QO‘QON DAVLAT PEDAGOGIKA INSTITUTI ILMIY XABARLARI
(2026-yil 1-son)

TABIIY FANLAR

NATURAL SCIENCES

INVESTIGATION CHEMICAL-MINERALOGICAL COMPOSITION, PORE STRUCTURE, AND MOISTURE RETENTION CHARACTERISTICS OF SOILS UNDER THE INFLUENCE OF ORGANIC ADDITIVES

https://doi.org/10.70728/qdpi.v08.i01.005

[1]Shamuratova M.R., [2]Abdikamalova A.B.,
[3]Eshmetov I.D., [4]Xudayberdiyev J.X.
[1]PhD, doctoral student, [2]DSc, chief research associator, [3]DSc, Head of the Laboratory of Colloid Chemistry and Industrial Ecology of the Institute of General and Inorganic Chemistry of the Academy of Sciences of the Republic of Uzbekistan,
[4]Associate Professor of the Department of Chemistry and Ecology, Kokand State University

Аннотация.В данной работе изучены химико-минералогический состав почвы из двух месторождении районов Южного Приаралья - Кегейли и Халкабад, а также рассмотрены влияние органических добавок на ее пористую структуру и влагоудерживающие способности. Опыты проводились с применением 1%-ных растворов карбоксиметилцеллюлозы и алкилбензолсульфоната натрия в объёмах 4, 6 и 8 мл на 50 г образца. Определено, что во всех исследуемых образцах параметры, рассчитанные по бензолу, оказались выше, чем по воде. Было выявлено, что введение добавок способствует увеличению удельной поверхности и перераспределению пор, улучшая при этом влагоудерживающие свойства, особенно в условиях засоленности, что может иметь практическое значение для улучшения сельскохозяйственных почв в засушливых регионах республики. На основании данных по рентгенодифракционным анализам установлено, что оба образца почв содержат кварц, полевые шпаты, глинистые и другие минералы.

Ключевые слова:минеральный состав, рентгенограмма, дисперсность, карбоксиметилцеллюлоза, алкилбензолсульфонат натрия, почва, изотерма адсорбции, пористость, влагоудерживающая способность.

Abstract. This study focuses on analyzing the chemical and mineralogical profiles of soils collected from Kegeyli and Khalkabad, located in the Southern Aral Sea basin. It examines how organic amendments influence their porous structure and ability to retain moisture. Experiments were conducted using 1% aqueous solutions of carboxymethyl cellulose and sodium alkylbenzenesulfonate in volumes of 4, 6, and 8 ml per 50 g of soil. It was found that, in all studied samples, the parameters calculated using benzene were higher than those with water. The introduction of additives contributed to an increase in specific surface area and redistribution of pores, improving moisture retention properties, particularly in saline conditions, which can be practically significant for improving agricultural soils in arid regions of the republic. X-ray diffraction analysis revealed that both soil samples contain quartz, feldspars, clay minerals, and others.

Keywords: soil structure, X-ray diffraction, dispersion, carboxymethyl cellulose, sodium alkylbenzenesulfonate, adsorption isotherm, porosity, moisture retention capacity.

Introduction.Soil salinization poses a significant challenge for regions dependent on irrigation, particularly in areas experiencing water scarcity and high evaporation rates. Such soils are characterized by deteriorated structure, reduced moisture retention capacity, and degradation of biological activity.

In arid ecosystems where irrigated agriculture is widespread, salinization presents a pressing concern due to its deteriorative effects on soil structure and fertility. The Southern Aral Sea region, particularly in Karakalpakstan, experiences intense soil degradation, reducing its productivity and exacerbating water imbalance.

Comprehensive understanding of the physicochemical behavior of such soils is vital for developing targeted remediation strategies. Recent works [1-4] underscore the adverse ecological consequences of salinization, including diminished moisture retention and biological activity.

The study by Chinese authors [5] highlights that excessive land use leads to soil function degradation and exerts enormous pressure on the ecological environment and agriculture. Mineral extraction and heavy metal pollution have caused numerous adverse effects on soils. Biochar is used for both agricultural and ecological purposes. The material presents a review of recent advances in the influence of various physicochemical properties and applications of biochar, including its use as a catalyst, soil enhancer, water retainer, pollutant adsorbent, gas storage medium, ion exchanger, and soil microbial activity stimulator.

In [6], the adsorption of anionic, cationic, and nonionic surfactants (SAA) on six soil types was studied. The results show that cationic surfactants have higher soil affinity compared to anionic and nonionic ones. A correlation was also established between the soil's cation exchange capacity and maximum adsorption capacity. In paper [7] a comparative analysis was conducted on the adsorption of anionic SAA (sodium dodecyl sulfate) and nonionic SAA (Triton X-100) on 18 soil types with varying organic matter and clay content. It was found that organic matter influences the adsorption of anionic SAA, whereas clay content affects the adsorption of nonionic SAA.

Study [8] investigates SAA and polymer adsorption on sandstone and their effects on surface morphology and wettability. It was shown that SAA adsorption significantly alters surface wettability, while polymers have a lesser impact.

Research on the chemical-mineralogical composition and moisture retention properties of degraded soils is an important step toward developing effective restoration and improvement methods [9]. One way to enhance soil moisture retention capacity is by introducing organic additives, such as the modified polymer carboxymethyl cellulose (CMC) and surfactants like sodium alkylbenzenesulfonate (sulfanol). Study [10] pays special attention to carboxymethyl cellulose as one of the key polymers used to improve soil structure. The findings demonstrate how CMC affects the soil's plastic strength and enhances its physical properties.

The aim of the present research is to assess the modification of soil pore structure and water-holding capabilities under the influence of organic compounds, namely CMC and SABS, using a series of comparative experiments.

Experimental Part

Samples were collected from saline territories within different agrozones of the republic. In the lab, soils were treated with aqueous solutions (1%) of CMC and SABS in variable volumes (4, 6, and 8 ml per 50 g of air-dried soil). Post-treatment, samples were dried at 60°C for five hours to stabilize, then prepared for physicochemical characterization.

Moisture content was monitored in 1 mm soil fractions. Results showed moisture before and after drying as 3.50% and 4.07% (KS), and 0.70% and 0.89% (KhS).

The pore structure is characterized by several key parameters sufficient for its evaluation: porosity and specific total pore volume, specific surface area of the porous system, characteristic pore sizes, and pore size distribution [11]. The particle size distribution (PSD) determines the relative content of various soil particle fractions from sand to clay (from 10 μm to 1 mm) and is one of the main factors influencing soil moisture retention and permeability [12].

In this case, the particle size distribution was determined by the sieving method, which is based on mechanical separation of particles by size using sieves or mesh with varying aperture sizes. A soil sample is placed on the top sieve of the set, and the entire stack is shaken on a mechanical shaker for 10–30 minutes. The remaining material on each sieve is weighed, and the output of each fraction in grams and as a percentage of the total sample mass is recorded in a table. The resulting particle size distribution data for KS and KhS soils are presented in Table 1.

Table 1

Sieve analysis data of KS and KhS soil samples

Size of sieve holes, mm	Product yield			
	KS		KhS	
	g	%	g	%
1,25	207,94	69,29	210,22	76,28
0,63	49,09	16,36	31,75	11,52
0,315	31,21	10,40	20,04	7,27
0,16	0,10	0,033	3,61	1,31
< 0,16	11,73	3,91	9,98	3,62
Total:	300,07	100	275,60	100

Soil texture was assessed via mechanical sieving. Cumulative weight fractions were calculated and used to categorize soil types. According to modified granulometric interpretation based on Kachinsky's principles [13], KS soil was classified as sandy loam due to its sand particle dominance (>85%). KhS soil followed a similar pattern.

Analysis of the chemical and mineralogical composition of soils. The composition of the soils was analyzed using the X-ray diffraction method with a Rigaku MiniFlex 600 X-ray diffractometer at an angle of 2θ (in degrees) and intensity (cps). For interpretation, the database of the International Centre for Diffraction Data (ICDD) and standards from the American Society for Testing and Materials (ASTM) [14] were used. **X-ray scanning and preliminary processing of obtained data.** X-ray diffractograms of the initial soils from the KS and KhS locations are illustrated in figures 1 and 2, respectively.

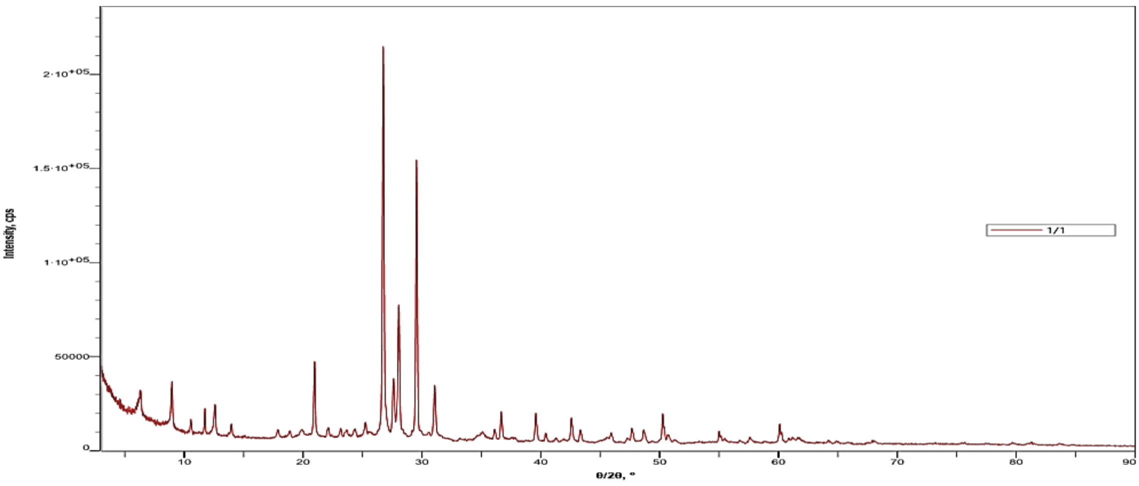

Fig. 1. X-ray diffraction of the source soil of the KS deposit

The results of the X-ray diffraction analysis revealed characteristic peaks of silicate minerals in the samples, such as quartz, feldspars, clays, etc. On the X-ray diffractogram of the initial KS soil, intense peaks were identified in the 20–30° 2θ range, characteristic of quartz (SiO_2). A peak at 29.52° 2θ corresponds to calcite ($CaCO_3$), while peaks at 11.73° and 20.95° indicate the presence of gypsum ($CaSO_4 \cdot 2H_2O$). Peaks in the ranges of 5.42°–5.97° and 27.6°–28.05° may correspond to montmorillonite (a type of clay), 12.57° and

12.59° to kaolinite ($Al_2Si_2O_5(OH)_4$), and 8.96° and 26.72° to illite (another clay mineral), among others (Fig. 1).

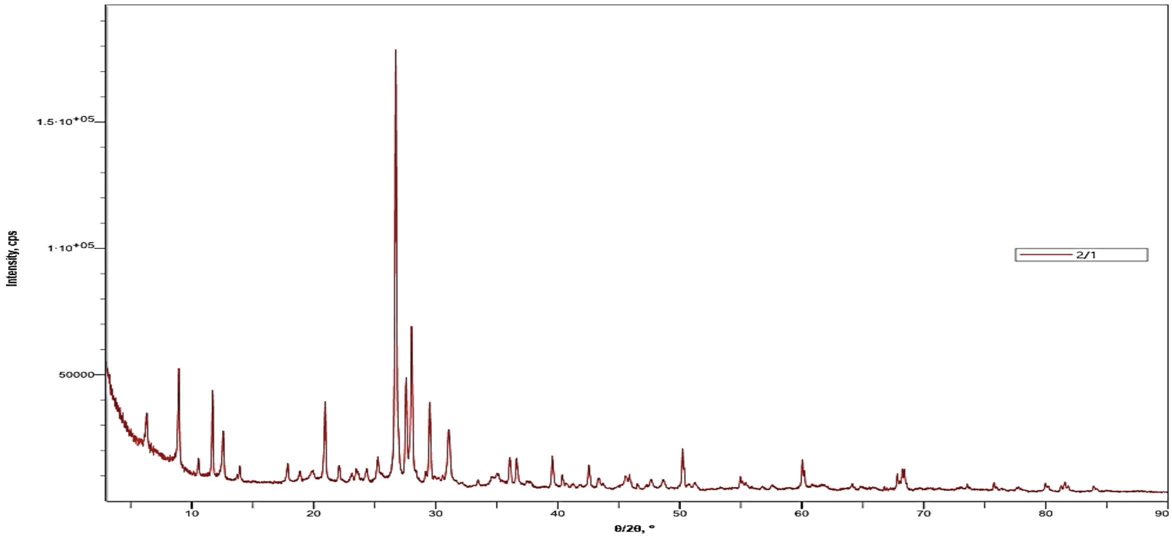

Fig. 2. X-ray diffraction of the source soil of the XS deposit

The analysis of the X-ray diffraction pattern of the initial KhS soil shows intensity peaks corresponding to quartz (SiO_2) at 20.92°, 26.70°, 26.90° and 50.19°; calcite ($CaCO_3$) at 29.49° and 39.52°; and gypsum ($CaSO_4 \cdot 2H_2O$) at 11.69° and 20.92°. Peaks associated with montmorillonite appear at 5.40°–5.99° and 27.56°–27.99°, kaolinite at 12.56° and 12.58°, illite at 8.57°–8.94°, 26.70° and 26.90°, and smectite at 5.91°–6.46° and 27.56° (Fig. 2).

In both cases, the compositions are quite similar, but the KhS soil sample contains higher amounts of quartz and calcite, as well as slightly different ratios of clay minerals.

Water and Benzene Vapor Adsorption Isotherms on Soil Samples. The pore structure and moisture retention capacity of soils play a crucial role in their agrophysical properties. In saline soils, water retention and moisture infiltration often present challenges due to high salt content. Significant improvements in these characteristics can be achieved by applying organic additives in specific doses.

Water and benzene vapors were used as sorbates to account for differences in molecular polarity and size. Adsorption isotherms of water and benzene vapors were obtained using the desiccator method at a temperature of 20–25°C. Textural parameters such as surface area, pore volume, and radius were derived using the standard BET methodology based on the obtained adsorption isotherms. To determine the pore structure and moisture retention capacity of soils, samples were prepared by adding 4, 6, and 8 ml of 1% aqueous solutions of CMC and sulfanol to 50 g of soil. The treated soil was placed in metal cylinders (ring diameter – 30 mm, height – 50 mm), then dried at 60°C for 5 hours. Pore structure and moisture retention capacity were assessed using the desiccator method, which is based on the equilibrium of soil moisture with water vapor in a desiccator at a given pressure or humidity. Sample mass changes were recorded daily. All calculations were performed using Origin software and referenced sources [17]. The results of water and benzene vapor adsorption on the studied samples are presented in Table 2.

Analysis of water vapour adsorption on KS soil showed isotherm curves, which first increase sharply from p/p_o = 0.18 to p/p_o = 0.46 relative pressure and then increase intensively in the saturation region p/p_o = 0.86-1.0. In the case of an KhS soil sample, a similar picture is shown, but with the lowest sorbent values. The graphical data from the adsorption of benzene vapours on the source soils KS and KhS indicate an increase in the amount of adsorbents at high relative pressures, compared to the adsorption of water vapours. This is due to the fact that benzene has larger pores and less polar areas, as it does not interact with hydrophilic microphones where sorption of water is particularly pronounced.

All samples were conventionally labeled as follows: $KSW_{orig.}$, $KhSW_{orig.}$, $KSB_{orig.}$, $KhSB_{orig.}$, KSCW, KSSW, KhSCW, KhSSW, KSCB, KSSB, KhSCB, KhSSB.

Table 2

Parameters of the porous structure calculated by BET based on water and benzene vapour adsorption isotherm on the soil samples

Sample name	Monolayer capacity am, mol/kg	Specific surface area Sssa, m2/g	Total volume of pores Wo, sm3/g	Median pore radius rm, Å
$KSW_{orig.}$	0,426	27,7	0,033	24,2
XSWorig.	0,377	24,5	0,032	25,7
KSBorig.	0,454	109,4	0,176	32,1
XSBorig.	0,422	101,7	0,164	32,3
KSCW	0,768	49,9	0,066	26,5
KSSW	0,718	46,7	0,066	28,2
KhSCW	0,760	49,4	0,067	27,0
KhSSW	0,720	46,8	0,068	29,2
KSCB	0,513	123,5	0,287	46,5
KSSB	0,686	165,3	0,254	30,8
KhSCB	0,715	172,2	0,322	37,4
KhSSB	0,626	150,8	0,309	40,9

The results presented in Table 2 show a significant difference in the surface area, total volume and mean radius of the pores obtained from water and benzene vapour sorption. In all the samples studied, the parameters calculated for benzole were higher than for water. The specific surface area (S_{ssa}) for benzene was 2-4 times higher than the corresponding values for water. Particularly pronounced increase was observed in samples with additives - KSSB and KhSCB, which indicates the formation of additional volume available for sorption of less polar pores. This may be due to the partial displacement of capillary-bound water and the exposure of meso- and macroporous structures. The total pore volume (W_o) for benzene was also significantly higher than in water. In particular, in the samples of KhSCB and KSCB this rate increased almost 3 times, which confirms the formation of a more developed porous structure with a predominance of wide pores into which benzene can penetrate without restriction. The median pore radius (r_m) determined by benzene was in all cases higher than water, reflecting the ability of benzene to penetrate a wider range of pores - including hydrophobic and less polar ones that are inaccessible to water.

Conclusion. The use of benzene as a probe in the BAT method allows to characterize more fully the porous structure of the soils studied, especially their physico-chemical properties under the action of organic additives. The data obtained show that organic additives contribute not only to increase the total pore space, but also to change the nature of the pores, which is confirmed by the difference in the sorption behavior of water and benzene. The results of this study confirm the effectiveness of the use of CMC and sulfonyl to improve the agronomic characteristics of the soil samples studied. This data can be used to develop effective methods for the reclamation of these saline lands.

The granulometric analysis showed that the soil of the KS field contains more than 85% of sand particles, and the soil of KhS 76% of sub-sand particles. It was determined that KS contains more clay minerals such as kaolinite, montmorillonite, illite, which affect its water retention capacity. High levels of halite and gypsum have been found in the soil of the KhS deposit, indicating a high level of salinity and potentially low water retention capacity.

List of references

1. Kholmirzaeva M., Kuchkarova M.N., Kuldasheva Sh.A., Abdurakhmonova F.A., Agzamkhodjaev A.A. Chemical fortification of some saline sands of the Aral Sea using complex additives. Republican Scientific and Practical Conference "Science and Technology of Chemical Education in Uzbekistan", 2002. Tashkent, p. 238-240.

2. Nauryzbayeva Z.S. Analysis of degraded soils in the conditions of Karakalpakstan. Universum: chemistry and biology: Scientific Journal. 2021. Vol.9(87)

3. Abdikamalova A., Abdurakhimov D., Ismailov B., Seytnazarova O., Iembergenov B. Hydrolysis of polyacrylamide and investigation of characteristics of its hydrolyzed forms. *AIP Conf. Proc.* 11 March, 2024, 3045 (1): 030061. https://doi.org/10.1063/5.0197882

4. Kuldasheva, S., Abdikamalova, A., Eshmetov, I. *et al.* Investigation of changes in the viscosity properties of acrylamide (co)polymer and their hydrolyzed forms depending

on the conditions of their preparation. *Polym. Bull.* (2023). https://doi.org/10.1007/s00289-023-04875-6

5. Yafu Zhang, Jinman Wang,Yu Feng. The effects of biochar addition on soil physicochemical properties: A review. Catena. Volume 202, July 2021, 105284. https://doi.org/10.1016/j.catena.2021.105284

6. Li K, Liu H, Ma Y, Zhang Y, Liu W. Adsorption characteristics of three types of surfactants in soils. Ying Yong Sheng Tai Xue Bao. 2004 November; 15(11):2067-71. Chinese. PMID: 15707314.

7. Rodríguez-Cruz M.S., Sanchez-Martin M.J. , Sanchez-Camazano M. A comparative study of adsorption of an anionic and a non-ionic surfactant by soils based on physicochemical and mineralogical properties of soils. Chemosphere. Volume 61, Issue 1, September 2005, pp. 56-64

8. Yahya Al-Wahaibi; Abdul-Aziz Al-Hashmi; Sanket Joshi; Nader Mosavat; Svetlana Rudyk; Sami Al-Khamisi; Thuraya Al-Kharusi; Hanaa Al-Sulaimani. Mechanistic study of surfactant/polymer adsorption and its effect on surface morphology and wettability. Society of Petroleum Engineers - SPE Oil and Gas India Conference and Exhibition, Apr 4 -6, 2017, Mumbai, India, pp. 594-609

9. Abdikamalova A., Tanatarov O., Seitnazarova O., Allamuratova A., Shamuratova M. Study of the physical and chemical characteristics of soils in Karakalpakstan. E3S Web of Conferences, Volume 537, id.03006. I International Scientific and Practical Conference «Sustainable development of the environment and agriculture: green and environmental technologies» April 24-26, 2024. Ekaterinburg, Russia

10. Tanatarov O.R., Dauletbaeva R.K., Shamuratova M.R. Abdikamalova A.B., Eshmetov I.D., Kuldasheva Sh.A. Investigation of the influence on solid characteristics of mineral and polymer structural formers. Scientific technical journal “Central Asian Food Engineering and technology”. Volume 2, Issue 5, May 2024, ISSN: 2181-385

11. Fandeev V.P., Samokhin K.S. Methods of investigation of porous structures// online journal «Science». Tom 7, №4 (2015) DOI: 10.15862/34TVN415

12. Salugin A. N., Ryzhova T. A. Hydrophysical characteristics of the soil and movements of moisture in the zone of aeration. Izvestia of NvAUC. 2020. 3(59). 152-162 DOI: 10.32786/2071-9485-2020-03-15

13. Kachinskiy N.A. Classification of soils by granulometric composition. https://bigenc.ru/c/granulometricheskii-sostav-pochvy-d1cdec

14. International centre for diffraction data. Comprehensive Mineral Collection. https://www.icdd.com/pdf-4-minerals/

15. Greg S., Sing K. Adsorption, specific surface, porosity: 2nd edition - M.: Mir, 1984. - 306p.