Flow hydraulics consideration information of the greywater reuse: towards sustainable water management (Case Study: Chah-Anari region, Isfahan University of Technology, Isfahan, Iran)

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Case Report

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Abstract

The effects of irrigation with treated wastewater on soil chemical and physical properties have been studied in many researches, but a few studies have done about wastewater flow on the soil surface. In this study flow hydraulic of wastewater on soil surface was investigated and magnetic field effects on it was also studied. This research was done in the field with furrows (length of 42m, width of 60cm, depth of 25cm and slope of 0.1%) in Isfahan University of Technology and were used three water quality treatments consists of fresh water (FW), wastewater (WW) and magnetized wastewater (MW). Magnetic field was created by three magnets with constant magnetic field intensity of 10mili-Tesla for each one. Basic differences between three water treatments were in biological parameters (Chemical oxygen demand (COD), Total-coliform) and total suspended solids (TSS). The Collected data were included of advance and recession time, inflow and outflow rates with four replications and five irrigation events for each treatment (overall 60 practices), in a randomized complete block design. The inflow rate for furrows was determined 0.8 lit/sec. The results showed magnetic field have not a considerable effect on the physical and chemical characteristics of the wastewater, though it changes oxygen demand and especially total coliforms. Also, no significant difference was observed between the effects of water quality treatments on water infiltration characteristics, consist of basic infiltration rate (fo) and mean infiltration rate in two 30 minutes time intervals (0-30 and 30-60 minutes), but in mean infiltration rate in 0-30 interval, mean relative changes for the WW and MW were about twice of the FW. Mean infiltration rate of the FW has also less reduction than WW and MW in these intervals. However, scrutinizing of parameters variations in charts showed that WW and MW treatments relation to FW ones created more changes in downtrend of "f_o" during irrigation season and magnetic field effect was inconsiderable. The "f_o" in WW and MW was more than FW mostly. It was found that magnetic field causes increasing of the “f_o” in MW related to WW. Similar results also were found in two-time intervals of infiltration process. Also excluding depletion time phase, evaluated time parameters, including advance time to furrow end, time to reach the “f_o” and recession duration had not difference significantly influenced by water quality treatments, but values of advance time and time to reach the “f_o” for WW and MW than FW were higher mostly. According to regressions equation between water quality parameters and flow hydraulic parameters, were found a negative correlation between “f_o”, mean infiltration rate for 0-30min and 30-60min ranges and advance time with TSS and irrigation number; and a positive correlation between these parameters with COD; also a negative correlation between time to reach the “f_o” and depletion time with COD; and a positive correlation between these parameters with TSS and irrigation number. In parameter of recession duration, positive correlations are with irrigation number and COD; and negative correlation is with TSS. So as to current hydraulic examination of the sewage on the soil were experienced channel irrigations with sewage that the subsequent consequences were gained: Attractive ground result on WW superiority was not substantial, but electrical conductivity amplified a little. The straightforward penetration degree had downtrend throughout irrigation period. MW had similarly maximum standards of elementary penetration degree and for WW was developed than FW. Without period of reduction stage, components of current hydraulic of WW and MW on soil for example development, collapse and loading period had not alteration meaningfully inclined by water superiority conducts, then standards of development and loading period for WW and MW than FW were developed regularly.

Keywords

Elementary Penetration Degree; Total-Coliform; Physical Properties; Chemical oxygen demand; Wastewater; Soil; Flow Hydraulic; Furrow Irrigation; Infiltration; Advance and Recession Time;

Introduction

The reuse of treated wastewater in agriculture can be a sustainable solution to face water scarcity [1]. Irrigation with wastewater may have implications at two different levels: alter the physicochemical and microbiological properties of the soil and/or introduce and contribute to the accumulation of chemical and biological contaminants in soil. The first may affect soil productivity and fertility; the second may pose serious risks to the human and environmental health. Thus simultaneously, affordable technological solutions with minimal environmental impacts must be developed in order to assure wastewater treatment processes compatible with sustainable uses [2]. Wastewater irrigation can be a very attractive proposition with benefits in the form of water conservation, nutrient recycling, surface and ground water pollution prevention, particularly for arid and semi-arid regions if used with proper and adequate management plans in place. For example, whenever and wherever wastewater irrigation is adopted, it is imperative that a regular monitoring of soil physical and chemical properties be done routinely in order to maintain the structural integrity of the already salt affected soils. Also some nutrients, particularly N, although is essential for plant growth, can often be a limiting factor [3]. Herbaceous crops irrigated with wastewater can produce appreciable biomass and energy yields. This is also an environmentally and economically sound way of wastewater disposal [4]. With treated sewage irrigation, a slight increase in the organic content of the soil was observed [5]. Saturated hydraulic conductivity of loam soil reduced with municipal wastewater. This reduction was more remarkable in the clay soil. Simulation of both ponded and sprinkler irrigation with municipal wastewater resulted in reduced infiltration and increased surface ponding condition compared to the application of fresh water [6]. Irrigation with treated wastewater has been reported to induce low to moderate hydrophobicity in soils of different texture with or without vegetation cover [7]. Studies have demonstrated that wastewater irrigation may decrease soil hydraulic conductivity and infiltration rate. Plots irrigated with highly sodic and alkaline industrial wastewater showed important structural damages, especially in the subsurface horizon where the soil pore network collapsed dramatically, resulting in a compact impermeable layer and also pH increase in the topsoil. Inadequate wastewater quality is likely to cause deep and irreversible damages to irrigated soils and resulting decrease of the yield [8]. Effects of irrigation with wastewater on soil chemical and physical properties have been investigated in many researches. However few studies have done about wastewater flow on the soil surface. Thus in this study flow hydraulic of treated wastewater in furrow irrigation was studied by parameters consists of infiltration and advance, storage, depletion and recession phases and fresh water was used as control. Magnetic field effects were also investigated on flow hydraulic of treated wastewater by magnetized wastewater.

Materials and Methods

Experimental Site

In order to achieve research purposes, three water quality treatments were selected included by fresh water (FW), wastewater (WW) and magnetized wastewater (MW). WW was effluent of treatment plant in Isfahan University of Technology. This plant has two lagoons of aeration (by some blowers) and stabilization (Fig. 1). FW was also supplied from piped water. Chah-Anari experimental field was also elected at the University of Technology, as well as its soil characteristics are presented in Table 1. According to Table 1, soil texture is light.

Field Preparing

To field preparing the operations of plowing, disking and initial leveling was performed on it. After smoothing and supplementary leveling, furrows with a length of 42m, width of 60cm and depth of 25cm were created by furrower set. Then furrows slope was determined by surveying separately. Average longitudinal and latitudinal slope were calculated 0.1% for furrows.

Experimental Instruments

The water transmission system into the furrows was consists of FW and WW tanks, a Stabilization tank (by float valves) and the gated pipe. Two tanks of six and ten cubic meters were used separately for FW and WW supply at upstream end of the furrow respectively. The inflow rate for furrows was determined 0.8 lit/sec using the furrow slope and maximum non-erosive stream [9] and according to outflow rate from stabilization tank. To create of mentioned inflow rate, opening value of the each gate on gated pipe was determined by graded container and timer and gate was opened the same amount in each practice. WSC flumes were used to measure of the inflow and outflow in furrow. Flumes were installed perfectly horizontal and with a manner that was prevented from leakage current in vicinity and the free flow was also established (Fig. 2). The MW treatment was also created using three magnets with constant magnetic field intensity (10mili-Tesla for each one). These magnets were installed on pipe in near of outlet gates.

Statistical Design and Experiment Implementation

The used experimental design in this research was randomized complete block with three treatments (FW, WW and MW) and four replications and five irrigation practices in each furrow.

To implement the research, the four experimental blocks were applied in the field. Each block had one main and two lateral furrows for any of water treatments (overall three main and six lateral furrows). To apply the actual conditions in the field, two lateral furrows were considered for each main ones and tests were done in the main furrow. 60 furrow irrigations were evaluated in this study with 4 days irrigation intervals (20 irrigation practices with FW treatment firstly and then 20 irrigations with WW and 20 irrigations with MW ones). It is important to note that MW irrigation was done with same quality of WW but in form of magnetized in each practice. The experimental farm had no cultivation and irrigation was not also done in it previously. Furrows length was divided with three-meter intervals from location of inlet flume installation toward downstream (15 stations in each furrow). Irrigation practice was begun with transfer of water to furrow and parameters were measured such as advance and recession time and inflow and outflow rate in each experiment. Water flow into the furrow continued until outflow rate was constant. Recession times were also recorded at various stations after cutoff time immediately.

Determining of Infiltration Parameters

To obtain the infiltration equation was used from the inflow-outflow method. In this method after the advance stage completion, infiltration rate is equal to the inflow and outflow rate difference at a specified time in furrow length with assumption of small changes in surface storage. Surface storage changes can be neglected in furrows with some conditions. For example, in this paper according to irrigation time, advance time [9] and furrow length [10] from changes in surface storage rate were neglected. Thus, infiltration rate and cumulative infiltration equations were determined by Eq. 1 and Eq. 2:

$$I = \frac{Q_{in} - Q_{out} - R_{ss}}{L} \ \& \ R_{ss} \approx 0 \ , \qquad \text{Eq. (1)}$$

$$Z = \int I \, dt \qquad \text{Eq. (2)}$$

Where Q_{in} = inflow rate; Q_{out} = outflow rate; R_{ss} = surface storage rate; L = furrow length; I_{ave} = average infiltration rate in furrow length; and Z = cumulative infiltration equation. "I" is for when the inflow and outflow rates are "Q_{in}" and "Q_{out}" values respectively. Finally, parameters of Kostiakov infiltration rate equation ($I = k.t^a$) were calculated by various values of "I" and times related to them. In this paper average infiltration in three time intervals consists of 0-30, 30-60 and 60-90 minutes was calculated for each water treatment from the following Eq. 3:

$$I_{ave} = \frac{Z_2 - Z_1}{t_2 - t_1} \qquad \text{Eq. (3)}$$

Where I_{ave} = average infiltration in time interval of "$t_2 - t_1$"; Z_2 , Z_1 = cumulative infiltration to "t_2" and "t_1" times respectively (using Eq. 2). The soil basic infiltration rate (fo) was also calculated with Eq. 4:

$$f_o = \frac{Q_{in-const} - Q_{out-const}}{L} \qquad \text{Eq. (4)}$$

Where $Q_{in-const}$ and $Q_{out-const}$ are fixed values of inflow and outflow rate in furrow irrigation practice.

Water and Wastewater Quality Experiment

Sampling is first step in identifying of the water and wastewater quality and decision for their management. In this study samples were indicative of water and wastewater quality of used supply in this paper. Samples were taken from the gates exit of the tube in the second, fourth and fifth irrigations. For FW treatment due to negligible changes in water quality, tests were done once in the irrigation season. Samples transfer to the laboratory was performed in a short time and at low temperatures (samples were near the pieces of ice). Sampling bottles were plastic and non-transparent. Standard used in determining experiments of water and wastewater quality were taken from “standard methods for the examination of water and wastewater” book [10].

Statistical analysis

Data were analyzed using SPSS and Excel software. Data relative changes were used for analysis and evaluation. These relative changes were calculated as follows Eq. 5:

$$P_r = \frac{P_5 - P_1}{P_1} \qquad \text{Eq. (5)}$$

Where P_r = relative change of “ P ” parameter in fifth irrigation than first one; P_5 , P_1 = measured parameter in the fifth and first irrigation respectively. The “ P_r ” shows that “ P ” parameter how much has changed after five irrigations. Multi-Soil-Layering eco-knowledge has full-fledged in approval for internal sewage conduct subsequently. Multi-Soil-Layering knowledge was showed effectual in eliminating postponed objects, organics, nitrogen and phosphorus from a quantity of diverse polluted waters with internal sewage, polluted river water, livestock sewage runoffs, nourishment dispensation waste, dairy sewages, leachate, textile sewage. The foremost objective was to control the result of irrigation applying dissimilar kinds of waters, specifically conduct sewage through crust bioreactor organization, conduct sewage through occasionally transferred sparkling pond procedure and blow water on soil pH and electric conduction. Water and soil examples removed from diverse soil depths were examined in workshop. Substantial variations happened in soil features under numerous conducts. a varied nitrogen-protective soil cyanophyte nation was confirmed to conduct community sewage and make entire carbohydrates in a one-phase process. Then, lesser hydraulic preservation period and therefore high nutrients load endorsed carbon reduction, which directed to minor nitrogen and phosphorus eliminations, short biomass production and pollution of green algae types. The consequences highpoint the nourishing and operative instruments of soil bacteria and plans to concurrently fresh waste watercourses and make appreciated by-creations.

Results and Discussion

Water Quality Analysis

Results of water quality experiments are presented in Table 2. According to Table 2, FW treatment is more acidic than WW and MW ones (in more cases). Electrical conductivity (EC) of MW is negligible more than WW and WW is more than FW too. Total suspended solids (TSS) of WW and MW are also more than five times compared to FW. It is important to say that basic differences between three water treatments are in biological parameters (Chemical oxygen demand (COD), Total-coliform). Results show that magnetic field has no significant effect on wastewater quality.

Water Treatments Effects on Basic Infiltration Rate

The values of f_o were calculated by Eq. 4. These values are shown for different treatments and irrigation numbers in Fig. 3. Parameter of "f_o" has a downtrend for irrigation treatments during the irrigation numbers in Fig. 3. This result observes always in infiltration process that is caused by soil compaction with passage of time and decreasing of soil Matric potential. The "f_o" for WW treatment is also with higher values than FW treatment in more cases (60% of irrigation practices). In 70% of irrigations, "fo" values are also more for MW than FW in the specific irrigation numbers. It can be also found that magnetic field causes increasing of the "f_o" in MW related to WW. Results show that downtrend of "f_o" for WW and MW is with more intensity (slope) compared to FW that for WW is most (Fig. 3) in five irrigations. Further reduction of "fo" in WW is justifiable with soil pore clogging affected by suspended solids of wastewater. It also seems, the water quality effects on soil infiltration will be less important with the passage of irrigation season; and after soil stabilization in several irrigations (three irrigations in this study), the "f_o" changes will not be too noticeable. But, inspecting of components differences in plans displayed that sewage and influenced sewage conducts linked to influenced sewage ones shaped more variations in downtrend of "f_o" throughout irrigation period and compelling ground consequence was negligible. Consequences display that downtrend of "f_o" for sewage and influenced sewage is with more concentration (gradient) contrasted to limnetic water that for wastewater is greatest irrigations. After soil defrosts, the newly liquefied frost water at the warming front changes down owing to a soil matric possible alteration amongst the unfrozen layer at the warming visible and the freezing deposit under the warming visible. In freezing soil, the downward measurement of penetrated water from a freezing soil superficial throughout a warming period is advanced in unsaturated soil having a little frost contented laterally with the attendance of fractures.

Table 1. Soil properties of the experimental field in two layers

Depth	Particle-size distribution			Textural class (USDA)	Bulk density	Initial volumetric moisture
	Sand	Silt	Clay			
cm	%	%	%		$gr.cm^{-3}$	%
0-15	50.4	21.8	27.8	Sandy clay loam	1.45-1.73	2.94
15-40	52.3	20.3	27.4	Sandy clay loam	1.56-1.79	2.87

Table 2. Fresh Water, wastewater and magnetized wastewater quality used in the study

Parameters	Unit	Fresh water	Wastewater			Magnetized wastewater		
			Second	Fourth	Fifth	Second	Fourth	Fifth
Na^{+}	$mmolL^{-1}$	5.20	9.50	-	4.80	10.50	-	4.80
K^{+}	$mmolL^{-1}$	0.06	0.90	-	0.30	0.90	-	0.30
Ca^{++}	$mmolL^{-1}$	2.30	2.25	-	3.10	2.35	-	3.20
Mg^{++}	$mmolL^{-1}$	0.70	0.85	-	2.50	0.45	-	3.10
HCO_3^{-}	$mmolL^{-1}$	7.75	4.40	-	4.90	4.80	-	4.80
CO_3^{--}	$mmolL^{-1}$	0.00	0.00	-	0.25	0.00	-	0.30
SO_4^{--}	$mmolL^{-1}$	0.55	0.79	-	0.15	0.79	-	2.10
Cl^{-}	$mmolL^{-1}$	6.25	10.63	-	10.60	10.63	-	8.10
SAR	$(mmol)^{0.5}L^{-0.5}$	4.25	7.63	-	2.87	8.87	-	2.70
pH	-	7.55	8.26	7.26	8.01	8.30	7.56	7.79
EC	dSm^{-1}	0.656	0.990	1.095	1.099	1.002	1.108	1.100
TSS	mgL^{-1}	10	60	68	53	61	65	56
DO	mgL^{-1}	6.8	-	-	-	-	-	-
COD	mgL^{-1}	0	92	110	84	95	102	93
Total-coliform	$MPN(100cc)^{-1}$	0	23.3×10^{4}	6.9×10^{4}	17.6×10^{4}	35.6×10^{4}	10.5×10^{4}	2.0×10^{4}

Note: second, fourth and fifth are irrigation numbers

Table 3. Statistical analysis for soil basic infiltration rate

Change source	Free degree	Significant level	Treatment	Mean values of relative changes	Significant level		
					FW	WW	MW
Treatment	2	94%	FW	-0.331a	100%	94%	67%
Replication	3	39%	WW	-0.337a	94%	100%	70%
Experimental error	6	-	MW	-0.363a	67%	70%	100%

Table 4. Statistical analysis for mean infiltration rate in 0-30 min

Change source	Free degree	Significant level	Treatment	Mean values of relative changes	Significant level		
					FW	WW	MW
Treatment	2	31%	FW	-0.094 a	100%	46%	31%
Replication	3	16%	WW	-0.209 a	46%	100%	73%
Experimental error	6	-	MW	-0.260 a	31%	73%	100%

Table 5. Statistical analysis for mean infiltration rate in 30-60 min

Change source	Free degree	Significant level	Treatment	Mean values of relative changes	Significant level		
					FW	WW	MW
Treatment	2	39%	FW	-0.360a	100%	30%	13%
Replication	3	51%	WW	-0.432a	30%	100%	47%
Experimental error	6	-	MW	-0.478a	13%	47%	100%

Table 6. Statistical analysis for advance time of water front to furrow end

Change source	Free degree	Significant level	Treatment	Mean values of relative changes	Significant level		
					FW	WW	MW
Treatment	2	55%	FW	-0.527 a	100%	30%	62%
Replication	3	3%	WW	-0.584 a	30%	100%	55%
Experimental error	6	-	MW	-0.552 a	62%	55%	100%

Table 7. Statistical analysis for storage time

Change source	Free degree	Significant level	Treatment	Mean values of relative changes	Significant level		
					FW	WW	MW
Treatment	2	25%	FW	0.041 a	100%	37%	28%
Replication	3	43%	WW	-0.200 a	37%	100%	69%
Experimental error	6	-	MW	-0.309 a	28%	69%	100%

Table 8. Statistical analysis for depletion time

Change source	Free degree	Significant level	Treatment	Mean values of relative changes	Significant level		
					FW	WW	MW
Treatment	2	17%	FW	-0.060 a	100%	2%	1%
Replication	3	69%	WW	0.630 a	2%	100%	26%
Experimental error	6	-	MW	0.864 a	1%	26%	100%

Table 9. Statistical analysis for recession time

Change source	Free degree	Significant level	Treatment	Mean values of relative changes	Significant level		
					FW	WW	MW
Treatment	2	69%	FW	-0.018 a	100%	19%	33%
Replication	3	19%	WW	0.312 a	19%	100%	55%
Experimental error	6	-	MW	0.184 a	33%	55%	100%

Fig 1. Aeration and stabilization lagoons (left to right respectively)

Fig 2. Three tanks and flume used in research (view from furrow end)

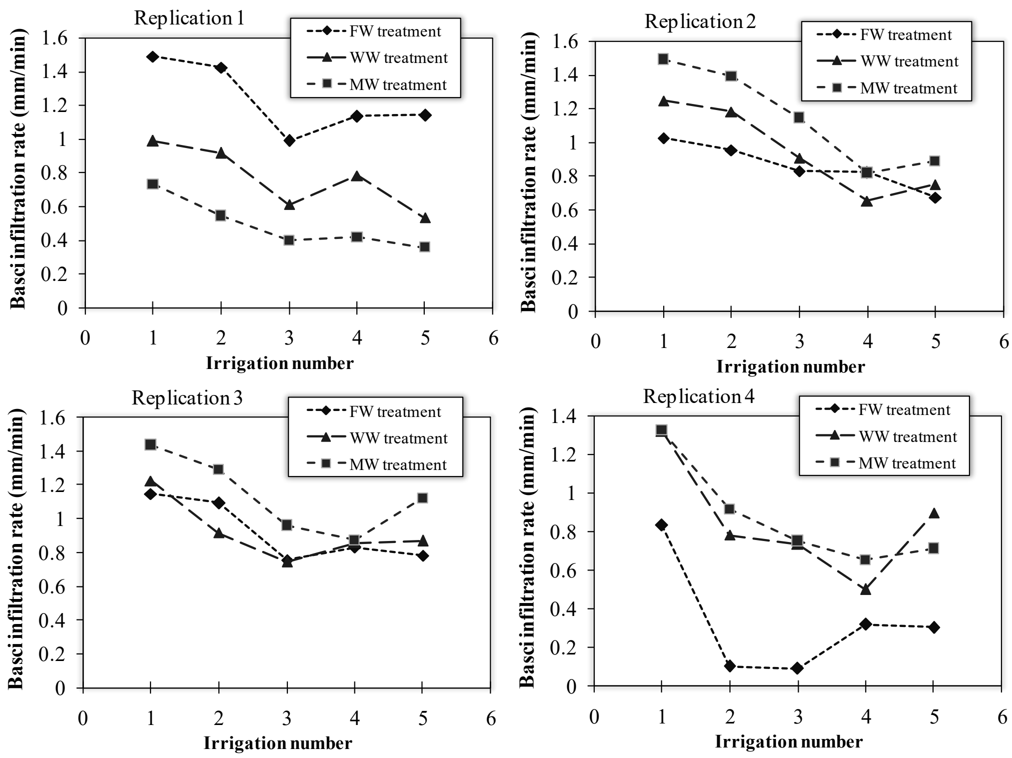

Fig. 3. Basic infiltration rate (f_o) in different irrigation numbers

(Note: Relative changes were calculated by Eq. 5.)

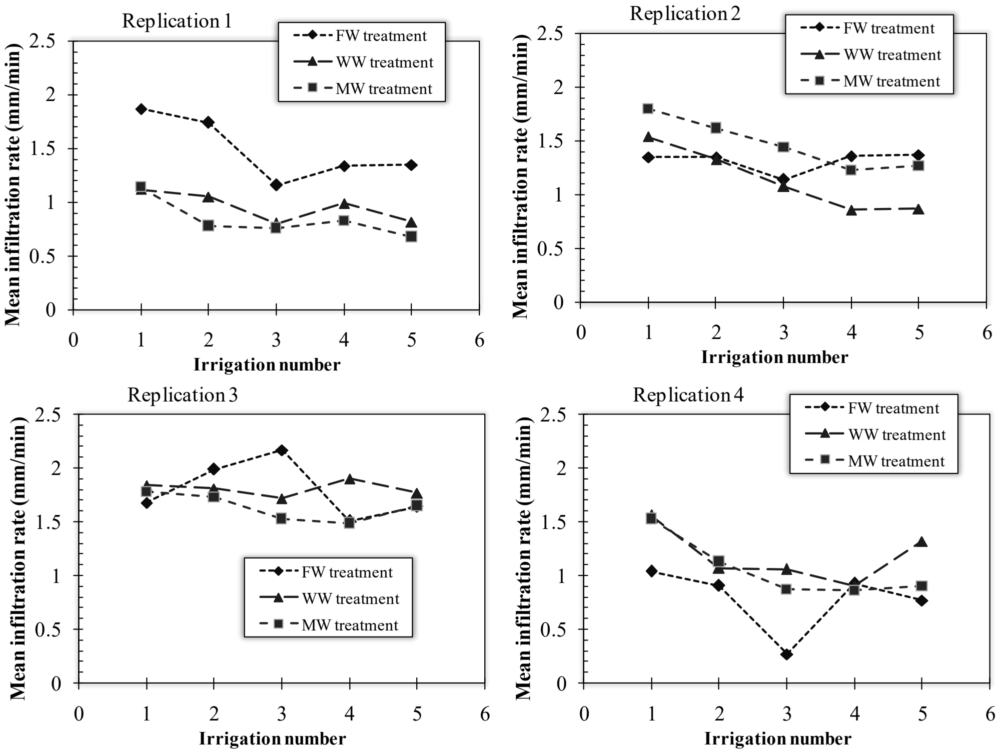

Fig 4. Values of mean infiltration rate for 0-30 min

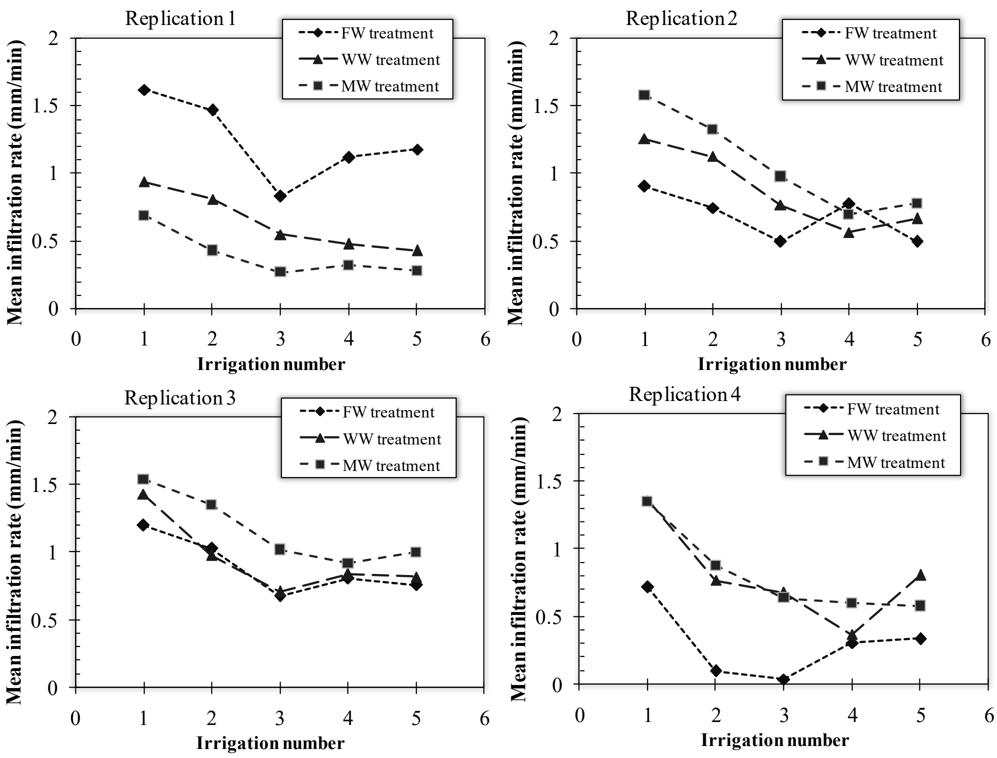

Fig 5. Mean infiltration rate for 30-60 min range

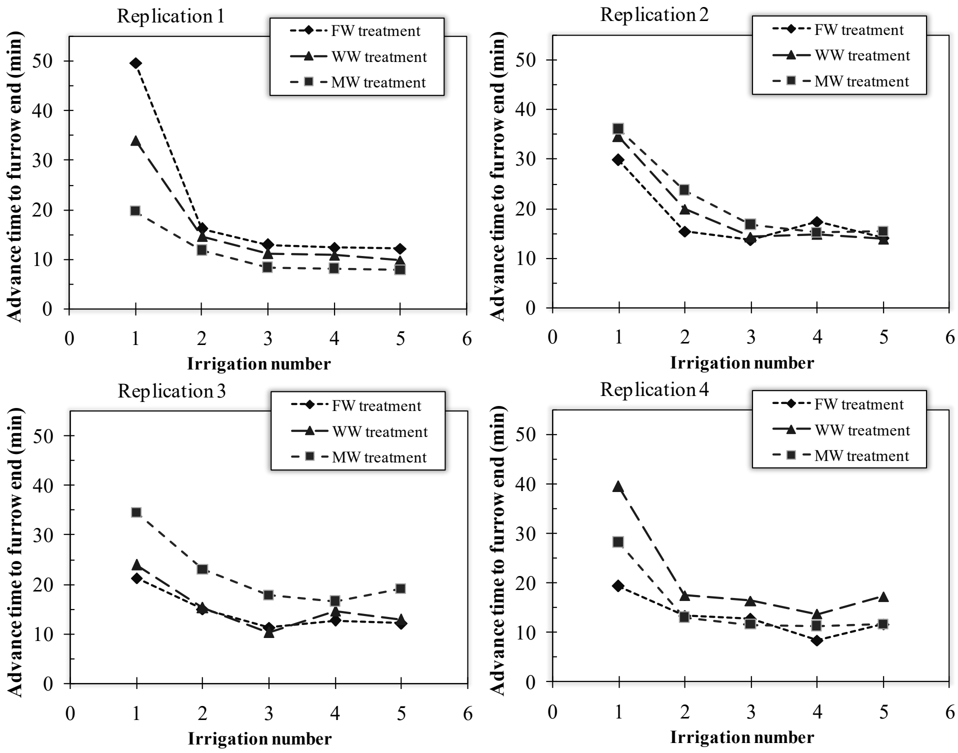

Fig 6. Advance time parameter

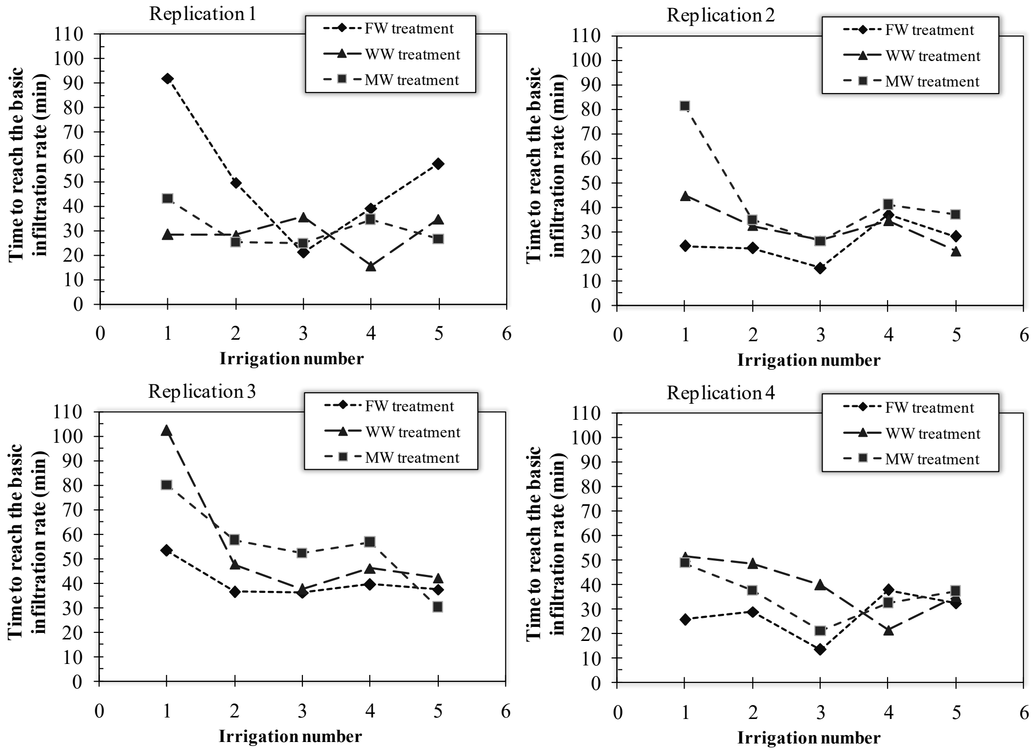

Fig 7. Time to reach the basic infiltration rate after runoff beginning

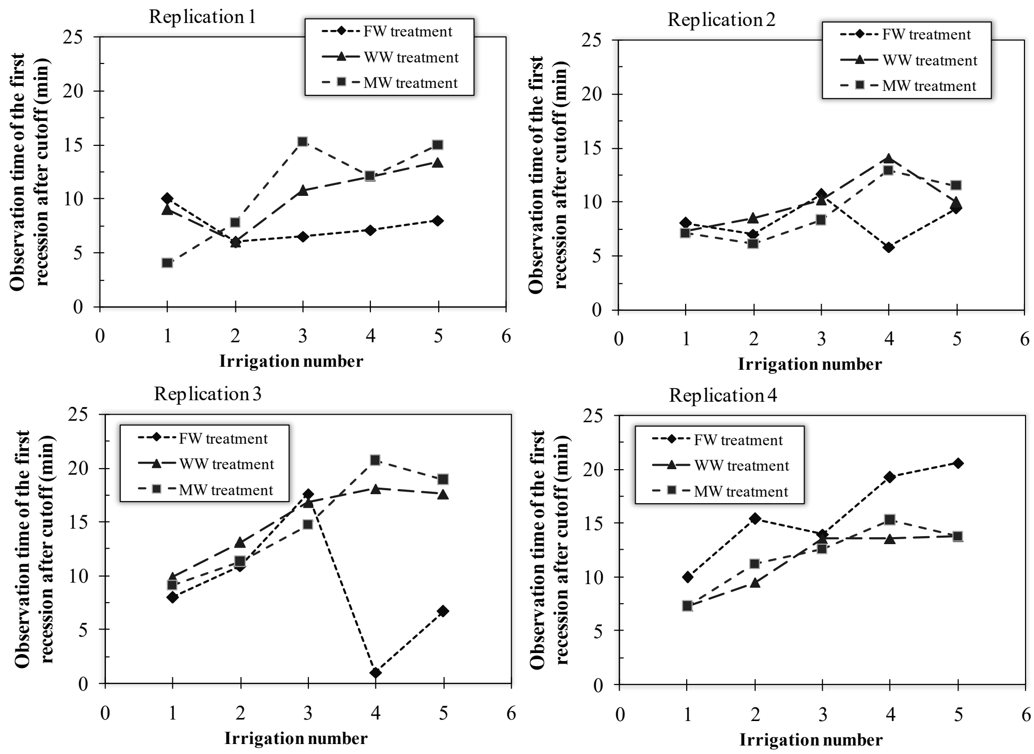

Fig 8. Depletion time after cutoff

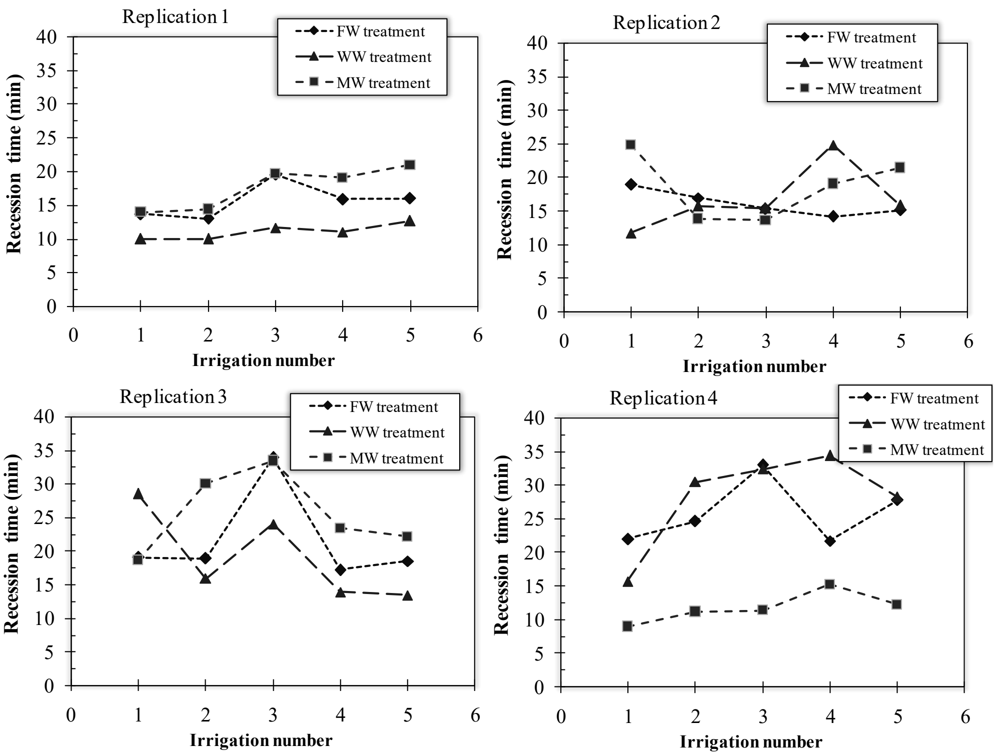

Fig 9. Recession time graphs

The regression equation was also determined by the multiple regression analysis between irrigation number, wastewater quality (TSS and COD because these parameters are basic differences between three water treatments in this paper) and "f_o". The resultant equation is as follows for "f_o" of WW and MW in different irrigation numbers follows as Eq. 6:

$$f_o = 2.185 - 0.042TSS + 0.017COD - 0.131N \qquad \text{Eq. (6)}$$

With a value for the coefficient of determination R2 of 0.26 (that is not very strong), where f_o = value of basic infiltration rate as mm/min; TSS = total suspended solids as mgL^{-1}; COD = chemical oxygen demand as mgL^{-1}; and N = 1, 2 . . . that is irrigation number. According to Eq. 6 the regression coefficients of TSS and N are negative that shows the decreasing value of "f_o" with increasing total suspended solids and irrigation number, but values of "f_o" have a positive correlation with COD. Using analysis of change sources was found that treatments had no significant effect on "f_o". The method of least squares differences (LSD) also showed that mean values of relative changes for "f_o" in FW, WW and MW treatments have no significant difference (Table 3). In this Table, whatever significant level is closer to 5% means that the difference data is near of 5% significance level and similarly for significance at 1% level. In Table 3 is also compared treatments difference together in terms of significant level.

Mean Infiltration Rate in 0-30 min and 30-60 min Intervals

Mean infiltration rate (using Eqs. 1-3) were used in three different intervals to changes investigate of infiltration equation (Kostiakov) parameters influenced by water treatments simultaneously. Mean infiltration rate values are presented for 0-30-minute interval in Fig. 4. According to Fig. 4

mean infiltration rate in 0-30min interval for FW is more than WW and MW in more cases. This is probably due to more pollution loads in WW treatment create difficult for rapid WW and MW infiltration into the soil in early infiltration time. This parameter for WW is more compared with MW in 70% of irrigations. A downward trend can be also seen for mean infiltration rate during irrigation numbers. The regression equation for mean infiltration rate in 0-30min interval of WW and MW is as following Eq. 7:

$$MIR_{0-30} = 1.922 - 0.012TSS + 0.003COD - 0.071N \qquad \text{Eq. (7)}$$

With a value for the coefficient of determination R2 of 0.05 (very poor), where MIR_{0-30} = value mean infiltration rate for 0-30min as mm/min; TSS, COD, and N as before. As can be seen regression coefficients of TSS and N are negative but for COD is positive. Results did not show significant effect of treatments on mentioned parameter in range of 0-30min. Comparison of mean relative changes did not also get significant results (Table 4). But mean relative changes for the WW and MW is about twice of the FW. Mean infiltration rate of the FW has less reduction than WW and MW referring to Fig. 4 and Table. 4. Mean infiltration rate was following for 30-60min interval. Mean infiltration rate for WW and MW treatments has more values in this range than FW ones (65% of total irrigations) and FW treatment has also less reduction than other two treatments (Fig. 5). Magnetic field has caused increasing of mean infiltration rate in 30-60min interval for MW related to WW in more cases. Also results show that changes of mean infiltration rate for MW is similar to WW. The regression equation for this parameter is Eq. 8 (for WW and MW treatments):

$$MIR_{30-60} = 2.272 - 0.026TSS + 0.006COD - 0.139N \qquad \text{Eq. (8)}$$

With R2 of 0.30 (stronger than R2 for 0-30min interval), where MIR_{30-60} = value mean infiltration rate for 30-60min as mm/min; TSS, COD, and N as before. Regression coefficients of wastewater qualities are more related to ones in 0-30min interval that shows the effect of wastewater quality becomes more tangible with over time. Statistical comparison of the results shows no significant differences after five irrigations for treatments effects on mean infiltration rate in this range (Table 5). However, these results compared to 0-30min range show less significant level in comparison of treatments together. (i.e., being more significant in differences).

Treatments Effects on Advance Time

Water reaching to the furrow end is presented for different replications in Fig. 7. From this parameter was used to compare the treatments effects on water advance speed on the soil. There is a downtrend in advance times during irrigation numbers that is due to infiltration decreasing. Advance time for WW and MW is more than FW in 60% practices and these results are due to high infiltration and roughness coefficient for WW and MW treatments (Fig. 6). The regression equation for this parameter is Eq. 9 (for WW and MW treatments):

$$T_{adv} = 31.555 - 0.560TSS + 0.254COD - 1.998N \qquad \text{Eq. (9)}$$

With R2 of 0.23, where T_{adv} = advance time as min; TSS, COD, and N as before. Advance time reduction for WW treatment is also more than the other treatments during the irrigation season. Magnetic field effect on advance times is impalpable and more differences are between FW and WW that Table 6 shows this result too. Advance times of treatments are close to each other (Fig. 6) for this reason statistical analysis showed that relative changes have no significant difference (Table 6).

Treatments Effects on Storage Stage

Time that late to reach the "fo" after the runoff beginning was analyzed as storage time in treatments, because time to reach the basic infiltration rate is equal with time for reaching the maximum surface storage. These times are as following graph:

About this parameter was understood a downtrend during the irrigations (Fig. 7). Water treatments did not cause significant difference between results (Table 7); but mentioned parameter for WW and MW is more t Statistical analysis han FW mostly. For this parameter in WW and MW treatments the regression equation is as following Eq. 10:

$$T_{str} = 35.553 + 2.213TSS - 1.398COD + 0.161N \qquad \text{Eq. (10)}$$

With R2 of 0.10, where T_{str} = time to reach the basic infiltration rate after runoff beginning as min; TSS; COD; and N as before. Also was found that magnetic field can be caused increasing of this parameter.

Treatments Effects on Depletion Stage

The time interval between the first observations in recession stage and cutoff time was measured (Fig. 8) to investigate of the treatments effect on depletion time. The increasing trend in depletion time was observed in all treatments (Fig. 8) that is caused by the common changes in soil structural during irrigations. Intensity of this trend is more for MW, WW and FW respectively. For this parameter in WW and MW treatments the regression equation is as following Eq. 11:

$$T_{dep} = -9.437 + 0.409TSS - 0.115COD + 2.316N \qquad (11)$$

With a value for the coefficient of determination R^2 of 0.47, where T_{dep} = depletion time as min; TSS, COD, and N as before. Water treatments had also slightly effects, but there is a significant difference in depletion time values of WW and MW treatments than FW treatment at the 5% ($p < 0.05$) level. These results in statistical analysis are in accordance with coefficient of determination (R2 of 0.47) between wastewater quality parameters and depletion time (Table 8).

Treatments Effect on Recession Time

Recession time was calculated as time interval between first and last recession observations in furrows for treatments (Fig. 9). Recession time in FW is more than WW and MW in 65% irrigations. This may be ascribed to the more basic infiltration rate for WW treatment that was caused recession time reduction in this treatment. For this parameter in WW and MW treatments the regression equation is as follows as Eq. 12 and Table 9:

$$T_{rec} = 5.795 - 0.173TSS + 0.233COD + 0.272N \quad \text{Eq. (12)}$$

With a value for the coefficient of determination R^2 of 0.03 (very poor), where T_{rec} = recession time as min; TSS, COD, and N as before. The possible for recycle of preserved sewage in irrigation can be measured over a collective three-dimensional and Rate Advantage Analysis. Economic practicality of recycle is complex to water equilibrium and zone to be irrigated. The cost of the tax for sewage releases affects the economic practicality of recycle in agronomic irrigation. For Higher stream washbasin economic feasibility was assumed in mainly due to little aquatic prices. The economic feasibility of recycle of treated sewage for the irrigation in the stream in Iran was considered. Price-Advantage Examination was applied to contrast the possibilities (recycle of conduct sewage). Cost of initial investment was considered. Profits were measured like evaded price by usage of nourishments, decrease of tolls for water usage and releases straight to water forms and savings budgets of substructure for irrigation with groundwater. The consequences of the Price-Profit Investigation and sensitivity investigation display that affect economic practicality of conduct sewage for the water equilibrium and irrigation necessities, and budgets conforming to the organization of sewage for agronomic irrigation, with supplementary conduct and the substructure to take the conduct sewage. The economic practicality of recycle was restricted since the standards of toll for sewage releases and water rates in Iran do not link to the standards. It was showed to examine the features of influx and discharge sewage of the sewage conduct herbal on the foundation of the information assembly of process dated. Similarly, the properties of normal-period usage of the sewage for irrigation on soil physical and chemical features were considered. Many examples were reserved from the influx and discharge sewage and many quality components were examined. Consequences displayed that even though some limitations happen about chlorine and bicarbonate, the conduct sewage is appropriate for irrigation depend on state and worldwide values and standards. In contrast with soft water, the average-period uses of sewage triggered a slight rise of soil brininess. In comparison with fresh water, the middle-period uses of sewage triggered the rise of total N, absorbable P and absorbable K in soil owing to great absorption of those fundamentals in conduct sewage. Irrigation with sewage had diminutive result on vegetable dry weight, shoot N and P absorption or obtainable N and P, and bacterial biomass N and P in soil in together implanted and unfarmed conducts. The soil, brief-period sewage irrigation had diminutive consequence on herbal development, N and P approval, and N and P absorption in soil. But, attendance of floras condensed obtainable N and P in soil contrasted with unfarmed soils which would decrease possible of nutrient leakage after sewage irrigation.

Conclusions and Results

Scrutinizing of parameters variations in charts showed that WW and MW treatments relation to FW ones created more changes in downtrend of “f_o” during irrigation season and magnetic field effect was inconsiderable. The “f_o” in WW and MW was more than FW mostly. It was found that magnetic field causes increasing of the “f_o” in MW related to WW. Similar results also were found in two-time intervals of infiltration process. Also excluding depletion time phase, evaluated time parameters, including advance time to furrow end, time to reach the “f_o” and recession duration had not difference significantly influenced by water quality treatments, but values of advance time and time to reach the “f_o” for WW and MW than FW were higher mostly. According to regressions equation between water quality parameters and flow hydraulic parameters, were found a negative correlation between “f_o”, mean infiltration rate for 0-30min and 30-60min ranges and advance time with TSS and irrigation number; and a positive correlation between these parameters with COD; also a negative correlation between time to reach the “f_o” and depletion time with COD; and a positive correlation between these parameters with TSS and irrigation number. In parameter of recession duration, positive correlations are with irrigation number and COD; and negative correlation is with TSS. So as to current hydraulic examination of the sewage on the soil were experienced channel irrigations with sewage that the subsequent consequences were gained: Attractive ground result on WW superiority was not substantial, but electrical conductivity amplified a little. The straightforward penetration degree had downtrend throughout irrigation period. MW had similarly maximum standards of elementary penetration degree and for WW was developed than FW. Without period of reduction stage, components of current hydraulic of WW and MW on soil for example development, collapse and loading period had not alteration meaningfully inclined by water superiority conducts, then standards of development and loading period for WW and MW than FW were developed regularly. In order to flow hydraulic investigation of the wastewater on the soil were practiced furrow irrigations with wastewater that the following results were obtained:

1. Magnetic field effect on WW quality was not significant, however electrical conductivity increased slightly.

2. In all treatments, the basic infiltration rate had downtrend during irrigation season. In most cases, MW had also highest values of basic infiltration rate and for WW was higher than FW.

3. A downtrend for mean infiltration rate in 0-30 and 30-60 intervals was found during irrigations. Values of this parameter for WW and MW than FW are less and more in 0-30 and 30-60 intervals in more cases respectively.

4. Excluding duration of depletion phase, parameters of flow hydraulic of WW and MW on soil such as advance, recession and storage time had not difference significantly influenced by water quality treatments, but values of advance and storage time for WW and MW than FW were higher mostly.

5. According to regressions equation was found a negative correlation between “fo”, mean infiltration rate for 0-30min and 30-60min ranges and T_{adv} with TSS and irrigation number; and a positive correlation between these parameters with COD.

6. Regression equations were showed a negative correlation between T_{str} and T_{dep} with COD; and a positive correlation between these parameters with TSS and irrigation number.

7. In parameter of Trec, positive correlations are with irrigation number and COD; and negative correlation is with TSS.

FOR COI STATEMENT

Conflict of Interest Statement

There is no conflict of interest.

Availability of Data and Materials

Some or all data, models, or code generated or used during the study are available from the corresponding author by request

Ethical Approval

The present Study and ethical aspect was approved by Water Engineering Department, College of Agriculture, Shahrekord University, Shahrekord, Postal Code: 8818634141, Iran and Department of Irrigation, College of Agriculture, Isfahan University of Technology, Isfahan, 8415683111, Iran

Consent to Participate

All authors designed the study, collected data, wrote the manuscript and revised it.

Consent to Publish

All authors agree to publish this manuscript. There is no conflict of interest.

Author's Contributions

All authors designed the study, collected data, wrote the manuscript and revised it.

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Competing Interests

There is no competing of interest.

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