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Modeling desalinization to reclamation of saline-sodic soils

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Soil Salinity is one of the most important environmental factors limiting and agricultural hazard in arid and semi-arid regions. Accumulation of soluble salts within the root zone is one of the major problems because most of the crop plants are sensitive to salinity caused by high concentrations of salts in the soil. For prevail over this problem, leaching of accumulated salts and controlling soil salinity is necessary. The primary method of controlling soil salinity is to permit of the irrigation water to leach the soil, be drained and discharging through an appropriate drainage system. The objectives of this study were to introduce an empirical model to account for reclamation water and to compare the obtained results with some available models. Consequently, a large-scale field experiment was conducted in Jofeir region at south part of west Khuzestan plains, covering an area of 21285 ha with S3A3 and S3A4 salinity-sodicity classes. The intermittent pounding experiment was conducted with six double ring infiltrometers in a circular array. All experiments were accomplished by applying 100 cm of water in four-25 cm intervals. The leaching water was supplied from Karun rive. Four mathematical models were applied to the collected experimental data to derive a suitable empirical model. The results indicated that the proposed power model with maximum correlation coefficient of 0.88 and minimum standard error of 0.25 can provide reasonable estimates for leaching process compares to the previously proposed models.

Keywords: desalinization curve; saline-sodic soils; salt leaching; soil reclamation

INTRODUCTION

The accumulation of soluble salts in soil, affect the physical and chemical characteristic [1]. This effect may lead to the disorder of plants development or the complete stop of plants growth [2]. Soils become salty by natural way or human activities [3-6]. Low rainfall and high evaporation are two natural factors, which leads to salty soils. The numerous studies have been conducted because of the expansion of saline soils especially in arid and semi-arid regions in the world. Some of these studies have been done in terms of the survey of the salinity on the different operation of plants [4,7-9]. In addition, some of the researchers have been done the nutritional effects and saline soils fertility [3,10]. In some of the studies have been conducted around the plant response modeling to the salinity in different situations [11-12]

Regardless the salinity factor related to the natural or humanistic factors, the leaching action with or without the generation of drainage networks are the non-alternative solutions for saline soils desalinization [1,13]. The main purpose of leaching is the reduction of soli salinity in the certain level of root zone, unless internal drainage of soli is not appropriate or there is no way to build an artificial drain [8, 14].The physical and chemical properties of soils are the main and determiner factors of required amount of water for leaching. The leaching curves are used in term of the detection of how much water need for salt leaching and reaching the balance level of salinity [14].

Leaching of soli soluble salts from the plants root zone have been done in two ways pounding irrigation (intermittent and Permanent) and sprinkler irrigation. In addition of leaching action, the salinity of irrigation water affected on crop yield and the fertile fields which becomes saline again [7-9, 15] In the case of irrigation by saline water, the decrease of performance is related to the soil and the type of water use [16]. In arid and semi-arid regions such as Iran, which water resources have high amount of soluble salts and soil texture almost is medium to heavy, the rainfall is not enough for natural removing of salts in soil profile. The application of required amount of water in terms of reduction of salts soils is very important.

In this case, many studies have been done in terms of estimation the amount of required water for leaching the soluble salts which results has been shown that for removing 80 percent of soluble salts from soils, the water volume should transmitted around 1.5 times of pore volume [17-18].

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The amount of required water for reclamation of 100 centimeter of soil in different condition of fields is about 0.30 to 2.58 meter [19].

The assessment of the required amount of water in terms of leaching of soluble salts from soils is the important stage in management of reclamation of saline soil. The depth of required water for leaching depends on some factors such as initial salinity, texture, soil depth and the way of leaching [19]. Leaching efficiency with unsaturated methods compare to permanent pounding because of emerges of unsaturated condition and as a result, water transmission from tiny mesh is higher [20].For increasing the leaching efficiency, it is better; that soil humidity has been less than the saturated humidity [21] because the high amount of soluble salts leaching has done in this situation [22]. Before every leaching test, a question that is discussed is what amount of water should add to soil. For this reason, the simulation models are used for determine the amount of required water for leaching. There have done many studies around this subject. In one study, a new way of leaching for soil modification and leaching at a pistachio field in south of California has been applied [23]. In this survey, the required water was used in terms of salts transmission from trees root zone by means of mild flow way in multiple lines. These researchers reached a conclusion that proposed way for leaching and farm modification is appropriate. An economic assessment was done by Corwin et al. [24] for comparison of leaching ways. The results of this survey around salts transmission show that stable models are excel than unstable models. Rao and Leeds-Harrison [25] has cloned different irrigation ways with the aim of increasing the leaching efficiency in Haryana region of India and they applied the solved numerically Laplace equation to obtain the water flow models and a mass flow equation in terms of obtain the salt spatial distribution of soil. The results shown that, for soils modification of region; firstly soils should be pounding then taken into the intermittent irrigation. Because of spatial distribution of soil properties, the use of simulation models in field condition provides some problems. However, the uses of empirical models for soil modification programs are useful. Empirical models are provided by observational data and empirical measurements that are fitted on a mathematic relation. In this case, mathematical models were represented for determination of the pace of water absorb by plants in high level of soil salinity [11-26]. Empirical relations and leaching curves have used in the soil type, amount of salinity or the exchangeable sodium percent in special depth of soil. Numerous empirical models are presented by researchers such as Reeve [27], Dieleman [28], Pazira and Kawachi [29] and Verma and Gupta [30]. The leaching tests were done in most of the Iran's Provinces that face with salinity problem [29]. Based on numerous tests and studies in central region of Khuzestan province, the empirical relation has been presented in the shape of hyperbola. In addition, Pazira and Keshavarz [31] have represented the estimation of required water for leaching in brine and sodium fields of Eastern south of Khuzestan province. Mohsenifar et al. [32] have done the application of leaching models types in two region of eastern west of Khuzestan province. The goal of this study was drawing of salinity curves, desodification and studying the effect of amendment material on salts leaching and exchangeable sodium in mentioned regions. In addition, the other aim of this study was the presentation of appropriate empirical relation for using in estimation of required water in terms of modification of neighborhood region. Rajabzadeh et al. [33] have done pounding way in a survey of middle fields of Khuzestan province. In this survey, empirical models have been presented for modifying and improving the brine and sodium soil in the studied region [33]. In addition, the other study because of estimation of required water for leaching the sodium and brine soils in south of Khuzestan province was done, the logarithm model compare to other prevalent models has the most efficiency with the application of leaching water in 4 frequency (0.25 meter) [1, 34]. The purpose of this study is the assessment of empirical leaching curves. In addition, in this study with apply of some models on field data, the new model was presented for desalinization of studied region soils.

MATERIAL AND METHODS

Leaching experiments carried out in three series of Jofeir region soil in south of Khuzestan plain. The annual height of region from sea level is 18 meter and has a very hot summers and moderate winters. This region based on the Amberjeh measurement is classified in mean warm desert climate. The annual rainfall is 223 millimeter and the measured amount of evaporation by pen evaporation-class A is 2169-millimeter year. This study carried out region in Khuzestan province that is a sedimentary plain that has been created by the sediments of Karun and Karkheh rivers. The quality of Karun and Karkheh Rivers has fluctuated in different seasons although with consideration on Wilcox diagram [35] in long term they are classified in $C_2 S_1$ and $C_3 S_1$ classes respectively.

In this study, Sableh, kushk and Salman soil series, with 3425, 5080 and 14845-Hectare area have been studied.

In terms of salinity and sodic are classified in class S_3A_3, $S_3A_3$and S_3A_4 class. Humidity and thermal regime of region are Aridic and Hyperthermic, respectively. The permability of these soils varying from average to slow. Sableh soils series based on the American classification is Fine, Carbonatic, Hyperthermic, Fluventic, Haplocambids. kushk soil series is fine, fine loamy, Carbonatic, typic haplosalids and Salman soil series is Fine, Carbonatic, Hyperthermic, Gypsic Haplosalids. Leaching of soluble salts from soil profile was done for desalinization of soil.

The water required for leaching was supplied from Karun River with intermittent pounding [17] that has 1.47 ds/m electro conductivity. For survey of the possibility of desalinization and desodification the intermittent pounding experiment was conducted with six double ring infiltrometers in circular array. All experiments were accomplished by Appling 100 cm of water in four-25 cm internal sampling was conducted rom 0-25, 25-50,50-75 75-100 and 100-150cm layers. Soil sample were collected before and after leaching and were measured the require analysis.

In every experiment were measured electro conductivity, soil reaction, Cation exchange capacity, sodium absorption Ratio, percentage of exchangeable sodium and lime, and gypsum percentage. Physical and chemical properties of different layers of soil profile for studied soil series were presented in Tables 1-3. For prevention of evaporation from soil surface during the sampling, the soil surface was covered by plastic sheets. Tables 1 and 2 have shown that the soil texture of Sableh series is Loam to silty clay loam and in kushk series is clay loam to silty loam and Salman series is clay to silty clay loam (Table 1). The soil Bulk density in Sableh soil is between 1.48 to 1.52, 1.55 to 1.60 in kushk soil series and in Salman series is 1.55 to 1.60 g/cm^3. This varies density depending on soil texture (Table 2).

The electro conductivity of saturation extract in Sableh Series was fluctuated between 16.00 to 26.60 and increase by depth. The same situation was seen in kushk and Salman Series. The amount of electro conductivity was fluctuated between 24.00 and 28.40 and between 30.80 and 24.10 ds/m in kushk and Salman series respectively (Table 2).

The changes of soil reaction are very low in every three series. These changes were also seen in calcium carbonate and gypsum in salman, kushk and sableh soils series.

Based on the Tables 1 and 2, the weight average of EC_e and ESP were computed. Because it is possible that all content of applied water didn't used in terms of the leaching salts from soil profile, and some portion of it, was used for compensation lack of soil humidity, in this case using amount of water, may not lead to soil chemical balance. It means that, the amount of soil equilibrium electro conductivity is a little more than electro conductivity of irrigation water. In this study, the equilibrium electro conductivity is calculated around 1.29 times higher than the salinity of irrigation water. Based on the amount of. EC_e , ESP, EC_{eq} and ESP_{eq} of different layers and according to tables 2, 3 and 4, the variable were define like these relations:

Table 1. Some physical properties of the soil layers before leaching

Soil series	Depth (cm)	soil moisture			Cumulative moisture deficit (cm)	Total porosity (%)	Bulk density (g/cm3)	Soil particles			Soil texture
		Wilting point	Filed capacity	Before leaching				clay	silt	sand	
Sableh	0-25	15.5	26.00	8.94	6.48	41.54	1.52	40.00	38.00	22.00	C
	25-50	17.5	32.00	17.6	11.88	42.31	1.50	48.00	40.00	12.00	C
	50-75	15.5	33.00	19.6	17.04	43.08	1.48	54.00	38.00	8.00	C
	75-100	15.5	31.00	15.5	22.85	42.31	1.50	40.00	40.00	20.00	CL
	100-150	7.00	28.00	15.48	32.37	41.54	1.52	40.00	44.00	16.00	SiCL
Kushk	0-25	7.00	8.00	10.00	6.80	39.62	1.60	11.20	53.40	35.40	SiL
	25-50	7.00	23.00	2.70	14.67	40.38	1.55	15.20	59.40	25.40	SiL
	50-75	7.00	25.00	6.85	21.70	41.51	1.55	17.20	67.40	15.40	SiL
	75-100	8.00	16.00	5.88	25.62	41.51	1.55	11.20	47.40	41.40	L
	100-150	5.00	14.00	8.70	29.73	41.51	1.55	7.20	31.40	61.40	SL
Salman	0-25	12.00	21.00	10.26	4.16	41.51	1.55	38.00	42.00	20.00	CL
	25-50	13.00	24.00	12.64	8.56	41.51	1.55	34.00	48.00	18.00	SiCL
	50-75	13.00	24.00	14.60	12.21	41.51	1.55	36.00	42.00	22.00	SiCL
	75-100	13.00	20.00	17.40	13.23	40.38	1.58	30.00	48.00	22.00	SiCL
	100-150	7.00	22.00	18.93	15.69	39.62	1.60	24.00	54.00	22.00	SiL

$$x = \frac{D_{lw}}{D_s}, y = \frac{EC_f - EC_{eq}}{EC_i - EC_{eq}} \quad (1)$$

$$x = \frac{D_{lw}}{D_s}, y = \frac{ESp_f - ESp_{eq}}{ESp_i - ESp_{eq}} \quad (2)$$

That EC_i and EC_f are the electro conductivity of soil saturation extract before and after of leaching (ds/m) respectively. EC_{eq} is the electro conductivity of soil saturation extract in equilibrium condition (ds/m), ESP_i and $ESP_f$are the exchangeable Sodium percentage of before and after leaching in equilibrium condition respectively, $ESP_{eq}$is the exchangeable Sodium percentage in equilibrium condition, D_w is the depth of practical leaching water (cm). D_{lw} is the depth of leaching water (cm)

Table 2. Soil chemical properties before leaching in soil series

Soil series	Depth (cm)	Electro conductivity (dS/m)	ESP * (%)	(SAR) $(Meq/lit)^{0.5}$	Ex.Na Meq/100gr	C.E.C Meq/100gr	gypsum (%)	Calcium Carbonate (%)	(pH)
Sableh	0-25	16.00	19.67	10.12	2.65	13.50	1.86	44.62	7.70
	25-50	18.91	27.30	12.51	4.75	17.40	1.65	46.40	7.80
	50-75	13.70	29.08	19.70	4.74	16.30	6.74	39.10	7.70
	75-100	19.00	28.74	19.55	5.00	17.40	4.90	42.30	7.50
	100-150	26.60	30.49	30.72	4.97	16.30	2.49	41.52	7.60
	Avg	18.84	27.05	18.54	4.42	16.18	3.53	42.78	7.66
Kushk	0-25	15.40	10.09	8.20	0.83	8.20	3.97	47.57	7.60
	25-50	18.40	10.69	11.10	0.83	8.70	12.48	48.87	7.40
	50-75	15.00	8.32	5.80	0.90	10.80	30.90	46.00	7.50
	75-100	14.00	5.22	3.90	0.43	8.20	15.80	46.80	7.70
	100-150	14.20	4.21	3.90	0.26	6.20	7.48	48.90	7.40
	Avg	15.40	7.70	6.58	0.67	8.42	13.96	47.62	7.52
Salman	0-25	30.8	42.86	12.90	5.31	12.40	8.89	44.02	7.40
	25-50	29.5	41.59	13.10	4.97	12.00	4.98	45.60	7.30
	50-75	28.2	34.68	14.20	4.45	12.80	2.62	44.65	7.20
	75-100	24.1	33.64	11.80	3.70	11.00	4.24	46.37	7.40
	100-150	28.6	35.00	18.91	3.50	10.00	0.80	48.10	7.30
	Avg	28.24	37.55	14.18	4.38	11.64	4.30	58.61	7.32

*ESP = Ex.Na+×100/CEC

Table 3. Soil chemical properties after leaching in soil series

Soil series	Depth (cm)	Electro conductivity (dS/m)	ESP * (%)	(SAR) $(Meq/lit)^{0.5}$	Ex.Na Meq/100gr	C.E.C Meq/100gr	gypsum (%)	Calcium Carbonate (%)	(pH)
Sableh	0-25	1.88	5.05	4.15	0.68	13.50	2.52	-	7.70
	25-50	5.20	6.90	3.33	1.20	17.40	4.54	-	7.80
	50-75	10.23	12.94	14.14	2.11	16.30	4.77	-	7.60
	75-100	16.73	25.57	12.71	4.45	17.40	1.18	-	7.70
	100-150	23.73	23.68	36.26	3.86	16.30	2.25	-	7.40
	Avg	11.55	12.83	14.12	2.46	16.18	3.05		7.64
	Diff	- 7.29	-14.22	- 4.42	- 1.96	0	-0.50	**n.d	-0.02
Kushk	0-25	2.33	8.54	2.27	0.70	8.20	4.56	-	7.70
	25-50	4.85	10.46	6.00	0.91	8.70	6.57	-	7.50
	50-75	5.68	7.96	4.68	0.86	10.80	26.01	-	7.10
	75-100	4.50	3.29	3.49	0.27	8.20	5.49	-	7.40
	100-150	4.63	5.32	3.88	0.33	6.20	4.58	-	7.50
	Avg	4.39	7.11	4.06	0.61	8.42	11.88		7.44
	Diff	-21.01	-0.59	-2.52	-0.06	0	- 2.08	**n.d	-0.08
Salman	0-25	4	8.72	8.73	1.08	12.40	8.50	-	7.60
	25-50	14.87	8.03	15.10	0.96	12.00	9.50	-	7.70
	50-75	13.07	6.39	3.20	0.82	12.80	14.30	-	7.50
	75-100	11.17	4.73	2.30	0.52	11.00	13.50	-	7.70
	100-150	17.515	32.60	40.30	3.26	10.00	4.20	-	7.20
	Avg	12.12	12.02	13.92	1.33	11.64	10.00		7.54
	Diff	-16.12	-25.53	-0.26	-3.05	0	- 1.64	**n.d	+ 0.22

- represent decreasing + represent increasing *ESP = Ex.Na+×100/CEC n.d* not determination and D_S is the depth of soil layer (cm). The reduction of EC_{eq} and ESP_{eq} from numeration and denominator the fractions of 1 and 2 equation lead to the results become independent from the effects of external factors such as the amount of evaporation, condition of international soil drainage, the quality of leaching water and the condition of applying the experiment. In this way, in fact, function is changed from explicit to the implicit function [36]. Analysis was done by SPSS, Curve Expert and Excel soft wars. Then four mathematical models fitted to values. The best empirical model was selected for every series of soils. Then with combination of all results, the best empirical model was obtained for studied region. These models were analysis in 1% significant level with some statistic criteria such as correlation coefficient and standard error. Then the appropriate model was determined for desalinization.

RESULTS AND DISCUSSION

The amount of EC_e in soil has decreased after applying the leaching water (Table 3). Because of removing salts from surface to depth is the inversion of salts distribution before the leaching. After the leaching the sharp decrease was seen in EC_e and ESP in all of the layers.

This decrease was higher in surface layers specially the layer 0- 25 cm. after leaching, soil ESP has decreased and this reduction was higher in the layer 0-25 cm. Since, the secondary factor of soil salinity is sodium chloride, by increasing the concentration and as a result, increase the salinity the amount of sodium is rising (Table 3).

However, because of high solubility, this salt is removed easily from the soil. Overall, after leaching the amount of in Sableh, kushk and Salman have decreased to 7.29, 21.01, and 16.12 respectively. Similarly, ESP has had this trend in mentioned regions around 14.22, 0.59, and 25.53 respectively (Table 3).

By using data, obtained from two variables, X and Y, and according to analysis, four mathematical models were fitted to them. Exponential model with correlations coefficient of 0.9098 and standard error of 0.29 in significant level 1 percent was derived as a best model for kushk series that showed following:

$$Y = 0.854e^{-0.294x} \qquad (3)$$

The most appropriate estimated model of sableh series was exponential model with correlations coefficient of 0.9172 and error standard of 0.40 in significant level 1 % achieved like this:

$$Y = 0.9172\, e^{-0.444x} \qquad (4)$$

One of the advantages of exponential model is that, it is possible to add leaching correlations coefficient into mentioned model like that:

$$Y = 0.854e^{-0.296x(\frac{f}{\theta_v})} \qquad (5)$$

$$Y = 0.9172.exp^{-0.444.X.(\frac{f}{\theta v})} \qquad (6)$$

F is a leaching efficiency quantity without distance and depends on soil texture (volumetric soil moisture). The leaching efficiency can be achieved by using empirical relations:

$$f = \frac{r.ECw}{ECeq} \qquad (7)$$

$$r = \frac{Dw}{Ds} \qquad (8)$$

By using relations 5 and 6 the leaching efficiency for sableh and kushk series was calculated 0.34 and 0.54 respectively that is in line with soil texture of region.

Logarithm model showed the best result in Salman series. The correlations coefficient and standard error in significant level 1% were 0.9107 and 0.34 respectively. The following relations were derived:

$$Y = 0.3181 + (0.144)\,lnx \qquad (9)$$

Based on relations 5 and 6 the leaching efficiency of Karkheh and Salman series were calculated 0.36 that it is consistent with soil texture.

Four mathematical models were applied to the collected experimental data to derive a suitable empirical model. The proposed exponential model with maximum correlation coefficient of 0.8821 and minimum standard error of 0.747 Can provide reasonable estimates for leaching process. The following relations were derived:

$$Y = 0.1107\, e^{-1.025} \qquad (10)$$

If the variables were clear, water depth for required leaching in terms of soil modifications by using relations 10 can calculate:

$$D_{lw} = D_s.[ln.\frac{\frac{EC_f - EC_{eq}}{EC_i - EC_{eq}}}{0.7898})(1.0.25.\frac{f}{\theta_v}) \qquad (11)$$

By applying relations 3, 4 and 9 the desalinization curves for soil series of region are derived. The results are shown in Figure 1.

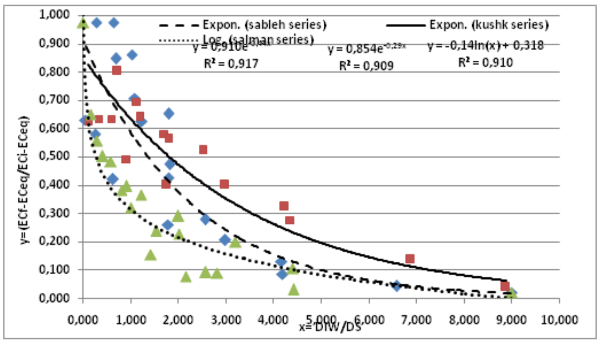

Fig. 1. Soil desalinization curves in soil series in case study.

As seen in Figure 1 salt leaching of Karkheh, Sableh and Salman were easy, average and hard respectively. In addition, these three curves shown that, leaching of Salman series needs more water compare to Karkheh and Sableh series.

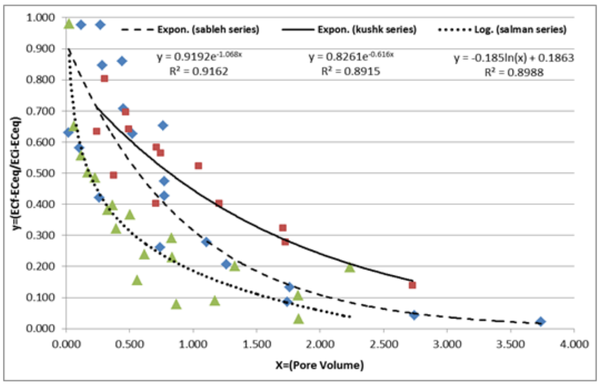

Fig. 2. Soil desalinization curves in soil series in case study.

Desalinization express based on pores volume compare to D_{lw}/D_s (Figs. 1&2) can be presenting better the salt leaching from soil layers. In fact, this hypothetic is not existence in the nature. However, the pore volume is the volume that leaching water passing toward it. The achieved correlation coefficients based on pore volume are less than toward water to soil, although the amounts were more real and more appropriate in assessment of the soil salinity changes (Fig. 2). Achieved desalinization curves based on the relation 9 for soils of region that shown in Figure 3. By using of this curve, the last soil electrical conductivity (EC_f) and pure depth of required water for reclamation actions (D_{lw}) can estimate (Fig. 3). It should be considered for estimating all amount of required water for leaching, moisture reduction of the soil layer, evaporation from water and soil surface, and the level of rainfall. Furthermore, these factors should considered into calculation and leaching planning.

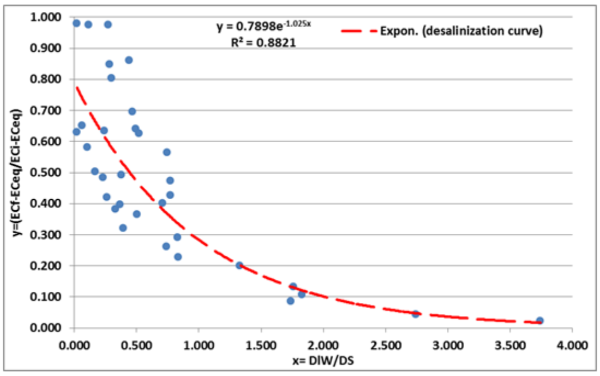

Fig. 3. Soil desalinization curves in case study

It should attend that the application of these curves in the soil of case study in primary amount is in 13.70 to 30.8 ds/m of electro conductivity and 4.21 to 42.86 of sodium changes. By using figures of weight average, soil EC_e was calculated by applying tests and following relations of the percentage of removing initial salts and the percentage of leftover initial salts.

$$Y = \frac{EC_f}{EC_i} \times 100 \qquad (12)$$

$$Y' = 100 - \left(\frac{EC_f}{EC_i} \times 100\right) \qquad (13)$$

$$Y' = 100 - \left(\frac{EC_f}{EC_i} \times 100\right) \qquad (14)$$

D_w is the depth of applied leaching water (cm), Y is the percentage of leached salts, Y' residual initial salt content, P.V is a pore volume and n is pores. Figures 4-6 show the relation of leached initial salt content with pore volume.

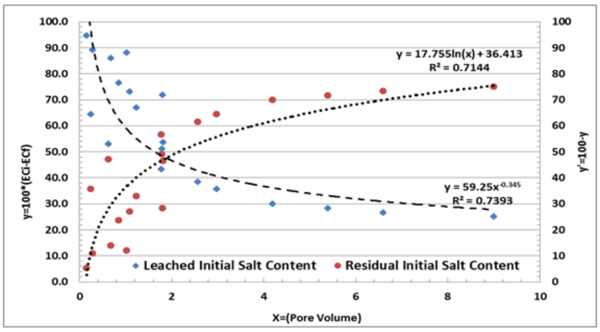

Fig. 4. Soil desalinization curve and fraction of excess salts removed in sableh series.

By applying 100 cm water in Sableh soil series, which results in the leaching of 75.5, 73.30, 64.43, 48.95 and 32.98 percent of initial salts that equaling by 9.20, 6.60, 2.98, 1.80 and 1.23 unit of pore water in mentioned layers (Fig. 4).

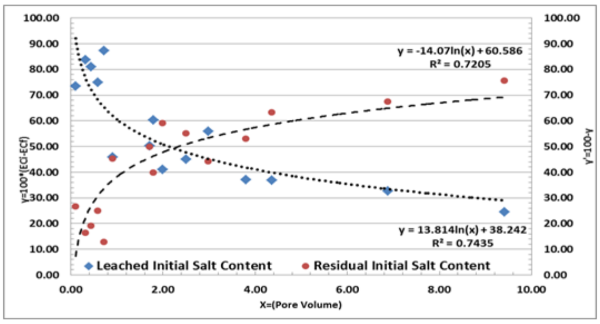

Fig. 5. Soil desalinization curve and fraction of excess salts removed in kushk series.

According to results that shown in figure 5, applying 100 cm depth of leaching water in kushk series leads to the removing of 75.67, 67.41, 53.01,44.20 and 39.82 percent of initial salts of soil layers that are equaling by 9.41, 6.88, 3.80, 2.99 and 1.79 unit of pore water for those layer (Fig. 5).

The survey of figure 6 show that the application of 100 cm water in Salman series leads to leaching of 86.04, 85.39, 81.26, 57.63 and 68.00 percent of initial salts of 25 cm layers. These data are equal by 9.24, 6.83, 4.41, 2.02 and 1.21 unit of pore volume for soil layers respectively (Fig. 6).

By considering the results in Figures 4-6 it is seen that in Sableh soil series the salts are removed around 35% for one unit of pore volume and around 58% for two unit of pore volume (Fig. 4).

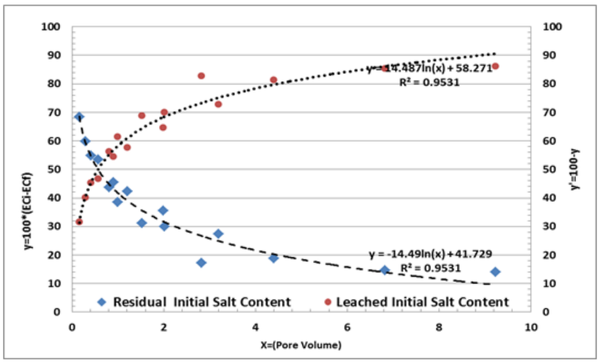

Fig. 6. Soil desalinization curve and fraction of excess salts removed in salman series.

This trend also is seen in kushk series soil for unit of pore volume about 45% and for two unit of pore volume around 60% of salts are removed (Fig. 5). While, for one and two unit of pore volume of salman series around 65 and 78% of initial soils are removed (Fig. 6). The results of this study agree with of some researcher. Based on Neilson and Biggar [21] theory, for each of pore volume and two unit of this volume around 50 and 80 % of salts should remove. In addition, some researchers have reported that about 75% salts in sandy loam soils are transferred from unit of pore volume. Van der Molen [37] showed that 50% of soluble salts are removed for applying per unit of pore volume from soil profile. In addition, there is a need for 120 cm leaching water that equaling by 35 unit of pore volume [38].

As a result, this study has shown that leaching efficiency of kushk series higher than Salman and Sableh series. This difference is associated with physical characteristics of soil and distribution of soil pores. In the case of soil texture, kushk, Sableh and Salman series have light to average, average to heavy and heavy to very heavy respectively.

Because of preferential flow, in heavy texture soil a part passed of water from cracks, penetrate to down ward without passing the real path of soil pores, as a result leaching efficiency are less than moderate and light texture soils.

The other factor that can mention is infiltration. Infiltration is impressing by sustainable and large pores. The existence of intensive structures in soil leads to soil infiltration is more affected by the relative frequency soil particles. Therefore, the water permeability of heavy soils is slow. In addition, number and continuity of large pores of soils have the high influence on the rate of water permeability to soil. Large soil pores are affected by type of soil structure. Therefore, variables such as bulk density and soil pores as an index represented soil structure that effective on the water permeability to the soil.

In this condition, the effect of some soil characteristics such as capillary power affected by relative frequency of soil particles has decreased and large pores (number, arrangement and continuity) characteristics, water permeability to soil and as a result the better salt leaching from soils become inhibits.

The results in Table 4 showed that, the sharp decrease around 4 ds/m or less of initial electro conductivity needs significant pure leaching water. Furthermore, 2645 m3 leaching water is need for decreasing the initial soil electro conductivity from 46 to 32 ds/m. Similarly, for decreasing the electro conductivity from 32 to 16, 16 to 8 and 8 to 4 ds/m, 2720, 2885 and 4160 m3 leaching water is require respectively. For analyzing the presented desalinization model (relation 9), the comparison between presented model, and some empirical leaching models was done (Table 4).

That Initial soil electro conductivity until 150 cm of depth, the final soil electro conductivity, and the equilibrium of electro conductivity are considered 46.4 and 1.29 ds/m respectively.

The result show that Verma and Gupta model [30], Pazira and Keshavarz [31], Asadi et al. [39], Dieleman [28], and Hoffman [40] are estimating

Table 4. Required desalinization water for gradual decreasing of initial soil salinity from 46 ds/m to 4 ds/m

Initial soil salinity (ds/m)	Soil depth(cm) 0-25	0-50	0-100	0-150	Initial soil salinity (ds/m)	Soil depth(cm) 0-25	0-50	0-100	0-150
6.00	0.10	0.19	0.38	0.576	28.00	0.40	0.40	1.61	2.416
8.00	0.16	0.32	0.63	0.948	30.00	0.42	0.42	1.66	2.493
10.00	0.20	0.41	0.82	1.224	32.00	0.43	0.43	1.71	2.565
12.00	0.24	0.48	0.96	1.443	34.00	0.44	0.44	1.76	2.633
14.00	0.27	0.54	1.08	1.625	36.00	0.45	0.45	1.80	2.696
16.00	0.30	0.59	1.19	1.781	38.00	0.46	0.46	1.84	2.756
18.00	0.32	0.64	1.28	1.916	40.00	0.47	0.47	1.88	2.813
20.00	0.34	0.68	1.36	2.037	42.00	0.48	0.48	1.91	2.866
22.00	0.36	0.71	1.43	2.145	44.00	0.49	0.49	1.95	2.918
24.00	0.37	0.75	1.50	2.243	46.00	0.49	0.49	1.98	2.967
26.00	0.39	0.78	1.56	2.333					

Table 5. Comparison of require desalinization water for different available models and newly proposed model

Model	Water require for desalinization(cm) 0-25	0-50	0-100	0-150	Needed water (weighted mean) (m)	Rank
Reeve [27]	0.61	1.23	2.45	3.68	1.61	8
Dielman [28]	0.40	0.80	1.60	2.40	1.05	4
Leffelaar & Sharma [41]	0.54	1.08	1.62	2.16	1.42	7
Hoffman [40]	0.80	1.59	3.19	4.78	2.10	9
Verma & Gupta [30]	0.31	0.62	1.25	1.87	0.82	2
Pazira & Keshavarez [31]	0.31	0.63	1.26	1.88	0.83	3
Pazira & Kawachi [29]	0.48	0.96	1.91	2.87	1.26	5
Rajabzade et al. [33]	1.72	3.44	6.88	10.32	4.53	10
Asadi etal. [39]	0.26	0.52	1.05	1.57	0.69	1
new model (2013)	0.49	0.99	1.98	2.97	1.30	6

the amount of leaching water for soils less than new model. Pazira and Kawachi [29] and Reeve [27] model estimate the amount of soils leaching water a little more than new model. Rajabzadeh et al. [33] and Leffelar and Sharma [41] models compare to the final model are not enough appropriate for estimating the required water in terms of modification the soil region. Some cause of this lack of appropriateness that can mention involving the differences among chemical and physical properties of tested soils and the leaching applied way. The similar results are reported by other researchers [31] (Table 5).

RESULTS

The study of the percentage of leached salt in soil profile of all three case studies soil series showed that by considering the application of two-unit pore water volume as a leaching water, the differences of soil texture and the effect of soil texture of washing the soluble salts can associated as a causes. So that, when soil texture becomes lighter, it leads to increase the removing percentage of soluble salts and because of the existence of natural calcium resources in soils, there was no tendency to sodiumic and this important subject indicates the lack of necessity of applying the amendment materials.

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