried out using various chemical reagents and materials capable of dissolving in water and forming a protective layer-peel (film) on their surface.

Researchers in different countries (Kazakhstan, Turkmenistan, etc.) dealt with the problem of fixing the moving sands of the Aral Sea due to the need for their environmental protection. A great contribution to the development of these studies was made by previous studies [3]. Sand is a system consisting of two phases: gaseous and solid, thus belongs to loose bodies. Sand is a free-dispersed system in which the content of the solid phase is high enough but due to the low adhesion force in the places of contact, the sand particles are able to move under the action of external forces, for example, under the influence of wind. At the same time, fluidization of sand is observed, that is, its flow, spraying. Particles lying on the surface of a layer consisting of the same particles move in three ways: they roll over the surface, break away from the surface and immediately fall back, go into an aerosol state, i.e. as a disperse system with a gas dispersed medium [4].

The aim of the work is to comprehensively substantiate the role of the studied surfactants on the effectiveness of chemical fixing the surface of the solid particles of the mobile sands of the Aral Sea with additives-fixers for obtaining the mechanical and water-resistant structure of the sandy dispersion.

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## II. SIGNIFICANCE OF THE SYSTEM

Thus, summarizing, we can conclude that the soils and sands of the Aral Sea are poly mineral and salt-containing, which, depending on climatic conditions and others, have different adsorption characteristics. The study of methodology is explained in section III, section IV covers the experimental results of the study, and section V discusses the future study and conclusion.

## III. METHODOLOGY

The cost-effective composition and production of suitable chemical reagents, such as water-soluble surfactants based on cheap industrial waste, is, therefore, one of the main tasks of the colloidal chemistry. Having detailed knowledge of the mineralogical, physio-chemical and colloidal characteristics of the surface sediments of the exposed lake-bed is an important prerequisite for engineering the most suitable reagents, which then, in turn, need to be studied for their abilities to create coherent surface crusts and reduce particle mobilization. For this, we used samples of saline mobile soil of the drained bottom of the Aral Sea of the Fisher's Bay (sections 7,8,9,10 - 20-30 km from Muynak), and Muynak bays (sections 2,3,4 - 15-20 km from Muynak ) and sand dunes taken in the area of the Kok-Darya river (the old drained bottom of the Aral Sea - 200 km from Nukus). Samples were taken at a depth of 0-5 cm.

The chemical and salt compositions of soil and sand were determined according to the methods described in (Ganzhara et al. 2002). One of the important indicators of the fixing of soil and sand is its mechanical strength, ie, erosion resistance, and wind resistance. Wind erosion of fixed soil and sands, i.e. the particle ablation, depending on the air velocity, the type, and concentration of the fixative additive, we determined in laboratory conditions in a model aerodynamic installation using the developed technique [5,6].

The water-resistance of the structure was characterized by the content of water-resistant aggregates (larger than 0.25 mm) according to the Pavlov method [7].

## IV. EXPERIMENTAL RESULTS

It is known that the effectiveness of fixing mobile sands depends on their mineralogical, chemical and dispersed compositions, as well as the climatic conditions of their location. Therefore, the study of these indicators for the Aral Sea is considered an important task of scientific and practical value. The results of the general chemical analyze in table 1.

From the table. 1. it is seen that in the soil of the Muynak and Fisher's Bays contains a significant amount of $AI_2O_3$ (9-10%), CaO (10-15%), $Na_2O$ (1-3.5%). Moreover, in the sand of Kok-Darya, their $SiO_2$ content reaches 90%.

**Table 1.**
**The results of chemical analysis of selected samples of soil and sand of the dried bottom of the Aral Sea (Chemical composition, %)**

| Samples | $SiO_2$ | $AI_2O_3$ | $Fe_2O_3$ | $SO_3$ | Cao | MgO | $K_2O$ | $Na_2O$ | ∑ | n.n.n. |
|---|---|---|---|---|---|---|---|---|---|---|
| Muinak Bay: | | | | | | | | | | |
| area №2 | 52.83 | 10.27 | 2.85 | 1.34 | 10.64 | 2.41 | 1.74 | 2.53 | 100.85 | 16.24 |
| area №3 | 47.38 | 9.49 | 2.69 | 4.27 | 13.97 | 3.02 | 1.62 | 2.68 | 100.38 | 15.26 |
| area №4 | 49.73 | 9.72 | 3.27 | 2.93 | 12.20 | 2.77 | 1.80 | 3.23 | 100.42 | 14.77 |
| Fisher's Bay: | | | | | | | | | | |
| area №7 | 40.55 | 10.11 | 13.29 | 1,43 | 10.76 | 3.59 | 1.99 | 3.32 | 10114 | 16.10 |
| area №8 | 46.38 | 8.27 | 13.60 | 2.27 | 10.71 | 2.72 | 1.82 | 1.89 | 100.54 | 12.88 |
| area №9 | 43.48 | 10 92 | 0.88 | 10.69 | 12.05 | 3.67 | 0.88 | 3.24 | 100.20 | 14.39 |
| area №10 | 46.21 | 8.90 | 2.64 | 7.29 | 15.10 | 0.93 | 2.46 | 3.67 | 100.24 | 13,04 |
| Sand Kok-Darya | 89,24 | 2,36 | 1,89 | 0,11 | 1,11 | 0,95 | 1,85 | 1,37 | 100,08 | 1,20 |

According to the results obtainedsoil samples of the Fisher's Bay, especially samples from area No. 9, are more mineralized (up to 46.0%) than Muinak Bay (from 2.6 to 7.0). Chlorides and sodium sulfates are predominant of water-soluble salts. Kok-Darya sand contains 1.9% water-soluble salts.

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The works [8] provide a classification of chemical reclamations used to fix moving sands. They are divided into natural, artificial, synthetic. For economic reasons (due to the need to fix very large areas), reagents based on industrial waste were used.

As additives were tested: a number of water-soluble polymers: K-4, K-9, PVA, PAA and PAA; surfactants – SDB (pulp and paper mill waste), EG (waste oil-fat plant (cotton tar)), soaponaft and apretan (waste non-woven plant); mineral additives - calcium hydroxide and fly ash. Table 2 shows the results of a study of the effect of these additives on the mechanical strength of the resulting crust and the formation of water-resistant aggregates. As can be seen, the EG and SDB additives themselves do not contribute to increasing the strength of the structure, and their composition with CaO, despite their water resistance and mechanical strength, also does not significantly increase the content of water-resistant aggregates (WRA).

To increase the strength of the crust and at the same time save lime and improve the fractional composition of the aggregates, it was proposed to replace lime with ash. At the same time, the strength of the formed structure was increased by 6-8 times. In parallel, the content of water-resistant aggregates was also determined in these systems.

**Table 2.**
**The effect of additive components on the strength of the surface crust and the formation of WRA in the salted sand of Kok-Darya Aral region**

| Additive Components | | | | strength of the crusts, MPa | The number of WRA,%, by fractions, mm | | | | Σ WRA, % |
|---|---|---|---|---|---|---|---|---|---|
| surfactant | | $Ca(OH)_2$, kg /m$^2$ | Ash, kg /m2 | | 2 | 1 | 0,5 | 0,25 | |
| name | Concentration.% | | | | | | | | |
| | - | - | - | 0,00 | - | - | 1,10 | 24,15 | 25,25 |
| K-4 | 0,1 | - | - | 0,58 | 0,50 | 0,50 | 2,30 | 24,10 | 27,40 |
| K-9 | 0,1 | - | - | 0,60 | 0,72 | 0,53 | 3,12 | 23,60 | 27,97 |
| **SDB** | 30,0 | - | - | 0,66 | - | - | 1,86 | 31,80 | 33,66 |
| **SDB** | 30,0 | 0,13 | - | 2,32 | 41,12 | 10,00 | 10,98 | 10,17 | 61,24 |
| SDB | 30,0 | - | 1,28 | 2,82 | 67,62 | - | 1,22 | 6,96 | 75,80 |
| EG | 5,0 | - | - | 0,65 | - | - | 1,96 | 32,74 | 34,70 |
| EG | 5,0 | 0,13 | - | 1,70 | 17,00 | 3,41 | 4,10 | 26,24 | 50,75 |
| EG | 5,0 | - | 1,28 | 1,85 | 18,10 | 3,25 | 3,95 | 25,30 | 52,60 |
| AP | 25,0 | - | - | 2,62 | 14,72 | 6,80 | 0,66 | 2,13 | 54,31 |
| AP | 25,0 | 0,13 | - | 2,02 | 56,20 | 7,50 | 2,35 | 3,89 | 70,06 |
| AP | 25,0 | - | 1,28 | 2,96 | 72,44 | 11,00 | 0,53 | 2,70 | 76,67 |
| SN | 5,0 | - | - | 1,42 | 15,64 | 2,64 | 3,00 | 14,08 | 35,36 |
| SN | 5,0 | 0,13 | - | 1,60 | 28,00 | 3,31 | 4,20 | 15,27 | 50,78 |
| SN | 5,0 | - | 1,28 | 1,62 | 31,30 | 2,78 | 2,18 | 15,48 | 51,64 |

An analysis of the results showed that the largest amount of WRA is formed during the integrated processing of sand by mixing with mineral finely dispersed fillers of aqueous surfactant solutions, and additivity in the effect of the action of the components was not observed. In the absence of lime (or mineral additives containing it), the surface-active substances of SDB or EG do not contribute to the formation of water-resistant aggregates; lime itself, introduced in an amount of 3-5%, provides additional formation of WRA up to 20%, and water (30%) - only up to 11% WRA. This is a consequence of the formation and ingrowth of surface crusts among themselves, consisting of the products of the interaction of $Si0_2$ with lime - calcium hydro silicates.

It should be noted that if the granulometric composition of sand plays a decisive role in the process of fixing it, the mineral composition is not significant, although it is noted that the effectiveness of the action on poly mineral sands and the strength of the resulting crust are higher than on mono mineral quartz and marble sand, similarly as was observed in the case of clay pastes and soil [9,10].

It is interesting that in the case of pure quartz sand, treatment with a complex additive of SDB+lime mainly leads to an increase in the content (up to 42% versus 1.8% in the initial) of large aggregates of the I-2 mm fraction, and in the case

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of pure marble sand it increases sharply also the content of small aggregates (0.25-0.5 mm fraction). If for mixtures with SDB with a small amount of WRA formed, a mechanically strong crust forms, then for mixtures with EG, on the contrary, with an increase to 70-76% of the amount of WRA, neither a strong crust nor macroaggregates arise. This difference in the influence of the studied surfactants is a consequence of the different mechanism of their action on the individual components of the fixed composition “sand - water”, “calcium hydroxide” and, accordingly, different dispersion and localization in the system of interaction products responsible for contact formation.

In our experiments, the best result was obtained for complex organo-mineral additives combining ash, lime (or only ash with a high content of free lime) and SDB, which in optimal dosages contribute to the production of up to 50-60% WAR and the formation of a crust with a strength of 30-40 kg/cm$^2$. Moreover, for convenience, it is recommended to pre-prepare a suspension of ash or clay sediment in the SDB solution and process a sand dispersion with it. In mixtures with ash, aggregates noticeably increase in size and form up to 50-60% of fractions consisting of grains larger than I-2 mm. Surfactants of the SDB, EG, AP, MN type turned out to be more effective - treatment of the soil with their aqueous solutions in combination (complex additive) with calcium hydroxide or ash, made it possible to obtain 50-90% water-resistant aggregates and a fairly strong surface crust.

It is known that liming of soils contribute to a sharp increase in the pH of soil solutions, the replacement of monovalent ions by $Ca^{2+}$ ions in the absorbing complex of soil particles, and, as a result, the strengthening of the soil microstructure and replenishment of the soil organic reserve. As for the other components of complex additives, it follows from what has been said that they must be substances capable of forming any composition (not necessarily chemical compounds) with salts, which should be localized in the structure formed in the soil-salt-$Ca(OH)_2$-additive-water.

As can be seen from the data table. 1 at doses of lime 0.13 or ash 1.28 kg/m2 in the soil, the amount of WRA increases by about 2 times and the surface structure - the crust - is especially noticeably strengthened. The strength of the surface crust in the process of fixing the soil increases to 2.80-3.19 MPa, against 0.56-0.59 MPa in the original. In fig. Figure 1 shows the dependences of the WRA content in the structures formed on the basis of the Aral sands.

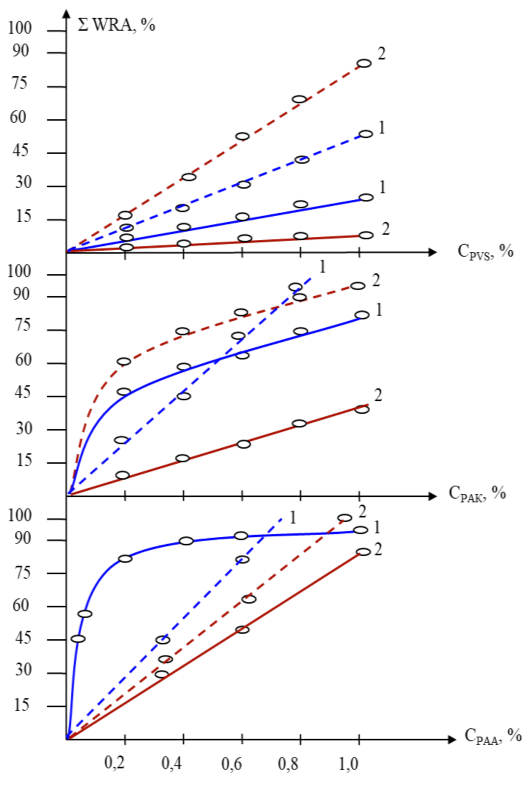


Fig. 1 The dependence of the content of water-resistant aggregates (0.25 mm) in the structure formed on the basis of Aral sands with a content of 1.8% (1) and 6.8% (2) of water-soluble salts on the type and content of polymers. (Designation: dotted line - samples purified from salts).

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The creation of WRA in mobile salted sands is already useful and therefore because they accelerate the salt suction, they clog pores and strengthen the crust due to their crystallization and interaction with additives. It is interesting to note that in sandy soil containing water-soluble salts, the latter affects the effectiveness of the action of structural reagents to a greater extent than the mineral components. Using the example of two sandy samples of similar mineralogical and particle size distribution of the Aral region (Rybatsky and Muynaksky bays) containing 6.63 and 1.87% water-soluble salts, respectively, we studied the effect of monofunctional, with hydroxyl (polyvinyl alcohol-PVA), and carboxyl (polyacrylic acid PAA) and amide (PAA polyacrylamide) groups and polyfunctional groups (K-4 and K-9 polymers) polymers, as well as recommended combinations of reagents for the formation of water-resistant aggregates.

As can be seen from fig. 1 in the case of PAA, especially PAA, the concentration curves of changes in the concentration of WRA for a sand sample with a low salt content (1.8%) are sharply upward in the region of low surfactant concentrations; with an increase in the salt content in sand, the amount of WRA at the same dosages of polymers decreases markedly, and its dependence on the dosage becomes close to directly proportional, the curves become linear.

The smallest amount of WRA is observed in suspensions with PVA in the entire studied concentration range (0.004 ... 0.6% by weight of sandy soil), and the largest - in suspensions with PAA in the same dosages. The presence of water-soluble salts has a different effect on the effectiveness of different polymers. From the results obtained in the study of samples washed from salts, it is seen that in the case of PVA and PAA, the more salts are washed, the higher their structure-forming ability is manifested, and in the case of PAA, on the contrary, the presence of small (up to 2%) amounts of chlorides and sulfates Sodium helps increase its effectiveness.

This may be due to the ability of the solutions of the polymers themselves to interact with salts present in the dispersions. So, if with the addition of the multifunctional water-soluble polymer K-9 containing all the types of the above functional groups and not reacting with salts, the established dependence of the WRA content on the number of salts in the original soil of Rybatsky and Muynaksky is preserved (1.3 and 18.6%, respectively), then for the same dosages.

To increase the efficiency of the use of reagents on saline samples of sand, as well as for soil, it is recommended to combine surfactants or water-soluble polymers capable of interacting with salts with minerals - lime or finely dispersed fillers containing it. In fact, in the case of soil secondly, the formed calcium hydrosilicate, interacting with surfactants obtained on the basis of industrial waste, forms an aggregate of the complex type $SiO_2$ + $Ca(OH)_2$ + surfactant, which has a high surface crust strength.

Consequently, the possibility of the formation of a water-resistant structure in dispersions of salted sands using complex reagents combining finely dispersed mineral lime and a surfactant providing the effect of dispersion hardening was revealed.

At a certain wind speed, particles protruding from a layer of sand begin to roll. These grains of sand, once in the largest recesses, stop. With an increase in wind strength, a certain number of grains of sand begins to roll again. The smaller the size of the sand, the lower the wind force causing their movement tab. 3.

Compared to clay suspensions or soil dispersions, the problem of structure formation in sand dispersions is complicated by a much coarser dispersion and weaker mechanical strength of their particles, this also applies to sand dunes of the Kok-Darya coast of the Aral region with a particle size modulus of 0.85 μm, which were taken by us as objects of research. The salt content in these sands is up to 1.9%. The fixer, in this case, was the same composition as when fixing the soil of the Muinak and Fisher's Bay (Kuldasheva 2019).

The translation of a free-dispersed sand system into a coherently dispersed state, as in the case of soil, is based on the creation of additives in the sand-water system with a water-resistant structure due to the emergence of relatively stronger contacts than simple dispersion forces between particles of a solid phase. The composite additives EG+$Ca(OH)_2$, EG + ash, SDB + $Ca(OH)_2$, SDB+ash used by us were investigated to create a strong surface structure (crust) in the dispersion of Aral sand dune.

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**Table 3.**
**The effect of additives on the intensity of removal of particulate matter from the saline soil of the Fishers Bay**

| Additive Components | | | | Airflow rate (v), m /s | The area of the plate with samples, (S), $cm^2$ | Air purge, (t), c | The difference in sample weight before and after purging (ΔP), g | The rate of removal of solid particles, q · 10-5, kg / $m^2 \cdot s$ |
|---|---|---|---|---|---|---|---|---|
| name | Concentration.% | $Ca(OH)_2$, kg /$m^2$ | Ash, kg /$m^2$ | | | | | |
| - | - | - | - | 61,43 | 103 | 120 | 0,0506 | 4,09 |
| К-4 | 0,1 | - | - | 61,43 | 103 | 120 | 0,04 | 3,23 |
| К-9 | 0,1 | - | - | 61,43 | 103 | . 120 | 0,0377 | 3,05 |
| SDB | 30 | - | - | 62,14 | 103 | 120 | 0,0229 | 1,85 |
| SDB | 30 | 0,13 | - | 61,15 | 103 | 120 | 0,0029 | 0,23 |
| SDB | 30 | - | 1,28 | 61,15 | 103 | 120 | 0,003 | 0,24 |
| EG | 5 | - | - | 61,15 | 103 | 120 | 0,0165 | 1,33 |
| EG | 5 | 0,13 | - | 60,58 | 103 | 120 | 0,0038 | 0,3 |
| EG | 5 | - | 1,28 | 60,58 | 103 | 120 | 0,0039 | 0,31 |
| AP | 25 | - | - | 61,43 | 103 | 120 | 0,0101 | 0,8 |
| AP | 25 | 0,13 | - | 61,86 | 103 | 120 | 0,002 | 0,16 |
| AP | 25 | - | 1,28 | 61,86 | 103 | 120 | 0,0021 | 0,17 |
| SN | 5 | - | - | 61,43 | 103 | 120 | 0,015 | 1,21 |
| SN | 5 | 0,13 | - | 61,86 | 103 | 120 | 0,062 | 0,49 |
| SN | 5 | - | 1,28 | 61,86 | 103 | 120 | 0,06 | 0,48 |

## V. CONCLUSION AND FUTURE WORK

Thus, summarizing, we can conclude that the soils and sands of the Aral Sea are poly mineral and salt-containing, which, depending on climatic conditions and others, have different adsorption characteristics. Accounting for these features when they are fixed is necessary because they determine the duration of the forming crusts. An experimental study of the effect of wind airflow on the mechanical strength of fixed soil and sands of the Aral has been established. Based on the proposed methods for fixing mobile saline sands, optimal conditions for phytomelioration have been established: the mechanical strength of the crust is 2.6-3.0 MPa, the number of water-resistant aggregates is 70-80%.

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