G-2.1 Study on the Present Situation of Salt Accumulation and Reclamation of Salt-Affected Soils[1]

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①Study on the Present Situation of Salt accumulation

Abstract

The relationship between salts accumulation and the characteristics of salt affected soils was investigated in both old (Meshet and Sartabn) and new (Yeltai) irrigation blocks within the kolkhoz along the Syrdariya river in Kazakstan. The old sites were abandoned and out of cultivation due to excess salt load, while the new site was being used for the cultivation of various grain and forage crops in rotation. Salt accumulation was dominated by sodium salts, notably sodium chloride and sodium sulphate. The amount of accumulated salt in the top soil of the Yeltai block was lowest in the irrigated blocks within the Kolhoz, and there was no remarkable salt accumulation on the surface. The values of ECe in the top soil of abandoned and cultivated fields were about 20 and 10dS/m respectively. However, the ECe of cultivated fields largely exceeded the criterion for salt affected soils (ECe>4dS/m). Moreover, there was a tendency for higher underground water level due to rice cultivation in the block and the lower layer also contained a lot of salts. The accumulation of salt was affected by the texture of the lower soil horizon such that the accumulation was relatively less when the underlying horizon was sandy, and more when it was clayey. The clay mineral composition of the soils was dominated by the 2:1 layer silicate clays, notably smectite. The nature of the composition was such that might impair the permeability of soluble salts within the soil. Sodium concentration in irrigation water was doubled by salt addition from water entering the irrigation system from the nearby river. The drinking water in the area surrounding the irrigation project was very high in SAR and pH, and this posses serious health risks for the local population especially children.

Key words Salt affected soil, Salt accumulation, Irrigation, Water quality, Central Asia.

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[1] As the research subjects "Study on soil amendment for salt-affected soils" and "Study on the present situation of salt accumulation" in 1996 and 1997 were unified in 1998, the research report was described separately by T. Yano(②) and T. Honna(①).

1. Introduction

Soil salinization is one of the most serious environmental problems affecting agricultural productivity in arid and semi arid areas of the world today. Salt affected soils are common in these areas because annual precipitation is not sufficient to meet the evapotranspiration need of plants. Consequently, salts are not leached from the soil, rather they accumulate in amounts or types detrimental to crop production. Attempts at bringing
arid lands into production through irrigation have only exacerbated the salt accumulation problem, especially in areas where the quality of irrigation water is poor.

The region around the Syrdariya and Amdariya rivers leading to the Aral sea in Kazakstan, Central Asia was developed for irrigation farming between 1950 and 1960, and it used to account for up to 70% of all rice produced in Kazakstan. This level of production has been declining steadily in recent times due among other factors, to salt accumulation problem. Furthermore, the area around Syrdariya and Amadariya are currently under the threat of desertification, while the Aral sea is shrinking steadily. These problems are evidences of environmental degradation in the region.

In this report, we present the results of our survey on the extent and impact of salt accumulation in some areas surrounding the Aral sea. The survey which lasted between 1996 and 1998 covered Meshet, Sartabn and Yeltai areas in Kazakstan.

2. Study objective

The study was designed to evaluate the present situation and mechanism of salt accumulation along the Syrdariya river in Kazakstan. The impact of salt accumulation on some soil chemical and mineralogical properties were also examined.

3. Research methods

The study involved a survey of the soils in two old (Meshet and Sartabn) and one new (Yeltai) irrigation blocks in Kazakstan, Central Asia. The old irrigation blocks have been abandoned due to salt accumulation problem, while the new block was under cultivation at the time of this study. We demarcated the Yeltai block into three units designated as E1, E2 and E3, based on the level of salt accumulation and current use. The E1 unit was not put to cultivation because of excess salt level, but E2 and E3 were cultivated to alfalfa, rice, corn and wheat in several rotations.

The soils in each block were studied in standard soil profiles of about 2m deep. Soil samples were collected by augering and from the profiles to analyze for EC, pH, SAR and clay mineralogy. Clay mineral composition was analyzed by X-ray diffraction and infra-red absorbance techniques. An analysis of EC, pH and SAR in river, rice field, underground, drainage and drinking water was also carried out.

4. Result and discussion

Soil pedon : A survey of soil pedon (1.6～2.0m) showed that the soil material is characterized by sediments from the Syrdariya river, but the sediment types differed within the same field. The organic matter content of the pedon was low and the pedons were very hard , measuring >30 on the Yamanaka compactness scale. The sand content in the cultivated field was more that of the abandoned field, but crop growth, especially root development in the cultivated field was poor.

All the profiles (50-100cm) contained iron mottles. This indicates temporary moisture saturation under reduced condition. The surface soil of the abandoned Meshet block had 1-2 cm of crust layer under which salt containing 0.6-9% NaCl accumulated.

The soils in Yeltai block also consist of sediments originating from Syrdariya river but salt accumulation in Yeltai was lower than in the abandoned plots because of its relatively shorter history of cultivation. However, there was an evidence of salt accumulation in some sections of the block. The soil profile was also very hard with an angular blocky structure.

The E1 and E2 units of Yeltai block was characterized by high clay content, up to 1m, while E3 was mostly sandy with abundant soil pores. The profile contained recognizable iron (Ⅲ) mottling and the water table was located at about 160cm depth. Irrigation water moves in both vertical and horizontal directions.

EC and salt content : The EC value of saturated extract of the arable surface soil ranged between 9.7 and 50 dS/m whereas that of the abandoned blocks ranged between 18 and 155dS/m. Both ranges are however, much higher than the EC criterion (ECe 4dS/m) set for salt affected soils. The major salt forms are NaCl and $MgSO_4$.

A significant relationship was found between the texture of the lower soil horizons and salt accumulation. Salt accumulation was higher in soils whose lower horizons were dominated by clay than those dominated by sand. This is because the high clay content causes soil dispersion and blocking of pores which impairs the infiltration of water and soluble salts. In addition, the clay horizon favors the upward movement of salt-bearing capillary water. Conversely, the sandy nature of the cultivated blocks enhanced water infiltration, hence the salt content was relatively lower.

Clay mineralogy : An analysis of the soil mineralogy in the Meshet block showed that while the surface soil was sandy, the subsoil was clayey. The clay is mainly dominated by the 2:1 layer silicate type, mostly smectite, chlorite, vermicullite and illite or sericite. This trend was common to all blocks since the soils share a common parent material derived from the river sediments.

Water quality : Water quality analysis indicated that the EC was highest in underground water while the EC of drainage water was about double that of the river water. The SAR and pH were highest in the drinking water, and this poses serious health risks for the human population, especially children in the area.

5. Conclusion

We conclude that the salt accumulation and water logging in the study area is linked to the clay content of the soil. Crop rotation as is currently practiced could promote a rise in capillary water which may aggravate salt accumulation, especially where the texture of the lower soil horizon is clayey. The rotation system needs to be reviewed in favor of monoculture. Irrigation water facilities and channels are already old and need be replaced or changed. A reservoir for collecting water used for washing salts from the soil should be created in a separate block. Finallly, a detailed soil mapping of the study area is suggested in order to enhance proper land use planning.

6. Reference

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② Study on Reclamation of Salt-Affected Soils

Abstract

Leaching experiments were conducted in both field and laboratory. In the field study, four leaching amounts with 300, 600, 900, 1200 mm were ponded on the soil surface continuously and intermittently. Although the fraction of initial soil electrical conductivity (EC) remaining after leaching showed high spatial variability, the average EC fraction showed the slightly higher leaching efficiency with intermittent ponding than with continuous ponding. A column study using sandy loam and clay loam from the site showed that for sandy loam, the leaching efficiency was similar under both leaching methods, but for clay loam, it was higher with intermittent ponding than with continuous ponding. The different leaching efficiency between the different soil texture was attributed to the different water flow modes (unsaturated or saturated flow). In order to determine the necessity of using soil amendment to improve soil physical properties that could be deteriorated during leaching, the soil hydraulic conductivity (HC) was also studied. Irrigation waters with the different solution concentration of $CaCl_2$ and NaCl with sodium adsorption ratio (SAR) of 10 were applied to soil columns with the length of 50 mm and the internal diameter of 50 mm. The saturated hydraulic conductivity was measured under each treatment. There was no difference in the soil HC leached with solution of 0.5 and 0.05 mol_c. Whereas, the soil HC decreased with 0.01 mol_c solution and distilled water; 60% and 40% of HC was obtained respectively compared with 0.5 mol_c solution. The decrease in the soil HC was considered to be mainly due to clay dispersion. Since this soil contains naturally occurring gypsum and lime, to prevent the clay dispersion when conducting leaching, flocculant as soil conditioner was assumed to be promising.

Keywords Soil Reclamation, Leaching, Hydraulic Conductivity, Soil Amendment

1. Introduction

Desertification in the arid region is mainly caused by mankind activities, as one of which is soil salinization resulted from irrigated agriculture in the arid land. Since irrigation has not been sophisticatedly established everywhere in the world, the desertified area out of this cause is not significantly greater than the figure existing in the nomad land and rainfed agriculture. However, due to the significantly higher productivity of irrigated agriculture, the increase in food production driven by the increasing population will turn the rainfed land into irrigated one in addition to exploiting the virgin land, under which premise, the reclamation of the salt-affected land in irrigated agriculture has become increasingly important.

2. Objective of the study

The basic concept to reclaim the salt-affected soil is to leach and remove the accumulated salt from the soil using water. However, it is of necessity to establish the site-suitable reclamation technique, due to the diversity lies in the soil composition of parent materials, textures, salt types and its solubility, and the drainage capacity of the targeted area. This study was carried out in a farm in the Kzyl-Orda region, the republic of Kazakstan, with the cooperation with the local research institutes. The objective of the study is to establish soil reclamation techniques that are highly advanced than the traditional ones through reclaiming the deserted land (due to high salinization) in the farm.

3. Research method

In the farm, the experimental plot was built on the deserted field due to high salinization. The effectiveness of soil reclamation was comparatively studied in terms of leaching efficiency both in the field and laboratory conditions. Regarding the reclamation methods, the optimum of leaching requirement for salt removal and the need for favorable soil amendment which can accelerate leaching process were determined.

4. Results and discussion

(1) Leaching experiment in the field

Two kinds of drainage system have been installed in a deserted field. One is a tile drain which was installed at the depth of 1.5 m at 10 m interval and the other is a system called a sheetpipe-type drain at the depth of 45 cm at 4 m interval. Four subplots were prepared in the experimental site for leaching study, with 5 m by 2 m and 10 m by 4 m in the tile drain plot and sheetpipe plot, respectively. Irrigation water was conveyed into each plot and ponded on the soil surface continuously and intermittently, at water depth of 300, 600, 900 and 1,200 mm, respectively. In continuous ponding, the predetermined amount of water was supplied at 7-10 cm water level, whereas, in intermittent ponding, the amount of water was supplied at 7-10 cm water level for 12 hours. Then, water supply was stopped for 12 hours and water was again supplied until the predetermined amount of water was obtained Each treatment had three replications. Soil was sampled in each plot before and after leaching at the soil layers of 0-5, 5-l0, 10-30, 30-50, 50-70, 70-90 and 90-110 cm for EC and chemical composition analysis.

Fig. 2.1 shows the profile of initial EC soil solution made at soil: water = 1:1 ($EC_{1:1}$). In Fig. 2.1, both average value and standard deviation of the measured values at each layer were plotted with the average values ranging between 20 to 45 dS/m. The EC of the saturation extract (EC_e) values will be equal to about 4 times as high as the $EC_{1:1}$ values.

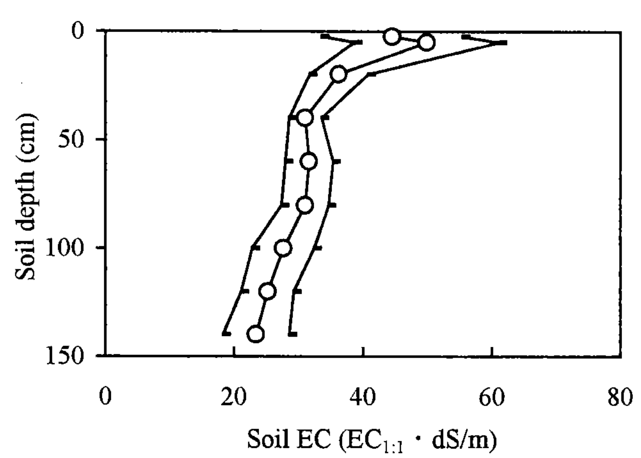

Fig. 2.1 Soil EC profile before leaching

Fig. 2.2 and Fig. 2.3 show the relationship between soil $EC_{1:1}$ fraction, EC/EC_0, and the amount of water leaching through the profile per unit depth of soil, D_w/D_s as all the measured values and the averaged value, where EC_0 and EC are soil EC (dS/m) before and after leaching, respectively. Fig. 2.2 denotes too high spatial variability of the leaching efficiency to recognize the different leaching efficiency between the different leaching methods. The reason why there is such high spatial variability must be due to the variable soil texture in the soil profile and soil disturbance after drainage system installation. In Fig. 2.3 in which the averaged values were obtained among the measured values in Fig. 2.2,

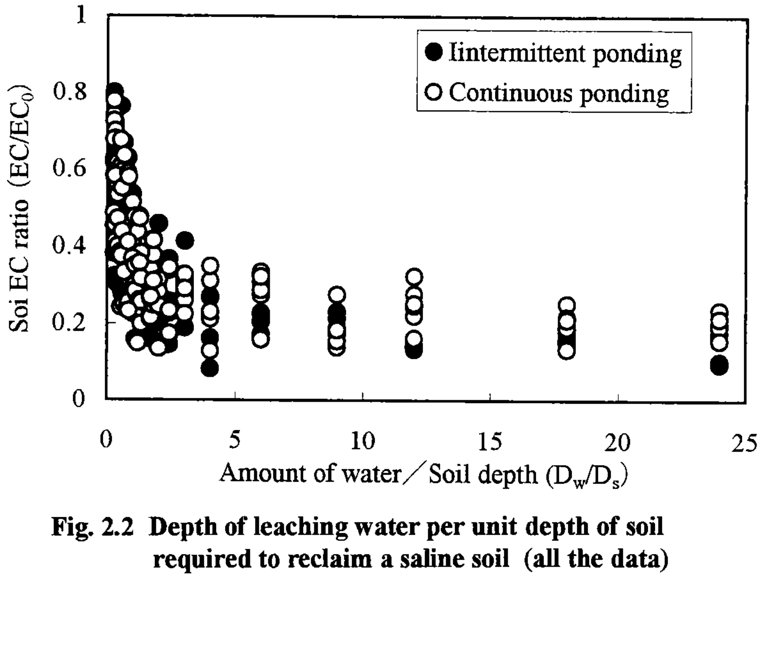

Fig. 2.2 Depth of leaching water per unit depth of soil required to reclaim a saline soil (all the data)

it shows that the leaching efficiency can be slightly higher in intermittent ponding than in continuous ponding in average. When $D_w/D_s = 1$, the reduction in soil $EC_{1:1}$ was about 60%, which means about 60% of the initial salt of the soil was removed. This value was apparently lower than the one Hoffman[1] presented; that 70% or more salt would be removed at D_w/D_s = 1 under continuous ponding in the field condition. This discrepancy was considered to be caused mainly by the increased dissolution of gypsum when measuring soil EC at soil: water = 1: 1 solution, whereas, EC of the soil saturation extract was used in Hoffman's experiment. The relatively high EC of irrigation water (EC_w = 1.8 dS/m) used in the leaching also negatively might have influenced the leaching efficiency.

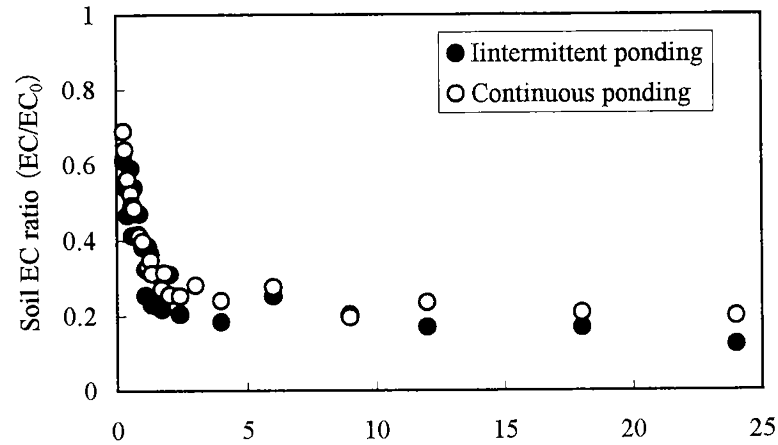

Fig. 2.3 Depth of leaching water per unit depth of soil required to reclaim a saline soil (averaged data)

(2) Leaching experiment by using soil columns

A series of soil column study on these two leaching methods were conducted in the laboratory to clarify the effect of soil texture on the leaching efficiency by simplifying the experimental conditions. Sandy loam from the A horizon and clay loam from the B horizon of the experimental plot were used as soil samples and were packed into a plastic cylinder with 100 mm of soil layer at the dry bulk density of 1.4 and 1.2 g/cm^3, respectively. The plastic cylinder was composed of a series of plastic rings with the length of 20 mm and the internal diameter of 50 mm.

As shown in Fig. 2.4, the leaching efficiency of sandy loam was similar with both continuous ponding (CP) and intermittent ponding (IP), whereas, that of clay loam was higher with intermittent ponding than with continuous ponding. This tendency was in agreement with Hoffman's result that leaching efficiency was less affected by leaching methods on the sandy loam soils. However, the constant values of EC fraction at the range of $D_w/D_s > 1$ for sandy loam are too high compared with Hoffman's result and those for clay loam in Fig. 2.4. It may have been caused by the gypsum dissolution present in the soil during the process of solution extract for EC analysis. $EC_{1:1}$ was used for sandy loam instead of EC_e which is usually recommended to use, because extractable soil solution at 2 cm of soil layer was too less for EC analysis. Whereas, EC_e was used for clay loam and the gypsum dissolution must not have happened for clay loam.

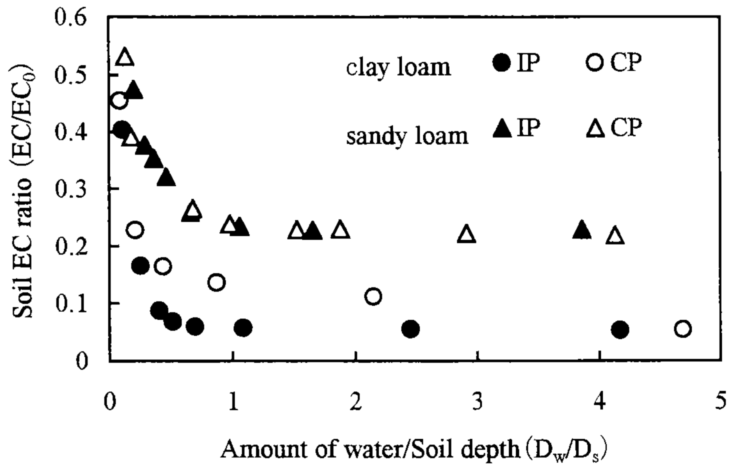

Fig. 2.4 Depth of leaching water per unit depth of soil required to reclaim a saline soils (column experiment)

Thus, the leaching efficiency can be increased by ponding leaching water intermittently on the soil surface, compared with continuous ponding. The mechanism that intermittent ponding can yield higher leaching efficiency will be explained as follows: Water passes quickly through large pores, compared with small pores. Saturated flow that occurs under continuous ponding condition results in low leaching efficiency during water passage with one pore volume or more. Whereas, intermittent ponding causes unsaturated water flow in the soil, and the fraction of water passage through large pores decreases relatively and it keeps the high leaching efficiency even with more water than one pore volume..

(3) Experiment of the necessary soil amendment

To determine the necessity of using soil amendment in the reclamation process, both laboratory and field experiments were conducted. In laboratory study, silty clay that contained 40% of clay from the B horizon of the experimental plot was used as soil samples. Soil samples were packed into plastic cylinders with the length of 50 mm and the internal diameter of 50 mm at the bulk density of 1.4 g/cm^3. Columns were first saturated with a solution that contained 0.5 mol_c Cl^- ($CaCl_2$ and NaCl) at SAR = 10, After saturation, the column was leached consecutively with solutions of the same SAR but diluted concentrations (0.05, 0.01 mol_c) and distilled water. EC of the solution was 50 dS/m for 0.5 mol_c Cl^-, 5 dS/m for 0.05 mol_c. Cl^- and 1 dS/m for 0.01 mol_c Cl^- solution, respectively. The effluent was collected by a fraction collector and saturation hydraulic conductivity (HC) was measured.

Effect of water quality (concentration and SAR) on the relative hydraulic conductivity

Fig. 2.5 shows the relative HC as influenced by water quality and the cumulative effluent volume. The relative HC is the ratio of treatment HC and HC at 0.5 mol_c Cl^- concentration. HC of the soil at 0.05 mol_c Cl^- concentration was not changed with the increase of effluent volume, and kept constant at 10 mm/hr. Whereas, HC was only 60% and 40% with leaching solution of 0.01 mol_c Cl^- and distilled water compared with 0.5 mol_c Cl^- solution, respectively. The decrease in the soil HC was resulted from clay dispersion and/or swelling. When the concentrations of soil solution become lower than certain value, clay swelling and/or dispersion occur which causes soil pores narrowed or clogged, thus, HC of the soil was decreased. Clay swelling is the major cause for the decrease of soil HC when soil ESP > 5, whereas clay dispersion is responsible for the decrease of soil HC when ESP < 5[2]. As leaching continuing, soil ESP decreases, thus, the decrease of soil HC was mainly caused by clay dispersion. Since the soil contains 3-6% of gypsum and 15% of lime, the decrease in soil HC, was not actually prevented by divalent cation (Ca^{2+}) released through dissolution of these compounds. Therefore, we propose to use flocculent as soil conditioner to improve the soil HC in the reclamation.

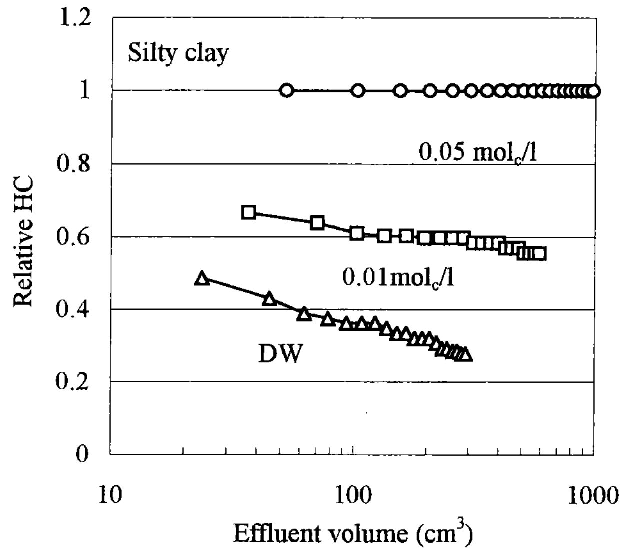

Fig. 2.5 Effect of water quality (concentration and SAR) on the relative hydraulic conductivity

References

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(2) Shainberg, I. and J. Shalhevet (1984). Soil Salinity under irrigation. Springer-Verlag. pp. 15-31.