JJEES

Jordan Journal of Earth and Environmental Sciences

JJEES (2022) 13 (3): 223-231
ISSN 1995-6681

Impact of the Effluent Characteristics of Industrial and Domestic Wastewater Treatment Plants on the Irrigated Soil and Plants

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Received 1st September 2021; Accepted 27th March 2022

Abstract

Treated wastewater (TWW) reuse became a common practice and a significant component of the water budget in Jordan due to the shortages in available water sources. TWW is being diluted with harvested rainwater to improve its quality for its subsequent reuse for irrigation. However, the reuse of TWW without dilution may pose an adverse effect on the irrigated soils and plants. This study investigates the effect of TWW reuse for irrigation on soil and plants. The TWW in this study is the effluents of domestic and industrial wastewater treatment plants namely Mutah-Al-Mazar (MMWWTP) and Al-Hussein II Industrial City (HICWWTP). The TWW from both plants has been tested for several quality parameters (pH, EC, BOD_5, COD, TSS, TDS, NO_3^{-2}, PO_4^{-3}, Cl^-, Na, K, Cu, Fe, Pb, and Cd). The obtained results have been compared with the allowable limits specified by the Jordanian standard for reclaimed WW reuse. Concentrations of the measured elements were below the allowable limits except for lead and cadmium. The average concentrations of lead and cadmium in TWW from HICWWTP were 0.65 mg/L, and 0.035 mg/L respectively. Whereas the concentrations of these elements in the TWW from MMWWTP were 0.58 mg/L, and 0.047 mg/L respectively. The allowable limit for these elements according to the Jordanian standard for the use of treated wastewater in irrigation is 0.2 mg/L and 0.01 mg/L respectively. Soil and plant samples irrigated with TWW from both plants and control samples irrigated with fresh water were tested for (pH, EC, Fe, Cu, Pb, Cd, K, and Na). The results showed that there was no difference in the chemical properties of soil and plant samples irrigated with fresh water and those irrigated with TWW. Therefore, this study concluded that the reuse of TWW for irrigation did not have adverse effects on the properties of the irrigated soils and plants.

Keywords: *Wastewater, Treatment plants, Heavy metals, Soil pH, Irrigation*

1. Introduction

Jordan suffers from a severe water shortage in its water resources. The water situation is one of the most important and strategic challenges facing Jordan. The per capita water availability has decreased from 3,600 cubic meters per year in 1946 to <100 cubic meters per year in 2017 (MWI, 2017). The per capita consumption is below the level of the global water poverty line (1000 m^3 / capita/year) and represents less than 15% of the global per capita rate (The Ministry of Water and Irrigation, 2015). Jordan is characterized by limited renewable and non-renewable water resources, where about 94% of Jordan's area is desert and dry land which has a long-term rainfall of about 100 mm and an evaporation rate of 93 % (Ministry of Water and Irrigation, 2015). Recently water crisis has been exacerbated by the impact of climate change, low rainfall, lack of alternative water sources, and sudden population displacements. Matouq et al. (2013), had predicted of escalating climate change impact on Jordan in the coming decades especially in lowering the rainfall which may reach 80 mm in the central and eastern regions of Jordan. Moreover, the annual population increase besides the improved living standard and decline in water quality due to depletion of many sources also lead to an increase in water scarcity. It is estimated that the average rate of water consumption by Jordanian individuals could increase by 50-60% by 2025, which will strain scarce water resources Ministry of Water and Irrigation, (2015). Therefore, Jordan has classified as one of the poorest countries in terms of water availability in the world, which form the biggest challenge for decision-makers and sustainable development in Jordan.

Despite all the difficulties in that facing the Jordanian water sector, the percentage of the population served by the public drinking water network is 97% and by the sewage network is 67%. To overcome the above-mentioned challenges, applying good planning programs for water resources to balance the current and future needs is of high importance. One of the available alternatives which can bridge the gap between supply and demand is the reuse of reclaimed wastewater, specially treated domestic wastewater mainly for agricultural purposes to save more fresh water for domestic purposes.

In Jordan, most of the TWW is being used for irrigation. TWW contributed approximately 13% of the water budget of Jordan in 2015 (Ministry of Water and Irrigation 2015). Wastewater is 99.9% water and 0.01% concentrations of suspended and dissolved organic and inorganic solids (Aljbour et al., 2021a and b). Many researchers had studied the impact of using TWW of different sources for irrigation on the environment mainly on the irrigated plants and soil.

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Al-Hamaiedeh and Bino (2010) studied the effect of the reuse of treated grey water for irrigating olive trees and some vegetative crops, the results showed that salinity, sodium adsorption ratio (SAR), and organic content of soil increased as a function of time, therefore they recommended that the soil should be leached with fresh water. The chemical properties of the irrigated olive trees and vegetable crops were not affected, while the biological quality of some vegetable crops was adversely affected. However, the reuse of TGW for irrigation in home gardens showed an adverse effect on public health and safety in terms of breeding of flies and Unpleasant odors (Al-Hamaiedeh, 2010). Mohawesh et al., (2019) investigated the effect of olive mill wastewater (OMW) application on soil properties and wheat growth performance under rain-fed conditions, the results showed that the application rate of OMW at 60 $m^3 ha^{-1}$could improve significantly wheat growth without significant negative impact on soil properties. Another study (Mohawesh et al., 2020), investigated the sustainable controlled land application of OMW to enhance soil properties and improve barely production under rain-fed conditions, the results revealed that no harmful effect of OMW application for all application rates on growth parameters of barely as well as soil properties.

Baker (2007) studied the use of untreated WW for irrigation, the results showed that WW quality parameters are extremely above the permissible limits for WW reuse in irrigation and vary spatially and temporally. Reuse of untreated WW in irrigation showed clear effects on the top soil texture, total carbon and total nitrogen amounts, and the accumulation of heavy metals in soil profile especially arsenic, cadmium, and lead. The study concluded that it is a danger to use untreated WW for irrigation.

TWW is considered the main non-conventional source of water in Jordan. The strategy of the Ministry of Water and Irrigation approved the use of 133 million m^3 of TWW in 2015 (Ministry of Water and Irrigation, 2015). This amount is projected to reach 250 million m^3 in 2050 as a result of the increasing demand and the heavy stress on groundwater resources (Ministry of Water and Irrigation, 2004).

This study aims to study the effect of the reuse of TWW from domestic influent wastewater treatment plants (MMWWTP) and industrial influent wastewater treatment plants (HICWWTP) on the quality of irrigated plants and soils.

1.1 Study area settings

Mutah – Al-Mazar wastewater treatment plant (MMWWTP) is located in Al-Karak Governorate; it treats domestic WW since 2014. The plant includes an activated sludge system, it is a design capacity of 7060 cubic meters per day with a polishing pond. The treated wastewater from the plant is used to irrigate the feed and the remainder is disposed to the nearby valleys. The present average daily flow rate is 800 m^3/day, the organic design load = 673 mg/L, and the actual organic load = 1120 mg / L (Ministry of Water and Irrigation, 2015). Al-Hussein II Industrial City WWTP (HICWWTP) is one of the small WWTPs in Al- Karak governorate (Fig. 1).

The plant treats industrial wastewater generated mainly from textile fabrics and the food industry since 2000. The plant design capacity is 1500 m^3 / day, the present average daily flow rate is 500 m^3 / day. It includes an activated sludge system as secondary treatment, part of the TWW from the plant is used for fodder irrigation and the remainder is disposed to the nearby valleys.

This study aims to evaluate the suitability of TWW produced in the two WWTPs in the Al-Karak governorate for irrigation and study the impact of long-term irrigation with TWW on the characteristics of the irrigated soil and plants.

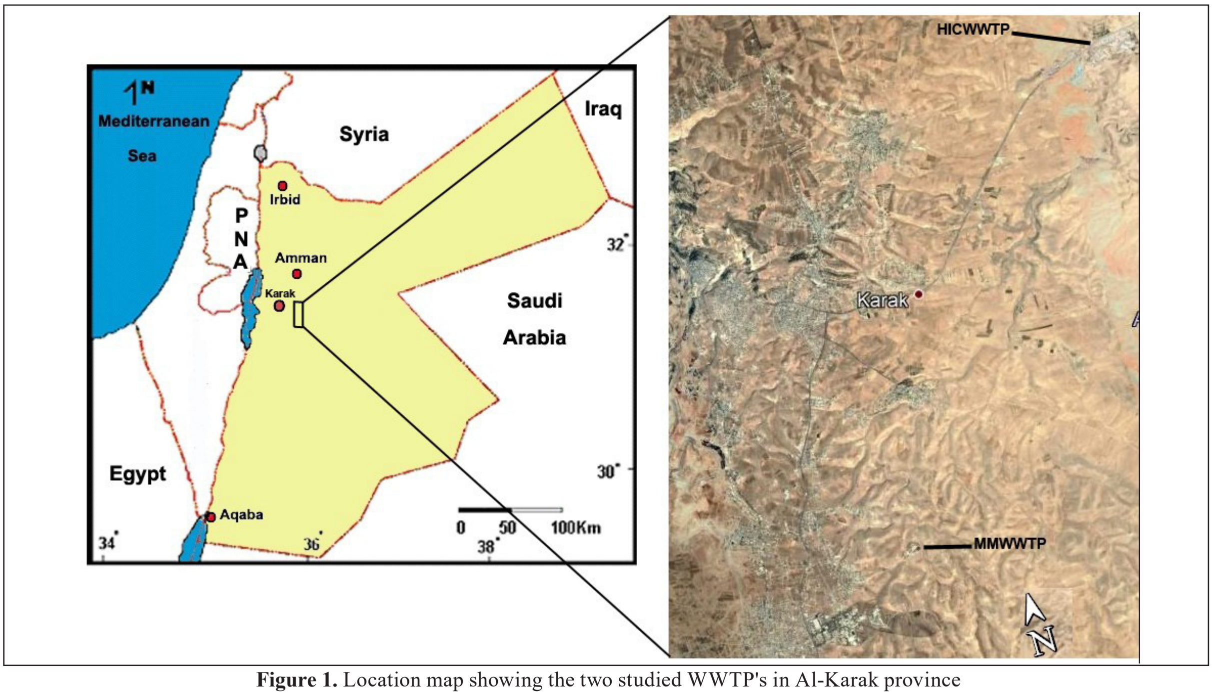

Figure 1. Location map showing the two studied WWTP's in Al-Karak province

2. Methodology

Fifteen TWW samples were taken from the middle depth of the TWW receiving channel for two successive months (April and May) from the studied WWTP's. The volume of the samples collected was 10 liter, the samples were kept in a polyethylene container, transported to the laboratory, and stored at 4˚C as outlined by (Kulikowska and Klimiuk, 2008) to be tested for different parameters as suggested by the Standard Methods of Chemical Analysis (Tatsi et al., 2003) and the standard conservation methods for the examination of water and wastewater (APHA, 1998).

Fifteen TWW samples have been tested for main quality parameters (pH, EC, BOD_5, COD, T SS, TDS, $Cl^–$, PO_4^{-3}, NO_3^{-2}, Cu, Fe, Pb, Cd, Na, and K). Water sample analyses were conducted according to the Standard Methods for the Examination of Water and Wastewater, (Barid and Bridgewater, 2017). The average values for each parameter were compared with the Jordanian standard for reclaimed wastewater reuse. The total dissolved solids (TDS) for each sample was determined as the mass of the dissolved solid normalized to the volume of water filtered. The value of TDS was measured according to the standard method 2540C (Barid and Bridgewater, 2017). The total suspended solids (TSS) for each sample was determined as the mass of the suspended solid normalized to the volume of water filtered. The value of TSS was measured according to the standard method 2540D. The water samples were analyzed for NO_3^{-2}, $Cl^{-,}$ and PO_4^{-3} following the standard method 4110B. Using an Ion Chromatography Analyzer (IC) (761 compact IC, Metrohm AG, Ionenstrasse, Herisau, Switzerland). The BOD_5 and COD were analyzed following the standard methods 5210-B and 5220-B respectively. Total Nitrogen TN was determined by calculating the sum of organic and inorganic nitrogen.

Fifteen soil and plant samples irrigated with these TWW from both WWTP's were collected. Soil samples were taken before the start of the rainy season from a selected site, fifteen soil samples were taken based on the specific protocols and tools. Where each sample was collected from three pits that dogged each site at two depth intervals of 0- 30cm, and 30-60 cm. A portion of soil from each depth was taken and then all were mixed up until homogenization. Samples were then labeled to show the depth and location. Control soil samples from similar soil not irrigated with TWW were taken from a nearby location.

The soil samples were dried at 105 °C for 2 hours, sieved in a 2 mm mesh sieve, and grinded by using a soil mill. From each sample, 500 gm was filled in a plastic bag and labeled. The soil acidity pH and electrical conductivity (EC) had analyzed by mixing 1:5 ratios of soil and de-ionized water following the procedure of (Blakemore et al. 1987). To determine the heavy metals contents (Fe, Cu, Pb, Cd, Ni, K, and Na), the soil leaching procedure had done as follows: 2 g of soil sample was mixed with 10 ml of 2 M HNO_3 solution, shaken and ultra-sonicated for4 h, then it was filtered using 45-µn Whitman filter paper according to (El-Hasan, 2002; and Fialova et al. 2006). The solution was then transferred into 25-ml polyethylene bottles, filled up with distilled water exactly to 25 ml, then stored in the refrigerator until the analysis time. The concentrations of heavy metals Fe, Cu, Pb, Cd, Ni, K, and Na) in the soil samples were determined by using Flame Atomic Absorption Spectrophotometer (AA-7000, Shimadzu Scientific Instruments, Japan) according to the Standard Method 3111 B.

The pH values of all soil samples were measured according to the standard method SM 4500 H+B (Greenberg, 2005) by preparing 1:5 (Soil: Water) suspensions. The suspensions were prepared by shaking 10 g air-dry soil < 2 mm in 50 ml deionized water in a rotating shaker for 1 h at 15 rpm. The obtained pH values (pH meter 315i, WTW GmbH, Weilheim, Germany) were recorded when the equilibrium (stability in the reading) was reached while stirring with a mechanical stirrer (El-Hasan and Al-Tarawneh, 2020), (Al-Hamaiedeh and Maaitah 2011).

The EC values of all soil samples were measured according to the standard method SM 2510. The soil EC was determined by shaking a 1:2.5 (w/w) ratio of soil and deionized water. The mixture was homogenized for 30 min at 15 rpm using a horizontal shaker and then left at room temperature until the soil settled down before EC measurement. The conductivity of the supernatant liquid was determined using the conductivity meter without disturbing the settled soil (Conductivity meter 4310, JENWAY, UK) (El-Hasan and Al-Tarawneh, 2020).

The alfalfa samples were taken from the same sites where soil samples were taken from both WWTP's. After drying the samples in the oven at a temperature of 105 ±2 C° for 2 hrs and grinding the samples then were digested in Aqua regia, 0.5 g of alfalfa leaves were added to 10 ml of Aqua regia solution (Garnaud et al. 1999). The bottle was heated on the hotplate and then the distilled water is added to the bottle to complete its volume to 100 ml, then filtered using 0.45-micrometer cellulose nitrate filters. The plant was tested for heavy metals (Cu, Pb, Cd, and Fe) and was measured by Flame Atomic Absorption Spectrophotometer (AA-7000, Shimadzu Scientific Instruments, Japan) according to Standard Method 3111 B. Standard solutions with concentrations of 0.05, 0.1, 0.2, 0.5, and 1 ppm from these elements by standard method 3111 B were prepared and used for calibration. In all analyses triplicate measurements were done for each sample; the error was within ± 5%.

3. Results and Discussion

3.1. HICWWTP

The TWW effluent from (HICWWTP) which is used for irrigation of Alfalfa is about 300 m^3/day. Its chemical and physical characteristics and the maximum allowable limits for these parameters stated in the Jordanian Standard Specification for reuse of Industrial reclaimed wastewater (Jordanian Standard JS202:2007) are shown in Table (1). Alfalfa is a field crop that was compared with the Jordanian specifications for industrial wastewater reuse for irrigation of field crops. Jiries et al. (2004) have shown that industrial wastewater effluent generated from phosphate mining effluent water fell within the allowable limit and could be used for crop irrigation.

3.2. MMWWTP

The TWW of MMWWTP, which is about 550 m^3/day, its chemical and physical characteristics, and the maximum allowable limits for these parameters according to Jordanian

Standard Specification for reuse of reclaimed domestic wastewater (Jordanian Standard JS 893:2006) are shown in Table (2).

From the data presented in Tables (1 and 2), it can be seen that all quality parameters for the treated Industrial WW in HICWWTP and treated domestic WW in MMWWTP are below the allowable limits that are present in the Jordanian standard for reclaimed WW reuse except the concentrations of cadmium and lead.

As for heavy metals in treated wastewater, there was a high concentration of lead and cadmium in the effluent of both plants, the average value of the concentration of lead in treated wastewater at HICWWTP is 0.65 and at MMWWTP is 0.575, which is greater than the allowable limits in the Jordanian specifications for reclaimed WW reuse 0.2.

The average concentration of Cadmium in treated wastewater at HICWWTP was 0.035 and at MMWWTP was 0.043 which exceeds the allowable limits in the Jordanian specifications for reclaimed WW reuse 0.01 as shown in Fig. (2). Cadmium is a toxic heavy metal present in wastewaters from a variety of industries and its harmfulness come from its ability to accumulate in the human body if it enters through contaminated water or food chain (Dojlido and Best, 1993). Cadmium is predominantly found in rechargeable batteries for domestic use (Ni-Cd batteries), in paints, and in photography. The main sources of urban wastewater are diffuse sources such as food products, detergents, and body care products, stormwater (Ulmgren, 2000a, and Ulmgren, 2000b). Therefore, the sources of Pb and Cd might be the paints, pigments used in the cloths, and treatment materials in textile industries.

Table 1. Chemical and physical characteristics of treated wastewater used for irrigation from HICWWTP

ID	Parameter	April 2018	May 2018	**Average**± SD	Jordanian Standard	Unit
1	pH	6.98	7	0.014±6.99	6-9	-
2	EC	1360	1300	42.42±1330	700-3000	µs/cm
3	BOD$_5$	15	15	0003.15±	300	mg/l
4	COD	45	45	0.003±45	500	mg/l
5	TSS	20	20	0.02±20	300	mg/l
6	TDS	880	850	21.21±865	2000	mg/l
7	$^{-}$Cl	340	340	0.05±340	400	mg/l
8	PO$_4$	1.96	1.94	0.014±1.95	30	mg/l
9	NO$_3^-$	12.5	11.7	0.57±12.1	70	mg/l
10	Cu	B.D	B.D	B.D	0.2	mg/l
11	Fe	0.21	0.27	0.0.04±0.24	5	mg/l
12	Pb	0.57	0.73	0.11±0.65	0.2	mg/l
13	Cd	0.027	0.043	0.01±0.035	0.01	mg/l
14	Na	126.35	116.03	7.3±121.19	230	mg/l
15	K	4.60	3.56	4.08±0.74	-	mg/l

B.D ≡Below Detection Limit = 0.1 mg/l; Standard Deviation

Table 2. Chemical and physical characteristics of treated wastewater used for irrigation from MMWWTP

ID	Parameter	April 2018	May 2018	**Average**± SD	Jordanian Standard	Unit
1	pH	7.7	7.5	7.6±0.07	6.9	-
2	EC	1850	1785	1817.5±22.98	700-3000	µs/cm
3	BOD$_5$	26.5	20	23.25±2.3	300	mg/l
4	COD	168	114	141±19.09	500	mg/l
5	TSS	24	24	24±0.003	300	mg/l
6	TDS	1209	1165	1187±15.56	1500	mg/l
7	$^{-}$Cl	-	-	-	400	mg/l
8	PO$_4$	NA	NA	NA	30	mg/l
9	NO$_3^-$	4	4.4	4.2±0.28	70	mg/l
10	Cu	B.D	B.D	B.D	0.2	mg/l
11	Fe	0.5	0.61	0.55±0.04	5	mg/l
12	Pb	0.52	0.62	0.57±0.03	0.2	mg/l
13	Cd	0.041	0.047	0.043±0.003	0.01	mg/l
15	Na	206.24	197.56	201.9±3.07	230	mg/l
15	K	39.76	28.94	34.35±3.82	-	mg/l

B.D ≡Below Detection Limit = 0.1 mg/l; NA: Not analyzed; SD: Standard Deviation

The concentration of Copper and Iron in treated wastewater was within the permissible limit in the Jordanian specifications of the both WWTPs, the concentration of the copper in treated wastewater at HICWWTP and MMWWTP are below the detection limit (0.1 mg/l), and also the concentration of the iron in treated wastewater at HICWWTP was 0.245 and at MMWWTP is 0.55.

On the other hand, the concentration of sodium in TWW was within the allowable limits in the Jordanian specifications for reclaimed WW reuse in both WWTPs (230), it was in the HICWWTP 121.9 and at MMWWTP 201.9. The risk is high in lead and cadmium because they are toxic heavy metals if they exceed their permissible concentration. Lead increase in wastewater is due to pipes used in the water distribution system or from dry cell batteries or welding process or released from fossil fuels (Thornton et al. 2001).

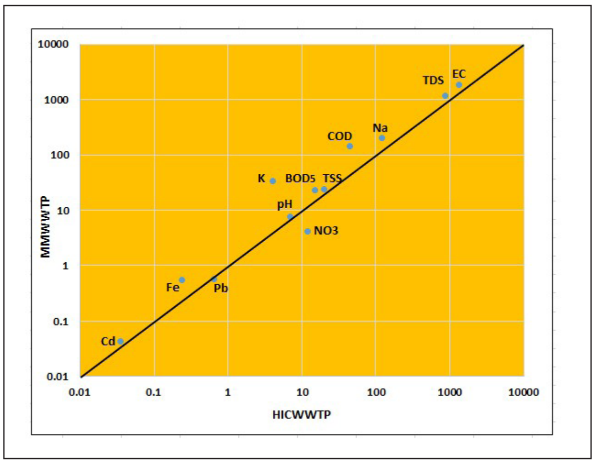

Figure 2. 1:1 ratio plotting showing the comparison between TWW from the two studied WWTP's

3.3. Results of Soil Analysis

Three locations were selected for sampling from each area that was irrigated with treated wastewater from both plants and two samples from each location for different depths. Samples were tested for (pH, EC, Cu, Fe, Pb, Cd, Na, K, and Total Nitrogen). Table (3) shows the chemical characteristics of soil samples irrigated by treated WW generated from HICWWTP and MMWWTP, the comparison between the two WWTP's illustrated in Fig. (3).

The pH results presented in Table (3) and Fig. (3) show that soil in both locations is alkaline where pH is around 9. The HICWWPT soils are slightly more alkaline values than MMWWTP soils, which can be explained by the that pH of MMWWTP effluent water is slightly less alkaline than HICWWPT effluent water as shown in Fig. (2). Moreover, there is no big difference between upper and lower soils pH value. These results are consistence with other studies on Jordanian soils (El-Hasan, 2002; Hararah et al. 2012; El-Hasan and Lataifeh, 2002 and 2013, El-Hasan and Al-Tarawneh, 2020). The pH in the soil is rarely to be a problem by itself, but it is an indication of soil conditions such as the mobility of heavy metals and the availability of special ions that increase or decrease the pH value (Sposito, 2008)

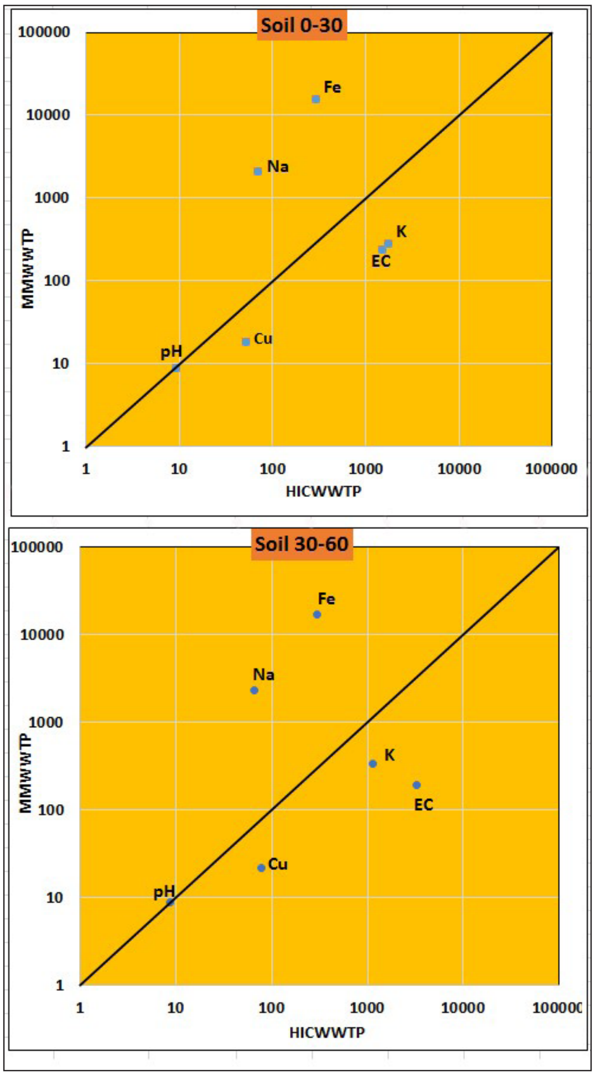

Figure 3. 1:1 ratio plotting's showing the comparison between the soils at both studied WWTP's within the upper and lower soils.

Table 3. Summary table showing the average values of the soil parameters after irrigation with TWW from both studied WWTP's.

Parameter	Depth (cm)	Unit	HICWWTP	MMWWTP
pH	0-30	-	9.09	8.74
	30-60		8.80	8.78
EC	0-30	µs/cm	1491.3	240.8
	30-60		3253.6	194.4
Cu	0-30	mg/kg	52.0	18.2
	30-60		77.3	22.1
Fe	0-30	mg/kg	294.7	15518
	30-60		301.3	17038
Pb	0-30	mg/kg	BD	204.8
	30-60		BD	215.3
Cd	0-30	mg/kg	BD	3.55
	30-60		BD	5.09
Na	0-30	mg/kg	70.2	2121
	30-60		65.4	2305
K	0-30	mg/kg	1736.7	284
	30-60		1143.3	338.7
Total N	0-30	mg/kg %	3.78	2.94

BD: Below Detection Limit

Electrical Conductivity (EC) is a measure of salt concentration in the soil; crops exhibit a spectrum of responses under salt stress (Shrivastava and Kumar, 2015). The EC of the soil is directly related to salinity where salinity usually refers to the presence of soluble salt in the soil. Salinity not only decreases the agricultural production of most crops, but also, affects soil physicochemical properties, and the ecological balance of the area. The impacts of salinity include low agricultural productivity, low economic returns, and soil erosions (Hu and Schmidhalter, 2004). A productive soil's EC should be below 150 µs/cm (Reid and Dirou, 2004). The pH of the soil probably affects salt solubility and soil moisture content. Alkaline soils will have a lower amount of soluble salt (Mohd-Aizat et al. 2014).

The EC values in soil samples from HICWWTP has very higher than the EC values that should be in productive soil, Table (3), there EC values were (1491.3 and 3253.6 µs/cm) for upper and lower soils Fig. (3), whereas, the soil samples from MMWWTP has much lower EC values (240.8 and 194.4 µs/cm), Fig. (3). Which might have attributed to the different input water types, where HICWWTP input is mainly industrial water, but the MMWWTP is domestic water.

3.3.1 Heavy Metal Accumulation

Results of analysis for copper, iron, lead and cadmium for soil samples of the depths (0 – 30) cm and (30 – 60) cm were evaluated. Copper is one of the most valuable and prevalent metals used in the industry and it's important for good health (Minnesota Department of Health, 2018), but higher concentrations can cause harmful health effects, especially for infants. From the results shown in Table (3), the Cu concentration in upper soil ranges (from 48 mg/kg to 132 mg/kg), and in lower soils, it ranges (from 9.7 mg/kg to 42.6 mg/kg). Copper in wastewater comes from industrial sources such as alloy manufacturing and heat exchangers and households such as pipes and tips. Therefore, it is being higher in soil irrigated by industrial wastewater effluents (HICWWTP) than in the soils irrigated by domestic wastewater effluents (MMWWTP) as shown in Figs. (3 a and b).

In both sites, there is no difference in copper values in soil samples and control samples. Most of the copper values in the soil samples are within the allowable level of copper for agricultural soil (2-50) mg/kg) (Reid and Dirou, 2004). There is no cumulative effect of copper in the soil as a result of irrigation with TWW.

Iron is considered one of the most abundant micronutrients in surface soils (Fageria et al. 2002), Iron is an essential element needed by all organisms for growth and development. Because iron becomes toxic at higher concentrations, the concentration of iron in the plant should be monitored (Agafonov et al. 2016). Iron is a catalyst needed to form chlorophyll, which is why the symptoms of iron problems appear as changes in plant color (Rout and Sahoo, 2015).

From the results that are shown in Table (3), the concentration of iron in the soil from HICWWTP samples ranges (from 252 mg/kg to 356 mg/kg. Whereas, is very high in soils from MMWWTP samples (13560 mg/kg to 35548 mg/kg). It is clear from Fig. (3 aand b) that the upper and lower soils of MMWWTP bear a very high iron concentration than HICWWTP, which might be attributed to the soil iron content not related to Fe in the irrigated wastewater, as evident from its high concentration in both upper and lower soil. Moreover, Tables (1and2) showed that Fe contents in effluent wastewater from both WWTP are very low, and it is far below the allowable limits. There is no difference in the concentration of iron in soil samples irrigated with TWW from both WWTP's and control soil samples. This indicates that there is no accumulation of iron because of irrigation with TWW.

Lead is toxic to plants and human beings; Pb is less toxic to plants than mercury and copper. Lead is found in paint and it's also used in several alloys, flashing solder, and some batteries. Lead is released during the combustion of fossil fuels and many manufacturing processes produce or release lead (Dojlido and Best, 1993). Soil may become contaminated with Pb if it is exposed to any of these substances or processes or if water runoff from such substances infiltrates the soil, mining activity may also lead to lead contamination.

The Pb concentration in the soil samples from HICWWTP was below the detection limit (BD). All values appeared below the permissible lead values in the soil, (35 mg/Kg) (Reid and Dirou, 2004), this indicates the lack of accumulation of the element in the soil due to using TWW for irrigation. Whereas, it's an average of 204.8 mg/kg and 215.3 mg/kg in the upper and lower soil from MMWWTP site Table (3). Despite that, the TWW from both sites has Pb concentrations slightly above the permissible limit Tables (1and2), however, the irrigated soils at HICWWTP in BD mean no accumulation effect. But for MMWWTP the Pb values could be from lithogenic sources as in the case of Fe.

Cadmium is very toxic and its harmfulness comes from its ability to concentrate in the human body if it enters through contaminated water or food chain (Dojlido and Best, 1993). One of the potential causes of the appearance of cadmium in the soil is the use of phosphate fertilizers, sewage sludge, and industrial usage (Dojlido and Best, 1993).

The cadmium concentration in the soil samples irrigated from HICWWTP was below detection limits in upper and lower soils, Table (3). These results showed that despite Cd being slightly above the permissible limits in the wastewater effluents from HICWWTP, however, there is no value for cadmium in soil. This indicates that the element is not accumulated in the soil and not affecting the soil, we cannot confirm whether the values allowed in the soil are permissible or not (1 mg/Kg) (Reid and Dirou, 2004). Whereas, the soil from MMWWTP has average concentrations of 3.55 mg/kg and 5.09 mg/kg for upper and lower soil. The TWW effluent from MMWWTP has Cd slightly above the permissible limit (Table 2). The concentration of cadmium in the soil is higher than the normal existing amount of cadmium in the soil (1 mg/kg) (Reid and Dirou, 2004), but the concentration of cadmium in control samples is higher than the concentration of cadmium in the soil samples that irrigated with treated wastewater, this indicates so there is no cumulative effect of Cadmium on the soil as a result of irrigation with treated wastewater. Moreover, soil leaching with rain water during the wet season is the main reason behind the low concentrations of heavy metals in the soil, and subsequently in the irrigated plants.

3.3.2 Sodium

Sodium content is a very important factor in plant irrigation. The roots absorb sodium from the soil and transport it to the leaves, where it accumulates and can cause damage (Castro et al. 2011). From the results that are shown in Table (3), the minimum concentration of sodium in soil samples was 21.32 mg/kg while the maximum was 91.06 mg/kg.

The concentration of sodium in soil samples is lower than the appropriate quantity of concentration of sodium in the agricultural Soil (230 mg/Kg) (Reid and Dirou 2004), also the small difference between the concentration of sodium in the soil samples irrigated with TWW and concentration of sodium in the control samples indicates that the concentration of sodium in the soil is unaffected by irrigation with TWW.

From the results that are shown in Table (3), the minimum concentration of sodium in soil samples was 1480 mg/kg while the maximum was 2976 mg/kg. The concentration of sodium in the soil is higher than the normal amount of sodium found in soil (230 mg/kg) (Reid and Dirou, 2004), and the concentration of sodium in control samples is less than the concentration of sodium in the soil samples that were irrigated with TWW this is a result of using treated wastewater in irrigation.

3.3.3 Potassium

Potassium concentration in wastewater is not known to cause adverse effects on plants or the environment. It is an essential macronutrient and affects positively soil fertility, crop yield, and quality (FAO, 2003). From the results that are shown in Table (3), the minimum concentration of potassium in soil samples HICWWTP was 550 mg/kg while the maximum was 1796 mg/kg, there is a small increase in the values of potassium in control samples compared to soil samples that irrigated with TWW, this possibly occurs due to plant uptake of potassium from the soil. As for MMWWTP soils, the Potassium minimum concentration was 132 mg/kg while the maximum was 504 mg/kg Table (3). There was no effect on the concentration of Potassium in the soil due to irrigation with TWW because there was no difference in the concentration of Potassium in the soil samples that were irrigated with treated wastewater and control samples.

Figure (3) showed that Potassium in soils irrigated with TWW from HICWWTP is higher than in the soil irrigated with TWW from MMWWTP, the average K content was 4.08 and 34 mg/kg for TWW from MMWWTP and HICWWTP respectively (Tables 1 and 2). This might be due to the difference in the influent water sources. There is no risk of Potassium concentration in soil because the appropriate level of Potassium concentration in soil is above 195 mg/kg (Reid and Dirou, 2004).

3.3.4 Total Nitrogen

Nitrate levels fluctuate widely, depending on the rainfall season; agronomists generally like to see a level of 10 mg/kg or more in pasture soils, and a level greater than 20 mg/kg in horticultural crops soil (Reid and Dirou, 2004).

Total Nitrogen (TN) content in the upper soil samples (0-30 cm) from HICWWTP ranges from 0.34% (1.68 mg/Kg) to 0.76% (3.78 mg/Kg) and it falls within the required allowable level of the soil. More studies and more samples are needed to study the effect of using TWW for irrigation on nitrogen in the soil. Meanwhile, the total Nitrogen content in soil upper soil samples (0-30 cm) samples from MMWWTP ranges from 0.34% (1.82 mg/kg) to 0.59 % (2.94 mg/kg) and falls within the normal level of the nitrogen content of the soil. The results showed that there is slightly higher TN in the soils irrigated by TWW from HICWWTP than those irrigated by TWW from MMWWTP as shown in Table (3). This might be attributed to the nature of the soil rather than TWW characterization. Therefore, there is no solid evidence for the increased nitrogen content in the soil due to the use of TWW. The high percentage of nitrogen in one soil sample to that of soil control samples because the Alfalfa plant is a natural source of nitrogen (Wikiarmer, 2017).

3.4 Results of Plant analysis

The control plant is the same type of plant that was irrigated with TWW (Alfalfa), it was irrigated with fresh water and was taken from a nearby farm. Table (4) shows the chemical characteristics of plant samples irrigated by TWW from MMWWTP, and HICWWTP and the chemical characteristics of the control sample.

Table 3. Chemical characteristics of plants samples

ID	Cu mg/kg	Fe mg/kg	Pb mg/kg	Cd mg/kg	Na mg/kg	K mg/kg
HICWWTP	62	414	B.D	B.D	50.66	1974
MMWWTP	B.D	10820	242.1	6.48	4076	26752
Control plant	B.D	8996	212	7.7	4580	12900

B.D =Below detection limit = 20 mg/kg

From Table (4) the concentration of copper in the plant irrigated with TWW from HICWWTP is higher than its concentration in the plant irrigated with TWW from MMWWTP and the sample irrigated with fresh water.

While the concentration of iron, lead, cadmium, sodium, and potassium in the plant irrigated with TWW generated from both WWTP's are below their concentration in the Control plant that is irrigated with fresh water.

It is noticed that heavy metals concentration in the plant from the two studied WWTP are identical to their counterpart soil samples., as Cd and Pb were below the detection limits in the plant from HICWWTP and similarly the soil samples from the same WWTP are below detection limit too. Despite that TWW from HICWWTP has noticeable Pb and Cd Concentrations Table 1). The same trend was found between the plant and soil of MMWWTP, where Cd and Pb are noticed in soil and plant heavy metal concentration Table (4). This is inconsistent with MMWWTP TWW that have considerable concentrations of heavy metals (Table 2). This confirms that there is no effect of TWW on the plants' uptake due to lower accumulation. And that the plant chemistry is reflecting the original soil chemical composition. More investigation should be made to explain why the uptake of copper by alfalfa took place from TWW from HICWWTP while this did not happen to the plant that was irrigated with TWW from MMWWTP.

4. Conclusions

The results of TWW analysis produced from HICWWTP and MMWWTP showed that its quality is comply well with Jordanian standards for reclaimed WW reuse for restricted irrigation. The results showed that the quality of treated wastewater for irrigation, whether it was generated from domestic or industrial influent wastewater is safe because the chemical characteristics of the irrigated plant with treated wastewater at HICWWTP and MMWWTP were below the allowable limits for the irrigation of plant with fresh water. TWW produced from both WWTP's is recommended for fodder plantations such as (Alfalfa). Also, there is no adverse effect on the irrigated soil's chemical characteristics, which might be due to the low accumulation rate because of a short time interval of application and lower heavy metal concentrations in the produced TWW. In addition to the leaching with rainwater in the wet season which prevents contaminant accumulation. Although, the reuse of TWW for irrigation did not show any adverse effect, however continuous monitoring of irrigated soil and plant units is highly recommended to ensure high treatment efficiency. Frequent analysis of both irrigated plants and soils should be conducted to monitor the long-term heavy metal accumulation

Acknowledgment:

This research was financially supported by the Deanship of Scientific Research – at Mutah University. The authors are grateful to the staff of Prince Faisal Center for their efforts in the sample analytical procedures.

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