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ORIGINAL ARTICLE

Effect of effluent and magnetized effluent on Manning roughness coefficient in furrow irrigation

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Abstract
Due to the water crisis, wastewater utilization is an effective way to meet the water needs of plants and also reduce environmental pollution. In order to know the effect of treated and magnetic wastewater on Manning roughness coefficient, a study was conducted in the form of randomized complete blocks with three irrigation treatments with "wastewater outlet", "magnetic effluent" and "normal water" in four replications. Statistical analysis on the relative changes of the roughness coefficient in the design did not show a significant difference. At the same time, a decreasing trend was observed during the irrigation season in the roughness coefficient, which was expected due to the smoothing of the flow path and the effect of organic matter of the effluent on the bed. The magnetic field was not affected by the magnetism. Manning roughness values with more irrigation with effluent and magnetic effluent, in most cases had a decreasing trend, but due to the use of water, an increasing trend was observed in them. However, the increase in normal water treatment could not be analyzed according to the information of this project. There was no statistically significant difference between the treatments of the project.

Keywords Effluent · Magnetism · Soil properties · Manning roughness coefficient · Furrow irrigation · Magnetic wastewater · Environmental pollution

Introduction

Iran has an area of 165 million hectares, different parts of which have many climatic differences. In general, in Iran, the temporal distribution of rainfall is non-uniform and rainfall occurs mainly in winter (Vanani et al. 2022). Quantitatively, the average rainfall in the country (240 mm per year) is less than one third of the average rainfall on the planet, while the rate of evaporation is relatively high (Karandish et al. 2017; Eslamian et al. 2018a, b). These cases have made the issue of drought one of the serious problems of the country (Abdollahi et al. 2021; Ostad-Ali-Askari et al. 2017a). In arid and semi-arid regions, due to water scarcity, the replacement of new and reliable water sources for use in agriculture should be considered. In this regard, the implementation of measures to develop and utilize unconventional water resources, such as industrial, urban, rural and agricultural effluents, can compensate for the deficit of the country's agricultural water shortage, and also prevent the adverse effects of effluents on the environment (Ostad-Ali-Askari 2022a). Another advantage of utilizing these resources is their availability in densely populated areas and areas where agriculture is flourishing (Jesmanitafti et al. 2014; Nafchi et al. 2022). On the other hand, in non-arid regions, the constant increase in demand for water has raised the need to use wastewater as an economic source of water supply in planning (Wakeel et al. 2016; Todeshki et al. 2015; Razmi et al. 2022; Nafchi et al. 2021).

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Advantages and disadvantages of using effluent

Utilization of wastewater (albeit in a purified form) can have advantages and disadvantages, some of which will be mentioned below (Talebmorad et al. 2022). Some of the benefits of wastewater consumption are:

1. Supplying the required water and reducing the limitation of water resources (Talebmorad et al. 2021).
2. Reducing surface and groundwater pollution.
3. Low price of wastewater compared to water (Ostad-Ali-Askar et al. 2018a).
4. Rich in nutrients and reducing the cost of chemical fertilizers.

Some of the disadvantages of using effluent are:

1. Blockage of output in pressurized irrigations.
2. Physical blockage of soil pores and thus reduction of permeability.
3. Possibility of plant toxicity or soil salinity stress due to soluble cases in effluents (Talebmorad et al. 2020).
4. Causing contamination in the farm and crops, and subsequently causing disease in users and consumers (Iakovleva and Sillanpää 2013; Crini and Lichtfouse 2019; Ostad-Ali-Askari, 2022b; Shayannejad et al. 2022).

Accordingly, the use of effluent in irrigation can be "beneficial or harmful" depending on the area used and the conditions of use as well as water quality. In this regard, a lot of research has been done, a significant part of which is focused on improving the quality of unconventional water (Ostad-Ali-Askari 2022d). The subject of magnetism, meanwhile, is a controversial option (Ostad-Ali-Askari et al. 2021a).

Magnetic water

Magnetic force can convert plain water into a liquid with special chemical effects, so that the physical properties of magnetized water can be changed such as temperature, specific gravity, surface tension, viscosity and conductivity (Ostad-Ali-Askari 2022h). One of the changes that occur in magnetized water is the arrangement of electric charges and water molecules. In fact, by applying a magnetic field, the arrangement of electric charges of water molecules from an irregular and almost neutral state becomes ordered and has a positive force (Ostad-Ali-Askari 2021b). This change eventually causes an increase in water molecules per unit volume as well as an increase in water solubility (Fallah 2008; Rabiei et al. 2022). By applying an inductive force from an electric field, water molecules become smaller and penetrate the soil faster. Also, the water molecules that were involved with the ions under the influence of hydrogen bonding and van der Waals force are released, and the water particles easily adhere to the colloidal and micron particles of the soil and escape deep into the soil (Eslamian et al. 2018c). This increases the water holding capacity of the soil and prevents salinity and drought stress (Ostad-Ali-Askari 2021c). Accordingly, one of the advantages of using magnetic water in agriculture is soil remediation by reducing the use of chemicals and acids and lower costs. With the physical purification of water, its physical properties such as surface tension, viscosity and density are changed and eventually softens the soil lime, enabling root growth and development (Ghashghaie et al. 2022). With changes in water, even gypsum, which does not normally dissolve in normal water (hard water), dissolves in magnetic water and facilitates water permeability in soil in exchange for soil sodium (Golian et al. 2020). This process contributes to the formation of aggregates, which will eventually lead to soil fertility, void and ventilation (Kruse et al. 2018). This technology, while changing the physical and chemical properties of water, can improve its purification power and solubility; So that the plant easily absorbs and uses the necessary substances for its growth and the rest of the useless salts and substances are directed to the drainage systems (Kiani et al. 2008; Fattahi Nafchi et al. 2022). However, in addition to issues related to the reduction of water quantity and quality in agriculture and the need to use unconventional water, reports suggest that the use of magnetic fields may be effective in reducing or intensifying the effects of wastewater use and create new space for Open the use of unconventional waters (Ostad-Ali-Askari 2022e).

Investigation of the effect of effluent and magnetic field on flow roughness coefficient

In the field of flow roughness coefficient in open ducts (Manning coefficient), various studies have been done, but most of these studies evaluate equations or different methods for determining the roughness coefficient (De Doncker et al. 2009; Zhu et al. 2020; Vanani et al. 2017; Ostad-Ali-Askari 2022c; Derakhshannia et al. 2020). Roughness coefficient in surface irrigation is also one of the important factors in flow hydraulic performance. Roughness of soil surface, size and shape of substrate materials, presence of different plants, unevenness of flow path, sedimentation, irrigation turn, etc. are among the factors that affect this coefficient (Ostad-Ali-Askari et al. 2020b). However, estimating this coefficient is not easy with mathematical relations, and studies related to measuring this coefficient have usually been experimental (Kamali et al. 2018; Nie et al. 2018; Abedi-Koupai et al. 2022). It seems that few studies have been done on the effect of effluent or magnetism on this coefficient, and therefore little information is available. However, due to the changes caused by the solutes in the effluents on the bed roughness, the study of the effect of the effluent and the magnetic field on the flow roughness coefficient is one of the research needs (Salehi-Hafshejani et al. 2019). Addressing the issue of "surface irrigation" and its technical issues, using unconventional water (from an environmental point of view) and combining it with the discussion of water magnetization, is one of the tasks that is felt in scientific-research reports (Pirnazar et al. 2018). It is hoped that the results of this study will be of great help in identifying and quantifying the impact of using unconventional water on surface irrigation and the effectiveness of magnetic water technology. In this study, by focusing on the expected changes owing to the use of municipal wastewater, and the magnetic field on the actual roughness coefficient of the furrow was followed.

Materials and methods

Plan specifications

This research was carried out in Bagh-e Anari farm located in Isfahan University of Technology, with longitude and latitude of 51 degrees and 32 min east and 32 degrees and 42 min north and 1645 m above sea level, respectively. To investigate the effect of effluent and magnetic field on some soil properties, research experiments with three treatments of normal water (non-wastewater), effluent from the wastewater treatment basin of Isfahan University of Technology, effluent with the effect of magnetic field (created by a constant magnetic field) in the form the complete block design was randomized and performed in four replications (Excel software and SPSS analysis software were used to analyze the data) (Ostad-Ali-Askari et al. 2018b). To store water, two metal tanks (capacity above 6 cubic meters) were used for treated wastewater and water upstream of the farm. The installation of the tanks was carried out in such a way that the required height could provide the required current intensity. Also in a smaller tank, a float valve was used to stabilize the height and intensity of the flow. Hydro Flume pipes were used to irrigate the furrows. The flow rate of each valve was estimated to be one liter per second according to the slope of the ground and soil texture. The duration of the study was about two months during which five irrigation operations were performed for each furrow (60 Irrigations in Total).

Steps of field operations

At the farm site, a suitable location was selected for the experiments and the average longitudinal and transverse slope of the farm was determined by mapping. Land preparation operations including plowing and crashing the lumps (with a disc, disc) were performed by the tractor. The land was leveled with a hammer. Finally, 12 furrows 42 m long and 60 cm apart were created by the hatchery. The average

Table 1 Some basic soil properties in the experimental field

Section	Depth (cm)	Soil particles (%)			Soil texture	Gravel (%)	Organic matter (%)	Bulk density (g/cm^2)	EC (ds/m)	pH	Initial moisture (%)	FC (%)	PWP	Field gradient (%)	
		Sand	Silt	Clay										Longitudinal	Transverse
1	0–15	50.4	21.8	27.8	Loam sandy clay	38	< 1	1.57	1.82	7.87	4	31.57	15	0.06–0.3	0.1
	15–40	52.3	20.3	27.4	Loam sandy clay	50	< 1	1.68	1.97	7.84	4	33.71	15		
2	0–15	54.2	18.8	27	Loam sandy clay	34	< 1	1.78	0.98	8.29	4.2	20.87	15	0.02–0.2	0.1
	15–40	56.1	17.3	26.6	Loam sandy clay	43	< 1	1.71	0.89	8.43	4.2	19.81	15		

longitudinal and transverse slope of the furrows was 0.1%. Using soil samples taken from the soil, soil texture and initial bulk density, as well as salinity and acid–base content of soil saturated pH (EC_e) were determined (Table 1).

EC_e: Electrical conductivity of soil saturated extract, pH_e: acid–base degree of soil saturated extract to measure the inflow and outflow of furrows, flume trapezoids (WSC) proportional to the size of the furrows, installed at the beginning and end. Flume trapezoids (WSC proportional to the size of the pupils) were installed at the beginning and end of the furrows to measure the intensity of incoming and outgoing currents. The vessels were leveled and the surrounding soil was completely compacted to prevent water leakage around the flume.The furrows were stationed at a distance of 3 m from the input ship downstream. The experiment of each furrow was started by transferring water to the furrows and the arrival time of water to each station was recorded. In each experiment, input and output hydrographs and forward–backward curves were determined. The geometric cross-sectional area of the furrow was measured after each irrigation by a furrow tachometer.

Magnetic device

The magnetic field was created by three magnets with a constant intensity of eight to ten Milli Tesla. These three magnets were closed at 120° compared to each other around the valve tube (Fig. 1). According to the description of the magnet manufacturer used (Paya Trade Company), the device was then the lowest turbulence (the least connections and conversion during water flow in the pipe) and the magnets used in each experiment were mounted on the door of the valve at the nearest output of water. These magnets were selected as much as five inches in diameter to enter the magnetic field to the entire cross-sectional level and the efficiency of the field to be acceptable.

Fig. 1 The magnetic machine mounted on the valve pipe

Hydraulic properties of the flow bed

Manning roughness coefficient in this design is considered as the hydraulic characteristic of the flow bed and this coefficient was obtained by using the equations of cross-sectional flow shape and Manning relationship. The coefficients of the flow section equations (including:$\gamma_2, \gamma_1, \sigma_2, \sigma_1$) were obtained by reading the values of X (width of the furrow) and Y (depth of the furrow) of the furrow cross section and fitting the power functions to the data of the flow cross section $A = \sigma_1 \times y^{\sigma_2}$, and the wetting environment $P_{wet} = \gamma_1 \times y^{\gamma_2}$. Using the inverse application of the flow equation in the furrow, the value of the true roughness coefficient of the furrow (n) was estimated (Walker and Skogerboe 1987) follows as Eq. (4):

$$A_o = C_1 \left(\frac{Q_o \times n}{\sqrt{S_o}} \right)^{c_2} \tag{1}$$

in which; $$C_1 = \sigma_1 \left(\frac{\gamma_1^{2/3}}{\sigma_1^{5/3}} \right)^{c_2} \tag{2}$$

$$C_2 = \frac{3\sigma_2}{5\sigma_2 - 2\gamma_2} \tag{3}$$

$$\Rightarrow n = \left(\frac{1}{C_1} A_o \right)^{\frac{1}{C_2}} \div \frac{Q_o}{\sqrt{S_o}} \tag{4}$$

In these equations, A_o is the cross-sectional area of the flow at the beginning of the furrow, S_o is the floor slope, and Q_o is the intensity of the flow entering the furrow.

Results and discussion

In this study, the effect of effluent and magnetic effluent were investigated on some physical and chemical properties at two depths and soil hydraulic properties (Manning roughness coefficient) in furrow irrigation. The results are as follows.

Qualitative study of effluent and magnetic effluent

Characteristics of normal water, magnetic effluents and effluents used in the plan was investigated in the terms of

Table 2 Some chemical, physical and biological variables of water, effluent and magnetic effluent

Variable	Unit	Normal water	Effluent			Magnetic effluent			Standard boundary in effluent	
			First	Middle	Last	First	Middle	Last	Agriculture	Drain for water
Electrical conductivity	Desi Siemens per meter	0.7	1.0	1.1	1.1	1.0	1.1	1.1	–	–
The total load of suspended material	Mg per liter	10	60	68	53	61	65	56	100	40
Degree of acidity	pH	7.6	8.3	7.3	8.0	8.3	7.6	7.8	6.0–8.5	6.5–8.5
Sodium	Mill equivalents per liter	5.2	9.5	-	4.8	10.5	-	4.8	–	–
potassium	Mill equivalents per liter	0.1	0.9	–	0.3	0.9	-	0.3	–	–
Calcium	Mill equivalents per liter	4.6	4.5	–	6.2	4.7	-	6.4	–	75
Magnesium	Mill equivalents per liter	1.4	1.7	–	5.0	0.9	-	6.2	100	100
Bicarbonate	Mill equivalents per liter	7.8	4.4	–	4.9	4.8	-	4.8	–	–
Carbonate	Mill equivalents per liter	0.0	0.0	–	0.5	0.0	-	0.6	–	–
Sulfate	Mill equivalents per liter	1.1	1.6	–	0.3	1.6	-	4.2	500	400
Chlorine	Milliequivalents per liter	6.3	10.6	–	10.6	10.6	-	8.1	600	600
Sodium uptake Ratio	–	3.0	5.4	–	2.0	6.3	-	1.9	–	–
Dissolved oxygen	Mg per liter	6.8	–	–	–	–	–	–	2	2
Bio-oxygen requirements	Mg per liter	0.0	55	66	50	57	61	56	100	30
Chemical oxygen requirements	Mg per liter	0.0	92	110	84	95	102	93	200	60
Total number of coliforms	1000 per 100 cc	0.0	233	69	176	356	105	20	1	1

physical (electrical conductivity, total suspended solids, etc.), chemical (acid–base degree, different cations and anions), and biological (number of bacteria, viruses, etc., Pathogenic organisms). Urging the research, different irrigation water, effluent and magnetic effluent treatments were sampled at the beginning, middle and end of the research. The decomposition results of these waters are shown in Table 2.

Some anions, cations, and effluents and magnetic effluents

Normal water quality was suitable and permissible for irrigation. In the case of effluent, except for the total number of coliforms, all variables are within the allowable irrigation limit. Regarding the effect of magnetic field on effluent quality, the amount of positive and negative ions does not change significantly after the effluent possess through the magnetic field.

pH and electrical conductivity (EC)

As shown in Table 2, the mean pH of the effluent and the magnetic effluent are 7.84 and 7.88 dS/m, respectively, which is acceptable compared to the standards introduced for use in agriculture and magnetic (Table 2). The average electrical conductivity of the effluent and magnetic is 1.06 and 1.07 dS/m, respectively, and similar to pH, there is no difference in magnetic effect.

Chemical and biochemical oxygen demand of effluents and magnetic effluents

As shown in Table 2, the standard boundary of wastewater for biological and chemical oxygen demand (BOD5 & COD) for agricultural use is set at 100 and 200 mg/L, respectively. It should be noted that generally the amount of compounds that can be chemically oxidized is greater than the number of compounds that can be oxidized biologically. In any case, the values of these indicators are within the allowable range for the applied wastewater and a small change is observed in them due to the magnetic field. This effect was more significant in the number of coliforms and the amount of coliforms increased significantly in two of the three tests.

Effect of magnetic effluent and effluent on Manning roughness coefficient

The values of the roughness coefficient in the furrow in different treatments and turns of irrigation water are presented in (Fig. 2). As can be seen in these diagrams, the values of Manning roughness coefficient with more irrigation with magnetic effluent and magnetic effluent, in most cases show a decreasing trend, while decreasing changes in this hydraulic characteristic were obtained due to the use of water.

Hydraulically, the main expectation (in the case of pant immaturity) is a reduction in roughness due to the smoother flow path during the irrigation season. This is to be expected in effluent treatments where organic matter is likely to help reduce runoff roughness and was also observed in the design results. However, the increase in normal water treatment is a result that cannot be analyzed according to the information of the plan, especially due to the fluctuations of the roughness coefficient in different iterations (Fig. 3).

As can be seen from the statistical analysis of these results (Table 3), there is no significant difference between the plan treatments. At the same time, more accurately in the binary comparison of the effects of treatments (Table 4) it can be concluded that the effects observed as a result of water quality treatments on the roughness coefficient are mainly due to the effluent and the magnetic field created for the effluent and has no effect on the results.

Conclusions and results

Due to the water crisis, wastewater utilization is an effective way to meet the water needs of pants and also reduce environmental pollution. In order to know the effect of treated and magnetic wastewater on Manning roughness coefficient, a study was conducted in the form of randomized complete blocks with three irrigation treatments with "wastewater outlet", "magnetic effluent" and "normal water" in four replications. Statistical analysis on the relative changes of the roughness coefficient in the design did not show a significant difference. At the same time, a decreasing trend was observed during the irrigation season in the roughness coefficient, which was expected due to the smoothing of the flow path and the effect of organic matter of the effluent on the bed. Manning roughness values with more irrigation with effluent and magnetic effluent, in most cases had a decreasing trend, but due to the use of water, an increasing trend was observed in them. However, the increase in normal water treatment could not be analyzed according to the information of this project. There was no statistically significant difference between the treatments of the project.

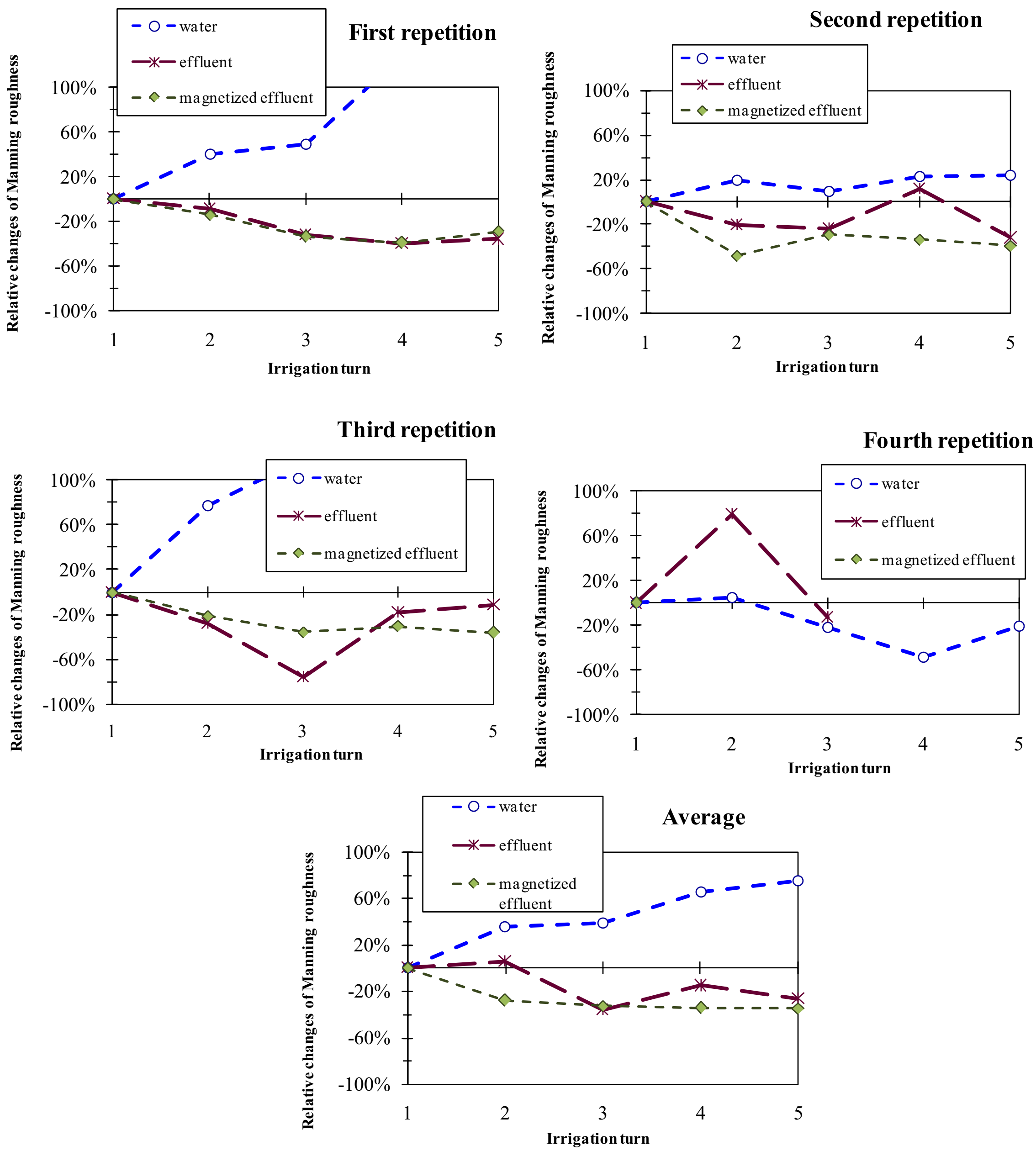

Fig. 2 Relative changes in Manning roughness coefficient during the irrigation season and their average

Fig. 3 Manning roughness coefficient during the irrigation period with different water treatments and their fluctuations

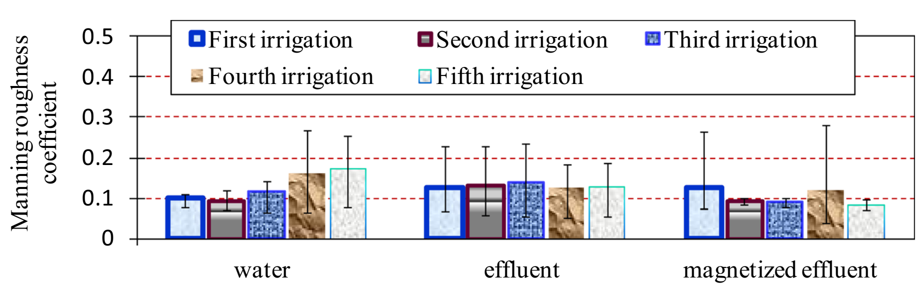

Table 3 Significance level of relative changes in soil manning roughness coefficient

Change Source	Degree of freedom	Significant probability level	Degree of freedom	Significant probability level by deleting unreliable data
Treatment	2	18%	2	21%
Block	3	50%	3	53%
Experimental error	6	–	5	–

Values less than 5% or 1% of the minimum significant level (*p*) are indicative (significant) or (very significant) differences, respectively

Table 4 Mean of "relative changes" and the level of significance of Manning roughness coefficient in different irrigation treatments

Treatment	Average relative changes	Average relative changes		
		Water (%)	Effluent (%)	Magnetic effluent (%)
Water	0.766	100	–	–
Effluent	0.102	13	100	–
Magnetic effluent	0.074	14	95	100

Suggestions

It seems that in order to complete the knowledge chain, in the field of work related to this article, the following items can be suggested:

Investigation of the effect of different irrigation systems with magnetic wastewater on soil properties and hydraulic properties of water flow on the soil and on infiltration and leakage in the soil.

Author's contributions All authors designed the study, collected data, wrote the manuscript and revised it.

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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.

Declarations

Conflict of interest There is no competing of interest.

Ethical approval The present study and ethical aspect was approved by Water Engineering Department, Aburaihan Campus, Tehran University, Tehran and 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.

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