



# Local desalination treatment plant wastewater reuse and evaluation potential absorption of salts by the halophyte plants

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## Abstract

The expansion of arid and semi-arid areas and consequently water scarcity are affected by climate change. This can influence on availability and quality of water while demands on food and water are increasing. As pressure on freshwater is increasing, utilization of saline water in a sustainable approach is inevitable. Therefore, bioremediation using salt tolerant plants that is consistent with sustainable development objectives might be an alternative and effective approach. In this study, saline wastewater from a local desalination treatment plant was utilized to irrigate four halophyte plants, including *Aloevera*, *Tamarix aphylla*, *Rosmarinus officinalis* and *Matricaria chamomilla*. A field experiment was designed and conducted in Zarrindasht, south of Iran in years 2012-2013 accordingly. Two irrigation treatments consisting of freshwater with salinity of 2.04 dS.m<sup>-1</sup> and desalination wastewater with salinity of 5.77dSm<sup>-1</sup> were applied. The experiment was designed as a split plot in the form of randomized complete block design (RCB) with three replications. The results of variance analysis, ANOVA, on salt concentration in *Aloevera* showed that there was no significant difference between the effects of two irrigation water qualities except for Na. In *Rosmarinus officinalis*, only the ratio of K/Na showed a significant difference. None of the examined salt elements showed a significant difference in *Tamarix aphylla* irrigated with both water qualities. In *Matricaria chamomilla*, only Mg and K/Na ratio showed a significant difference (Duncan 5%). As a result, no significant difference was observed in salt absorption by the examined plants in treatments which were irrigated by desalination wastewater and freshwater. This could be a good result that encourages the use of similar wastewater to save freshwater in a sustainable system.

**Keywords:** Salinity, desalination wastewater, bioremediation, irrigation with wastewater, halophytes.

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## Introduction

Water scarcity and salinity are the most serious challenges of sustainable agriculture in irrigated lands in arid and semi-arid areas, (Bernstein et al., 1993; Epstein, 1972). Soil salinity is a growing challenging issue, and about 70 percent of available water which is used for irrigation is adding millions of tons of salts to the fertile lands. Increasing human populations and food demands, will cause need more lands for agriculture (Kalantari

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and Hassanli, 2012; Tester and Davenport, 2003), consequently, the use of water resources with less quality including brackish water and recycled waste water for irrigation is vital. Also, the increase of evaporation as a result of global warming increases the risk of soil salinity especially in arid and semi-arid regions (Negahdari, 2012; Tester, and Davenport, 2003). Antcliff et al. (1983) stated that plant species which are able to limit the salt accumulation in the shoot are more resistant to salinity. According to Javadi et al. (2010) studies the extent of arid and semi-arid lands in Iran is enhancing and one of the associated challenges is salinity. They believe that one of the appropriate approaches to overcome this challenging issue can be the use of biological methods. Kalantari et al. (2015) emphasized that halophyte plants attracted more attention due to the salinity of soil and water resources. Larcher (1995) reported that as population growing, the greater emphasis needs to be put on more tolerant plants in the intensive conditions which resulted from the environmental degradation. The salt tolerant plants can be mostly found in salty and arid environments. Abedi et al. (2001) indicated that lack of adequate water generally is one of the important limited factors that lead to the restriction of maintenance and development of agricultural lands in arid and semi-arid areas. Therefore, wastewater can be used in order to overcome this congestion. The main requirement of efficient use of salty water is to consider the measures that may enhance sustainability of agricultural practices through soil and water conservation approach. The limited freshwater availability and the easy access to unconventional waters such as desalination wastewater and bioremediation as a sustainable approach, necessitate to carry out more research. Literature shows there is no much related research to the utilization of desalination plant wastewater and the absorption of salts ions by the halophytes.

The aim of this study were (i) indicating the impact of desalination waste water on the halophyte plants and (ii) reflecting the role of such plants on potential absorption of salt.

## Material and Methods

This research was carried out in Zarrin Dasht Desalination Plant Station, located in south east of Iran; with area of 624 m<sup>2</sup>, and longitude of 53° 58' 46" to 55° 01' 40" and latitude of 28° 00' 31" to 28° 36' 25" with elevation of 1021m above the sea level. The climate of Zarrin Dasht is hot and dry with average rainfall (2002-2012) of 179 mm, mostly occurs in January and February ([www.frrw.ir](http://www.frrw.ir)). The average annual and average maximum temperature is 22 C° and 46.2 C°, respectively. The absolute minimum temperature in February is -3.2C° while the annual average evaporation is 2976 mm. Prior to soil and water data collection a field observation was carried out. The results of water and soil analyses prior to plantation are shown in Table 1 and 2.

Table 1. Chemical characteristics of irrigation water

Water	EC	pH	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	SAR	Total hardness	TDS
	dS/m									ppm	mg/l
Wastewater	5.77	7.96	10	3.04	38.8	6.13	29.1	16.99	4.05	1760	3692.8
Freshwater	2.04	7.58	7.2	2.9	1.3	2.7	6.1	9.15	4.36	440	1305.6

EC: electrical conductivity; SAR: sodium adsorption ratio; TDS: total dissolved solid

Table 2. Chemical and physical characteristics of the soil before plantation (Bioremediation)

Sampling depth	EC	pH	Cl <sup>-</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	K	OC	SAR	BD	FC	PWP
	dS/m							%		g/cm <sup>3</sup>		wt (%)
0-25	9.08	7.58	50	15.25	24.8	19.4	152	0.15	4.3	1.43	40	25
25-50	6.3	7.71	43.9	12.96	23	15.4	182	0.13	3.6	1.21	40	25
50-75	7.63	7.99	50.8	14.47	25.5	18.8	154	0.13	4.2	1	40	25

OC: Organic Carbon; BD: Bulk Density; FC: Field capacity; PWP: Permanent Wilting Point

The experimental design was a randomized split plot with two main treatments (desalination wastewater, freshwater) and four sub-main treatments (*Rosmarinus officinalis* L, *Matricaria chamomilla* L, *Aloevera barbadensis* Miller and *Tamarix aphylla*), each with three replications. This design consisted of 24 experimental plots. In each plot 90 plants were implanted and 30 plants were considered as the main line of monitoring and the rest were considered to eliminate the possible marginal effects. Monitoring of soil, water and plant was conducted in a 15-month period (October 2012 to December 2013). The statistical analysis was performed using the SAS statistical software package. For water monitoring (HosseiniFard and Aminiyan, 2015) ion analysis was performed using vanadate and molybdophosphoric acid method for potassium, nitrogen and phosphorus; bioassay method with EDTA for sodium, magnesium

and calcium; turbid metric determination of sulfate; carbonate and bicarbonate ion concentration measured by titration method with sulfuric acid. In order to assess the amount of ions absorbed by the plants spectrophotometer for calcium and magnesium; flame photometry for sodium and potassium, vanadate and molybdate method and yellow color method for phosphorus were applied. Walky-block and flame photometry methods were used to calculate the amount of organic carbon and sodium and potassium, respectively. For calcium and magnesium, the bioassay method with EDTA was used (Van Reeuwijk, 2002). In addition, pH and salinity were measured using a digital pH meter and EC meter (Metrohm, 660). It worth to mention that the tests were repeated three times in order to increase the accuracy and reliability of the results. The applied irrigation water was based on the soil moisture at field capacity (FC) and the roots depth monitoring with a fixed interval time but the variable irrigation depths depending on the seasonal weather conditions and root depth. At each irrigation event, the soil moisture at root zone was measured by gravitational method, soil bulk density within the root zone was measured by a cylinder with given volume from the undisturbed soil. The volume of irrigation water at each event was estimated using Equations 1 to 4 and was controlled by a water meter and an automatic valve which was equipped to a timer.

$$\theta_w = (B - C) / (C - A) \times 100 \quad \text{Equation 1}$$

$$d_n = (\theta_{fc} - \theta_w) A_s \times R \quad \text{Equation 2}$$

$$d_g = \frac{d_n}{E_a} \quad \text{Equation 3}$$

$$V = d_g \times A \quad \text{Equation 4}$$

where  $d_n$  is the net water required to provide the soil water deficit to reach field capacity within the root zone (mm);  $\theta_{fc}$  and  $\theta_w$  are soil water contents at field capacity and at measuring time, respectively (%);  $A_s$  is the bulk density ( $\text{g cm}^{-3}$ );  $R$  is the root depth (mm);  $n$  is the number of days between the last irrigation and the current irrigation event;  $V$  is the volume of irrigation water (liters); and  $A$  is the area of each plot ( $\text{m}^2$ ).  $d_g$  is gross irrigation depth (mm);  $E_a$  is the application efficiency. The measured irrigation water was applied through a drip irrigation system and noany fertilizers were used throughout the growing season.

## Results and Discussion

### Sodium ( $\text{Na}^+$ ) accumulation in the irrigated plants

Analysis of variance (ANOVA) showed a significant difference between the effect of freshwater and wastewater on sodium accumulation in *Aloevera* at a rate of five percent (Figure 1). The plants irrigated with wastewater showed a significant increase of sodium concentration in plants' dry matter (7.66%) compared to those irrigated with freshwater (4.23%). This could be justified as a result of more sodium concentration in the wastewater (16.99 meq/l) comparing to the freshwater (9.15 meq/l). This finding is consistent with the results reported by Moghbeli et al. (2012). However, the results of variance analysis did not show a significant difference in sodium absorption by *Rosmarinus officinalis*, *Matricaria chamomilla* and *Tamarix aphylla* irrigated with freshwater and wastewater at significance level of 0.05 (Figure 1).

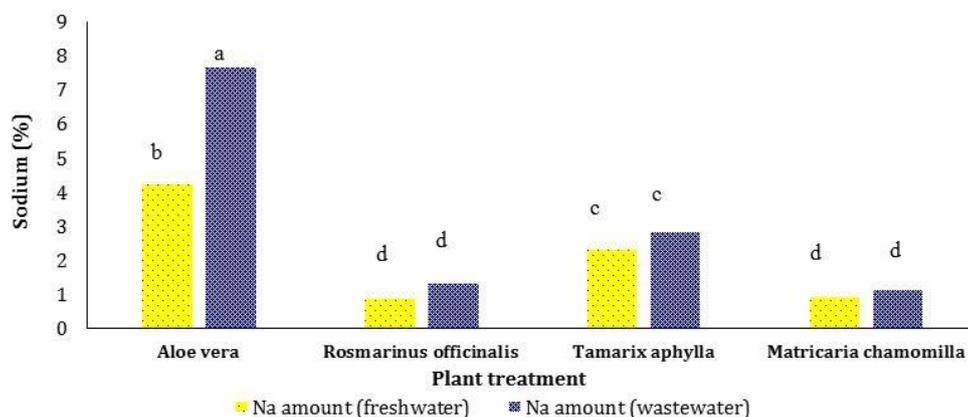


Figure 1. Comparison between the average sodium accumulations in plants irrigated with fresh water and wastewater

### Potassium (K<sup>+</sup>) accumulation in the irrigated plants

ANOVA analyses showed that there was no significant difference between potassium absorption in the examined plants irrigated with freshwater and wastewater at a rate of five percent, (Figure 2). This could be justified due to lack of significant differences of potassium in the both irrigation water qualities. Hassanli et al. (2009) showed that the absorption of potassium in the leaves and seeds of corn are not affected by water quality. It is worth to note that the amount of potassium in plants' dry matters for an appropriate growth has been reported more than 1% (Moghbeli et al., 2012). As shown in Figure 2 the amount of potassium in the examined plants irrigated with both types of irrigation water was in acceptable limits.

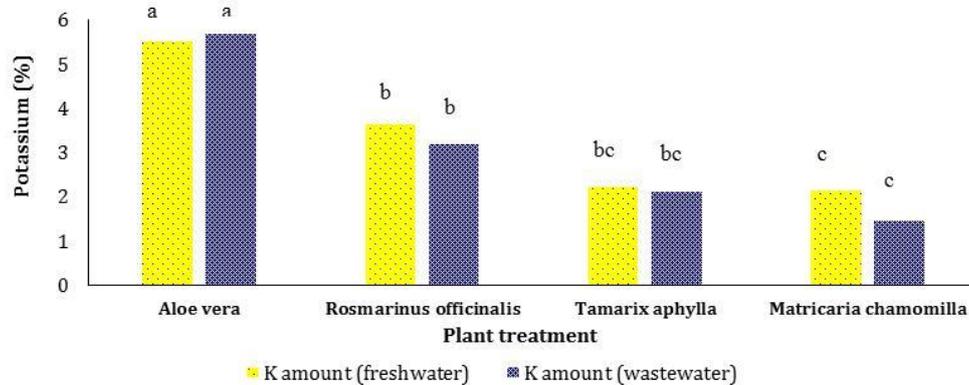


Figure 2. Comparison between the average potassium accumulations in the plants irrigated with freshwater and wastewater

### Calcium (Ca<sup>2+</sup>) accumulation in the irrigated plants

Calcium plays a crucial role in the protection of the structure and proper functioning of plant organs as well as strengthening of cell walls in regulating ion transportation and in selection and activities of cell wall enzymes (Ashraf, 2004; Aminiyan and Aminiyan, 2016). According to Patel et al. (2010), sodium chloride in Saline soils can have direct effect on the absorption of nutrients, for example on the reduction of calcium while calcium presence in the cell wall is necessary for salt tolerance in plants. In this study, ANOVA analysis indicated no significant difference for uptake of calcium in the all examined plants (Figure 3). Generally, irrigation with wastewater has not a significant effect on the accumulation of calcium in the plants due to lack of significant differences of Ca<sup>2+</sup> between with the freshwater and wastewater. This result is consistent with the result of Hassanli et al. (2008). The concentration of this element in the plant for appropriate growth conditions is more than 1.5 percent in the dry matter of plant (Epstein, 1972). The amount of calcium absorbed in plants (Figure 3) indicates that the all plants are active in absorption of this element. It is shown that the amount of this element in all plants is much more than the desirable level.

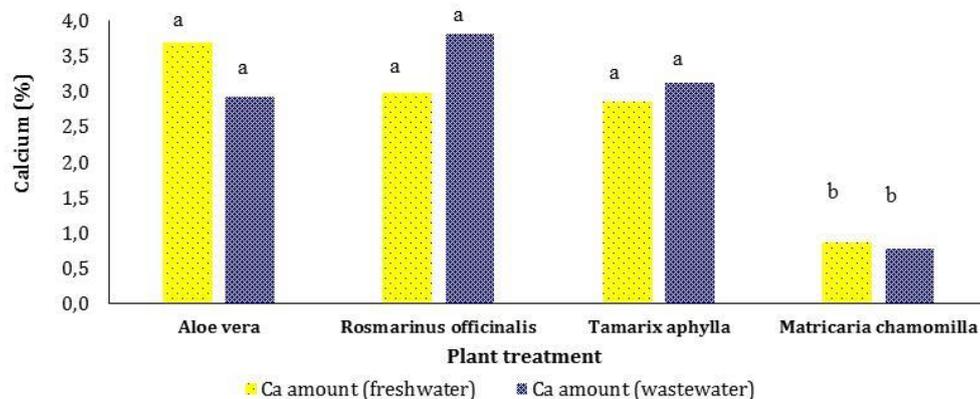


Figure 3. Comparison between the average calcium accumulations in all organs of the plants irrigated by two different water qualities

### Magnesium accumulation (Mg<sup>2+</sup>) in the treatment plants

ANOVA analysis showed that there was no significant difference in magnesium absorption by *Aloevera*, *Rosmarinus officinalis* and *Tamarix aphylla* plants irrigated with freshwater and wastewater at a rate of five percent (Figure 4). However, the results indicated that there was a significant difference in magnesium

accumulation at a rate of five percent in *Matricaria chamomilla*, irrigated with two types of irrigation water. It was shown that absorption of magnesium in the dry matter of *Matricaria chamomilla* was significantly increased by 2.4% irrigated with freshwater compared to those plants irrigated with wastewater by 4.4%. As Mahler reported the desired amount of magnesium in the dry matter is 0.1 to 1% (Mahler, 2004). This indicates the role of *Matricaria chamomilla* in the absorption of magnesium. While there is no significant difference in the absorption of magnesium by *Aloevera*, *Rosmarinus officinalis*, *Tamarix aphylla* irrigated with freshwater and wastewater. But the absorption of magnesium by *Matricaria chamomilla* irrigated with freshwater is significantly more than that irrigated with wastewater.

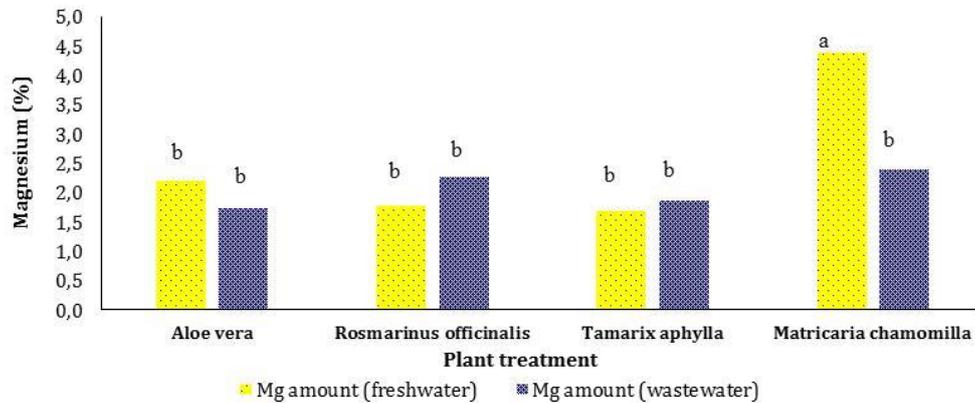


Figure 4. Comparison between the average magnesium accumulations in plants irrigated with freshwater and wastewater

#### Chlorine accumulation (Cl) in the treatment plants

The results of statistical comparison (Duncan 5%) of all examined plants showed that there is no significant difference in the absorption of the chlorine in the plants irrigated with two types of water as shown in Figure 5. One of the reasons could be the similarities of the chlorine concentration in both freshwater and wastewater (Table 1). As this experiment shows irrigation with wastewater has not a significant effect on chlorine absorption by the examined plants that is consistent with those of the Hassanli et al. (2009), Asano and Pettygrove (1987). The safe amount of chlorine in dry matter of a healthy plant recommended 70 to 100 ppm (0.007-0.01 %). As shown in Figure. 5 the chlorine concentration in the all examined plants are within the safe limits and only the concentration of this element in *Matricaria chamomilla* is beyond the border of the safe limit. Usually, in saline regions the main limiting anion is chlorine for crop growth, which is absorbed faster than the sodium. Damages caused by chlorine ion is more intense than sodium and its damage gets visible sooner. These ions are absorbed by the roots and accumulate in the leaves. Chlorine concentration varies in plant tissues and depends on the time when the plant is exposed to salt stress and also depends on the concentration of irrigation water (Negahdari, 2012). Comparative results in Figure 5 shows that *Matricaria chamomilla* can absorb more chlorine than the other examined plants.

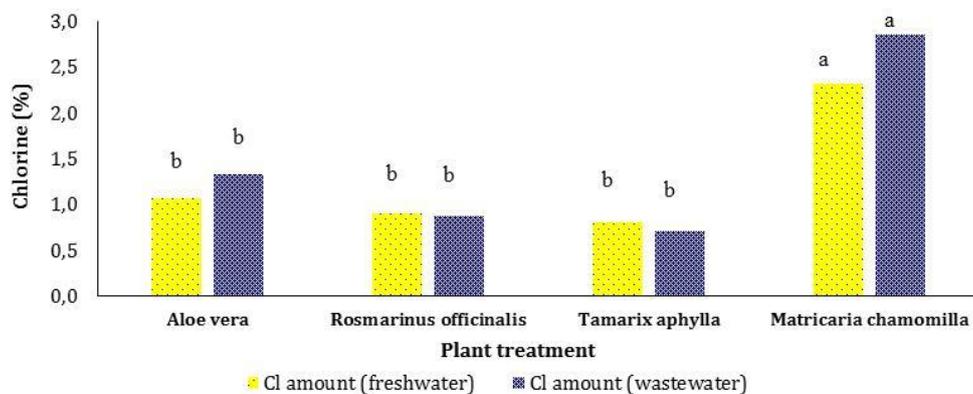


Figure 5. Comparison between the average chlorine accumulations in the examined plants irrigated with two different water qualities

### The ratio of potassium to sodium in the irrigated plants

Based on the variance analysis there was a significant difference in the potassium to sodium ratio ( $K^+/Na^+$ ) in the *Rosmarinus officinalis* and *Matricaria chamomilla* irrigated with freshwater and wastewater. The highest ratio was 4.28 in *Rosmarinus officinalis* irrigated with freshwater and the lowest ratio was 2.44 irrigated with wastewater. According to the variance analysis the ratio of potassium to sodium in the *Matricaria chamomilla* irrigated with freshwater was 2.3 and with wastewater was 1.2 with a significant difference (Figure 6). In contrast, the average ratio of potassium to sodium in *Aloevera* and *Tamarix aphylla* irrigated with freshwater and wastewater was 1.314 vs. 0.75 and 0.99 vs. 0.96, respectively without a significant difference. The high ratio of potassium to sodium in plants under salinity conditions could be an index to scale salinity (Ashraf, 2004). In fact, the ratio of potassium to sodium in the plant affected by saline conditions is one of the criteria for salinity resistance of the plant (Ashraf and Orooj, 2006).

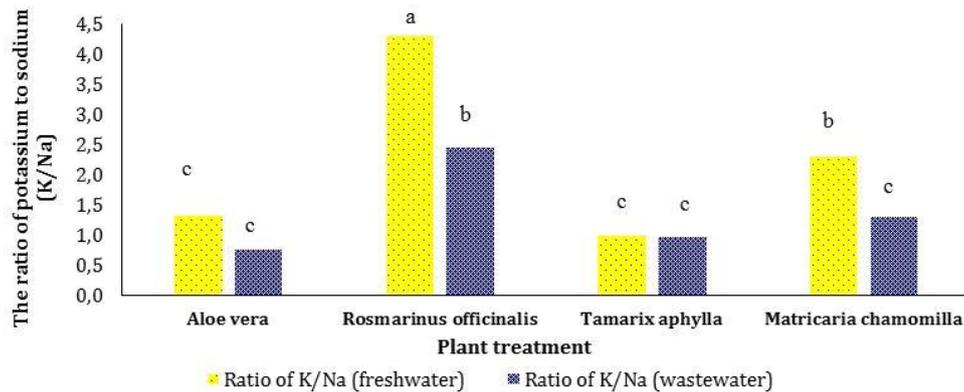


Figure 6. Comparison between the averages K/Na accumulations in plants irrigated with freshwater and wastewater

### Organic carbon (OC %) in the plants

Based on Figure 7, the results indicated there is no significant difference in accumulation of OC in the examined plants with significance level of 0.05. The organic carbon percentage adsorbed by the plants irrigated with wastewater and freshwater was 0.41 and 0.43 for *Aloevera*, 0.48 and 0.50 for *Rosmarinus officinalis*, 0.47 and 0.49 for *Tamarix aphylla*, respectively.

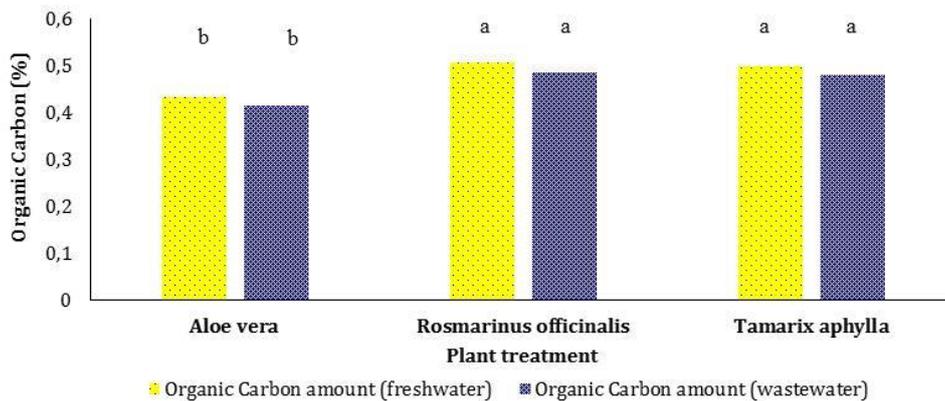


Figure 7. Comparison between the average organic carbon accumulations in plants irrigated with freshwater and wastewater

### Essential oil and efficiency

Comparison results of average (Duncan 5%) for *Rosmarinus officinalis*'s essential oil samples indicated no significant difference between the effects of two water quality types. The average essential oil obtained from *Rosmarinus officinalis* irrigated with freshwater and wastewater was 0.75 and 0.67 grams per hundred grams of total dry matter, respectively. The amount of essential oil from *Matricaria chamomilla* irrigated with freshwater and wastewater was 0.40 and 0.43 grams, respectively. Similarly, the variance analysis results at significance level of 0.05 showed no significant difference between the effects of water quality on

the essential oil obtained from *Matricaria chamomilla* (Figure 8 and 9). These results suggest that irrigation with desalination wastewater, which is saltier than the freshwater may not affect the quantity of essential oil production. Analysis of variance on *Rosmarinus officinalis* and *Matricaria chamomilla* as shown in Figure 9 indicated that there is no significant difference between the effects of quality of irrigation water on essential oil efficiency at significance level of 0.05. The results showed that essential oil efficiency in *Rosmarinus officinalis* and *Matricaria chamomilla* irrigated with freshwater and wastewater was 1.50 vs. 1.35 and 0.96 vs. 0.91 percent, respectively. It can be concluded that irrigation with desalination wastewater with salinity of 5.77 dS/m might be used for irrigation without inverse effect on essential oil efficiency. One of the challenges in relation to irrigation of medicinal plants with saline waters is possible change in the quality and quantity of their effective substances. [Baghalian et al. \(2008\)](#), and [Bernstein et al. \(1993\)](#), concluded that the effects of saline water on the quantity and quality of essential oil in *Matricaria chamomilla* and *Rosmarinus officinalis* had no significant differences.

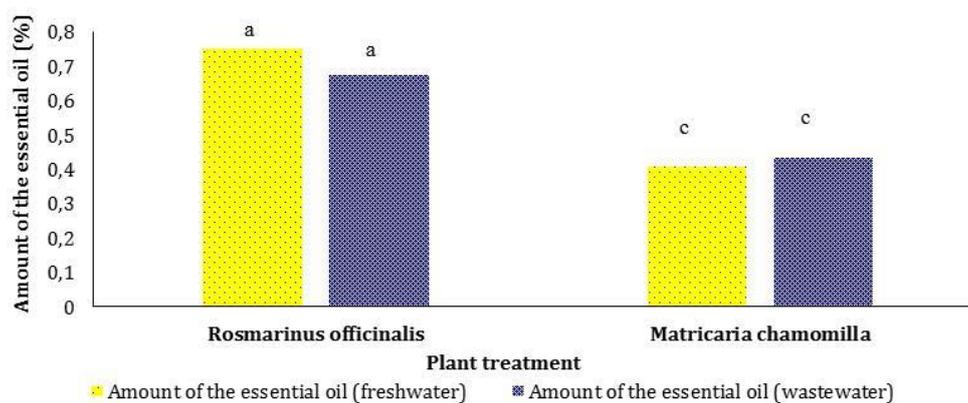


Figure 8. Comparison between the averages essential oil in hundred grams of dry matter in two plants irrigated with freshwater and desalination wastewater

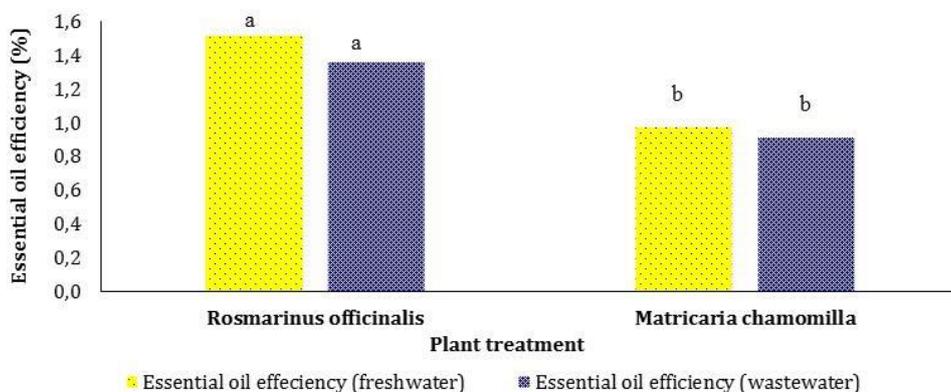


Figure 9. Comparison between the average essential oil efficiency influenced by irrigation with freshwater and desalination wastewater

## Conclusion

Based on the achieved results, application of desalination wastewater in this study didn't show a significant difference compared to freshwater in terms of accumulation of potassium, calcium, chlorine, and organic carbon. Also the amount of essential oil and essential oil efficiency for *Tamarix aphylla*, *Aloevera*, *Rosmarinus officinalis* and *Matricaria chamomilla* irrigated with desalination wastewater and freshwater were not significantly different. However, ANOVA analyses showed that concentration of sodium and magnesium was significantly differences in *Aloevera* and *Matricaria chamomilla*, respectively (at significance level of 0.05). Also a significant difference in ratio of potassium to sodium in *Rosmarinus officinalis* and *Matricaria chamomilla* irrigated with wastewater and freshwater was observed. It might be concluded that due to the high proportion of potassium to sodium, the plants which are irrigated with freshwater would be more secure than the plants irrigated with wastewater. The complexity of the impact of desalination wastewater

on the plants in this research indicates that it is necessary to extend and repeat this research to increase the validation of the findings. Since water in arid and semi-arid regions is a very scarce input it is essential to practice the sustainable use of desalination wastewater for irrigation.

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