TRACKING HEAVY METAL CONCENTRATIONS IN SOILS AND DATE PALMS IRRIGATED BY GROUNDWATER AND TREATED WASTEWATER

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ABSTRACT

This research was conducted to evaluate the suitability of using treated wastewater in irrigating date palm trees and monitor heavy metals movements between soil, plant and fruits. Soil and plant (leaves & fruits) samples were taken from date palm farms located inside and outside Sultan Qaboos University and irrigated by groundwater and treated waste waters. All samples were analyzed for heavy metals concentrations. Results indicated that the concentrations of heavy metals in ground and treated waste waters were within the national and international standards. There were variations in metal concentrations between soil samples of all three locations. Most heavy metals in plant leaves were insignificantly different from each other. Date palm fruits had lowest concentrations of heavy metals compared to soil and plant leaves samples. However, the concentrations of Fe, Zn and Ni were high in all three locations especially in plant leaves, which could be related to soil formation and continuous accumulations of those elements in plant tissues. In all three locations, the concentrations of heavy metals were high in treated waste water compared to ground water. Fruits had significant differences in the mineral composition of plants irrigated by treated waste water and ground water. Longer exposure to treated water did not indicate major effects on fruit minerals, including heavy metals.

Keywords: Salts, Plants, leaves, fruits.

1. Intoduction

In water-scarce regions, the use of wastewater in agriculture will free up and prevent the contamination of good quality water resources for the use in urban centers and industry (Abdelrahman *et al*., 2011). The use of treated wastewater in agriculture could help in conserving freshwater and fertilizer application. However, it may contain high concentrations of salts, heavy metals, pathogens, and emerging pollutants with unknown effects on the ecological system (Mohammad and Mazahareh, 2003). In many parts of the world, treated wastewater has been successfully used for irrigation, and many researchers have recognized its benefits (Mujeriego and Sala, 1991; Levine and Asano, 2004). The continuous use of treated wastewater in irrigation increases the total soluble salts in the soil. The cation exchange capacity values are increased by increasing the period of using treated wastewater for irrigation, especially in the surface layer (0-30 cm). Moreover, Fe, Zn, Cu, Mn, Pb and Co were increased by irrigation using treated wastewater as compared to virgin soil (Selem *et al*., 2000). In addition, the accumulation of heavy metals in the edible part of plant was detected which adversely affect human and animal health through the food chain (Abd-Elfattah *et al*., 2002).

The rapid development of Oman urbanization, increase in population and increase in agricultural production has led to high demand for agricultural water and urgent need to use treated wastewater as alternative source of freshwater. However, treated wastewater could have some limitations such as presence of heavy metals which could accumulate in soil, plant and fruits. High concentrations of

heavy metals in plant fruits could affect human health and cause many environmental problems. In Oman, little information is available concerning heavy metals concentrations and translocation between soil, plant and fruits of date palms. Therefore, this study was conducted to evaluate the suitability of using treated wastewater in irrigating date palm trees and monitor their movements between soil, plant and fruits and how they will affect the edibility of date palm fruits.

2. Materials and methods

The study area was located along the (N21° 0' 0") and (E57° 0' 0") where sewage effluents originating from Government sewage treatment plants were used to irrigate landscapes and some date palms trees.

Composite soil samples were collected from three different agricultural locations inside and outside Sultan Qaboos University (location 1: 22° 56' 0" N / 57° 32' 0" E, location 2: 22° 56' 2" N / 57° 46' 30" E and location 3: 23° 36' 47" N / 58° 35' 35" E) irrigated by groundwater (G) and tertiary treated wastewater (T) for more than 7 years. The distance between each two locations is more than 50 Km. Date palms in those locations were irrigated using flood irrigation system. Samples of soils, date palm leaves and fruits were collected.

Soil samples were air dried, thoroughly mixed and passed through a 2 mm sieve and kept for chemical analysis. Whereas, plant leaves and fruits were dried in the oven with temperature of 70 ^{o}C. All samples were digested with concentrated hydrochloric acid (HCl) to determine some basic macro and micro elements using inductively coupled plasma (ICP) instrument. Data were analyzed statistically using the analysis of variance and the means was compared at the probability level of 5% using least significant difference (SPSS, 1998).

3. Results and discussion

3.1. Heavy metals in soil samples

Continuous irrigation with any kind of water could lead to salts accumulations if un-sustainable management is followed. From Table 1, it can be seen that most soils contained low values of heavy metals. However, soil in location 3 irrigated by treated wastewater had the highest concentrations of Mn, Fe, Pb and B which usually accumulated when the same water was used for long time without suitable management such as leaching process. Whereas, location 1 which was irrigated by groundwater and treated wastewater got the lowest values. However most values are significantly different from each other which mean irrigation water quality and farm management could be the main reasons behind that.

Table 1: Metals concentrations (mg/l) in soil samples*

Soil	Mn	Fe	Zn	Cu	Cr	Cd	Pb	Ni	B
Location 1-T	0.200c	0.170 d	0.050 a	0.040 b	0.010 d	0.001 c	0.14 d	0.001 b	0.21 d
Location 1-G	0.300a	0.180 c	0.001 b	0.010 c	0.030 c	0.001 c	0.20 c	0.001 b	0.32 c
Location 2-G	0.001d	0.330 b	0.001 b	0.070 a	0.050 b	0.040 b	0.61 b	0.001 b	0.52 b
Location 3-T	0.230b	0.460 a	0.001 b	0.010 d	0.110 a	0.070 a	1.03 a	0.010 a	0.97 a

*Means in the column with same letter indicate no difference at Duncan's Multiple Range Test at P< 0.05.

Extent of build-up of metals in wastewater irrigated soils depends on the period of its application (Palaniswami and Sree Ramulu, 1994). Rattan *et al*. (2004) observed a build-up of Zn, Pb, Ni, Mn, Fe, Cu, Cr, Co and As in the sewage irrigated soils, over the well water-irrigated ones. Significant effect of irrigation through sewage water was observed in case of studied metals. There has been an enormous build-up in the available Fe content in the sewage irrigated soils. All the soils, both under well and sewage irrigation are well supplied with Zn and Cu as their levels are generally higher than

their critical levels of deficiency of 0.6 and 0.2–0.5 mg kg^{-1}, respectively. In case of the sewage irrigated soils, some of the soils have accumulated more than 70 mg kg^{-1} total Zn, which has been listed as critical level of phyto-toxicity (Rattan *et al*., 2004).

3.2. Heavy metals in date palm leaves

For soil, usually there is a direct relationship between salts found in the irrigation water and irrigated land. Whereas, for plants, root selectivity and present of salts in different forms could play a role in elements movement and translocation from soil to plant. From Table 2, it can be seen that concentrations of many elements were significantly different from one sit to other. Whereas, in plant leaves, it can be seen that most elements were not significantly different from each other. However, some differences like in Fe, Zn and Ni were found and that could be due to soil formation or plant growth and its age.

Table 2: Metals concentrations (mg/l) in date palms leaves*

Plant leaves	Mn	Fe	Zn	Cu	Cr	Cd	Pb	Ni	B
Location 1-T	0.001 b	6.62 a	2.26 e	0.001 a	0.001 a	0.001 a	0.001 a	9.53 c	0.001 b
Location 1-G	0.001 b	4.80 d	6.50 d	0.001 a	0.001 a	0.001 a	0.001 a	9.93 b	0.001 b
Location 2-T	0.001 b	6.51 b	45.31 a	0.001 a	0.001 a	0.001 a	0.001 a	8.01 d	0.001 b
Location 2-G	0.001 b	5.66 c	12.92 b	0.001 a	0.001a	0.001 a	0.001 a	10.19 a	0.001 b
Location 3-T	0.04 a	4.10 e	7.52 c	0.001 a	0.001 a	0.001 a	0.001 a	5.26 e	2.60 a

*Means in the column with same letter indicate no difference at Duncan's Multiple Range Test at P< 0.05.

Abd-Elfattah *et al*. (2002) data indicated significant differences between leaves grown in soils irrigated with treated wastewater and leaves grown in soils irrigated with Nile water of both seasons. Manganese (Mn) level had insignificant difference between the two studied seasons. Crops raised on the metal contaminated soils accumulate metals in quantities excessive enough to cause clinical problems both to animals and human beings consuming these metal rich plants (Rattan *et al*., 2001). Elgala *et al*. (2003) found that Fe and Cu concentrations in clover tissues grown in Elgabal Elasfar soil exceeded the permissible limits.

3.3. Heavy metals in date palm fruits

Fruits are the most important part for human consumption and concentrations of all elements should be within the range of safety standards. As shown in Table 3, most elements were in low concentrations except for Fe, Zn and Ni which is a reflection of what was found in Table 3 and their high concentrations in plant leaves. Many reasons could interfere with element concentrations in plant leaves and fruits such as water quality, soil formation, fertilizers added by farmers or any external sources. In our case, each location was irrigated by different owner and different intervals. In addition to that, each owner was applying different type of fertilizers which could be one of the main sources for difference in elements concentrations between all three locations. However, date palm is an old plant that could accumulate different salts with each season and later those salts will be reflected in plant leaves and fruits. Therefore, it can be seen that concentrations of the measured heavy metals were within the international ranges published by some organizations (Table 4). Small increment in some metals was found due to the soil formation and misuse of irrigation water and fertilizer applications.

The accumulation of heavy metals in the edible part of plant was detected which adversely affected human and animal health through the food chain (Abd-Elfattah *et al*., 2002). Effect of irrigation with treated wastewater on heavy metals contents in Seewy fruits prolonged use of treated wastewater in irrigation resulted in substantial increase in the available contents of the different heavy metals in the

soil. These levels of heavy metals can be toxic to plants and harmful to animals and human, when found their food substances. Abd-Elfattah *et al*. (2002) data indicated that there was a significant difference in fruit contents of heavy metals and trace elements (Pb, Cd, Ni, Cu, Mn, Fe, Zn) between fruits produced by treated wastewater compared with Nile water in both seasons.

Table 3: Metals concentrations (mg/l) in date palms fruits*

Plant fruits	Mn	Fe	Zn	Cu	Cr	Cd	Pb	Ni	B
Location 1-T	0.001 d	5.93 b	7.92 a	0.001 e	0.001 a	0.001 e	0.001 d	4.52 b	0.001 e
Location 1-G	0.03 c	3.65 c	4.29 b	0.03 d	0.001 a	0.47 d	0.04 b	3.15 c	0.14 d
Location 2-T	0.001 d	7.29 a	1.02 d	0.001 e	0.001 a	0.001 e	0.001 d	8.82 a	0.001 e
Location 2-G	0.06 a	0.25 e	0.15 f	0.05 b	0.001 a	0.62 a	0.01 c	0.001 e	0.18 b
Location 3-T	0.06 a	3.11 d	3.58 c	0.05 c	0.001 a	0.51 c	0.001 d	1.97 d	0.18 c
Location 3-G	0.06 b	0.24 f	0.20 e	0.08 a	0.001 a	0.53 b	0.88 a	0.001 e	0.23 a

*Means in the column with same letter indicate no difference at Duncan's Multiple Range Test at P< 0.05

Data gathered by El Mardi *et al*. (1995) on the concentration of various minerals in fig, lime, mango, pomegranates, and mulberry were pooled and analyzed to show the overall concentration in the fruit and leaf of these crops. The results indicated that there is a significant correlation between leaf and fruit concentration ($y = 0.0069x + 1.6518$, $R^2 = 0.63$). Overall, the fruits had the highest macronutrients and heavy metals, whereas leaves contained higher concentration of micronutrients Fe, Mn, Al and B. This may be attributed to the ability of the crops to translocate certain elements within the plants. This may also indicate that these elements do not accumulate within the plant over extended periods of irrigation as described earlier. In other study, El-Motaium and Badawy (2000) found that heavy metals were accumulated as in the following order: roots > leaves > stems.

Table 4: Guideline for safe limits of heavy metals in plants (mg/kg)

Standards / Elements	Cd	Cu	Pb	Zn	As	Ni	Cr
WHO/FAO (2007)	0.2	40	5	60	-	-	-
European Union (EU 2006)	0.2	-	0.3	-	0.4	-	2.3
Indian Standard (Awashthi, 2000)	1.5	30	2.5	50	-	1.5	20

4. Conclusions

In view of the shortage in water resources it can be concluded that wastewater reclamation and reuse can play a major role in alleviating the problem, and hence, wastewater reuse should be considered within the framework of the overall water master plan. However, to avoid any health or environmental problems, reuse of treated wastewater should be subjected to continuous monitoring and fruit qualities should be evaluated. In this study most of heavy metals were low in concentrations except for Fe, Zn and Ni which could be originated in rock materials and groundwater. However plant age and selectivity could play a major role in elements absorptions.

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