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NOTE

GENESIS, PHYSICO-CHEMICAL, AND MORPHOLOGICAL CHARACTERISTICS OF A HIGHLY SALINE-SODIC SOIL AFTER RECLAMATION AT THE AHOO-CHAR STATION IN SEMIARID SOUTHERN IRAN[1]

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ABSTRACT

Effects of leaching with irrigation water and cropping practice were studied at the Ahoo-char reclamation station in southern Iran. The salinity and SAR of the soils in the upper 1-2 m of the soil profile under natural conditions were about 3% and 60, respectively. By instalation of a drainage system, leaching and other cropping practices, the soil physical, chemical, and morphological characteristics changed markedly. Due to leaching of the excess salts, exchangeable Na caused dispersion and migration of clays and as a consequence formation of natric B horizon. In the Salorthid (Ahoo-char undisturbed series) pedon 1, clays were coagulated in spite of high SAR, due to the presence of salt in the soil solution. On the other hand, in the Ahoo-char reclaimed series (pedon 2) and after leaching the excess soluble salt, the exchangeable Na appears to be the major cause of clay dispersion and migration (Aquic Natrixeralf). The type of salinity changed from chloride type in the Salorthid to sulphatic type after reclamation.

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مشخصات ژنتیکی ،فیزیکوشیمیائی ومرفولوژیکی یک خاک شوروقلیا بعدازعملیات اصلاحی درایستگاه آهوچر واقع‌درمنطقه‌نیمه‌خشک جنوب ایران

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خلاصه

اثرشستشو بـــا آب آبیاری وعملیات زراعی درایستگاه اصلاح خاک آهوچر واقع‌درمنطقـــه نیمه‌خشک جنوب ایران موردمطالعه‌قرارگرفت . میزان شوری ونسبت سدیم‌جذبی دریـــک تادومترا ولیه‌خاک درشرائط طبیعی بترتیب ۳ درصدو ۶۰بـــــود. با احداث زهکـــش و

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وشستشووسایرعملیات زراعی مشخصات فیزیکی،شیمیائی ومرفولوژیکی خاک تغییرات
مهمی نمودند.دراثرشستشوی زیادی نمک ،سدیم‌قابل تبادل باعث پراکندگی وحرکت
رس ودرنتیجه‌تشکیل طبقه‌ناتریک گردید .درسالورتید (سری آهوچر قبل ازاصلاح)
پروفیل شماره ۱ علی رغم‌جذب نسبی زیاد ،بعلت وجودنمک درمحلول خاک ،رس منعقد
شده‌بود .درحالیکه‌درسری آهوچر اصلاح یافته (پروفیل شماره۲) بعدازخارج نمودن
نمک اضافی ، همین مقدارسدیم‌قابل تبادل باعث پراکندگی رس وحرکت آنها گردید
(آکویک ناتریزرالف).بعدازعملیات اصلاحی،نوع‌شوری نیزازنوع‌کلروردرسالورتید
به‌نوع سولفاته‌تغییرپیدانمود.

INTRODUCTION

Iran, with the exception of the northern Elburz mountain region which is influenced by the humid Caspian sea climate, belongs to the arid and semiarid zone. According to the data of Ministry of Agriculture and Rural Development (10), the total area of saline and sodic soils of Iran is about 25 million ha which is about 15% of the total land areas of the country. In relation to the area of the plains and flat sloping land, this amounts to approximately 30%, and in relation to irrigatable land, present and potential, as much as 50% is affected by salinity and alkalinity.

Regional distribution of these salt-affected soils is well known and problems of soil management have been discussed in many soil survey reports (2, 4). However, no fundamental research work has been carried out on the formation of these salt-affected soils.

This paper presents data on the morphology and physico-chemical properties of a representative salt-affected soil before and after reclamation, and discusses the implications of these properties for soil genesis and classification.

MATERIALS AND METHODS

The soil in this study lies in the lowland area of the Ahoochar reclamation statoin, about 30 km north of Shiraz, in the Southern inland belt of Iran. The climate is of Mediterranean type with very high summer temperatures and rather cold winters. The average annual rainfall of the area is 330 mm. The highest and lowest mean monthly temperatures (1965 to 1975) are 27.2 and 5.7°C for July and January, respectively. Soil moisture regime of the study area is "xeric" according to the Soil Moisture and Temperature Regime Map of Iran (5).

The native vegetation consists of halophytic plants, such as Atriplex halimus, Halocnemum strobilacem, Artemisia maritima, and Alhagi camelorum.

The parent material of the soils is fine-textured, highly calcareous, alluvial materials from the Kur River.

The soils were described and classified (Table 1) according to the Soil Survey Manual (15) and USDA Soil Taxonomy (16).

On the basis of soil data (4) duplicate pedons of each siol type were sampled and analysed. Because of similarity of field and laboratory data obtained for the two pedons within each soil type , data related to only one representative pedon within each soil type are reported (Tables 1 and 2). Pedon 1 represents lowland area of Ahoo-char series under natural conditions, while pedon 2 shows some part of the same area twelve years after reclamation. According to the soil map of the area (4), the soils of the two pedons were similar with regard to clay content, morphology, and drainage regime prior to tilling and irrigation activities.

Samples of water for quality determination were collected during the end of spring from each study site in two-liter plastic bottles after rinsing the bottle with water being sampled.

Particle-size analysis of soil samples was determined by the hydrometer method after gypsum and other soluble salts were removed from samples by repeated washing with distilled water (7). The soil pH was measured in a saturated soil-water paste using a Beckman pH meter. Electrical conductivity (EC) of the soil saturation extract and irrigation water were measured and the results were expressed in

Table 1. Morphology and classification of the studied soils.

Horizon	Depth cm	Munsell color (moist)	Texture†	Structure†	Consistence† (moist)	Boundary†	Other features‡
		Ahoo-char series (Typic Salorthid, fine, mixed (carbonatic), thermic)					
A1sacs	0-10	10YR 4.5/4	c	m2pl	f	as	Very saline; many gypsum crystal and mycelia; few fine roots
C1sacs	10-30	10YR 5/4	c	m	vfi	cs	Very saline; many gypsum crystals and mycelia
C2sag	30-50	5Y 4/1	sic	m	fi	gw	very saline; f1f mottles of 10YR 6/6
C3sag	50-80	2.5Y 5/2	sicl	m	fi	dw	Very saline; f2d mottles of 10YR 6/6
C4sag	80-100	5Y 5/3	cl	m	fi	cs	Very saline; c2d mottles of 10YR 6/6
C5sag	100-150	5G 4/2	c	m	fi	-	Very saline
		Ahoo-char reclaimed series (Aquic Natrixeralf, fine, mixed (carbonatic), thermic)					
A2	0-16	10YR 5/4	sicl	f2abk	f	cs	Common fine roots
B21t	16-36	10YR 4/4	c	f3pr-m2cpr	fi	gw	Few fine and coarse roots; thin patchy clay skins on the ped faces
B22tg	36-72	5Y 6/6	c	m3pr	vfi	gw	Few fine roots; thin, broken clay skins on the ped faces; f1f mottles of 10YR 6/3
B23tg	72-92	5Y 6/2	c	m3abk	vfi	cs	Thin, patchy clay skins on the ped faces; f2d mottles of 6/8
C1csg	92-124	5Y 5/2	c	m	fi	gw	c2d mottles of 6/8
C2g	124-150	5Y 3/1	c	m	fi	-	m2d mottles of 10YR 6/6

†Symbols used according to abbreviations given in Soil Survey Manual, USDA Handb. No. 18, P. 139-140, 1951.

‡All horizons were strongly calcareous throughout.

Table 2. Physico-chemical properties of the studied soils.

Horizon	Depth	Ec	pH (paste)	Water dispersible clay: of soil	Water dispersible clay: of total clay	Organic matter	$CaCO_3$	Gypsum	Particle-size distribution: Sand	Silt	Clay	Soluble cations and anions: Ca	Mg	Na	HCO_3	Cl	SO_4	Cation exchange capacity	SAR	Salinity type[†]: Anion composition	Cation composition
	cm	Sm^{-1}					%					meq l^{-1} (saturated extract)						me $100g^{-1}$			
Ahoo-char series (Typic Salorthid, fine, mixed (carbonatic), thermic)																					
A1Sacs	0-10	6.3	7.7	1.2	2.5	1.3	31.0	10.3	10.0	39.5	50.5	46	194	717	3	734	86	17.2	65	Chloride	Mg-Na
C1sacs	10-30	5.1	7.9	1.1	2.0	0.8	33.0	10.1	16.0	38.5	45.5	40	127	565	2	553	78	15.2	62	"	"
C2sag	30-50	4.2	8.1	4.0	6.3	0.7	38.4	0.7	11.0	44.0	44.5	39	80	21	1	461	78	20.1	67	"	"
C3sag	50-80	4.2	8.2	2.3	4.0	0.7	39.1	1.4	15.5	48.5	36.0	36	93.0	465	2	421	75	17.5	58	"	"
C4sag	80-100	5.6	8.2	1.9	3.3	0.7	39.4	1.4	22.0	39.0	39.0	42	142	630	2	593	79	17.5	66	"	"
C5sag	100-150	3.6	8.1	4.1	7.3	1.1	40.3	0.3	15.0	34.0	51.0	32	78	380	2	322	69	21.2	52	"	"
Ahoo-char reclaimed series (Aquic Natrixeralf, fine, mixed (carbonatic), thermic)																					
A2	0-16	0.3	7.7	2.3	7.0	1.7	44.0	0.1	17.5	47.0	35.0	21	7	17	3	6	38	18.6	4.5	Sulfate	Na-CA
B21t	16-36	0.2	7.9	3.9	11.0	1.0	43.0	0.2	16.0	39.0	45.0	7	8	11	2	3	19	20.6	3.9	"	Mg-Na
B22tg	36-72	0.7	8.5	36.3	73.0	0.8	44.0	0.1	15.0	36.0	48.0	2	4	63	3	15	39	21.1	36.0	Chloride-sulfate	Mg-Na
B23tg	72-92	1.3	8.4	28.8	70.0	0.5	47.0	1.0	17.5	42.0	40.5	22	18	125	1	43	59	21.1	28.0	" "	Ca-Na
C1csg	92-124	1.1	8.2	7.5	13.9	0.6	44.0	5.0	20.0	39.0	41.0	22	17	93	1	38	58	15.8	21.0	" "	Ca-Na
C2g	124-150	1.7	8.3	18.0	41.5	0.5	46.0	0.1	15.0	34.5	50.5	5	20	143	2	119	29	20.1	40	Chloride	Mg-Na

[†]According to the Russian system (7).

Siemens m^{-1} and milliSiemens m^{-1} at 25°C, respectively (17). Soluble cations and anions, gypsum, and alkaline-earth carbonates were also determined (17). Organic carbon in the soil was measured by wet-oxidation with chromic acid and back titration with ferrous sulfate (11). Cation exchange capacity (CEC) was determined with 1N NaOAc, pH=8.2 (8).

Water-dispersible clay was determined on untreated samples of soil and clay by the pipette method (9) with some modifications. To find the rate of dispersion of clay under natural conditions, the soils were dispersed in water without addition of any dispersing agent. After required period of time, the amount of clay was determined and assumed to be equal to dispersed clay under natural conditions.

The type of salinity, based on the composition of anions and cations present in the saturated soil extract and ground and irrigation water, was determined according to the Russian system (6). In this system, soil salinity is estimated on the basis of three major criteria: the chemistry (type) of salinization (anion and cation composition), the degree of salinity, and the depth of the upper saline horizon.

X-ray diffraction was carried out on a efflorescence salt sample from the undisturbed soil by using a philips apparatus with CuKα radiation, a range factor of 400 cps and a time constant of 1 s.

RESULTS AND DISCUSSION

The soils of lowland area of the Ahoo-char reclamation station under natural conditions (pedon 1) are not suitable for agricultural purposes because of their high salinity (sometimes more than 10 Siemens m^{-1}). Natural drainage conditions are unfavorable and a highly saline and alkali ground water table fluctuates from the soil surface during the winter to a depth of 150 cm during the dry period of summer season (Table 3).

The lowland area, temporarily flooded with water of the

Table 3. Chemical composition and salinity type of leaching water, drainage water and ground water of the study area.

Source	EC msm^{-1}	pH	Soluble cations and anions						SAR	Salinity type[†]	
			Ca	Mg	Na	HCO_3	Cl	SO_4		Anion composition	Cation composition
			meq^{-1}								
Leaching water	100	7.9	3	4	2	6	1	2	1	Carbonate-sulfate	Ca-Mg
Main drainage water	5900	7.7	27	178	728	6	618	69	71	Chloride	Mg-Na
Ground water of Ahoo-char series	3800	6.8	53	120	359	2	376	91	39	"	" "
Ground water of Ahoo-char reclaimed series	7400	8.2	43	239	880	4	871	84	74	"	" "

[†]According to the Russian system (7).

Kur river during the winter, but dry in summer, frequently accumulates on the soil surface salts which form a white crust. Salt also accumulate at or in the upper horizon due to evaporation of highly saline-and alkali-ground water present at shallow depth (Table 3). According to Kovda (13), under the natural conditions (with or without poor watering and leaching similar to the study area), the capillary fringe of concentrated ground water might cause strong salinization of soils from depth of 3.75 m.

Sodium and chloride ions make up the major ionic composition of the soil solution (Table 2). In the Russian system these ionic compositions are generally considered as chloride and sodium salinity types (Table 2). The quantity and quality of ground water salinity are directly related to soil salinity (salinity of about 8000 mSm^{-1} or higher and SAR value up to 80, Table 3).

In spite of the high SAR values for the Ahoo-char series, the pH and the amount of water-dispersible clay are low throughout the profile mainly due to the presence of excess soluble salts (Table 2).

X-ray diffraction of the efflorescent salts shows the presence of halite (NaCl), gypsum ($CaSO_4 \cdot 2H_2O$), calcite ($CaCO_3$), thenardite (Na_2SO_4) and kieserite ($MgSO_4 \cdot H_2O$) (Fig.1).

The presence of rather high amounts of gypsum in the surface horizon of the Ahoo-char series (Table 2) might be of secondary origin accumulated by the evaporation of saline ground water lying close to the surface.

For reclamation practice, part of the area was cleared of the over-growth of halophytic shrubs and then levelled within an accuracy of 5 cm. Prior to leaching, the water table was controlled by installation of a tile-drain system with 100 m spacing and approximately 2 m depth. Irrigation water with an electrical conductivity of 100 mSm^{-1} was used for leaching purposes. A systematic method of frequent watering was used for removing soluble salts from the soil

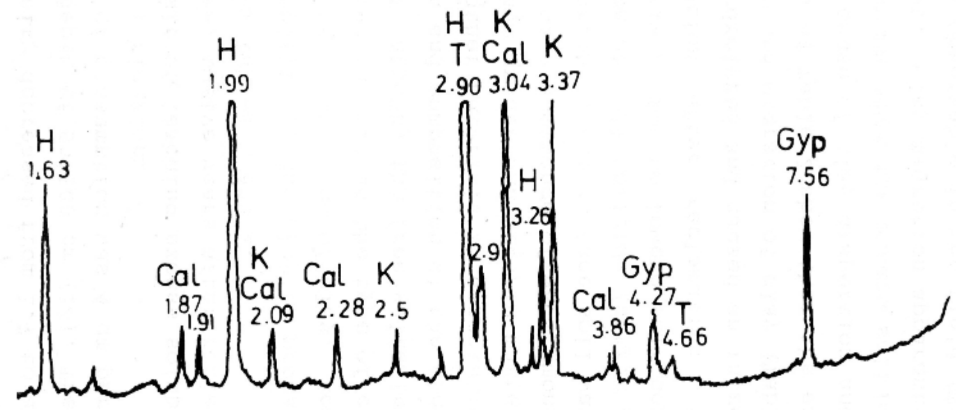

Fig. 1-X-ray diffraction of the typical salts of the Ahoo-char series:
Cal, calcite; Gyp, gypsum; H, halite, K, kieserite; and T, thenardite.

profile into the ground water during winter seasons. Rice (*Oryza sativa* L.), and sugar beet (*Beta vulagris* L.) were the first crops grown during reclamation. According to Javaheri (12), salinity in the 0-30 cm of the soil was decreased from 3.1 to 1.2 Siemens m^{-1} by leaching before rice transplanting, and from 1.2 to 0.3 Siemens m^{-1} during cultivation. When sugar beets were grown as the first crop, soil salinity decreased from 1.7 to about 0.4 Siemens m^{-1} within a depth of 50-100 cm (12). The amount of leaching water in excess of consumption was 4 cm per wk and was applied by furrow irrigation.

The result of leaching excess soluble salts from the Ahoochar series, twelve years after reclamation, is shown for pedon 2 in Tables 1 and 2.

Dispersability of the clay is probably affected by the same factors as swelling of clay. Rowell *et al.* (14) have listed these factors as the type of clay, the types of exchangeable cations, the free salts in the soils, the concentration and composition of the electrolyte, and the presehce of other materials in association with clay such as iron and aluminum oxides and organic matter.

Because of a dominance of NaCl among the soluble salts, desalinization of the surface soil was followed by the peptization of soil colloids (natric clay soils, sodic soils). Consequently , due to lowerd salt concentration in the soil solution after reclamation , the high exchangeable Na hydrolyzed and caused an increase in soil pH and dispersion and migration of clay (Tables 1 and 2).

The data of Table 2 show that the exchangeable Na which is the major cause of clay dispersion and migration (1), became more effective when the excess salt in the soil solution had been leached out. Clay migration apparently formed the continuous clay skins observable in the field (Table 1). The high content of water - dispersible clay (Table 2) of pedon 2 shows that the clay migration is still continuing twelve years after leaching of excess salt.

The fact that the carbonate which is dominantly of calcitic type (3), is relatively inactive in the solubility and exchange reactions suggests that it may be coarse size and well crystallized. Determination of carbonate content in the various fractions of the soil under natural conditions (Table 4) shows that its content is low (6-10%) in the clay

Table 4. Carbonate content of various fractions of the soil components under natural conditions

Horizon	Depth cm	Soil	Clay	Silt	Sand
		%			
Alsacs	0-10	31.0	5.6	52	76
Clsacs	10-30	33.2	7.0	57	81
C2sag	30-50	38.4	7.9	58	82
C3sag	50-80	39.1	6.0	51	79
C4sag	80-100	39.4	6.0	54	73
C5sag	100-150	40.3	10.0	66	85

fractions (2μ) , high (51-60%) in silt fractions (2-50μ), and very high (73-85%) in sand fractions (50-2000μ). The high pH of such sodic soil would also be a major factor in maintaining its initial insolubility. With further leaching, the $CaCO_3$ tends to come into solution with the possibility that the sodic soil could ameliorate, leading toward the development of a steppified solonetz. The low water-dispersible clay content of the upper horizons of the Ahoo-char reclaimed series might be due to this ameliorative process.

As a result of this investigation, it may be concluded that:

1. High exchangeable Na may cause soil dispersion whenever the excess salts are leached out of the soil.
2. In spite of the high flocculating effect of Ca in calcareous soils, Na can disperse soil clays.
3. In arid regions under highly calcareous conditions, illuvial migration of clay (natric and argillic horizons) occurs only in the presence of high exchangeable Na and low concentration of soluble salts.

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