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# Impacts of Irrigation with Reclaimed Wastewater on Forages Production, Nutrients, and Heavy Metals Content

[1] National Center for Agricultural Research and Extension (NCARE), Amman, Jordan

[2] Ministry of Climate Change & Environment, Dubai, UAE

[3] International Center for Agricultural Research in Dry Area, Arabian Peninsula Regional Program, Dubai, UAE

Correspondence: A. Ouled Belgacem, International Center for Agricultural Research in Dry Area, Arabian Peninsula Regional Program, Dubai, UAE. Tel: 917-4238-9513. E-mail: a.belgacem@cgiar.org

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## Abstract

In order to investigate the effect of reclaimed wastewater (RWW) on soil chemical properties and heavy metal uptake of selected forages, an experiment was carried out at Dhaid Research Station, UAE during three growing seasons (2014-2016). Alfalfa, Rhodes and Buffel grass were irrigated by RWW and grown in a randomized complete block design with four replications. Composite soil samples were collected from the experimental site before starting the study and every six months from planting date to test the macro and heavy elements concentration in soil and forages tissues. Chemical analysis for soil, crops and wastewater were analyzed. RWW irrigation has significantly increased the soil salinity (1 to 8 $dSm^{-1}$) in 2014 but soon these values were declined in 2015 and 2016 growing seasons due to the enhanced irrigation water quality and the use of good water management.

Results revealed that UAE (Sharjah) domestic RWW is suitable to be reused for irrigate forages as its quality match international standards for RWW irrigation except its Na and Cl content. The results of the plants tissues analysis during 2014 season indicated a rise in the nutrients concentration, particularly nitrogen, potash, iron and boron, compared with the critical limits. While, the results have also shown a significant increase of zinc (Zn) and copper (Cu), especially in Buffel grass and Alfalfa tissues during the third season (2016) which exceeded the critical limits.

The highest mean yearly dry weight yield during the study period were recorded for Buffel grass (50.5 ton $ha^{-1}$) followed by Rhodes (44.5 ton $ha^{-1}$) and Alfalfa (11.1 ton $ha^{-1}$). It can be concluded that regular monitoring of recycled wastewater, soil and appropriate management are needed to mitigate the negative impacts of sodium and salts accumulations.

**Keywords:** reclaimed wastewater, heavy metals, macro elements, Alfalfa, Rhodes grass, Buffel grass

## Introduction

Reclaimed wastewater (RWW) is a valuable source for plant nutrients and organic matter needed for maintaining fertility and productivity of arid soils. However, the reuse of RWW for irrigation may potentially create environmental problems if not properly treated and managed (Mohammad & Mazahreh, 2003). Also irrigation with municipal wastewater is considered an environmentally sound wastewater disposal practice that helps to minimize the pollution of the ecosystem subjected to contamination by direct disposal of wastewater into surface or groundwater (ICBA, 2014). RWW irrigation provides water, N and P as well as organic matter to the soils, but there is a concern about the accumulation of potentially toxic elements such as Cd, Cu, Fe, Mn, Pb and Zn from both domestic and industrial sources.

The main challenge facing agriculture development in United Arab Emirates as the rest of Arabian Peninsula countries is the limitation and scarcity of water resources. The yearly water consumption in UAE is about 4.6 ×

$10^9$ $m^3$ and the agricultural sector is considered as the biggest water consumer with about 67% of the total available water resources. RWW is considered the most important water resource that will reduce the gap between the water demand and supply in agriculture sector and save the fresh water for human priorities. The main use of domestic RWW in UAE is for irrigation of landscapes and limited amount are used for irrigation of forage crops. In 2008 about $5.6 \times 10^8$ $m^3$ of tertiary RWW were produced from the treatment plants in AUE, and it estimated to increase to about $1.44 \times 10^9$ $m^3$ in 2030 (ICBA, 2010).

With this severe limitations on the availability of water in UAE, conservative and efficient use of available water resources is a major consideration for balancing future demand and supply, therefore the application of RWW is beneficial because this disposal process removes some of the pollutants, and increase crop yields by supplying essential nutrients, but this disposal requires a special agronomic practices and management guidelines to ensure practical and safe use of RWW in irrigation for the production of forages with minimum hazard to the surrounding environment.

Nutrients make RWW an effective fertilizer, while organic matter improves soil texture and enriches the humic content, which increases soil humidity, retains metals (through cationic exchange and the formation of organo-metallic compounds), and enhances microbial activity (Mohammad & Ayadi, 2004).

ICBA (2014) noted that reclaimed water irrigation decreased soil pH and increased soil salinity, soil phosphorus, potassium, iron, and manganese levels, but soil organic matter was increased only in the topsoil. Darwish et al. (2015) noted that the uptake of macro and micronutrients by corn increased with RWW irrigation, implying that secondary RWW could be a source of plant nutrients and can be reused for irrigation to increase forage crop production.

Ahmed (2013) conducted a review study in Qatar using scientific, economic and technical evidence to show that RWW is a valuable and safe resource for crop irrigation, posing minimal risk to the soil, groundwater, and crops, and is a key factor towards Qatar's food security. Highlighted was the real challenge of using RWW in Qatar for crop production as being social, but that highly treated domestic wastewater could be a real water resource for irrigation. Technical and economic calculations show minimum risks associated with reuse.

In Bahrain Mapanda et al. (2005) conducted a study across six farms Kingdom irrigated with RWW aimed at studying the effect of irrigation with RWW on the concentration of heavy metals in soil and Alfalfa crop. The results indicated that the concentration of heavy metals in RWW did not exceed the international standards, except for cadmium, which was double the allowable limit. He concluded that RWW can be used safely for irrigating fodder crops with continuous monitoring of heavy metal content in the soil and the crops irrigated with it. Alghobar and Suresha (2016) indicated that the use of wastewater for irrigation led to significant differences in mean values of pH, EC, N, P, Ca, Mg, Na, Mn, Cu, Zn, Cd, Ni, Pb and Cr of soil as compared to the control groundwater irrigated soil sample.

Knowledge about the selection and management of appropriate forage species and management systems that maximize the economic return and minimize the environmental hazards associated with the use of RWW is still limited and un available. This study will assess the quantities and qualities of the RWW resources, the environmental impact, and the proportion suitable for forage production, along with appropriate crop management practices suitable for the use of RWW irrigation.

## 2. Methodology

### *2.1 Study Site*

This experiment trail was investigated at Al-Dhaid Agricultural Research Station, Sharjah, UAE (latitude 25.3° N, longitude 55.9° E). The experimental site is located in arid climate with generally light and erratic precipitation. The soil is classified as sandy and considered marginally suitable for various crop production systems under strict management conditions.

### *2.2 2 Experimental Design*

This experiment was implemented using Randomized Complete Block Design (RCBD) as seen in Figure 1, with three forages (Alfalfa, Buffel and Rhodes grass) in four replications for each treatment (Experimental unit area 16 $m^2$).

Planting seeds and transplants of the forages was implemented on February 2014. Seedlings of two different grass Buffel (*Cenchrus ciliaris*) and Rhodes (*Chloris gayana*) in 0.50 m rows and 0.25 m between plants while

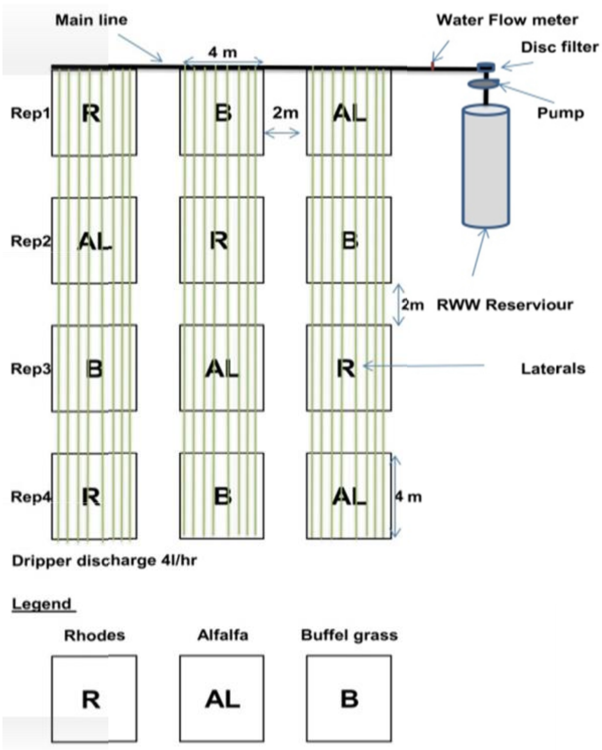


Figure 1. Recliamed wastewater experiment lay-out at Dhaid Research Station

Alfalfa (*Medicago sativa*) seeds were planted at seeding rate of 70 kg $ha^{-1}$ at Dhaid Research field experiment, using drip irrigation systems (0.5 m between laterals and 0.30 m between inline drippers (4 L $h^{-1}$ disch rge). Irrigation using the RWW was scheduled by applying daily 100% of the potential evapotranspiration (ETo) of the reference crop which estimated using Penman-Montieth equation based on 4 years' historical climatic data in the Station.

### *2.3 Water, Soil and Plant Samples Collections*

Yearly RWW Irrigation water and plant samples from the three forage crops were collected and the chemical analysis (EC, Na, Ca, Mg, P and K) and heavy metal (Cu, Pb, Zn, Ni, Cr, Co, Fe, Hg) parameters for soil, crops and wastewater.

Three soil samples were collected and analyzed from 25, 50 and 75 cm soil depths from four locations to represent the soil properties at initial conditions before starting the experiment from each experimental unit. The soil samples were collected from each crop site and the same chemical analysis were repeated every 6-month interval during the study period.

Fresh and dry matter weights were collected for each cut (6-8 cuts per year) for the three forges namely Alfalfa, Rhodes and Buffel grass. Nine fiber glass access tubes (1 m depth) were installed to monitor the soil moisture using TRIME soil moisture instrument.

## 3. Results and Discussion

### *3.1 Irrigation Water Analysis*

The water analysis for the irrigation Reclaimed waste water effluent (RWW) used in this trail showed that heavy metals were below the critical levels while the Na and Cl concentrations were more than the recommended levels specially during 2014 which reflected the EC value (Table 1). Table 1 shows that water electrical conductivity EC decreased during 2015 growing season, but it started to increase at the end of 2016 and these fluctuation values indicated the instability of the treated water quality, which requires monitoring and conducting tests on a regular basis. The water analysis results showed that this water can be used to irrigate fodder under correct irrigation management to avoid the salts accumulation in the soil and crop reduction.

Table 1. Results of water chemical analysis during the study period in comparison with recommended value

| Element | Irrigation water analysis (ppm) | | | | | |
|---|---|---|---|---|---|---|
| | July 2014 | Feb. 2015 | July 2015 | March 2016 | October 2016 | Critical limits[1] |
| EC | 1626 | 920 | 768 | 889.6 | 1632 | 1500 |
| Cu | 0.01 | 0.021 | 0.020 | 0.010 | 0.000 | 0.2 |
| Fe | 0.0125 | 0.234 | 0.230 | 0.170 | 0.130 | 5,000 |
| Zn | 0.002 | 0.026 | 0.030 | 0.020 | 0.100 | 2.00 |
| Mn | 0.001 | 0.083 | 0.080 | 0.050 | 0.010 | 0.200 |
| Mo | 0.009 | 0.001 | 0.000 | 0.010 | 0.360 | 0.010 |
| Cd | 0.000 | 0.000 | 0.000 | 0.000 | 0.020 | 0.010 |
| Cr | 0.07 | 0.029 | 0.030 | 0.000 | 0.160 | 0.100 |
| Pb | 0.000 | 0.000 | 0.000 | 0.000 | 0.010 | 2,00 |
| Ni | 0.0005 | 0.014 | 0.010 | 0.000 | 0.010 | 0.200 |
| Co | 0.000 | 0.01 | 0.010 | 0.000 | 0.000 | 0.050 |
| Hg | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| AS | 0.0035 | 0.005 | 0.010 | 0.000 | 0.040 | 0.100 |
| Cl | 591.0 | 280.75 | 245.0 | 251.0 | 606.2 | 350.0 |
| $SO_4$ | 110.98 | 139.68 | 139.3 | 110.0 | 212.4 | 500.0 |
| $HCO_3$ | 384.3 | 207.4 | 218.3 | 191.5 | 244.0 | 520.0 |
| Na | 412.85 | 236.0 | 190.1 | 201.0 | 433.5 | 230.0 |
| Ca | 65.85 | 25.0 | 32.2 | 42.4 | 28.0 | 400.0 |

Source: [1] Food and Agricuture organization of United Nations (FAO).

### *3.2 Soil Analysis*

Soil samples were collected from the experimental treatments sites of 0-75 cm depth in the middle of the s ason July 2014. The results of the analysis showed that there is a slight accumulation of heavy elements within allowable limits, but there is an increase in the salinity of the soil from 1 to 8 dS/m (Figure 2). This could be explained by as a result of increased sodium and chlorine elemental concentration in irrigation water at higher than the recommended values in 2014 but soon these values declined in 2015 and 2016 growing seasons due to the enhanced irrigation water quality and the use of good water management.

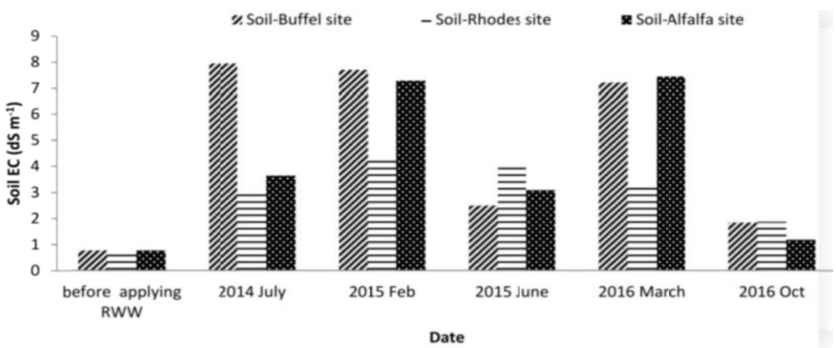


Figure 2. Soil salinity before planting and after different periods of application of reclaimed wastewater for the three forage crops cultivation sites included in the study

Irrigation with RWW has increased the fertility of the soil phosphorus and potassium, and increased accumulation of other elements such as sodium and chlorine, as shown in Figures 3 and 4. The RWW increased the soil fertility specially P and K (Figure 3) which supplied the plants with the main nutrients and improved the yield. Irrigation with this water quality led to enrich the soils with heavy metals in the first layer (0-30 cm). Similar results were noticed by Mapanda et al. (2005). Also many reported similar increase in the salt content of soils after wastewater irrigation led to increase soil EC (Mallaet al., 2007; Berna et al., 2007). Fro the results it is observed that the concentration of K, P, Na and Cl significantly increased in the soil irrigated by RWW.

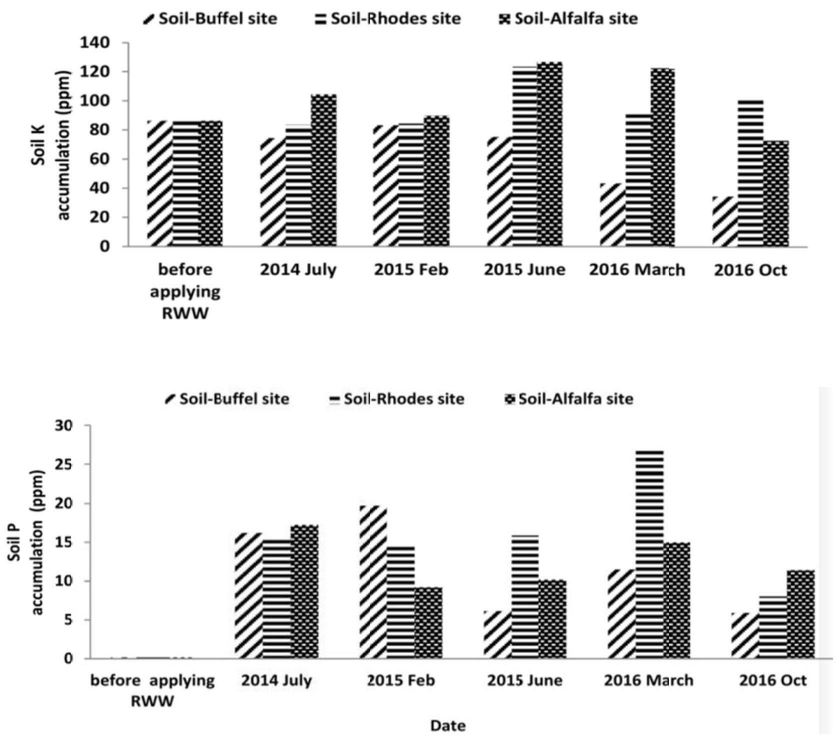


Figure 3. Phosphors (P) Potassium (K) accumulations in the root zone at the studied forage crops sites as results of irrigation by reclaimed wastewater

This is due to the content of high concentrations of nitrogen, like in many investigations showed tha soil fertility increased as a consequence of irrigation with wastewater (Galavi et al., 2010). Figure 4 reveale that high salt accumulation in the soil after irrigation the studied crops with RWW which has high concentration values of Na and Cl as aresults of using domestic detergents in washing.

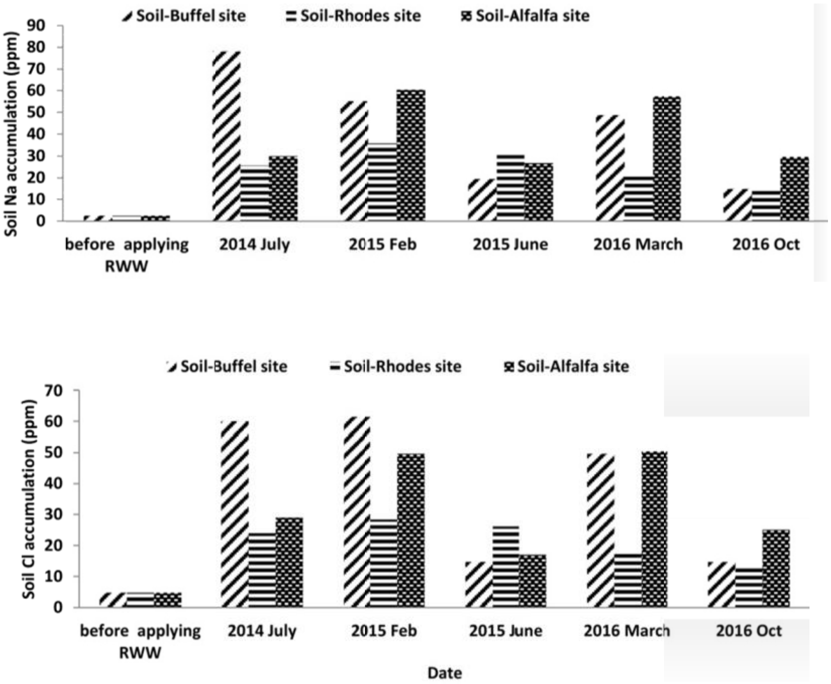


Figure 4. Sodium (Na) and chlorine (Cl) accumulations in the root zone at the studied forage crops sites s results of irrigation by Reclaimed wastewater

These results confirm the previous study of Amin (2011) who tested the effect of municipal wastewater o soil and plant. Rusan (2007) studied the effects of municipal wastewater treatments on physical and chemical properties of saline soil, showed an increase of EC, TN, K, Na, Cl, Fe, Cd and Zn but a decrease of soil pH. In the similar way, ICBA (2014) found an increase of soil salinity level due to the wastewater salt content with along with the reuse of wastewater for irrigation becomes the need to understand potential environmental impacts of this practice.

Figure 5 Shows that the heavy metals started to be accumulated in the soil profile but they didn't reach the toxic levels for the growing of forages (5-10 ppm). This means that the accumulation of these heavy metals in long term especially for Ni, Cr, Zn and Cu should be monitored. Accumulation of micronutrients and heavy metals could be caused directly by the RWW composition or indirectly through increasing solubility of insolubl soil heavy metals as a result of the chelation or acidification action of the applied RWW. Based on this consider tion, the study showed a significant ($P \leq 0.05$) increase of concentrations of heavy metals as Ni, Cr, Cu and Zn in the soil with the RWW irrigation (Bai et al., 2008; Gadallah, 1994).

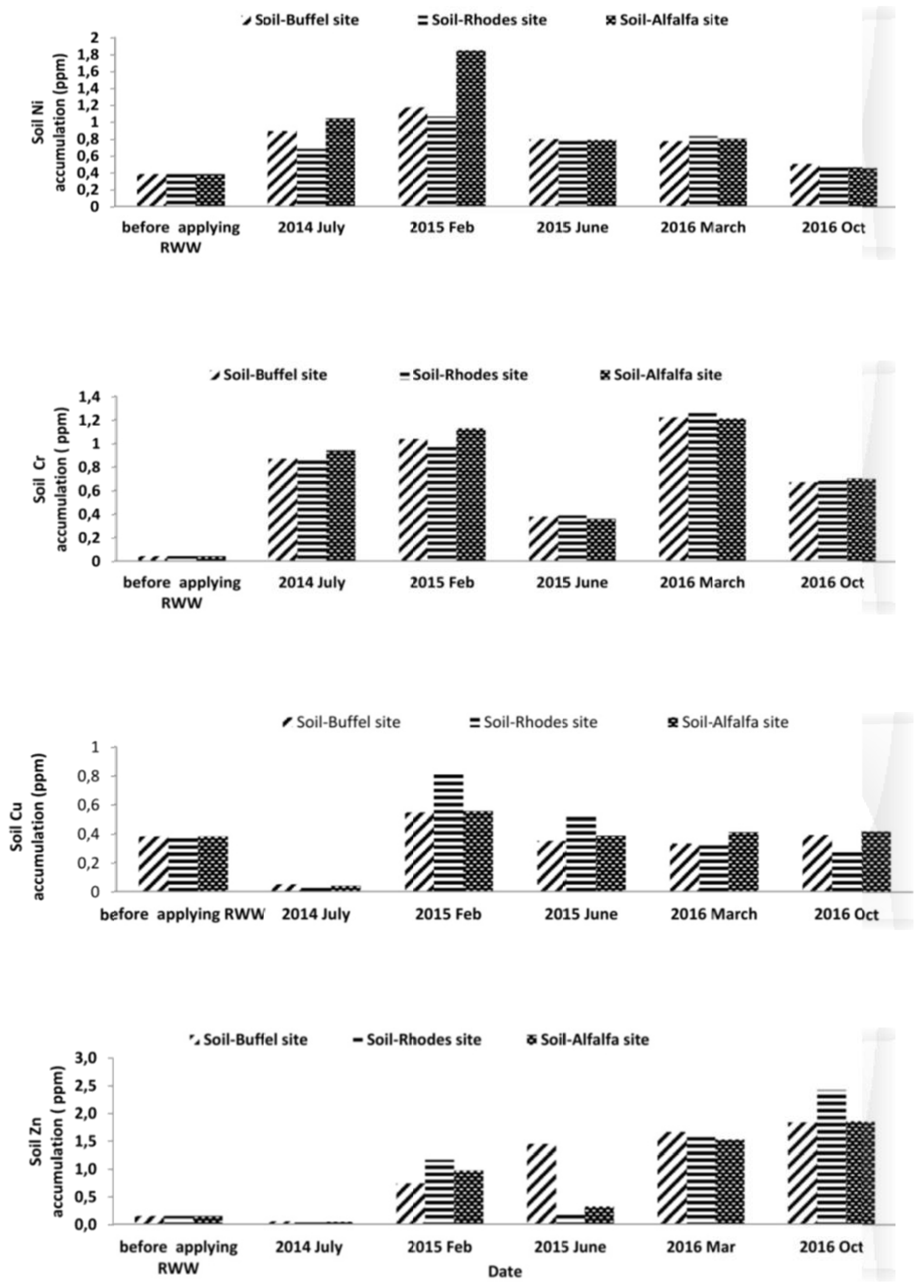


Figure 5. Heavy metals accumulation in the soil profiles from different soil crops sites in comparison to the soil before adding the RWW at the Dhaid Research Station during 2014-2016 growing seasons

### *3.3 3 Plant Analysis*

The results of analysis of crop samples are presented in Figure 6 which indicated that the plant contents of T. N%, K% and Fe were exceeded the critical limits especially in Alfalfa crop (legume crop) Our investigation showed that irrigation with RWW reuse led to a significant increase ($P \leq 0.05$) of N, P, Na and Mn contents of the three studied forages. This is in lines with the results of Olowoyo (2012) on sunflower crop and Bai et al. (2008) on forage crops.

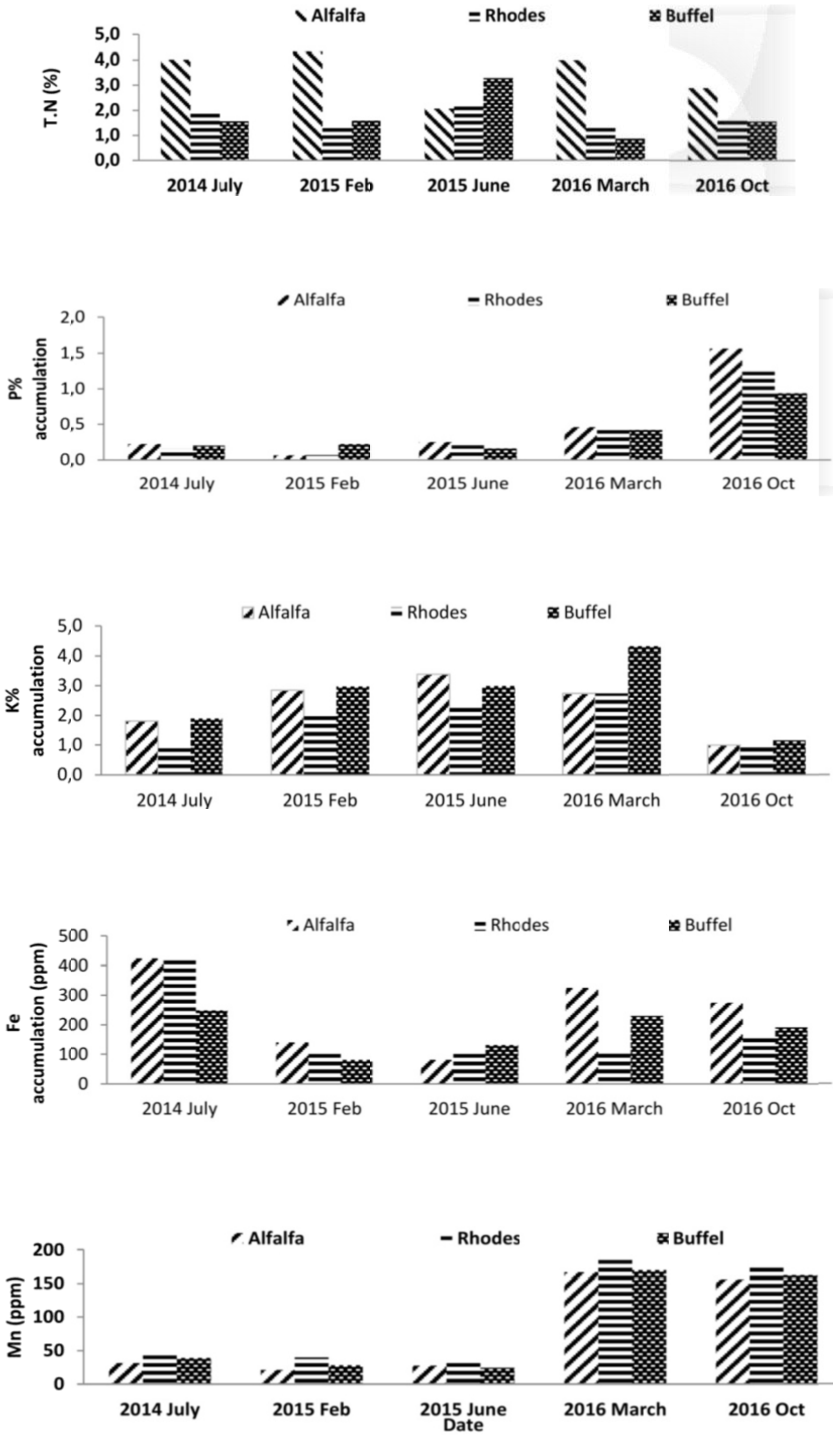


Figure 6. Total Nitrogen%, P%, K%, Fe and Mn from crop dry weight concentration for the selected forages irrigated with RWW at Dhaid Research Station during 2014-2016 growing seasons

Irrigation with this water quality led to enrich the soils with heavy metals in the first layer. Similar results were noticed by Amin (2011). For Cd, Pb and Ni level, our study was corroborated with these obtained by Bai et al. (2008) on Barely. While the most of heavy metals concentration still in the save ranges except the Ni which reached the toxic limits in Alfalfa crop in 2014 and Zn concentrations during 2015-2016 growing seasons for all studied forage crops (Figure 7).

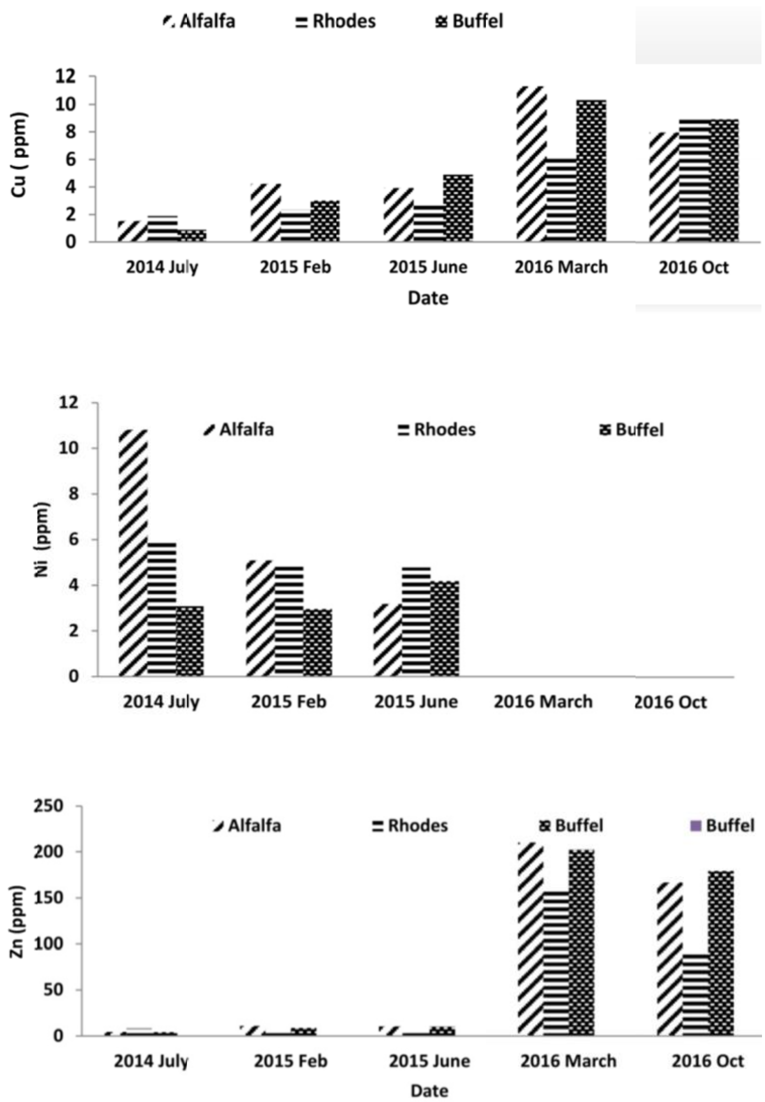


Figure 7. The Ni, Cu and Zn contents in crop dry weight samples for the selected forages irrigated with RWW at Dhaid Research Station during 2014-2016 growing seasons

### *3.4 Forages Yield*

The total fresh and dry yields of the three forages under RWW irrigation are represented in Table 2. The r sults indicated that Buffel grass average dry yield is significantly higher than Alfalfa and Rhodes ($P \leq 0.05$). The best average yield production is recorded for Buffel grass using RWW (50.45 ton ha$^{-1}$ year$^{-1}$) when comparing with Alfalfa and Rhodes under the same conditions or in comparison to the previous records (dry weight of 20 ton ha$^{-1}$ year$^{-1}$) using conventional water at the same station. This is due to the RWW nutrients content which are useful for the crops to enhance the yield.

Table 2. Total dry yield (ton $ha^{-1}$ $year^{-1}$) of the three studied forage species irrigated with reclaimed wastewater during the period 2014-2016 in UAE

| Crop | 2014 | 2015 | 2016 | Mean |
|---|---|---|---|---|
| Alfalfa | 12.30 c | 6.29 c | 14.84 b | 11.14 c |
| Buffel grass | 35.07 a | 51.66 a | 64.62 a | 50.45 a |
| Rhodes grass | 29.50 b | 41.41 b | 62.62 a | 44.51 b |
| $P \leq 0.05$ (LSD) | 3.3 | 4.24 | 4.2 | 3.9 |
| CV% | 12 | 13.7 | 34 | 19.9 |

## 4. Conclusions and Recommendations

On the light of the results obtained from using RWW in irrigation of three selected forages, the main conclusions and recommendations can be summarized as follows:

(1) The heavy metals contents in RWW were below the critical levels but the Na and Cl concentrations were more than the recommended levels especially during 2014 growing season.

(2) The contents of toxic element s in the plant tissues of the forage crops were found to be below the critical level except the Ni in Alfalfa crop during 2014 but it reduced during 2015 growing season due to enhancement of reclaimed water quality.

(3) Soil salinity and some heavy metals were accumulated in the soil profile as a result of using RWW in irrigation.

(4) The RWW used in this trail contain sufficient nutrients for forage crops production, and the highest mean yearly dry weight yield during the study period were recorded for Buffel grass (50.45 ton $ha^{-1}$) followed by Rhodes (44.51 ton $ha^{-1}$) and Alfalfa (11.1 ton $ha^{-1}$)

(5) Irrigation water, soil and crop should be monitored and tested for chemical and biological analysis in addition to evaluate crop management practices that maximize production and reduce the negative impact of RWW irrigation on plant products.

(6) The quality of forages produced on Reclaimed wastewater and their impact on animal health and productivity should be assessed.

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