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Investigation of Water Solubility of Soil Minerals in the Navbakhor District of Navoi Region

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Abstract. The article delves into the application of IR-spectroscopic, chemical, and X-ray diffractometric methods to assess the mineralogical composition and salinity levels of soil samples collected from Navoi city and Navbakhor district, specifically the settlement of Shurkishlak. Through these studies, the researchers were able to discern the salinity characteristics of the region's old-irrigated soils.Findings indicate a predominance of carbonate salinity in Navoi city, while the Navbakhor district exhibits a notable prevalence of sulfate salinity, surpassing carbonate levels. Additionally, a third salinity type, characterized by chloride, is identified. Importantly, all observed soil minerals demonstrate varying degrees of water solubility, presenting in ionic form within aqueous soil extracts.These insights shed light on the soil composition and salinity dynamics of the studied regions, providing valuable information for agricultural planning and soil management strategies. Understanding the mineralogical composition and salinity profiles of soils is crucial for optimizing agricultural practices and ensuring sustainable land use in Navoi city and Navbakhor district.

1. Introduction

The Zarafshan River, which includes the territories of Samarkand, Navoi and Bukhara regions, is located in the Turan lowland, occupies the central part of Central Asia, borders the Republic of Kazakhstan to the north, the Republic of Turkmenistan to the south, the Republic of Karakalpakstan to the west, and the Samarkand and Kashkadarya regions of Uzbekistan to the east [1-2].

With its varied surface structure, the Zarafshan Valley is situated between the Kyzylkum Desert and the Pamir-Alai ranges. The soil-forming rocks are alluvial deposits of the Zarafshan River, mainly heavy and medium loamy, sometimes with layers of sandy and gravel-sandy composition, underlain by pebbles from a depth of 2-4 m [3-4].

Soil is a natural substance and the main means of production in agriculture. The main thing in the soil is its fertility. Living organisms, in particular green plants and microorganisms, play an important role in the formation of fertility. Agriculture is conducted on the so-called, gray-brown soils of the desert zone. However, due to severe reclamation conditions (tendency to salinity, plastering, compaction, leaching) they are used to a lesser extent [5-8].

Rocks that produce soil include sandstones, conglomerates, eluvial, proluvial, and gravelly pebble deposits, as well as loess-like loams and salt deposits. Although certain rain-fed light gray soils include horizons that are moderately to severely saline, the majority of these soils are not saline [9–13].

The mineralogical composition of the soils in the Navoi region is typified by a combination of primary and secondary minerals that first developed from rock-forming minerals. Integrated production management methods that support the health of the agro-ecosystem and are socially, ecologically, and economically sustainable are required to safeguard these types of soils from degrading processes while preserving their high production potential [14–16].

Therefore, to study the degree of preservation of the soil system from degradation processes, the following analysis methods were used: determination of the IR spectroscopic, mineralogical and chemical composition of soil in the

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Navoi region. The task of the research is to investigate the water solubility degree of soil-forming minerals, the presence of carbonate, sulfate and chloride ions in the water extract, as well as to determine the one of the three types of salinization[17-121].

2. Materials and Methods

Navbakhor district is situated in the oasis of the river "Zarafshan", bordering Kanimekh districtand the Kyzylkum desert. The Zarafshan River provides irrigation for agricultural cultivation within the boundaries of the Navbakhor district. Soil samples from the Navbakhor district and Navoi city were the subject of the study (Shurkishlak settlement, 22 km north-west of Navoi city. The word"shur" in Uzbek means salt).

The procedure for choosing soil samples was as follows: a 1 m^2 plot was made and split into three sections: the middle horizon (soil thickness: 2–10 cm), the lower horizon (10–30 cm), and the upper, saline horizon (soil selection to a thickness of 0.2–0.5 cm). Soil samples were sifted through a 1.0 mm mesh screen and dried at 50 °C in a drying cabinet for 48 hours. The choice of soil layers from 0 to 30 cm is justified by determining the degree of distribution of water-soluble minerals at this depth, as well as the distribution of the main part of the root system of cultivated plants at this soil level. A soil sample from Navoi served as the control spot. In order to ensure that the degree of salinity was roughly the same when visually assessing the morphological structure of the site appearance, the sampling process was done as close to homogeneously as feasible.

Salt crust, for example, is a more or less complex of "salt minerals", mainly chlorides and sulfates of sodium, potassium and magnesium, which can be both simple and complex in composition. Along with them, they include in their composition non-salty components that make up an insoluble salt residue, which include rock-forming minerals. A comparative analysis of the chemical composition of soil samples was carried out by two methods, including the dissolution of compounds with hydrochloric acid and aqueous methods. Acid dissolution makes it possible to determine the total volume of compounds contained in the soil, and water-soluble salts, mainly of alkaline and alkaline earth elements, are released into the aqueous extract.

Preliminary sampling of soil samples from the planned regions was carried out in accordance with GOST-28168-89.

To perform experiments on chemical analysis of soil samples, it was decided to determine the total amount of calcium oxides, phosphorus and sulfate ions in the soil using the acid analysis method. Analysis of compounds of productive elements-phosphorus and calcium from the soil is based on the method of extraction of mobile compounds of phosphorus and calcium from the soil with a solution of hydrochloric acid of molar concentration c (HC1)=0.2 mol /dm3 with a soil-to-solution ratio of 1: 5 for mineral horizons and subsequent determination of phosphorus in the form of a blue phosphorus-molybdenum complex on a photo electro colorimeter and calcium on a flame photometer [22]. Taking into account the practice of irrigation farming in these regions, it is interesting to study the degree of release of sulfate and chloride salts, as well as calcium and magnesium ions, into the water extract. This standard (GOST 26425-85) establishes methods for determining the chloride ion in water extract from saline soils during

soil, agrochemical, and land reclamation surveys,

monitoring the state of the salt regime of soils, and other survey and research activities.

With the standard GOST 26426-85 establishes methods for determining the sulfate ion in water extract from saline soils during soil, agrochemical, land reclamation surveys, monitoring the state of the salt regime of soils, as well as during other survey and research works.

GOST 26428-85 establishes methods for determining calcium and magnesium in water extracts from saline soils during soil, agrochemical, and land reclamation surveys, monitoring the state of the soil salt regime, and other survey and research activities .

Determination of the chemical composition of water extracts and the composition of ground water for saline soils was determined according to the Industry standard OST 46-52-76 / 1976 N 173 10 c- " Methods of agrochemical analysis of soils. Determination of the chemical composition of water extracts and the composition of ground water for saline soils ".

The concentration of dissolved solids (RSV) was analyzed by a refractometric method based on the refractive index and some of its functions. Refractometry of compounds for the determination of chemical compounds, quantitative and structural analysis, determination of physico-chemical compounds, concentration of soluble metal salts (chlorides, phosphates, sulfates, etc.).

Samples were prepared for IR spectroscopic examination using a pressed tablet method in KBr and an IR-Fourier spectrometer (IR-100) manufactured by SHIMADZU (Laboratory of NMTU, Department of Chemical Technology). The wavelengths of infrared light that fall between 400 and 4000 cm^{-1} are antisymmetric and correspond to the absorption bands. In accordance with Nakamoto's monograph [23], a comparison of functional groups of elements was conducted.

A diffractometer was employed to conduct X-ray diffraction analysis, which was carried out to ascertain the mineralogical composition of soil samples. The X-ray diffraction phenomena on a three-dimensional crystal lattice is the basis for this technique. The technique allows one to ascertain the size, shape, and spatial group of a unit cell, in addition to the symmetry group of a crystal, thereby providing information about the atomic structure of a given material. Prior to doing the analysis, the soil sample was ground, well mixed, and an average sample with an average content was obtained in order to ascertain the crystal lattice and shape of the minerals. A prepared powder's X-ray diffraction pattern was obtained on "a Panalytical Empyrean diffractometer with 0.01 to 2theta steps from 4 to 80 2theta degrees using a "Scintillation" detector. Quantitative X-ray phase analysis was performed by the Rietveld method and performed using the Profex-Open source XRD and Reitveld Refinement software" [24].

3. Results and Discussion

It is conceivable to create a chemically dependable, repeatable, and standardizable approach for analyzing different systems based on the findings of infrared spectroscopy [16-17-17].

A study of the composition of soil salts in Navbakhor district of Navoi region showed the location of peaks of carbonates, sulfates, and chlorides (Figure 1) with localization of functional groups inherent in carbonate ions in the form of CH groups at lengths of 2900 cm^{-1} and CO at wavelengths of 2500 cm^{-1}. There were three different types of soils: medium-salty, less salty, and normal soil, where the presence of these functional groups was even less noticeable. The functional groups that are typical of CH bonds were found at 2900 cm^{-1} peaks. In somewhat salinized soil, the CH peak was essentially undetectable. The SO and SH groups, which were found at wavelengths of 1800 cm^{-1} and 2400 cm^{-1}, were identified as the functional groups typical of sulfate ions. In addition, the SO group is identified at a fairly broad peak that falls between 900 and 1200 cm^{-1} in wavelength. ClO and O-Cl-O groups were used to characterize molecular interactions for the intrinsic functional groups in chlorides. These functional bonds were primarily localized at wavelengths of 900, 800, and 500 cm^{-1} (Figure 1). Because of the existence of crystal hydrate linked water, the hydroxyl group O-H, which was typical of the Navbakhor region, has a large peak at wavelengths of 3800-3000 cm^{-1}.

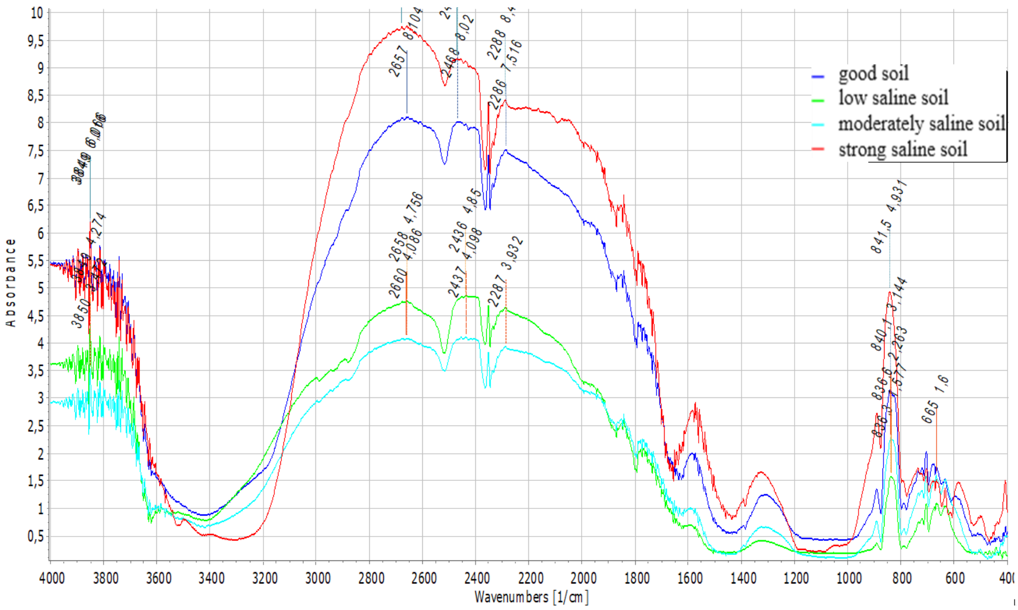

Fig. 1. IR spectroscopic appearance of soil structures in Navbakhor district (40.258977, 65 439654) of Navoi region.

The hydroxyl group (OH) in organic and organomineral compounds, clay minerals, and whole water molecules of crystal hydrates, primarily salts (hemihydrate), -$CaSO_4$*½H_2O, gypsumom – $CaSO_4$*2H_2O, and mirabiliteom – Na_2SO4 * 10H_2O, are examples of such chemically bonded water. The characteristics of a solvent do not apply to crystal hydrate water, which is a component of the solid phase of soil and not a separate physical entity [10]. Analysis of the water extract assumes the water solubility of salts and the direct effect of hardness salts directly on the root system of plants. When analyzing the results for water extract, the solution was dominated by sulfate ions from 0.427 to 0.776 g / l, instead of 0.262 in Navoi. The amount of chlorine ions in the salt crust was 1.144 g / l, instead of 0.026 g / l. The amount of calcium and magnesium ions was also quite high and amounted to 1.4 and 2.379 g / l instead of 0.21 and 0.24 g / l in Navoi. The total study of the amount of dissolved dry substances (RSV) in water extracts showed 0.6% in the initial version from Navoi, and in soil samples from Navbakhor for the salty crust (0.2-0.5 cm) was 7.5%, for the medium-salty part (2-10 cm) - 1.2%, and for the satisfactory part of the soil (10-30 cm) – 2.5%.

Table 1. Comparative analysis of the chemical composition of soils and their water extracts (Navoi region, Navoi city and Navbakhor district)

Districts	Soil condition	Acid treatment			Water extraction, (g/l)				RSV, %
		CaO, total.,%	P_2O_5, total, %	SO_3, g / l	SO_4^{2-}	Cl^-	Ca^{2+}	Mg^{2+}	
Soil from Navoi, good		7.32	0,446	0,442	0,262	0,026	0,21	0,240	0,6
Navbahor	Udovl. (10-30 cm)	5.367	0.046	18.3	0.585	0.301	0.9	0.488	2.5
	Medium-salted (2-10 cm)	8.4	0.159	1.121	0,776	0,027	0,2	0,025	1,2
	Salty crust (0.2,2-0.5 cm)	7.328	0.146	6.18	0.427	1,144	1,4	2,379	7.5

Thus, the study of acid and water dissolution of soil samples from Navoi city and Navbakhor district showed the predominance of chloride salinity (1.144 g/l), then sulfate salinity (0.776 g / l), and the total dissolution of these salts averaged more than 3%, instead of 0.6%. The amount of dissolved solids (RSV) confirmed a high content of chlorides and sulfates. The high content of calcium and magnesium ions in the salty crust of the soil, equal to 1.4 and 2.44 g / l, suggests the formation of compounds in the form of calcium and magnesium chlorides and sulfates in the soil solution.

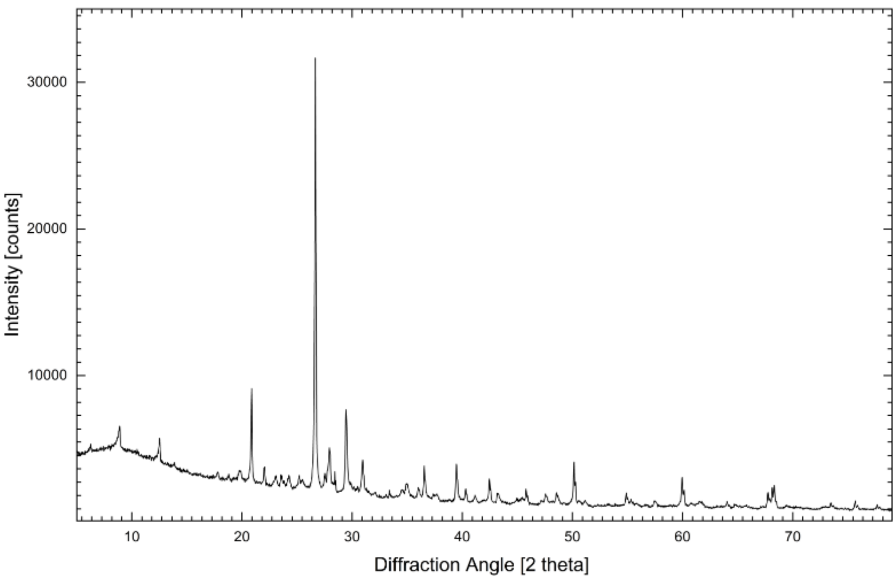

Fig. 2. Diffractometric diagram of a sample of normal soil from Navbakhor district (Shurtepa settlement).

A crucial factor in determining the existence of soil minerals in soil samples examined by X-ray diffraction techniques is the radiation's degree of absorption. It establishes the X-ray's penetration depth and flaw detection capabilities. From this vantage point, the crystals and molecules of different soil minerals are the most typical examples of crystals with weak absorption. An X-ray diffractometric study of soil from Navoi city, on the grounds of Navoi Mining and Technological University (NSTU), revealed that quartz accounts for 37.3% of the soil's mineral content, with muscovite (19.4%) and albite (15.3%) following closely behind. Next come chlorite (7.3%) and calcite (11.2%). Within the experimental error range, the remaining minerals—actinolite, rutile, gypsum, dolomite, astrakhanite, and microcline—are found in negligible proportions. The mineral halite is absent in soil samples from Navoi. All soil minerals are formed from rock-forming minerals.

Analysis of soil samples from Navbakhor district (Fig. 2) showed the predominance of the soil mineral quartzite in the amount of 35.4 %, muscovite – 18.1%, albite – 12.3%, calcite – 10.7%, astrakhanite – 6.2%, dolomite and microcline in the amount of 3.6 and 4.4%, halite – 1.4%.

An elementary X-ray diffractometric diagram of a satisfactory soil sample from the Navbakhor district looks like this in Figure 2, where peaks of various minerals are indicated, and the interpretation of these peaks is presented in Table 2.

Results of the X-ray diffractometric method of analysis of soil samples of Navbakhor district (tab. 2), where the dominant mineral in all soil samples is quartz (SiO_{SiO2}), the amount of which is from 27 to 38 %, the second place in quantitative terms is the mineral muscovite ($[KAl_2(AlSi_3O_{10}(FOH)_2]$) in an amount of 6.5 in a salty crust or more in medium-saline and normal soils - 18%.

Table 2. X-ray diffractometric mineral composition of soil samples from Navbakhor district (Shurkishlak settlement).

Mineral	Formula	Satisfactory ground (10-30 cm) %	Medium-salted ground (2-10 cm) %	Salty crust (0.2-0.5 cm) %
Quartz	SiO_2	35.4	37.8	26.9
Chlorite	$(Mg.Fe)_3(Si.Al)_4O_{10}(OH)_2 \cdot (Mg.Fe)_3(OH)_6$	6.0	6.8	0
Albite	$NaAlSi_3O_8$	12.3	13.1	8.6
Calcite	$CaCO_3$	10.7	12.5	7.3
Muscovite 2M1	$[KAl_2(AlSi_3O_{10}(FOH)_2]$	18.1	18.6	6.5
Gypsum	$CaSO_4 \cdot 2H_2O$	0.5	0.7	1.6
Dolomite	$CaMg(CO_3)_2$	3.6	3.0	2.8
Microcline	$(KAlSi_3O_8)$	4.4	5.6	3.5
Astrakhanite	$Na_2Mg(SO_4)_2 \cdot 4H_2O$	6.2	0.8	3.6
Coquimbite	$AlFe_3(SO_4)_6(H_2O)_{12} \cdot 6H_2O$	1.1	1.0	0
Thenardite	Na_2SO_4	2.3	4.80	34.3
Kokim bit	$(Mg.Fe)_3(Si.Al)_4O_{10}(OH)_2 \cdot (Mg.Fe)_3(OH)_6$	0	0	4.5
Rutile	TiO_2	0	0	0.1
Sylvine	KCl	0	0.2	0
Halite	NaCl	1.8	0.0	0.4
Кварц	SiO_2	35.4	37.8	26.9

Then there is albite ($NaAlSi_3O_8$) in the amount of 8.6% (salty crust) to 13% in medium-salty and satisfactory parts of the soil. The mineral chlorite in the deeper layers of the soil from 10 to 30 cm is distributed evenly in the amount of 6.0-6.8%, and in the salty crust it decreases to 4.5%.

A distinctive feature of different soil layers is the additionof the mineral thenardite($NA2SO4_4$) in an amount of 34.3%, which indicates a significant sulfate salinity of the salt crust.

To summarize the degree of salinity, minerals with the presence of carbonate, sulfate, and chloride ions were isolated from the minerals listed in Table 2. Table 3 shows the results of the presence of minerals bearing carbonate, sulfate, and chloride ions.

The mineral calcite, which makes up 11.2% of the total mineral content in Table 3, indicates that the carbonate type of salinity is predominant in Navoi. Sulfate salinity is only 1.0%, which is a negligible amount. A normal soil sample from Navbakhor (Shurkishlak) is represented by a slightly overestimated amount of carbonates in the range of 10-15%, instead of 11% in Navoi. The nature of sulfate salinization is interesting by the addition of the mineral tenardite – sodium sulfate, which is found in high amounts in the salty crust in an amount of 34.3%. When compared with the original soil from Navoi (1.0%), the amount of sulfates is quite high and exceeds the initial amount from 7 to 34 times. There is no chloride salinization in the initial soil sample from Navoi, however, two minerals appear in soil samples from Navbakhor – halite and sylvin, which to some extent increase the amount of chloride ions to 0.6%.

Table 3. The salinization characteristics of soil samples in Navbakhor district (Shurkishlak settlement) and Navoi city

Mineral	Formula	Characteristics of soils			
		in Navoi	Navbahor (Shurkishlak)		
		norm. grunt	norm. (10-30 cm)	withlabo solen. (2-10 cm)	Withol (0.2-0.5 cm)
		Carbonate salinity			
Calcite	$CaCO_3$	11.2	10.7	12.55	7.3
Dolomite	$CaMg(CO_3)_{2-3}$	-	-	3.0	2.8
Total, %		11.2	14.3	15.5	10.1
		Sulfate salinity			
Gypsum	$CaSO_4 \cdot 2H_{2o}O$	0.4	0.55	0.77	1.6
Astrakhanite	$Na_2Mg(SO_4)_2 \cdot 4H_2O$	0.6	6.2	0.8,8	3.6
Coquimbite	$AlFe_3(SO_4)_6(H2o_2)_{12} \cdot 6H_{2O}0$	0	1.1	1,0	0
Thenardite	Na_2SO_4	0	0	0	34.3
Total, %		1,0	7.8	1.5	39.2
		Chloride salinity			
Halite	NaCl	-	-	-	0.4
Sylvine	KCl	-	-	0.2	0
Total, %		-	-	0.2	0.44

4. Conclusions

When soil samples from Navoi were compared to samples from Navbakhor district, the results of the IR spectra, chemical analysis, and X-ray diffractometric analysis revealed the presence of two different types of functional groups that contained carbon (11.2%) and sulfur (1.0%). And in the soil from Navbakhor (Shurkishlak settlement), the dominance of the sulfate type of salinity was first noted – 16.1%, instead of 1.0%, then carbonate – 13.3, instead of 11.2%. Last of all, a third type of salinity appears, represented by chloride – 0.6%.

Thus, the obtained analysis results showed that all the noted soil minerals are more or less water-soluble and manifest themselves in an aqueous soil extract. In Navoi, a carbonate type of salinization was noted, and in the Navbakhor district (Shurkishlak), along with the dominance of carbonate, sulfate salinization is present and chloride salinization appears. During the carbonate type of salinization, the main carbonaceous minerals were calcite and dolomite, sulfur–containing minerals were gypsum, astrakhanite and coquimbite, and chlorine–containing minerals were halite and sylvin.

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