Shahid Chamran University of Ahvaz

Irrigation Sciences and Engineering (JISE)
Vol. 46, No. 4, Winter 2024, p. 13-27

Original Paper

Journal homepage: https://jise.scu.ac.ir

Effects of Using Agricultural Drainage Water on Chemical, Biological, and Physical Properties of Soil and Yield of Tomato in Moghan Plain, Iran

F. Abdiaghdam Laromi[1], A. Rasoulzadeh[2], A. Ghavidel[3], M. Torabi Giglou[4] and J. Azizi Mobaser[5*]

1-Water Engineering Department, University of Mohaghegh Ardabili, Ardabil, Iran.
2- Water Engineering Department, University of Mohaghegh Ardabili, Ardabil, Iran.
3- Soil Science and Engineering Department, University of Mohaghegh Ardabili, Ardabil, Iran.
4- Horticulture science Department, University of Mohaghegh Ardabili, Ardabil, Iran.
5- Corresponding Author, Water Engineering Department, University of Mohaghegh Ardabili, Ardabil, Iran. (Ja_mobaser@uma.ac.ir)*

ARTICLE INFO

Artlcle history:
Received: 12 January 2022
Revised: 27 July 2023
Accepted: 29 July 2023

Keywords:
Wastewater, Soil Properties, Microbial Population, Biological Indices, Substrate-induced Respiration, Water Re-Use.

TO CITE THIS ARTICLE:

Abdiaghdam Laromi, F., Rasoulzade, A., Ghavidel, A., Torabi Giglou, M., Azizi Mobaser, J. (2024). 'Effects of Using Agricultural Drainage Water on Chemical, Biological, and Physical Properties of Soil and Yield of Tomato in Moghan Plain, Iran', Irrigation Sciences and Engineering, 46(4), pp. 13-27. doi: 10.22055/jise.2023.39612.2011.

Abstract

This study assesses the use of drainage water in agriculture by mixing irrigation water and agricultural drainage water to examine the effects of the mixture on soil properties and the yield of tomatoes in Moghan Plain, Iran. The experimental design was completely random, conducted with three irrigation treatments and four replications for two years. The treatments were the control treatment (only irrigation water) (T0), 50% drainage water +50% irrigation water treatment (T1), and only agricultural drainage water treatment (T2). The results showed the treatments had significant differences ($p \leq 0.05$) in terms of the microbial population, basal respiration, and substrate-induced respiration. There were also significant differences among the treatments in terms of soil pH and EC ($p \leq 0.01$). However, the soil organic matter, yield, bulk density, and chlorophyll content of tomatoes showed no significant differences among the treatments. The treatments did not differ significantly in terms of the saturated hydraulic conductivity (K_s) in the first year, whereas the K_s for the drainage water treatment differed significantly ($p \leq 0.05$) in the second year. No significant differences were observed in the parameters of van Genuchten (θ_s, θ_r, and α) among the treatments. Whereas the statistical results showed that there was a significant difference ($p \leq 0.01$) in the parameters of van Genuchten (n) between T0 with T1 and T2 treatments, there was no significant difference between T1 and T2 treatments. It can be concluded that the use of drainage water negatively affected soil pH, salinity, and biological properties; but it did not decrease the plant yield.

Introduction

Iran is among the countries affected by the water shortage problem. One strategy that could moderate water shortage is the re-use of agricultural drainage. In recent years, the conditions of water resources in Iran have urged national policies toward increasing the productivity of water resources (Ghazavi and Orst, 2017). Therefore, optimized use of current water resources, such as drainages, is among the fundamental tasks to be fulfilled by the custodians and consumers. The agricultural

 DOI: 10.22055/JISE.2023.39612.2011

drainage water in the Moghan Plain of Iran is one of the largest water drainage systems in the country (Seshadri et al., 2016). The agricultural drainage water can be returned to the agricultural lands for irrigation by proper management, diminishing severe water short-use of drainage water should be evaluated in terms of the long-term and short-term effects on soil properties. The direct use of drainage water on the farmlands is usually conducted without mixing with fresh water (Al-Isawi et al., 2016; Norton-Brandao et al., 2013).

The leading cause of the adverse effect of drainage water is the high concentration of ions, which is referred to as salinity. One way for decreasing water salinity is the mixing of saline water with freshwater or less saline water so that its quality is improved for the irrigation of crops. There are some studies about the feasibility of drainage water re-use in agriculture (Rasoulzadeh and Nasiri, 2013; Beltrán, 1999; Abu-Rizaiza, Sarikaya, 1994; Sharma and Rao, 1998; Suyama et al., 2006; Barnes, 2014; Reinhart et al., 2019; El-Zawily et al. 2019; Liang et al., 2005). Using agricultural water drainage has a different effect on soil and the quality and quantity of crops. In this regard, Rasoulzadeh and Nasiri (2013) investigated the effects of re-using drainage on soil properties in the Moghan Plain. According to their findings, the use of drainage water mixed with a ratio of 50%, and 70% with irrigation water had no significant impact on the soil-water retention curve (SWRC) after one year. Nasiri and Rasoulzadeh (2011) assessed the effects of re-using drainage water on the chemical soil properties. According to their results, sodium concentration had a significant difference in the treatments, and the levels of SAR and ESP were significantly different in the treatments. Abu-Rizaiza, Sarikaya (1994) examined the biological, chemical, and physical quality of drainage water and reported that because of high salinity, this water resource is not appropriate for irrigation. In another study, Beltrán (1999) declared that low-quality water resources (e.g., drainage water, saltwater, and wastewater) could be used for irrigation due to the water shortage in arid and semi-arid areas. Using these water resources requires soil salinity to be controlled by the leaching or draining of the extra saltwater. Cetin and Kirda (2003) assessed temporal and spatial changes in soil salinity in cotton farms under low-quality irrigation water. According to their results, the risk of increased soil salinity was near zero for two years. In this regard, Sharma and Minhas (2005) evaluated the necessary measures for the management of saline/alkaline waters for efficient production in the agriculture section of southern Asia. Salinity, toxicity, sodicity, and water resources not only reduce production but also restrict the selection of crops. Choudhary et al. (2006) investigated the effect of irrigation with sodic and non-sodic water on the properties of soil and the yield of the sunflower plant. Since the sunflower has an average tolerance to salinity, its response to sodic water remains unclear. Their results showed that the continuous use of sodic water increased soil ESP and pH while reducing the relative permeability and yield of sunflowers. Therefore, it was concluded that sodic water could be used for irrigation only if it was mixed with non-sodic water in a specific proportion. In another study, Sharma and Rao (1998) assessed the possibility of the long-term use of drainage saltwater for agricultural irrigation in arid and semi-arid regions where the drainage outlets usually are saline. They used drainage saltwater with salinity levels of 6, 9, 18, 8, and 19 $dS.m^{-1}$ for the irrigation of wheat for seven years. The high salinity and sodicity of the drainage water increase the salinity and sodicity of the soil. They indicated that the use of low-quality drainage water for the irrigation of winter wheat showed no significant decline in plant yield and soil degradation. Reinhart et al. (2019) declared that quantifying nutrient load reductions and irrigation potential showed that drainage water recycling is a promising practice for the tile-drained landscape of the U.S. Midwest. Karimi et al. (2019) declared that the application of treated urban wastewater had a significant effect on the increase of tomato yields because these water resources contain nutrient elements (nitrogen, phosphorus, and other macro-and micro-nutrients). Aghajani Shahrivar et al.

(2020) assessed the effect of irrigation using recycled waters on soil pH and EC under Kikuyu grass production, and the result showed that compared to the initial EC of the soil, an increase recorded for EC of top soils irrigated with treated wastewaters. They indicated that Soil pH increased by about 1 unit under irrigation with treated wastewater. In another study, Smaoui et al. (2020) assessed the effects of raw and treated landfill leachate on the chemical properties of Tunisian soil. The result showed that the electrical conductivity of the soil increased significantly, but pH decreased due to the oxidation of organic compounds. Compared to irrigation water, the use of wastewater increases the electrical conductivity (EC) of the soil due to the containing of more ions (Tsigoida and Argyrokastritis, 2020). Although the long-term effects of saltwater use on the chemical and physical soil properties were investigated, limited research was conducted on soil biological properties in the Moghan Plain. This study aimed to assess the effects of using drainage water on the chemical, biological, and physical properties of soil and the yield of tomatoes in Moghan Plain, Iran. The present study could yield valuable data regarding the potential of using drainage outlet saltwater in irrigation, as well as its impact on the chemical and biological soil properties. In case the drainage outlet is usable, a vast area of the agricultural lands could be irrigated with these water resources, which prevents substantial loss of freshwater.

Materials and Methods

To evaluate the possibility of using agricultural drainage water in agriculture, incorporating normal water and saltwater was used. This study was carried out for two years (2015-2016) on a farm at Moghan Faculty of Agriculture, University of Mohaghegh Ardabili (UMA) in Pars Abad town which is in the north of Ardabil Province (Iran), in 39º 20´ to 39º 42´ east longitude and 47º 30´ to 48º 10´ north latitude (Figure 1). The mean rainfall in the studied area is 275 mm per year, with a maximum rainfall of 386 and a minimum of 111 mm per year. Maximum rainfall per month and day in the Moghan Plain was reported to be 124 and 94 mm, respectively. Also, the minimum and maximum temperature in the area was -15 and 41 Celsius, respectively. The average altitude of the area is 45 meters above sea level, with a humid and warm climate. The irrigation and drainage network of Moghan Plain was constructed to irrigate 70,000 hectares of agricultural lands. Its main canal is un-lining, with a capacity of 80 cubic meters per second. Its drainage network is subsurface drainage and discharges an average of about 220 million m^3 of drainage from the network annually.

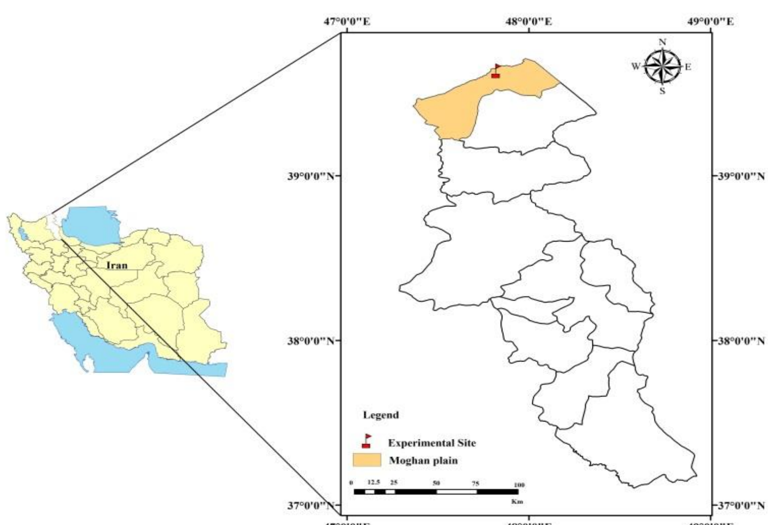

Fig. 1- Map of ran showing the location of the experimental site

Table 1- Results of Chemical Analysis for Irrigation Water, Drainage Water, and Soil

Sources	Date	Concentration (meq/lit)							dS/m	-	-	-
		Ca^{+2}	Mg^{+2}	Na^{+1}	K^{+1}	$HCO3^{-}$	Cl^{-}	$SO4^{-}_{2}$	EC	pH	SAR	ESP
Water drainage	Oct 2015	4.95	3.15	20.50	0.24	4.00	7.60	17.24	2.89	7.69	10.2	12.11
	Jan 2016	2.75	3.30	16.18	0.27	4.20	6.30	11.99	2.26	7.65	9.3	11.08
	Apr 2016	2.45	1.95	12.40	0.25	3.90	4.70	8.45	1.71	7.62	8.36	9.97
Water irrigation	Oct 2015	1.35	1.65	5.10	0.24	3.80	2.80	1.75	0.84	7.79	4.16	4.65
	Jan 2016	1.5	1.65	4.02	0.24	3.80	2.90	1.72	0.75	7.75	3.20	3.34
	Apr 2016	1.6	1.65	4.83	0.24	3.80	3.00	1.43	0.84	7.72	3.79	4.15
Soil	-	3.6	1.53	14.38	4.50	3.86	-	-	1.77	7.77	5.71	6.68

Table 2- Average Monthly Temperature and Rainfall in the Study Area

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation (mm)	15.7	23.4	30.8	31.8	31.1	14.8	7.1	12.4	26.7	33.5	25.4	18.4
Temperature ºC	4.1	5.8	9.9	15.7	20.9	25.3	27.1	25.2	20.1	13.8	8.1	4.6

Some quality characteristics of irrigation water, drainage water, and soil of the region, along with average monthly temperature and rainfall in the study area are shown in Tables (1) and (2), respectively. Treatments in this study were T0 (irrigation with water from the canal of Mil- o- Moghan dam), T1 (irrigation with 50% agricultural drainage water+50% water from the irrigation canal), and T2 (irrigation with agricultural drainage water only) at four replications in a completely random design. The 12 plots (3m×16m) were prepared to perform the treatments. For tomato irrigation, a furrow system was used. Three furrows were made inside each plot, and the width of each furrow was 0.75m.

A sampling of soil and plant were made from the middle furrow. Irrigation was performed based on the irrigation frequencies of the region every ten days. In the planting stage, the salinity was not applied until the plants were well established in the ground to increase the seedling resistance against salinity. Therefore, the plots were irrigated with irrigation water only in this stage. To apply treatments, the drainage water was first pumped into a tanker. Afterward, in an appropriate proportion, the irrigation water was added to the drainage water. In addition, 3 composite soil samples from different treatments were prepared, and some soil tests including the soil pH, electrical conductivity (EC) of the soil solution Gupta, (2009), soil texture Dane and Topp, (2002), organic matter Jones, (2001), basal respiration, and substrate-induced respiration Schinner, (2012) were carried out. Soil particle-size distribution was determined using a hydrometric method by four readings (Dane and Topp, 2002). Then, the soil texture was determined using the soil texture triangle. Moreover, basal and substrate-induced respiration was measured using the CO_2 emission method (Schinner, 2012; Anderson and Domsch, 1993). The EC and pH of the soil solution (water to soil ratio of 2:1) were measured using a pH meter and EC meter Gupta, (2009). Additionally, the absolute osmotic potential (OP), which directly shows the effects of salinity on plant growth (Mojalali, 1987), was obtained using equation (1):

$$OP = EC \times (0.36) \quad (1)$$

The undisturbed samples of soil were taken using 100 cm^3 stainless steel cylinders for measuring the bulk density. Soil samples were oven-dried at 105 ºC, and bulk density was obtained from cylinder volume and oven-dry soil mass. To obtain the Soil Water Retention Curve (SWRC), undisturbed (using 100 cm^3 stainless steel cylinders) and disturbed soil samples were used to measure less than one bar suction (1000 cm-water) and over 1 bar to 15 bar (1000 to 15000 cm-water), respectively. The undisturbed soil samples were saturated from below and after 24 hr.; they were dried down to different suction. For less than 100 and over 100 to 1500 cm-water suction, the hanging column apparatus and ceramic pressure plate extractors were used. The falling head method was used to measure the saturated hydraulic conductivity (Dane and Topp, 2002; Rasoulzadeh and Yaghoobi, 2014). The SWRC was fitted to the van Genuchten (1980) equation using WATREC software Rasoulzadeh, (2010) to obtain the parameters of the Van Genuchten equation.

In this study, to assess the impact of drainage water on soil hydraulic properties (SWRC), Van Genuchten (1980) function was used as follows:

$$\theta(h) = \theta_r + (\theta_s - \theta_r)(1 + |\alpha h|^n)^{-m} \quad (2)$$

Where h is the pressure head (cm-water) and $\theta(h)$ is the soil moisture at the h pressure head, θ_s and θ_r denote saturated and residual soil water content ($cm^3\ cm^{-3}$), respectively. The symbols α, n, and m=1-1/n are the shape parameters. The statistical design of this research was completely randomized blocks and ANOVA was conducted using SPSS 16.0 software, and the mean comparison was performed by Duncan's multiple range tests at the appropriate probability level (1% and 5%).

Results

The results showed that the percentage of soil particles (sand, silt, and clay) and soil texture were the same in all the treatments. The sand, silt, and clay made up were 24.6%, 32.4%, and 43% of the soil, respectively, and the soil texture was obtained from clay. Since the quality of the water in irrigation water and drainage outlets might differ at various irrigation times, the sampling from the drainage and irrigation water was carried out per each irrigation event, and each sample was analyzed in the laboratory for water quality (pH and EC) (Table 3). According to the results, the pH of drainage water and irrigation water was less than 7 in most irrigation events. The maximum and minimum EC of the drainage water was 2.531 and 0.98 $dS.m^{-1}$, respectively, which belonged to the ninth and fifth irrigations (during the first year of the study).

It is also noteworthy that the leading cause of low EC in the drainage water of the fifth irrigation was possible because of the rainfall and mixing of the surface runoff with the drainage water. In the classification of water resources, the EC of most drainage waters was within the range of 2-10 $dS.m^{-1}$, which is considered to be a medium salinity (Hasheminia et al. 1997). As observed in the results of the drainage water analysis in the Moghan Plain, the EC of these water resources also falls within the same range, classifying them as water resources with a medium salinity. These water resources are found abundantly in Moghan Plain and have a high potential for agricultural uses. This management practice is done during the shortage of water in Moghan (drainage water is returned to the main canal). According to Table 3, the quality of the irrigation water had a slight difference during the two years, with a similar trend. Evaluation of EC and pH in different months showed no changes. Therefore, it could be concluded that irrigation water had the same quality during the year in terms of these parameters. Due to salt leaching from the topsoil, drainage water has a higher ionic concentration and EC, compared to irrigation waters. In the present study, only a slight difference was observed in terms of pH in irrigation and drainage water.

Effects of Various Treatments on the Chemical Properties of the Soil

After applying the treatments, a chemical analysis of the soil was conducted in the laboratory. Results of ANOVA and the mean

 DOI: 10.22055/JISE.2023.39612.2011

comparison using Duncan's multiple range tests are presented in Tables (4) and (5), respectively. According to the results, the replications had no significant differences. Therefore, it could be concluded that the soil properties of all four replications in each treatment were the same in both years of the study. Furthermore, the results of variance analysis indicated that at the probability level of 1%, the treatments had a significant effect on the EC and OP of the soil in both years of the study. In treatment T2, pH showed a significant difference compared to the T1 and T0 treatments in the first year of the research (2015). However, soil pH showed no significant differences in various treatments during the second year of the research (2016) (Table 4).

Table 3- Results of Chemical Analysis for pH and EC (dS/m^{-1}) of T0 (Irrigation water only), T1 (50% drainage water +50% irrigation water), and T2 (drainage water only) Treatments in Each Irrigation Event in the First (2015) and the Second Year (2016).

Irrigation event	pH			EC		
	T0	T1	T2	T0	T1	T2
			Year-2015			
1	6.83	6.58	6.72	0.80	1.62	2.19
2	6.52	6.70	7.03	0.84	1.95	2.45
3	6.84	6.75	6.84	1.30	1.47	2.25
4	6.54	6.60	7.20	0.84	1.83	2.36
5	6.60	6.53	6.60	0.74	0.90	0.98
6	6.71	6.78	6.58	0.84	1.50	2.25
7	6.45	6.66	6.85	0.84	1.29	1.77
8	7.02	6.67	7.03	0.83	1.64	2.48
9	6.82	6.71	6.87	0.83	1.71	2.53
10	6.70	6.66	6.85	0.87	1.66	2.14
			Year-2016			
1	6.80	6.66	6.58	0.70	1.58	2.35
2	6.82	6.69	7.10	0.85	1.85	1.87
3	6.84	6.59	6.84	0.97	1.92	2.45
4	6.52	6.70	7.23	0.88	2.24	2.36
5	6.59	6.78	6.51	0.75	1.65	1.98
6	6.70	6.53	6.58	0.78	1.32	2.01
7	6.56	6.66	6.72	0.87	0.90	1.95
8	6.71	6.69	7.12	0.89	1.49	1.68
9	6.62	6.71	6.70	0.88	1.89	1.97

Table 4- Variance Analysis of Treatment Effects on pH, EC, organic matter (OM), and Osmotic Pressure (OP) of Soil in the First (2015) and the Second year (2016)

Source of variation	df	Mean squares (Year-2015)			
		pH	EC	OM	OP
Replication	3	0.004^{ns}	0.039^{ns}	0.096^{ns}	0.005^{ns}
Treatment	2	0.049**	0.322**	0.091^{ns}	0.042**
Error	6	0.003	0.009	0.068	0.001
		Mean squares (Year-2016)			
Replication	3	0.000^{ns}	0.045^{ns}	0.017^{ns}	0.006^{ns}
Treatment	2	0.004^{ns}	0.874**	0.027^{ns}	0.113**
Error	6	0.014	0.007	0.008	0.001

ns and ** show the non-significant and significant at $P \leq 0.01$, respectively.

Table 5-Means Comparison of the Effects of Using Drainage Water on pH, EC Organic Matter, and OP of Soil Solution in the First (2015) and the Second Year (2016)

Treatment	pH	EC ($ds.m^{-1}$)	OM (%)	OP (bar)
(Year-2015)				
T0	7.81^{a} (±0.033)	1.28^{a} (±0.053)	1.55^{a} (±0.130)	0.46^{a} (±0.019)
T1	7.83^{a} (±0.023)	1.43^{a} (±0.059)	1.67^{a} (±0.113)	0.52^{a} (±0.021)
T2	7.63^{b} (±0.032)	1.83^{b} (±0.089)	1.85^{a} (±0.169)	0.66^{b} (±0.032)
(Year-2016)				
T0	7.71^{a} (±0.058)	0.62^{a} (±0.040)	2.05^{a} (±0.040)	0.22^{a} (±0.014)
T1	7.76^{a} (±0.035)	1.24^{b} (±0.074)	2.14^{ab} (±0.046)	0.45^{b} (±0.021)
T2	7.70^{a} (±0.046)	1.54^{c} (±0.086)	2.23^{b} (±0.066)	0.55^{c} (±0.042)

Different letters in the same column denote significant differences ($P \leq 0.01$).

The results showed that the amount of indicators pH and OP of irrigation water had minor changes during the research period, but indicators EC and OM had more changes (Table 5). Change pH is proportional to the change in the type of ions in the water, which are not changed due to the constant of the river route, except by an external source or factor. But the changes of EC depend on the change of the sum of anions and cations in the water, in which the addition of impurities and evaporation increases. Measurement of EC in the current study showed with the higher concentration of drainage in the water resources of all the irrigation treatments, EC of the saturated soil mud significantly increases ($p \leq 0.01$). It could be attributed to the increased concentrations of calcium, magnesium, sodium, chlorine, and sulfate ions in the T2 treatment compared to the other treatments. According to the findings, the T2 treatment caused a significant increase in the EC and OP of the soil solution compared to the T1 and T0 treatments ($p \leq 0.01$) in both years (Table 5). On the other hand, the average value of EC and OP of the soil solution had no significant difference in the T0 and T1 treatments during the first year of the research (2015). While the difference was considered significant between these treatments in the second year (2016), therefore it could be concluded that the diluted drainage water did not increase the EC and OP of the soil solution in the first year of the study. It could increase these parameters compared to the T0 treatment after two years. It could be attributed to the quality of the irrigation water. Irrigation was performed with a higher proportion of the drainage water in the T1 and T2 treatment, which causes the cations and anions to enter the soil. Consequently, it leads to a significant increase in the EC of these treatments compared to the T0 treatment.

Effects of Various Treatments on the Biological Properties of the Soil

After the irrigation with T0 and T2 at the end of each year, some biological indices (basal and substrate-induced respiration, and the microbial population) were measured in the soil, and statistical results were presented in Tables (6) and (7). The results showed that there was a significant difference ($p \leq 0.05$) in the basal respiration between T2 with T0 treatments while there was no significant difference between T0 and T1 treatments as well as T1 and T2 at the end of the first year. Also, a significant difference ($p \leq 0.05$) was observed between all treatments in basal respiration at the end of the second year (Table 7).

Table 6-Variance Analysis of Treatment Effects on Basal Respiration, Substrate-Induced Respiration, and Microbial Population of Soil in the First (2015) and the Second Year (2016)

Source of variation	df	Mean squares (Year-2015)		
		Basal respiration	Substrate-induced respiration	Bacterial population
Replication	3	0.001^{ns}	0.000^{ns}	5.3E+12^{ns}
Treatment	2	0.002*	0.000*	5.6E+12**
Error	6	0.000	9.9E-05	3.5E+12
		Mean squares (Year-2016)		
Replication	3	0.000^{ns}	0.000^{ns}	5.3E+11^{ns}
Treatment	2	0.005**	0.001*	9.3E+12**
Error	6	0.000	0.000	10.1E+13

ns,*and ** show the non-significant, significance at $P\leq0.05$and $P\leq0.01$, respectively.

Table 7-Mean Comparison of Different Treatments in Terms of Basal Respiration, Substrate-Induced Respiration, and Microbial Population of Soil in the First (2015) and the Second Year (2016)

Treatment	(Year-2015)		
	Basal respiration (mg CO_2 g^{-1})	Substrate-induced respiration (mg CO_2 g^{-1})	Bacterial population (Number. g^{-1} dry Soil)
T0	0.2439^{a*} (±0.0293)	0.0965^{a*} (±0.0111)	5.4E+06^{a**} (±5.2E+05)
T1	0.2137^{ab*} (±0.0149)	0.0935^{a*} (±0.0040)	4.8E+6^{a**} (±1.3E+05)
T2	0.1987^{b*} (±0.0128)	0.0761^{b*} (±0.0030)	3.1E+6^{b**} (±1.0E+05)
	(Year-2016)		
T0	0.2475^{a*} (±0.0031)	0.0790^{a*} (±0.0076)	5.3E+06^{a**} (±1.5E+05)
T1	0.2122^{b*} (±0.0240)	0.0599^{b*} (±0.0029)	3.9E+06^{b**} (±1.6E+05)
T2	0.1782^{c*} (±0.0110)	0.0528^{b*} (±0.0058)	2.2E+06^{c**} (±8.9E+05)

Different letters in the same column along with asterisks denote significant differences at $P \leq 0.05$(*) and $P \leq 0.01$ (**).

Effects of Irrigation with Different Treatment Water Resources on soil physical properties

Variations of soil bulk density (BD) and saturated hydraulic conductivity (K_s) were shown in Figure 2. The treatments did not differ significantly in terms of the BD in 2015 and 2016 as well as the K_s in 2015, whereas the K_s for the T2 treatment differed significantly ($p\leq0.05$) in 2016 (Figure 2).

It is noticeable that with increasing the EC of irrigation water, the amount of Na ions increases. A higher concentration of Na can disperse soil aggregate and consequently decrease K_s. This result is in line with the results of Bagarello et al. (2006) who found that with increasing SAR in irrigation water, K_s decreases significantly in clay and sandy loam soils.

Effects of Irrigation with Different Treatment Water Resources on Plant Growth Properties

Tomato growth parameters, including the yield and chlorophyll content, after the first and the second year of irrigation with T0, T1, and T2 treatments were recorded, and the results are shown in Tables (8) and (9). According to the results of variance analysis Table (8), there were no significant differences among the treatments in terms of yield and chlorophyll content.

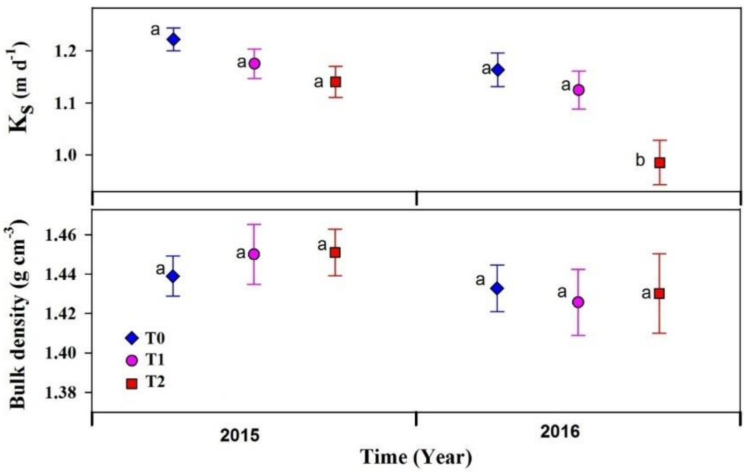

Fig. 2- Variation of bulk density and saturated hydraulic conductivity (K_s) (mean and ±SE values) for two years (the same letter indicates no significant difference (p≤0.05) (T0 (Irrigation water only), T1 (50% drainage water +50% irrigation water) and T2 (drainage water only) treatments)

Table 8- Variance Analysis of Treatment Effects on Tomato Yield and Chlorophyll in the First (2015) and the Second Year (2016)

Source of variation	df	Mean squares(Year-2015) Yield	Chlorophyll
Replication	3	1.551^{ns}	16.819^{ns}
Treatment	2	0.288^{ns}	0.528^{ns}
Error	6	0.784	7.461
Mean squares (Year-2016)			
Replication	3	9.700^{ns}	1.551^{ns}
Treatment	2	0.048^{ns}	0.288^{ns}
Error	6	1.745	0.784

ns shows the non-significant.

Table 9- Mean Comparison of Different Treatments in Terms of Tomato Yield and Chlorophyll in the First (2015) and the Second Year (2016)

Treatment	(Year-2015) Yield (ton ha^{-1})	Chlorophyll
T0	13.61^a (±0.43)	49.97^a (±1.69)
T1	13.86^a (±0.73)	50.53^a (±0.64)
T2	14.14^a (±0.26)	50.65^a (±0.55)
	(Year-2016)	
T0	16.91^a (±0.75)	50.74^a (±1.57)
T1	17.10^a (±0.82)	50.86^a (±0.71)
T2	17.44^a (±0.47)	50.95^a (±0.57)

Different letters in the same column along with asterisks denote a significant difference at P ≤ 0.05.

Discussion

Although the acidity of irrigation water affects the pH of the soil, after changing the effect of acidity of irrigation water, the soil pH returns to its stable state immediately (Tsigoida and Argyrokastritis, 2020; Smaoui et al., 2020), so according to the acidity of irrigation water (T0) and drainage water (T2) used in this study Table (1), which differs slightly from soil pH, no change in soil pH was expected. Soil pH reaction is a prominent measurement method for the chemical properties of the soil (Mclean 1983). Soil pH not only determines the acidic or alkaline condition of the soil, but it also determines the availability of essential nutrients and toxicity of the other elements to plants (Thomas,1996). Soil pH declines typically by increasing the soil-to-water ratio or the presence of salts. Soil pH was measured in the saturated soil mud in the irrigation treatments with various proportions of saline drainage water. There was a significant difference ($p \leq 0.01$) among the treatments in terms of soil pH, with the mean value estimated at 7.6, which is a healthy pH for most plants. Although there were minor changes in soil pH. The decrease in soil pH as an effect of the drainage water addition could be due to the higher concentration of soluble cations, which slightly releases exchangeable acidity (H+) (Neishabouri and Reyhani Tabar, 2010). Also, the increase in EC is due to the high mineral loads (Smaoui et al., 2020; Aghajani Shahrivar, 2020). Singh et al. (2017) stated due to the high levels of dissolved salts, and according to Tsigoida and Argyrokastritis (2020), using wastewater for irrigation increases soil EC. The boundary line between saline and non-saline soils is considered to be at the EC of 4 dS.m-1 for the saturated soil extract (Mojalali, 1987). Nevertheless, the risk of salinity is low in the treatments, which is expected only to affect highly sensitive plants. In this regard, many researchers have reported similar results. For instance, Choudhary et al. (2006) investigated the effects of alternative irrigation with sodic and non-sodic water on the properties of soil and yield of the sunflower plant and obtained similar results. Accordingly, constant use of sodic water increased soil EC, while decreasing the relative permeability and yield of the sunflower. Also, Suyama et al. (2006) evaluated the yield of the forage irrigated by sodic-saline drainage in the greenhouse, concluding that irrigation with sodic-saline water would significantly increase soil EC. In sum, current research showed that the application of T2 treatment significantly decreased soil pH compared to the T0 and T1 treatments in the first year. However, no significant difference was observed between the T0 and T1 treatments. Moreover, soil organic matter (OM) showed no significant difference among the treatments in the first year, while the OM in the T2 treatment was significantly ($p \leq 0.01$) more than the one in T0 treatment in the second year (Table 4). A certain amount of OM likely enters the T2 treatment during the leaching process. As a result, the T2 treatment obtains some organic materials, which will enhance the organic content of the soil irrigated with the T2 in the long term. According to the results, irrigation with the T2 decreased OP in the soil, such that the absolute OP showed a significant increase in the T2 treatment compared to the other two treatments. It could be attributed to the higher concentrations of ions in the soil and the increased EC after irrigation with the T2. This increase might influence plants by affecting the water-soil potential (Mojalali, 1987). According to the results, the mean comparison of soil substrate-induced respiration indicated no significant difference between the T0 and T1 treatments at the end of the first year. However, a significant difference was observed between these two treatments and the T2. The same trend was observed in terms of the bacterial population at the end of the first year. The results showed a significant difference ($p \leq 0.01$) between all treatments in the bacterial population at the end of the second year. There was a significant difference ($p \leq 0.05$) in the soil substrate-induced respiration between T0 with T1 and T2 treatments while there was no significant difference between T1 and T2 treatments at the end of the second year (Table 7). The variation of Van Genuchten function parameters is illustrated in Figure (3).

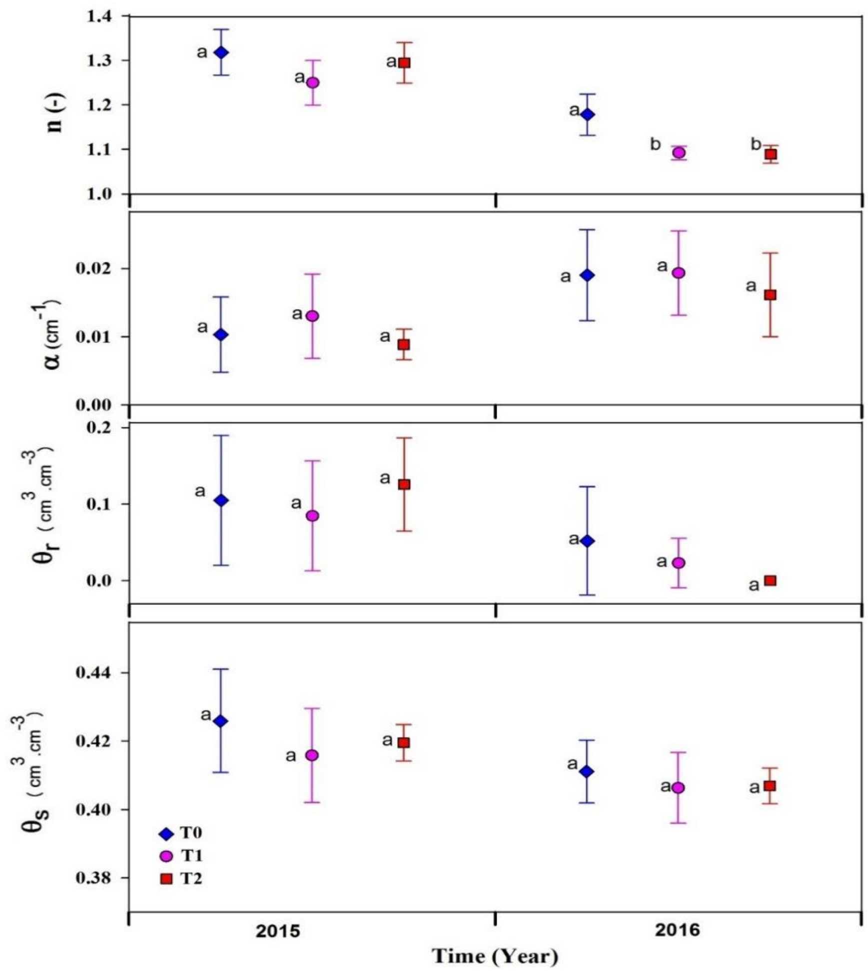

Fig. 3- Variation of van Genuchten's retention function parameters (mean and ±SE values) for two years (the same letter indicates no significant difference ($p \leq 0.01$) (T0 (Irrigation water only), T1 (50% drainage water +50% irrigation water) and T2 (drainage water only) treatments)

No significant differences were observed in the parameters of van Genuchten (θs, θr, and α) in all the treatments. This finding can be because of the low salinity of the drainage water and the existence of the drainage system in the study area. Kiremit and Arslan (2016) reported that if appropriate leaching and drainage systems are applied, slightly saline water can be used for irrigation with little or no soil damage. There was a significant difference ($p \leq 0.01$) in the n (the parameters of van Genuchten which is indicated the slope of the SWRC) between T0 with T1 and T2 treatments. While there was no significant difference between T1 and T2 treatments in the n. Furthermore, a comparison of the means of the yield and chlorophyll content in different treatments showed no significant differences in this regard (Table 9). Gatta et al. (2015) reported that irrigation with wastewater does not affect yield. But some studies have had different results (Karimi et al., 2019; Fereidoni et al., 2013) because irrigation with wastewater is effective if it contains so enough nutrients such as nitrate and phosphate. Irrigation with T2 compared to T0 treatment led to a 4% and 3% increase in the yield of tomatoes in the first and second years of the study, respectively. However, the increase was not considered statistically significant. Generally, the T2 treatment is high in nutrients because of fertilizer leaching from the soil column. Thus, the slight increase in tomato yield in irrigation with the T2 might be due to the possible nutrients in the T2 treatment, which enhanced the yield of the crops.

Conclusion

It is essential to use unconventional water resources, such as drainage water in the agricultural sector because of population growth and a freshwater shortage problem in the semi-arid regions. This study focuses on the effect of the re-using of drainage water in agriculture on soil chemical, biological and physical properties and the yield of tomatoes. The results showed that re-use of drainage water decreases pH and increases EC, OP, and OM of the soil solution. It is noticeable that the increase of OM in the effect of irrigation with drainage water probably is because of the leaching process. It is expected that due to the salinity of drainage water, irrigation with this water causes a decrease in the yield of tomatoes whereas it causes an increase in the yield. It can be justified by increasing OM. Results suggested that the use of drainage water decreased soil microbial population, basal respiration, and substrate-induced respiration. The application of the drainage water for two years significantly affected the soil's biological properties in all the treatments. In other words, in comparison with irrigation water, long-term use of drainage water has more clear adverse

effects on the biological properties of soil. The basal and substrate-induced respiration are expected to reduce because of the use of the drainage water so that the soil respiration would decrease because of the reduction in soil microbial population. Re-use of the drainage water increased soil salinity and OP, which adversely affected the microbial population, microbial activities, and soil respiration. Soil respiration and substrate-substrate-induced respiration are the sensitive indices for the determination of the effects of non-biological stress, such as salinity, on the microbial activities in the soil. Based on the results, re-use of the drainage water causes a decrease in saturated hydraulic conductivity and water content as well as an increase in bulk density. The reason for the lack of significant effect of the drainage water on the physical parameters is the presence of organic matter and the medium salinity of the drainage water. It can be concluded that re-use of the drainage water has no significant effect on the mentioned soil physical parameters. The effect of re-use of drainage water on the shape parameters of van Genuchten function (α, n) showed that only the n parameter was significantly ($p \leq 0.01$) affected by the re-use of drainage water in the second year of the experiment. It can be concluded that the organic matter in the drainage water is affecting α greater than n.

Acknowledgements

The authors wish to thank to the Vice Chancellor for Research and Technology, University of Mohaghegh Ardabili for providing the financial assistance to carry out this research work.

References

1- Aghajani Shahrivar, A., Hagare, D., Maheshwari, B. and Muhitur Rahman, M., 2020. The effect of irrigation using recycled waters obtained from MBR and IDAL wastewater treatment systems on soil pH and EC under kikuyu grass (Pennisetum clandestinum) production. *Water Supply*, *20*(4), pp.1313-1320. Doi: 10.2166/ws.2020.049.

2- Al-Isawi, R.H.K., Scholz, M., Al-Faraj, F.A.M. 2016. Assessment of diesel-contaminated domestic wastewater treatedby constructed wetlands for irrigation of chillies grown in a greenhouse. *Environmental Science and Pollution Research*, 23: 25003-25023.

3- Anderson, T.H. and Domsch, A.K., 1993. The metabolic quotient for CO2 (qCO2) as a specific activity parameter to assess the effects of environmental conditions, such as pH, on the microbial biomass of forest soils. *Soil biology and biochemistry*, *25*(3), pp.393-395. Doi: 10.1016/0038-0717(93)90140-7.

4- Bagarello, V., Iovino, M., Palazzolo, E., Panno, M. and Reynolds, W.D., 2006. Field and laboratory approaches for determining sodicity effects on saturated soil hydraulic conductivity. *Geoderma*, *130*(1-2), pp.1-13. Doi: 10.1016/j.geoderma.2005.01.004.

5- Barnes, J., 2014. Mixing waters: The reuse of agricultural drainage water in Egypt. *Geoforum*, *57*, pp.181-191. Doi: 10.1016/j.geoforum.2012.11.019.

6- Beltrán, J.M., 1999. Irrigation with saline water: benefits and environmental impact. *Agricultural water management*, *40*(2-3), pp.183-194.

7- Cetin, M. and Kirda, C., 2003. Spatial and temporal changes of soil salinity in a cotton field irrigated with low-quality water. *Journal of Hydrology*, *272*(1-4), pp.238-249. Doi: 10.1016/S0022-1694(02)00268-8.

8- Choudhary, O.P., Ghuman, B.S., Josan, A.S. and Bajwa, M.S., 2006. Effect of alternating irrigation with sodic and non-sodic waters on soil properties and sunflower yield. *Agricultural water management*, *85*(1-2), pp.151-156. Doi: 10.1016/j.agwat.2006.03.017.

9- Dane JH, Topp GC. 2002. Methods of Soil Analysis, Part 4, Physical Method. Soil Science Society of America Journal, Inc. Madison, Wisconsin.

10- El-Zawily, A.E.S., Meleha, M., El-Sawy, M., El-Attar, E.H., Bayoumi, Y. and Alshaal, T., 2019. Application of magnetic field improves growth, yield and fruit quality of tomato irrigated alternatively by fresh and agricultural drainage water. *Ecotoxicology and environmental safety*, *181*, pp.248-254. Doi: 10.1016/j.ecoenv.2019.06.018.

11- Fereidoni, M.J., Faraji, H. and Owliaie, H., 2013. Effect of treated urban sewage and nitrogen on yield and grain quality of sweet corn and some soil characteristics in Yasouj region. *Water and Soil Science*, *23*(3), pp.43-56.

12- Gatta, G., Libutti, A., Gagliardi, A., Beneduce, L., Brusetti, L., Borruso, L., Disciglio, G. and Tarantino, E., 2015. Treated agro-industrial wastewater irrigation of tomato crop: Effects on qualitative/quantitative characteristics of production and microbiological properties of the soil. *Agricultural Water Management*, *149*, pp.33-43. Doi: 10.1016/j.agwat.2014.10.016.

13- Ghazavi, R. and Orst, M. (2017). Investigation the Effect of Irrigation with Municipal Waste Water on Accumulation of Some Pollutants and Chemicals Elements in Plant and Its Effect on their Ecological Characteristics (A Case Study: Eucalyptus Globulus). PEC2016; 4 (8):13-29. URL: http://pec.gonbad.ac.ir/article-1-169-en.html

14- Gupta PK. 2009. Soil, Plant, Water, and Fertilizer Analysis. Agrobios, India.

15- Hasheminia M, Koochaki A, Ghahreman N. 1997. Use of Saline Water in Sustainable Agriculture. Mashhad ACECR Publications (In Persian).

16- Jones Jr, J.B., 2001. *Laboratory guide for conducting soil tests and plant analysis*. CRC.

17- Karimi, B., Abdi, C.H. and Fathi Tileko, Z., 1970. Effects of Irrigation with Treated Urban Wastewater on Yield and Some Growth Characteristics of Tomato and Corn in Greenhouse Condition. *Water and Soil Science*, *28*(4), pp.19-29. (In Persian).

18- Kiremit, M.S. and Arslan, H., 2016. Effects of irrigation water salinity on drainage water salinity, evapotranspiration and other leek (Allium porrum L.) plant parameters. *Scientia Horticulturae*, *201*, pp.211-217. Doi: 10.1016/j.scienta.2016.02.001.

19- Liang, Y., Si, J., Nikolic, M., Peng, Y., Chen, W. and Jiang, Y., 2005. Organic manure stimulates biological activity and barley growth in soil subject to secondary salinization. *Soil Biology and biochemistry*, *37*(6), pp.1185-1195. Doi: 10.1016/j.soilbio.2004.11.017.

20- Mclean EO. 1983. Soil pH and lime requirement. P. 199-224. In A.L Page, R.H. Miller, and D.R. Keeney (eds.) Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, Wisconsin. Doi: 10.2134/agronmonogr9.2.2ed.c12

21- Mojalali H. 1987. Chemistry of the Soil. Tehran University Publishing (In Persian).

22- Nasiri N, Rasoulzadeh A. 2011. Evaluating the Effects of Reusing Drainage on the Chemical Properties of Soil (A Case Study: Moghan Plain). The First National Congress of Novel Agricultural Sciences and Technologies; Zanjan University; September 10-12 (In Persian).

23- Neishabouri M, Reyhani Tabar A. 2010. Interpretation of the Soil Test Results. Tabriz University Publications (In Persian).

24- Norton-Brandao, D., Scherrenberg, S.M. and van Lier, J.B., 2013. Reclamation of used urban waters for irrigation purposes–a review of treatment technologies. *Journal of Environmental Management*, *122*, pp.85-98. Doi: 10.1016/j.jenvman.2013.03.012.

25- Abu-Rizaiza, O.S. and Sarikaya, H.Z., 1994. Drainage water reuse or disposal, Jeddah, Saudi Arabia. *Desalination*, *98*(1-3), pp.173-183.

26- Seshadri, B., Bolan, N., Naidu, R. and Matheyarasu, R., 2016. Assessment of nitrogen losses through nitrous oxide from abattoir wastewater-irrigated soils. *Environmental Science & Pollution Research*, *23*(22).22633-22646.

27- Rasoulzadeh A, Nasiri N. 2013. Investigation of Saline Drainage Water Reuse Effect on Soil HydraulicProperties Using Inverse Method (Case Study: Moghan Plain). *Journal of Civil and Environmental Engineering.* 43(3):29-40 (In Persian).

28- Rasoulzadeh, A. and Yaghoubi, A., 2014. Inverse modeling approach for determining soil hydraulic properties as affected by application of cattle manure. *International Journal of Agricultural and Biological Engineering*, *7*(2), pp.27-35.

29- Rasoulzadeh, A., 2010. Evaluation of water retention functions by developing a code for quantifying the hydraulic functions of unsaturated soils. *Journal of Food, Agriculture & Environment*, *8*(2), pp.1180-1184.

30- Reinhart, B.D., Frankenberger, J.R., Hay, C.H. and Helmers, M.J., 2019. Simulated water quality and irrigation benefits from drainage water recycling at two tile-drained sites in the US Midwest. *Agricultural Water Management*, *223*, p.105699.Doi: 10.1016/j.agwat.2019.105699.

31- Schinner, F., Öhlinger, R., Kandeler, E. and Margesin, R. eds., 2012. *Methods in soil biology*. Springer Science & business media.

32- Sharma, B.R. and Minhas, P.S., 2005. Strategies for managing saline/alkali waters for sustainable agricultural production in South Asia. *Agricultural water management*, *78*(1-2), pp.136-151. Doi: 10.1016/j.agwat.2005.04.019

33- Sharma, D.P. and Rao, K.V.G.K., 1998. Strategy for long term use of saline drainage water for irrigation in semi-arid regions. *Soil and Tillage Research*, *48*(4), pp.287-295.

34- Singh, S., Raju, N.J. and RamaKrishna, C., 2017. Assessment of the effect of landfill leachate irrigation of different doses on wheat plant growth and harvest index: A laboratory simulation study. *Environmental nanotechnology, monitoring & management*, *8*, pp.150-156. Doi: 10.1016/j.enmm.2017.07.005.

35- Smaoui, Y., Chaari, L., Fersi, M., Gargouri, K. and Bouzid, J., 2020. Effects of raw and treated landfill leachate on the chemical properties of a Tunisian soil. *Euro-Mediterranean Journal for Environmental Integration*, *5*, pp.1-10.

36- Suyama, H., Benes, S.E., Robinson, P.H., Grattan, S.R., Grieve, C.M. and Getachew, G., 2007. Forage yield and quality under irrigation with saline-sodic drainage water: Greenhouse evaluation. *Agricultural Water Management*, *88*(1-3), pp.159-172. Doi: 10.1016/j.agwat.2006.10.011.

37- Thomas, G.W., 1996. Soil pH and soil acidity. *Methods of soil analysis: part 3 chemical methods*, *5*, pp.475-490. Doi: 10.2136/sssabookser5.3.c16.

38- Tsigoida, A. and Argyrokastritis, I., 2020. Electrical conductivity, pH and other soil chemical parameters after sub-irrigation with untreated and treated municipal wastewater in two different soils. *Glob Nest J*, *22*, pp.55-66. Doi: 10.30955/gnj.003217.

39- Van Genuchten, M.T., 1980. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. *Soil science society of America journal*, *44*(5), pp.892-898. Doi: 10.2136/sssaj1980.03615995004400050002x