Evaluating Different types of Irrigation Water and Their Impact on Soil and Date Palm in AL- Hassa Oasis, KSA

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ABSTRACT: The present study was conducted to evaluate different types of irrigation water and their impact on heavy metals content in soil and date palm grown in Al-Hassa Oasis, Saudi Arabia. The investigated irrigation water included groundwater (GW), mixture of groundwater and drainage water (GW+DW), mixture of groundwater and tertiary treated wastewater (GW+TTWW) and mixture of groundwater, drainage water and tertiary treated wastewater (GW+DW+TTWW). The results of this study indicate that the water types used may cause one problem or another according to the water type. By applying the criteria used for interpreting water quality for irrigation, the most domain problems are salinity hazard and potential salinity. Therefore, it is expected that continuous irrigation without good water management (leaching requirements) can led to severe problems from the salinity point of view. The mixed waters (GW+DW +TTWW) have the highest effect on elemental composition of plants and soil followed by (GW+TTWW), (GW+DW) and then (GW). Generally, a significant difference in heavy metals concentrations for both treated soil and plants was found. The contents of the heavy metals in both soil samples and plants are compared with the worldwide standards. Based on these comparisons, the results concluded that the heavy metals in the soil and plants were in acceptable range.

Keywords: Al Hassa Oasis, Water Quality, Heavy metals, Sodium hazard, Potential salinity, leaf mineral composition.

INTRODUCTION

Water insufficiency is one of the most critical problems that confront the world particularly in the arid and semi arid regions. The water policy of any country is to use all water resources for adding more land to increase agriculture production for the people demands. The limiting factor for reclaiming the arable land is the availability of good quality water. Using the treated wastewater for irrigation purposes becomes inevitable alternative to reduce the request of freshwater resources in the world, especially in arid and semiarid areas (Duan and Fedler, 2007).

The sources of irrigation water in Al-Hassa Oasis, Saudi Arabia are drainage water, tertiary treated wastewater and groundwater individually or mixed. Before using any source of water that mentioned before, it should be tested to find out its effect on soil chemical, physical, fertility and toxicity properties. Also, the effects on plant growth, yield and elemental analysis must be calibrated. Heavy metals are components of the biosphere, occurring naturally in soils and plants, but as a consequence of industrialization. Heavy metals from various sources such as fossil fuel combustion, sewage sludge, industrial waste and fertilizer, contaminate the environment. Plants growing on polluted soils may contain elevated levels of heavy metals (Gallego *et al*., 2002; Zornoza *et al*., 2002). Heavy metal ions such as zinc, manganese and nickel are essential micronutrients for plants, but when present in excess, these, and non-essential heavy metals such as cadmium, can accumulate in plant parts used for human or animal nutrition to undesirably high contents. At even higher levels, they can become toxic to the plant (Williams *et al*., 2000). The growing urbanization increases domestic water use while supplying wastewater that can be used for non-potable purposes, such as agricultural irrigation. The costs associated to wastewater source are low compared with those of other water sources (Bahri, 1999).

In developing countries agricultural sector, the predominant trend is reuse of treated wastewater in irrigation (Smith, 1996; Haruvy, 1997; Bahri, 1999,; Nicholson *et al*., 2003). In contrast, most developing countries such as Mexico, Peru, Chile and Argentina rely on raw wastewater for agricultural irrigation (Siebe and Cifuentes, 1995; Peasey *et al*., 2000). Some researches on the effects of treated wastewater on soil and plant have been done in the past years. Abedi-Koupai *et al*. (2006) reported that the accumulation of Pb, Mn, Ni, and Co in the soil significantly increased after wastewater land application, and such an accumulation decreased with the depth. Hussein (1991) found that sewage and drainage water significantly increased Fe, Mn, Cu and Zn in sandy clay loam soil, sandy soil and calcareous soil. These results are in harmony with those obtained by Hussein *et al.* (2008) and Al-Dakheel (2011). They reported that groundwater; drainage water and tertiary treated wastewater have the highest effect on Fe, Mn, Cu, Zn, Cd, Co and Ni content of soil followed by groundwater and tertiary treated wastewater, groundwater and drainage water and then groundwater. Pereira *et al*. (2012) found that, using reclaimed wastewater (RWW) leads to increase (P, Mg, B, Fe, Mn, Zn, Ni, Cu, Co, Cd, Cr, and Pb) in soil compared with well water irrigation. Gonca and Gokhan (2012) reported that, soil nutrient elements (Mn, Cu, Zn, and Fe), and heavy metals (Cd, Cr, Ni, and Pb) were higher in soil treated with wastewater than in control soil. On contrast, there was no significant difference in the concentrations of heavy metals in soils irrigated with reclaimed water and with ground water or tap water in different years (Yang *et al*., 2011). Keser and Buyuk (2012) reported that, plant nutrient contents (Zn, Ca, Mg and Na) and heavy metals (Cd and Pb) in parsley plant increased with wastewater irrigation. In addition, the wastewater-irrigated plants showed a significant accumulation of heavy metals (Pb, Cd, Cr, and Cu) in their edible parts and roots (Keser, 2013).

The present study aimed to evaluate different types of irrigation water and their impact on some of heavy metals content in soil and date palm grown in the Al-Hassa Oasis, Saudi Arabia.

MATERIALS AND METHODS

The investigated irrigation waters include groundwater (GW), mixture of groundwater and drainage water (GW+DW), mixture of groundwater and tertiary treated wastewater (GW+TTWW) and mixture of groundwater, drainage water and tertiary treated wastewater (GW+DW+TTWW). Characteristics of irrigation water quality used for irrigating the investigated soil are illustrated in (Table, 1).

Quality of the irrigation water was determined according to the following parameters (Wilcox, 1958 and FAO, 1973& 1976):

1. The soluble salts concentration of water, which can be expressed in terms of electrical conductivity (EC_{iw}, dS/m).
2. The chemical composition of water, by determining the concentrations of cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and anions (CO_3^{2-}, HCO_3^{-}, Cl^{-} and SO_4^{2-} ions).

The quality parameters were calculated as follows:

a. Sodium Hazard:

Can be expressed in terms of Sodium Adsorption Ratio (SAR) or Soluble Sodium Percentage (SSP, %).

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{2+} + Mg^{2+})/2}}$$

$$SSP = \frac{Na^{+}}{\sum Cations} \times 100$$

(The concentration of cations was expressed in me/L).

b. Magnesium hazard (SMgP):

It can be expressed by the value of Soluble Magnesium Percentage (SMgP, %),

$$SMgP = \frac{[Mg^{2+}]}{[Ca^{2+} + Mg^{2+}]} \times 100$$

c. Bicarbonate hazard:

It can be expressed by the value of Residual Sodium Carbonate (RSC, me/L):

$$RSC = \left[CO_3^{2-} + HCO_3^{-}\right] - \left[Ca^{2+} + Mg^{2+}\right]$$

(The concentration of ions was expressed in me/l.)
The concentration of toxic compounds can be expressed by the values of:

a. Potential Salinity (PS):

$$PS(me/l) = Cl^{-} + 0.5 \times SO_4^{2-}$$

b. The nitrate concentration (NO_3^- , mg/l).

c. The boron concentration (B, mg/L).

Table (1). Chemical characteristics of the irrigation waters used in the present study

Irrigation waters	EC, dS/m	pH	Soluble cations				soluble anions			NO_3^-	B
			Na^+	K^+	Ca^{2+}	Mg^{2+}	CL^-	HCO_3^-	$SO_4^=$		
			meq/l							mg/l	
GW	2.07	7.24	9.13	0.41	6.64	3.69	11.60	3.60	4.67	7.78	0.33
GW+DW	2.62	7.31	12.78	0.63	7.11	4.76	12.36	5.10	7.83	15.73	0.54
GW+TTWW	3.54	7.22	18.52	0.75	10.05	5.84	20.59	7.31	7.26	12.76	0.61
GW+DW+TTWW	4.43	7.14	20.61	0.57	12.86	9.85	24.00	4.64	15.25	21.11	0.48

Four farms in Al-Hassa Oasis were selected according to the irrigation water quality (One farm for each irrigation type) and approximately similar in soil texture. Four locations were selected in each farm. Four palm trees were selected to represent each location in the farms (16 palm trees for each farm). The palm trees were selected as uniform as possible in growth and vigor and subjected to the same cultural practices commonly adopted in the farm. From each date palm tree, five pinnate leaf samples were collected from the middle of the third leaf (from top) in all directions, i.e. 20 pinnate per each date palm tree. Leaf samples were washed with tap water, distilled water, air-dried, oven dried at 65Cº for 72 hrs, and then ground in a stainless steel mill and the powder stored for elemental analysis. The ground material (plant powder) was digested with concentrated Sulphuric acid + 30% hydrogen peroxide according to the method of Wolf (1982). In the digest, Fe, Mn, Cu, Zn, Cd, Co and Ni were determined by inductively coupled plasma optical emission spectrometer (Carter, 1993).

Four soil samples were collected from each farm, one for each location, from the surface (0 – 30 cm) depth for chemical analysis. All the collected soil samples were air dried, grounded and sieved through a 2mm sieve and kept for analysis. Mechanical analysis was carried out according to the international hydrometer method using sodium hexametaphosphate as a dispersing agent (Richards, 1972). pH and total soluble salts were measured in the soil paste extract (Jackson, 1973). The contents of Fe, Mn, Cu, Zn, Cd, Co and Ni in the soil were determined by inductively coupled plasma optical emission spectrometer (Carter, 1993) after extraction with DTPA extracting solution. Some physical and chemical properties of the soil samples are presented in (Table, 2).

The experiment was arranged in randomized complete block design, (four treatments or water quality) with four replications, represented by 4 locations with 4 trees for each location). The obtained results were subjected to statistical analysis of variance using SAS Software (SAS Institute Inc., 1996).

Table (2). Some physical and chemical characteristics of the experimental soil as affected by the different irrigation waters

Irrigation Water	Particle Size Distribution				pH	ECe (dS/m)	Soluble Cations				Soluble Anions		
	Sand %	Silt%	clay %	Texture			meq/l						
	%	%	%				Na^+	K^+	Ca^{2+}	Mg^{2+}	CL^-	HCO_3^-	$SO_4^=$
GW	87.9	2.0	10.1	LS		1.69	4.62	0.28	7.17	4.32	4.43	2.82	9.14
GW+DW	86.9	4.0	9.1	LS	7.62	2.15	7.84	0.35	8.49	5.56	9.04	3.63	9.57
GW+TTWW	82.8	6.1	11.1	LS	7.37	2.63	9.55	0.63	9.66	7.13	9.21	3.64	14.11
GW+DW+TTWW	87.9	4.0	8.1	LS	7.50	3.25	12.58	0.47	11.65	8.79	12.31	3.25	17.92

LS Loamy sand

RESULTS AND DISCUSSION

1. Quality of irrigation water

The water quality parameters for the all investigated water types are presented in Table (3). From these data, it appears that for all types of water, the EC_{iw} ranged from 2.07 to 4.43 dS/m. The critical level of EC_{iw} to cause severe salinity problems is 3 dS/m as reported by FAO (1976). The values of EC_{iw} for

(GW) and (GW+DW) are less than the critical limit and no problems of using these types of irrigation water. On the other hand, the (GW+TTWW) and (GW+ DW+TTWW) have EC_{iw} values more than the critical level. It could be considered as high salinity and may cause severe salinity problems. Therefore, it is expected that continuous irrigation without good water management (leaching requirements) can led to severe problems from the salinity point of view.

The data presented in Table (3) also revealed that the SAR value of all water sources is relatively low in comparing with the critical level of sodium hazard (less than 10) as reported by Richards (1972). With respect to the SSP as indicator for sodium hazard, the values of SSP for all types of water were ranged from 45.94 to 52.67%. The data revealed that all values of SSP were less than the critical limit (< 60%) as reported by Wilcox (1958).

Magnesium hazard is one of the criteria for suitability of water for irrigation. In this respect, the values of SMgP tabulated in Table (3) indicated that all types of water have a values ranged from 35.72 to 43.37%. The values are below the harmful level (> 50%). This means no problem of Magnesium hazard. The magnesium salts have toxic effects on the plant and the toxicity of Mg ion is higher than the toxicity of Na ion having the same concentrations.

The RSC value evaluates the tendency of irrigation water to form carbonates and to dissolve or to precipitate the calcium and to a less degree, the magnesium carbonates. The precipitation of poorly soluble carbonates increases the sodium hazard of irrigation water and as a result increases the sodicity of irrigated soils. The present values of RSC have a negative values, this means that Ca^{2+} + Mg^{2+} is more than the CO_3^{2-} + HCO^-_3 resulted in no problem of sodium hazard. Potential salinity (PS) for all water types used was ranged from 13.94 to 31.63 me/l. The high values of PS over the critical level (5 me/l) as reported by Richards (1972) may be due to high chloride and sulphate content in the irrigation water. The concentration of B for all the water types in the present study is < 1 mg/l. The palm trees are considered as semi-tolerant to Boron, which the limit of boron in irrigation water is from 1 to 2 mg/l (Wilcox, 1958). This would put these waters in the range of no problem of toxicity with respect to palm trees.

Table (3). Water quality parameters used for comparing the different irrigation waters

Irrigation water	EC_W dS/m	SAR	SSP (%)	Mg Hazard (%)	RSC me/L	Potential salinity (me/l)	B mg/l	NO_3^- mg/l
GW	2.07	4.02	45.94	35.72	-6.73	13.94	0.33	7.78
GW+DW	2.62	5.25	50.56	40.11	-6.77	16.27	0.54	15.73
GW+TTWW	3.54	6.57	52.67	36.76	-8.58	24.22	0.61	12.76
GW+DW+TTWW	4.43	6.12	46.95	43.37	-18.07	31.63	0.48	21.11

The nitrate contents (NO_3^-) in this water varied from type to another, but it is not exceeding the critical limit (45 mg/l) that cause nitrate poisoning (Wilcox, 1958).

Generally, from the presented data, it appears that the water types used in this work may cause one problem or another according to the water type. By applying the criteria used for interpreting water quality for irrigation, the most domain problems are salinity hazard and potential salinity. These results are in harmony with those obtained by Hussein *et al*. (2008) and Al-Dakheel (2011).

2. Leaf elemental composition

Crops can be characterized by typical chemical composition of growing or developed tissues. Chemical analysis of plant parts is often used for diagnostic purpose in determining fertilizer needs. Poor fertility level, excessive concentration of available nutrients, or high salinity in the root zone is reflected in lower or higher concentrations of certain elements in plant tissues in comparison with the optimum range (Feigin, 1985).

Table (4) shows the leaf elemental composition of palm irrigated by the different types of irrigation waters. The results revealed that (GW+DW), (GW+TTWW) and (GW, DW+TTWW) significantly increased Fe, Mn, Cu, Zn, Cd, Co and Ni contents in leaves of palm as compared with ground water (GW). It is observed that (GW+DW+TTWW) have the highest effect on elemental composition of plants followed by (GW+TTWW), (GW+DW) and then (GW). Campbell *et al.* (1983) obtained similar results; they showed that Fe, Cu, Zn, Pb, Ni and Cd contents in alfalfa, sweet corn and wheat crops were below hazardous levels. These results are in agreement with those obtained by Samia *et al*. (1989), they reported that the application of different treated wastewater effluents to three soils in Egypt (sandy, calcareous and clay) increased the concentration of heavy metals (Cd, Cu, Fe, Mn, Ni and Zn) in leaves of corn and wheat. In addition, Hussein (1991) reported that drainage and sewage water significantly increased Fe, Mn, Cu and Zn in corn, sugar beet and cotton plants. Moreover, Shahin and Hussein (2005) reported that the effect of different types of irrigation water on Cd content in cucumber, lettuce and tomato plants in the following order (GW+DW+TTWW)>(GW+TTWW) >(GW+DW) >(GW). Also, these results are in harmony with those obtained by Hussein *et al*. (2008). They found that (GW+DW+TTWW) have the highest effect on micronutrient contents of palm followed by (GW+TTWW), (GW+DW) and then (GW). On contrary, these results are in contrast with the results obtained by Abdel-Nasser et al. (2000), they found that the leaf micronutrient contents (Fe, Mn, Cu, Zn and B) in olive plants significantly decreased with increasing the salinity of irrigation water.

Referring to the nutrition criteria, the concentration of Fe in the plants of palm were more than the normal range found in plants (30-150 ppm), but generally these excesses concentrations are not toxic to plants (Hausenbuiller, 1985). The concentration of Mn in palm are within the normal range (15-100 ppm) (Hausenbuiller, 1985) except Mn concentrations in palm trees irrigated with (GW) were less than this range. The levels of Zn in the plants are much less than the general toxic limit (100 mg kg^{-1}) for plants given by Leeber (1972). The values of Cu concentration in the date palm were within the normal range found in plants (5-15ppm) (Hausenbuiller, 1985). Typical amount of risk elements (Cd, Co and Ni) in plant are 0.1-1, 0.05-0.5 and 0.1-5 mg/kg for Cd, Co and Ni, respectively, Vecera *et al*.(1999). According to Vecera *et al*. (1999) the concentrations of Cd, Co and Ni in leaves of date palm were within the normal range.

Table (4). The leaf elemental composition (mg/kg) of Palm irrigated by different irrigation water types

Irrigation water	Fe	Mn	Cu	Zn	Cd	Co	Ni
	mg/kg						
GW	122.48	11.47	4.01	9.41	0.19	0.24	2.24
GW+DW	153.64	16.70	6.14	13.51	0.28	0.32	2.65
GW+TTWW	194.58	27.60	8.96	16.68	0.33	0.47	3.07
GW+DW+TTWW	249.48	42.44	10.23	18.92	0.38	0.59	4.34
LSD (0.05)	4.23**	1.35**	0.88**	1.01**	0.05**	0.05**	0.19**

** Significant at 1% probability level

3. Soil elemental analysis

Table (5) illustrates the effect of different types of irrigation water quality on the chemical properties of soil cultivated with date palm. The results indicated that (GW+DW), (GW+TTWW) and (GW+ DW+TTWW) significantly increased available Fe, Mn, Cu, Zn, Cd, Co and Ni of the soil as compared with ground water (GW). It is noticed that the effect of different types of irrigation water quality on the elemental contents of soil are in the following order (GW+ DW+TTWW) > (GW+TTWW) > (GW+DW) > (GW). Also, the data showed that there were a positive significant correlation between soil contents of Fe, Mn, Cu, Zn, Cd, Co and Ni and plants elemental contents of Fe, Mn, Cu, Zn, Cd, Co and Ni. The correlation coefficients were 0.99, 0.93, 0.98, 0.99, 0.98, 0.99 and 0.92, respectively. The obtained results are in close agreement with those found by Hussein (1991), Hussein *et al.* (2008) and Al-Dakheel (2011). Also, these results are in agreement with those obtained by Abdel-Nasser *et al.* (2000), they found that available soil micronutrients (Fe, Mn, Cu and Zn) significantly increased with increasing the salinity of irrigation water. Moreover, these results are in harmony with those obtained by Shahin and Hussein (2005), they reported that (GW+DW+TTWW) have the highest effect on Cd content of soil followed by (GW+TTWW), (GW+DW) and then (GW).

Table (5). The elemental contents of soil irrigated by different irrigation water types

Irrigation water	Fe	Mn	Cu	Zn	Cd	Co	Ni
	mg/kg						
GW	1.79	2.61	0.48	1.05	0.16	0.35	0.33
GW+DW	2.72	5.94	0.66	2.78	0.21	0.47	0.42
GW+TTWW	4.18	8.03	0.98	4.02	0.27	0.59	0.52
GW+DW+TTWW	6.44	9.68	1.25	5.11	0.31	0.72	0.71
LSD (0.05)	0.47**	0.23**	0.11**	0.15**	0.05**	0.08**	0.05**

** Significant at 1% probability level

According to Follett and Lindsay (1970), the data in Table (6) illustrate that the concentration of Fe in soil irrigated with (GW+DW+TTWW) was adequate. The concentration of Fe in soil irrigated with (GW+DW) and (GW+TTWW) was marginal while, the concentration of Fe in soil irrigated with (GW) was deficient. The concentrations of Mn, Cu and Zn in the soil irrigated with different types of irrigation water were adequate. Typical amount of risk element (Cd, Co and Ni) in non-polluted soil are 0.01-3, 1- 40 and 10-1000 mg/kg for Cd, Co and Ni, respectively, Vecera *et al*. (1999). According to Vecera *et al*. (1999), the concentration of Cd, Co, Ni and Pb in soil treated with different types of irrigation water were within the normal range.

Table (6). Critical levels of DTPA- extractable micronutrients for sensitive crops (mg/kg)

Nutrient	Deficient	Marginal	Adequate
Zn	< 0.5	0.5 -1.0	> 1.0
Fe	< 2.5	2.5 4.5	> 4.5
Mn	< 1.0		> 1.0
Cu	< 0.2		> 0.2

Source: Follett and Lindsay (1970)

CONCLUSION

It can be concluded that the water types used in the present study may cause one problem or another according to the water type. By applying the criteria used for interpreting water quality for irrigation, the most domain problems are salinity hazard and potential salinity. Therefore, it is expected that continuous irrigation without good water management (leaching requirements) can led to severe problems from the salinity point of view. The mixture of (GW+DW+TTWW) have the highest effect on elemental composition of plants and soil followed by (GW+TTWW), (GW+DW) and then (GW). The results concluded that the heavy metals in the soil and plants were in acceptable range.

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الملخص العربي

تقييم أنواع مختلفة من مياه الري وتأثيرها على التربة ونخيل التمرفي واحة الإحساء بالمملكة العربية السعودية

يوسف بن عبد العزيز الملحم

مركز الدراسات المائية– جامعة الملك فيصل– المملكة العربية السعودية

أجريت هذه الدراسة لبحث تأثير نوعيات مختلفة من مياه الري على التربة ونخيل التمر النامي في واحة الإحساء بالمملكة العربية السعودية. وقد كانت نوعيات المياه التي استخدمت في هذه الدراسة هي مياه جوفية ومياه ري مخلوطة من (المياه الجوفية + مياه الصرف الزراعي) ومياه ري مخلوطة من (المياه الجوفية + مياه الصرف الصحي المعالجة ثلاثيا) ومياه ري مخلوطة من (المياه الجوفية + مياه الصرف الزراعي + مياه الصرف الصحي المعالجة ثلاثيا). وقد أوضحت النتائج انه بتطبيق المعايير المناسبة لتحديد مدى صلاحية المياه للري نجد ان خطورة نوعيات مياه الري المستخدمة في الدراسة تنحصر في الضرر الملحي وجهد الملوحة. لذلك فأن الاحتياجات الغسيلية يجب أخذها في الاعتبار مع هذه الظروف لإزالة الأملاح الزائدة من محلول التربة. كما أوضحت النتائج أن هناك فروق معنوية في تركيز العناصر الثقيلة التي تم تقديرها في كلا من التربة واوراق نخيل التمر وأن (المياه الجوفية + مياه الصرف الزراعي + مياه الصرف الصحي المعالجة ثلاثيا) كانت أكثر تأثير في محتوى التربة والنبات من العناصر الثقيلة يليها (المياه الجوفية + مياه الصرف الصحي المعالجة ثلاثيا) ثم (المياه الجوفية + مياه الصرف الزراعي) وبعد ذلك المياه الجوفية. أوضحت النتائج أيضا ان محتوى العناصر الثقيلة في التربة ونخيل التمركانت داخل الحدود المسموح بها.