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Status and evaluation of the selected soil nutrients irrigated by unconventional water (Case study: Qom)

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ABSTRACT: Population's exponential growth along with drought has increased water resources limitation, especially in arid and semi-arid area. Therefore, the use of non-conventional water is an important tool for water resource management. If unconventional water has no negative impact on soil properties and water, it can be used for irrigation coupled with desertification projects. So, this paper tries to present the effect of irrigation with municipal wastewater, salt water, brackish water, and combination of salty water and wastewater on some soil properties including nitrogen, phosphorus, and potassium in Qom plain. Soil samples were taken from agricultural land treated by wastewater, saline water, brackish water, combination of salty water, and wastewater and range land as control in five treatments from depths of 0-30 and 60-90 centimeter. The results showed that wastewater has increased the amount of N, P, and K to other treatments and control area. The concentration of potassium in surface layer of area treated by combination of salty water and wastewater with amount of 459.39 ppm has the most significant difference to control and other treatments. Also, the maximum amount of nitrogen was observed in sub layer of saline and brackish water treatment with amount of 0.08 percent.

Keywords: brackish water, nitrogen, phosphor, Qom plain, saline water, wastewater.

INTRODUCTION

Insufficient resources of water in most regions in addition to decreased quality of water will result in considerable concerns for urban societies, agricultural section, and natural resources. Usage of unconventional waters is a unique occasion and may increase capacity of traditional water supply (Payandeh et al., 2010).

About 15% to 25% of water used in domestic and urban consumptions will discharge to environment as wastewater. Considering required nutrients for plants, usage of urban wastewater as a resource of supplying sustainable water to eliminate agricultural demands is inevitable (Oron et al., 2007; Scott et al., 2002).

Using wastewaters and saline waters in irrigation of agricultural products is one of

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the main resolutions of water crisis which is highly observed in arid areas with risk of water scarcity (Alizadeh, 1996; Feizi, 2002).

Considering geographical conditions and water crisis in Iran, it is necessary to employ improvement methods including usage of low quality irrigation resources (wastewater, saline water, and brackish water) in agriculture. Moreover, most irrigating waters are low qualified with varied degrees of salinity that may be used for agriculture too (Feizi, 2002). In addition, the volume of waste water produced in very large cities and the need for its disposal has increased the need for wastewater re-uses (Najafi et al., 2015).

Wastewater induced improvements in soil fertility status and thus nutrient uptake and the crop yields have been reported widely (Saha et al., 2010; Simmons et al., 2010; Singh et al., 2012).

The wastewater affects the nutrient availability in soils in two ways: (i) by containing and adding these to soil and (ii) by contributing constitutes of sewage effluent (i.e. soluble organic and inorganic legends) that can alter soil and solution composition and processes that affect solubility, mobility, and bioavailability of nutrients (Bar-Tal et al., 2015).

Moreno et al. (2001) used saline waters (22.7 ds/m) in studying cotton and sugar beet. The results indicated that usage of one shift of waters with high degrees of salinity during flowering stage or other types of irrigations using qualified water (0.9 ds/m) in conditions that there are irrigation limitations will not cause considerable problems for plants and soil. Hussain et al. (2002) also performed studies on annual changes of soil salinity on results of employing saline waters. The results revealed that salt concentration is not equal in different years and there were no real connection between salinity of irrigation water and soil salinity in some regions or years. Feizi (2008) studied irrigation with saline water for duration of three crop years on cotton plant. The results of his study revealed about 50% reduction in usage of qualified water.

Some researchers believe that domestic wastewaters are appropriate solution to save water and reduce wastes treatment (Akbarnezhad et al., 2012; Bina, 1993). Although existence of qualified water is highly required in growth of plants, successful production of plants needs good soil and presence of appropriate nutrients. Determination of soil chemicals is the first step in specifying necessary elements for plant’s growth (Alizadeh, 1999). Nitrogen, Potassium, and Phosphor are main required nutrients for plant’s growth (Hanson, 1967; Jeffery et al., 2002).

Nitrogen accelerates plant’s growth and increases formation of soft tissue which causes resistance against diseases and has specific role in structure of proteins and chlorophyll (Zehtabian, 2005). Potassium intensifies synthesis and movements of carbohydrates, thickening septum and increasing plant’s resistance against diseases (Jamshidi, 2008). Phosphor has considerable role in cell structure which acts as energy resource in all chemical interactions in live cells (Tyson and Zand, 1991). Transferred potassium, total nitrogen value, and soluble phosphor are items that have important role in soil fertility (Basirani, 1992; Oron et al., 2007). These items all express the importance of investigating the role of irrigation on value of these three elements (nitrogen, potassium, and phosphor) in soil.

Hassan Lee and Javan’s (2005) study indicated that wastewaters with 10 mg/l of nitrogen, potassium, and phosphor with average respective values of 0.7, 0.76, and 0.85 will have considerable nutrient effects on irrigation of green space. Mojiri (2011) reported increase of total nitrogen in 0-20 centimeter depth of soils irrigated with wastewater compared to control group. Sharma et al. (2007) performed a study on olive, corn, and a type of cabbage in form of factorial random study with three repetitions.

They investigated chemical specifications of soil and revealed that increase of nitrogen-nitrate, phosphor-phosphate in different depth of soil profile was caused by repeated usage of wastewater. Researches indicated that using wastewater in irrigation of lettuce, carrot, and tomato will increase the performance. Moreover, Bina’s (1993) study performed on wheat, broad bean, cotton, and rice revealed that using wastewater may cause in higher performance in comparison with drinking water enriched with nitrogen, potassium, and phosphor fertilizers.

This study was performed in order to assess the impact of using unconventional waters (wastewater, saline, and brackish waters) on chemical specifications of soil (value of nitrogen, phosphor, and potassium) and recommend appropriate management methods in applying waters with different qualities in development of resistant agriculture.

MATERIALS AND METHODS

Geographical conditions of studied region

Qom plain is located in eastern longitude of 39’, 50° to 04’, 51° and northern latitude of 37’, 34° to 49’, 34° with total area of 179.93 km^2 (Fig. 1).

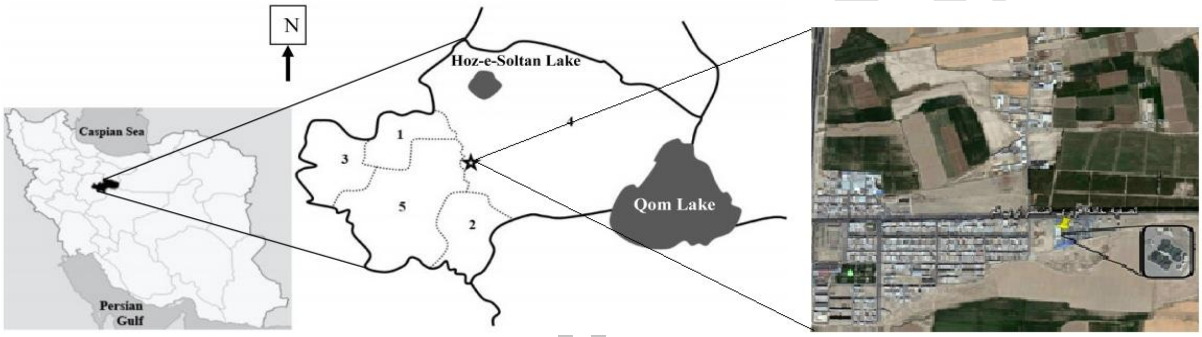

Fig. 1. Studied area in Qom Province, Iran

Study area has average sea surface height of 930 m with minimum lowest annual temperature of 16.5 ˚C, minimum highest temperature of 42.5 ˚C, and rainfall rate of 101.5 mm. According to studies performed in De Marttone method, this region has dry climate, according to Umberger method, it is a cold-dry desert, and in accordance with bioclimatic tables, it is located in cold and hot climate with general climate of semi-arid climate. As per related studies, the region’s soil is clay-loamy with high degree of salinity.

Soil sampling

Five points were considered in this study to assess impacts of unconventional waters of value of soil’s nitrogen, phosphor, and potassium. These points included five different conditions: not irrigated, irrigated with saline water, irrigated with brackish water, irrigated with wastewater, and irrigated with combination of wastewater and saline water. These farms were irrigated with mentioned treatments for duration of 6 months. The farms were planted by corn and alfalfa. The profiles (in 5 repeats) were excavated in mentioned regions to sample the soil in surface depth (0-30 cm) and vertical depth (30-60 cm) (Oron et al., 2007).

The samples were dried in open space and sieved (by 2 mm sieve) before transferring to laboratory. This process was performed with minimum damage and without any pressure to assess resistance of soil aggregates and then moved to laboratory (Imam Gholi, 2012). Percentage of nitrogen, potassium, and phosphor was estimated in next stage.

Laboratory operations

Chemical experiments included determination of absorbable potassium, phosphor, and nitrogen. Flame photometer was used to determine value of absorbable potassium which was calculated on the basis of meq/l after diluting extraction. Soluble nitrogen was calculated through Kjeldahl method which includes three parts of digestion, distillation, and titration. Soil phosphor value was also calculated by spectrophotometer and Olsen method. Measure potassium ion concentration of the filtrated solution with calibrated B-731 and with ICP-OES (e.g. HORIBA Jobin Yvon. Model ULTIMA2).

Statistical analysis

After performance of required tests and determination of related parameters in soil samples, statistical analyses were done in factorial form by SPSS software with linear ordination. Firstly, the data was normalized (Kolmogorov-Smirnov) which indicated that data have general normal distribution. Then, the data was analyzed in factorial design by employing Duncan test.

RESULTS AND DISCUSSION

Specifications of wastewater used in studied region

In order to use unconventional waters for irrigation in Qom Plain, they were studied and compared with related standards (Table 1). The results revealed that wastewater, saline water, and brackish water have normal acidity for irrigation and lack any limitation in acidity or alkalinity. Moreover, refined wastewater has average nitrogen and near standard sodium levels. Wastewater also has normal electrical conductivity while this parameter was excessive in saline and brackish waters. This high electrical conductivity will not cause any limitation in this study as a result of normal acidity of these waters.

Some chemical specifications of wastewater used in irrigation are summarized in Table 1.

General results of this study were considered for each treatment (saline water, brackish water, wastewater, and combination of wastewater and saline water) which are summarized hereunder.

Potassium

Potassium is one of the main regenerative soil factors which has an important role in its fertility. Although soils in different regions of Iran have no considerable potassium deficiency, its value may vary in different regions on the basis of excessive harvest (Hassan Lee and Javan, 2005). As per the results of one-way analysis (Tables 2 & 3) and comparing Tukey mean (Figs. 2 & 3), significant difference was observed in potassium value of all samples (both depths). Moreover, there were significant differences in all samples of surface layer 0-30 except in brackish treatment which faced us with potassium decrease from surface layers to deep layers. In depth of 30-60 cm, significant differences were observed in all treatments except in brackish water. Potassium concentration in surface layer of lands irrigated with combination of saline water and wastewater was in highest level (=459.39 ppm) compared to control group and other treatments. Potassium concentration of saline water treatment was higher in depth of 30-60 which revealed increase from surface to depth indicating leaching in related region.

Table 1. Chemical specifications of waters used for irrigation

Water Quality	Unit	Saline	Brackish	Wastewater	Recommended Values in IR Standards
pH	-	8.2	7.9	7.81	6-8.5
Ec	Ds/m	8.5	6.5	1.2	0.7-3
SAR	(mmol/Lit)/2	19.3	2.9	1.75	-
BOD	Mg/Lit	-	-	115	100
COD	Mg/Lit	-	-	140	200

Table 2. ANOVA test of soil potassium in depth of 0-30 cm

Source of Changes	Degree of Freedom (DF)	Means of Squares (MS)	Sum of Squares (SS)	F Statistics
Repetition	4	35858.326	143433.304	593.066*
Error	30	60.463	1813.878	-
Total	34	-	145247.182	-

* Significance in probability of 1%

Table 3. ANOVA test of soil potassium in depth of 30-60 cm

Source of Changes	Degree of Freedom (DF)	Means of Squares (MS)	Sum of Squares (SS)	F Statistics
Repetition	4	35858.326	143433.304	593.066*
Error	30	60.463	1813.878	-
Total	34	-	145247.182	-

* Significance in probability of 1%

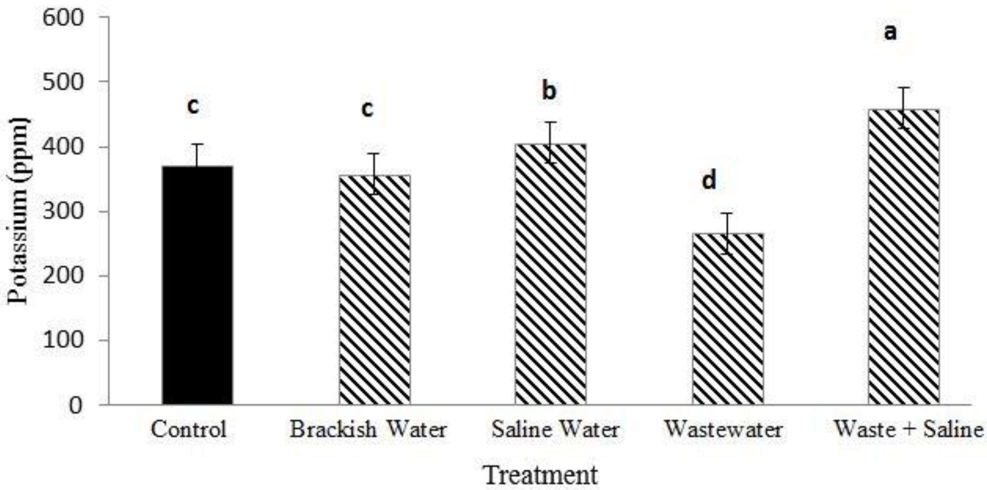

Fig. 2. Soil potassium in depth of 0-30 cm

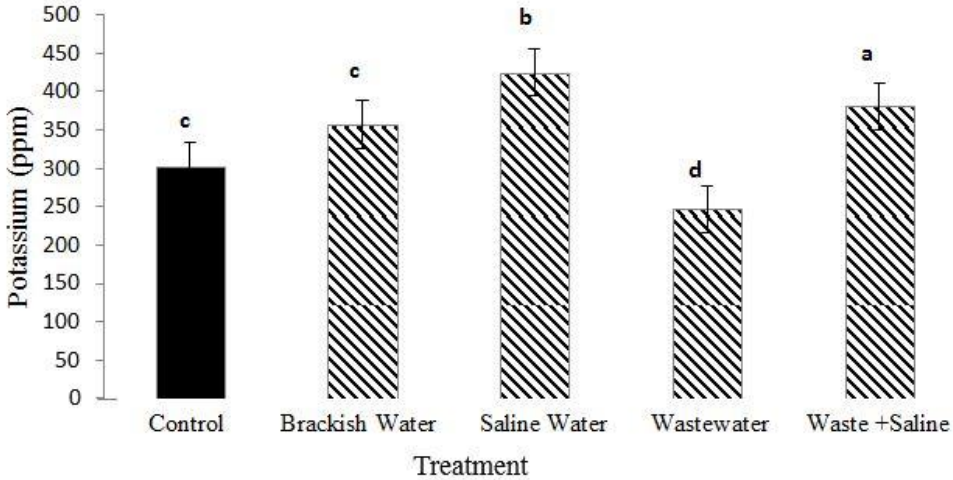

Fig. 3. Soil potassium in depth of 30-60 cm

Nitrogen

Nitrogen is one of the most important nutrients for plants (Zehtabian et al., 2005) which is rare in absorbable form. Therefore, we studied it in current experiment. As per the results of one-way analysis (Tables 4 & 5) and comparing Tukey mean (Fig. 4), no significant difference was observed in nitrogen value of all samples compared to control group (depth of 0-30). Accordingly, related Figure is not provided in this paper. It is noteworthy that value of mentioned nutrient was 0.3% higher in treatment which was irrigated with combination of wastewater and saline water. Moreover, samples irrigated with wastewater had 0.05% of absorbable nitrogen which was lowest degree in all treatments.

Samples from depth of 30-60 cm had no significant difference with control group. Treatment irrigated with saline water and wastewater indicated 0.297% of nitrogen in surface area and 0.049% in deep areas which indicated highest degree of difference in comparison with control group. Treatments irrigated with brackish water and saline water with degree of 0.08% in deep layers had highest level of nitrogen that contrasted surface layers. Nitrogen value had decreasing progress in treatments irrigated with brackish water and saline water from surface to deep layers.

Considering nitrogen percentage in both depths of samples in control group, it was revealed that studied farms had low degree of this element and usage of various treatments, especially combination of wastewater and brackish water, may improve soil's conditions.

Table 4. ANOVA test of soil nitrogen in depth of 0-30 cm

Source of Changes	Degree of Freedom (DF)	Means of Squares (MS)	Sum of Squares (SS)	F Statistics
Repetition	4	0.069	15.332	73.645^{ns}
Error	30	0.028	1.561	-
Total	34	-	16.893	-

^{ns} No significant difference in probability of 1%

Table 5. ANOVA test of soil nitrogen in depth of 30-60 cm

Source of Changes	Degree of Freedom (DF)	Means of Squares (MS)	Sum of Squares (SS)	F Statistics
Repetition	4	0.069	0.276	2.441^{ns}
Error	30	0.028	0.848	-
Total	34	-	1.124	-

^{ns} No significant difference in probability of 1%

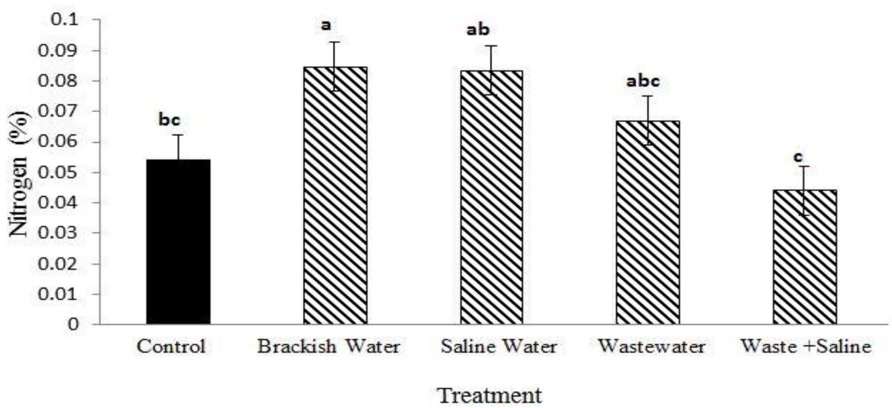

Fig. 4. Soil nitrogen (%) in depth of 30-60 cm

Phosphor

Phosphor is the other element which impacts soil's fertility. This element along with nitrogen and potassium are highly required for plants' growth. As per the results of one-way analysis (Tables 6 & 7) and comparing Tukey mean (Figs. 5 & 6), there were significant differences in value of phosphor in all treatments. Highest and lowest degrees of this difference were equal to 75.72 ppm in treatment irrigated with wastewater (depth of 0-30 cm) and 18 ppm in treatment irrigated with brackish water.

Significant differences were observed in depth of 30-60 cm of all treatments except the one irrigated with brackish water (=29 ppm). Phosphor value was increased from surface to deep layers in treatments irrigated with brackish water and saline water while this value was decreased in treatments irrigated with wastewater and combination of wastewater and saline water.

Table 6. ANOVA test of soil phosphor in depth of 0-30 cm

Source of Changes	Degree of Freedom (DF)	Means of Squares (MS)	Sum of Squares (SS)	F Statistics
Repetition	4	3381.071	13524.286	416.193*
Error	30	8.124	243.714	-
Total	34	-	13768.000	-

* Significance in probability of 1%

Table 7. ANOVA test of soil phosphor in depth of 30-60 cm

Source of Changes	Degree of Freedom (DF)	Means of Squares (MS)	Sum of Squares (SS)	F Statistics
Repetition	4	3381.071	13524.286	416.193*
Error	30	8.124	243.714	-
Total	34	-	13768.000	-

* Significance in probability of 1%

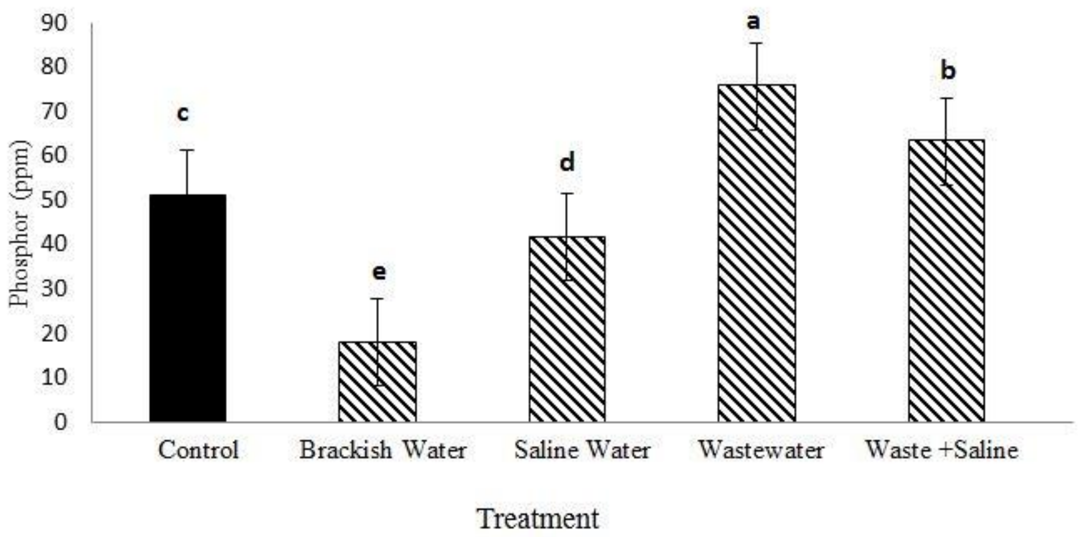

Fig. 5. Soil phosphor in depth of 0-30 cm

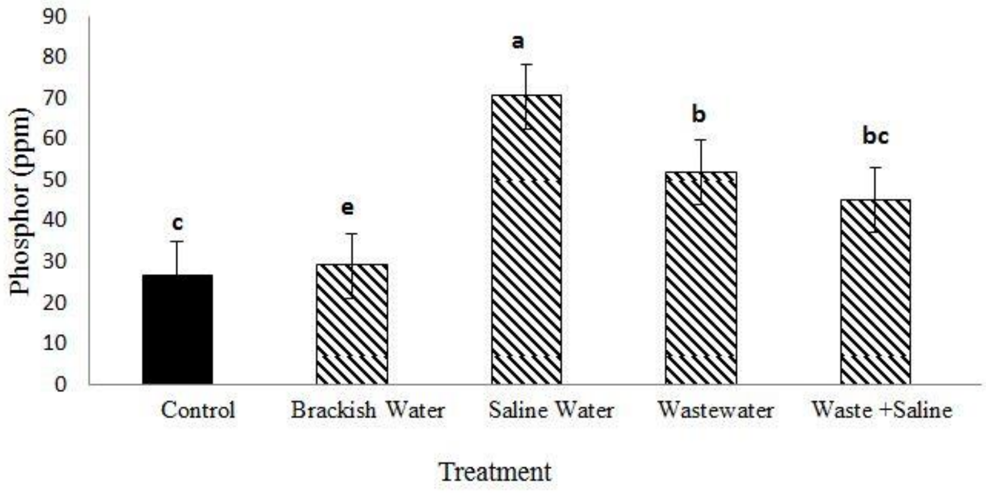

Fig. 6. Soil phosphor in depth of 30-60 cm

Conclusion

Studied wastewater includes considerable values of nutrients that may supply agricultural plant's demands using in combination with irrigation waters. The results of current study revealed that passage of wastewater may change mean value of soil phosphor in studied farms. In other words, these samples revealed considerable increase of phosphor value in both surface and deep layers in comparison with control samples. On the other hand, the samples of farms irrigated with saline water and brackish water had lower degree of mentioned element (compared to treatment irrigated with wastewater). Tester et al. (1973) indicated that nitrogen and phosphor will lose their movement during different levels of treating sewage sludge. But after 120 days, the mineralization will restart and result in increase of nitrogen and phosphor which are absorbable by plants.

Wastewater irrigation had both positive and negative effects on soil (Osakwe, 2012) properties. Irrigation with wastewater resulted in increase of potassium value in both sample depths. The main reasons of this increase are existence of potassium in regional wastewater and low value of this element in land's soil. However, samples treated with saline water indicated increase of average potassium compared to the samples of district's soil which may be caused by high percentage of salts in soil and irrigation water. Potassium value was higher in deep layer in comparison to the depth of 0-30 cm as the irrigation with wastewater resulted in leaching and transfer of potassium from surface layers to deeper ones. Existence of potassium in studied samples is a good result of using unconventional waters as potassium is the most important nutrient in wastewaters (Scott et al., 2002).

This result agrees with the findings of Osakwe (2012) who reported high P value from soil with irrigated wastewater. According to findings of research performed by Ghanbari et al. (2007), absorbable potassium was increased in soils irrigated with wastewater (compared to the soils irrigated with well water). Considering capability of potassium transfer in soil, this element may move in soil along with absorbent anions (Alizadeh, 1999; Barzegar, 2000). Wastewaters that include nitrogen, phosphor, and potassium may be employed as an appropriate source of nutrients and decrease application of chemical fertilizers in farmlands and increase efficiency of agricultural products (Moradmand, 2009; IWMI, 2006).

Irrigation with wastewaters increases soil's nitrogen percentage (in comparison with control area). Presence of nitrogen is irrevocable specification of wastewaters which causes increase of this element in areas irrigated with mentioned water source. Nitrogen will also increase in deep layers of areas irrigated with saline water and brackish water. Percentage of this increase in mentioned areas may be resulted from type of vegetation in related districts. Cultivated species (alfalfa and corn) in this study are among plants which are stabilizing nitrogen value. Therefore, we observed nitrogen increase in studied regions. Nitrogen, phosphor, and potassium are the most important nutrients in wastewaters (Scott et al., 2002) which is the main reason of using unconventional waters.

This issue is same as the results of Moradmand's (2009) study. He observed that values of nitrogen, phosphor, and potassium in wastewater which is used for irrigation of green pepper were more than well water. Other researchers also state that, in general, there was increased soil organic carbon and available N and P in soils. Long-term application of recommended NP fertilizers in the region has earlier been reported to result in improvements in the soil organic carbon and available NPK status due to rhizo-depositions, additions of root biomass, the above ground stubbles, etc. (Benbi and Brar, 2009; Brar et al., 2013). This specifically holds for SW irrigation that also substantially adds the organic carbon and the nutrients (Al-Omron et al., 2012; Singh et al., 2012; Bar-Tal et al., 2015).

Abegunrin et al. (2016) reported that wastewater resources are valuable because of improvement of soil fertility and enhanced crop growth compared to rainwater, however they need to be managed with caution, preferably treatment, before being reused in relation to soil functions and crop quality. Akbarnezhad et al. (2012) investigated impacts of urban wastewater and sewage sludge compost on chemical specifications of soil. The results of this study revealed that irrigation with urban wastewaters will increase nitrogen value in treated lands. In addition, the use of domestic wastewater boosts soil fertility and reduce the consumption of chemical fertilizers (Fine and Hadas, 2012). In general, usage of wastewater is an appropriate choice for irrigation of agricultural products in different districts, especially arid and dry regions (Abolhasani et al., 2015; Anderson et al, 2001; Asno and Levine, 1996; Beber, 1962).

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