Reuse of wastewater for irrigation in Saudi Arabia and its effect on soil and plant

Ali A. Aljaloud[A]

[A]Natural Resources and Environment Research Institute (NRERI), King Abdulaziz City for Science and Technology (KACST), Riyadh Kingdom of Saudi Arabia, Email aljaloud@kacst.edu.sa

Abstract

This paper addresses the reuse of treated municipal wastewater and its effect on soil and plants. The research study showed that reuse of treated municipal waste water in irrigation provided plants with sufficient levels of nutrients, such as Nitrogen (N), Phosphorus (P) and Potassium (K), and other micro-nutrients. Research results indicated that using treated municipal waste water in crop irrigation saved 45% and 94% in the cost of the fertilization programs for wheat and alfalfa, respectively. Additionally, wheat yield increased by 11% and alfalfa production improved by 23%. Overall profit for wheat and alfalfa were 14% and 28%, respectively, higher than the control. The concentration of heavy metals such as Copper (Cu), Lead (Pb) and Cobalt (Co) in plant tissue was low compared to established standards; these heavy metal concentrations are well below hazardous levels. This study showed that treated municipal waste water can be used safely for irrigation of a selected group of crops. It enriched the soil in minerals, increased plant nutrient uptake, promoted crop yield, and improved the overall profit

Key Words

Wastewater reuse, heavy metals accumulation in soil and plants, wastewater, use of municipal wastewater for irrigation**.**

Introduction

Use of waste water as a supplemental source of irrigation is inevitable for increased agricultural production in many arid and semi-arid regions where irrigation supplies are insufficient to meet crop water needs. AI-Shanghiti and Shammas (1985) found that irrigation with waste water reduced soil salinity and met some crop nutrient requirements. Research showed that use of some waste waters for irrigation increased trace metals in soils and plants, especially Zn levels in soils (Johnson *et al.* 1982, Abdou and El-Nennah, 1980, El-Mashhady and El-Nennah, 1982, Crites, 1984). The information on the use of treated municipal waste water for agriculture in Saudi Arabia is limited with regards to its optimum use to minimize pollution problems. This experiment was conducted to determine the effect of irrigation with treated municipal waste water on crop yield, plant composition and soil properties with special emphasis on accumulation of trace metals.

Methods and materials

The soil for the experiment was silty-clay (Sand 39%, Silt 39%, Clay 22%).

Table1. Physico-chemical properties of soils.

Parameters	Soil – 1[aa]	Soil – 1[2b]
pH	7.7 -8:1	7.6 - 7.8
EC at 25°C	0.9 – 3.3	2.0 - 4.7
Ca^{+2} meg ^{2} L^{-1}	1.9 – 20.2	8.1 - 20.4
Mg^{+2} "	1.9 – 11.9	8.0 - 16.1
Na^+ "	4.3 – 11.9	5.3 - 24.6
K+ "	0.3 – 0.9	0.8 - 1.4
SO_4^{2-} "	2.3 – 34.0	6.0 - 50.1
Cl^{-4}	1.7 – 3.1	2.4 - 4.0
HCO_3	1.3 – 2.3	0.9 - 1.4
P mg/kg	2.1 – 9.7	1.2 - 8.1
CO_3 – eq %	37 – 45	32 - 39
Sand* %	27 – 53	39 - 61
Silt %	29 – 47	25 - 37
Clay %	18 – 26	14 - 24

[a] Soil irrigated with Treated Municipal Waste Water (TMWW).
[b] Soil irrigated with Fresh Water (FW).
* Soil Texture Class = Silty-clay.

Two sources of irrigation water, namely Treated Municipal Waste Water (TMWW) from Riyadh Sewage Treatment Plant and Fresh Water (FW) were used. Water samples were collected on a monthly basis for analysis to monitor any change in chemical composition.

Table 2. Mean chemical composition of irrigation waters.

Parameters	TMWW	FW
pH	7.26	7.80
EC dS/M	1.61	0.70
COD mg/L	89	-
NH_4 –N "	20.7	-
PO_4-P "	7.0	-
K^+ "	15.1	2.9
Ca^{+2}	128	61
Mg^{+2}	28	23
Na^{+2}	140	45
$SO4^{+2}$ "	6.8	3.89
HCO_3 "	3.2	1.1
Cl "	4.8	1.9
Fe ug/L	0.24	-
Zn "	0.11	-
Mn "	0.04	-
Cu "	0.01	-
Pb "	0.002	-
Ni "	0.003	-
Cd "	0.0004	-
Cr "	0.003	-
C0 "	0.002	-

TMWW = Treated Municipal Waste Water.
FW = Fresh Water

Wheat and Alfalfa were grown as test crops. A composite soil samples were taken from 0-10, 10-20, 20-40, 40-70, 70-100 and 100-140 cm depth of soil at the beginning and after each cropping season. Plant samples of wheat were collected at flag leaf stage each year for analysis. Similarly, twenty branches were randomly collected from freshly cut alfalfa.

Results and discussion

Chemical composition of crops

Wheat

The mean concentrations for elements for the two waters were N 3.11% (TMWW) and 2.91% (FW), P 4.25 mg/g (TMWW) and 3.45 mg/g *(FW),* K 4.10% (TMWW) and 3.75% (FW), Fe 145 mg/kg (TMWW) and 133 mg/kg (FW), Zn 35.5 mg/kg (TMWW) and 26.5 mg/kg (FW) and Mn 102 mg/kg (TMWW) and 98 mg/kg (FW). The Fe and Zn contents of plants were significantly higher for TMWW plots than FW treatment plots at 5% level of significance. The difference in the element contents of the remaining elements was not significant between TMWW and FW irrigated plots in spite of the fact that crop received the same amount of fertilizer in both irrigation treatments.

Alfalfa

The mean concentrations of elements were N 4.10% (TMWW) and 4.20% (FW), P 3.75 mg/g (TMWW) and 3.35 mg/g (FW), K 3.60% (TMWW) and 3.50% (FW), Fe 359 mg/kg (TMWW) and 325 mg/kg (FW), Zn 27.0 mg/kg (TMWW) and 25.5 mg/kg(FW) and Mn 50 mg/kg (TMWW) and 44.5 mg/kg (FW). There was no significant difference in mineral composition of alfalfa irrigated with different irrigation treatments except Fe which was significantly higher in TMWW than FW irrigated plots. The results showed that irrigation with TMWW did not affect the chemical composition of the alfalfa crop as compared to FW irrigated plots. This might be due to the nitrogen fixing properties of alfalfa masking the effect of nutrients in TMWW treatments. Also fertilizer application might have overshadowed the beneficial effects of nutrients present in treated waste water.

Toxic metals
Wheat
The mean concentrations of toxic metals were for Cu 2.9 mg/kg (TMWW) and 2.4 mg/kg (FW), Pb 1.5 mg/kg (FW) and 2.3 mg./kg (TMWW), Ni 0.8 mg/kg (TMWW) and 0.5 mg/kg (FW), and Co 0.5 mg kg t (TMWW) and 0.5 mg/kg (FW). Toxic metal concentrations showed increasing trend under TMWW irrigation but the difference in the toxic mineral composition of wheat irrigated with TMWW and FW waters was not significant.

Alfalfa
The mean concentrations of toxic metals were for Cu 2.1 mg/kg (FW) and 2.9 mg/kg (TMWW), Pb 3.3 mg/kg (FW) and 3.3 mg/kg (TMWW), Ni 0.6 mg/kg = (FW) and 0.7 mg/kg (TMWW), and Co 2.6 mg/kg (TMWW) and 2.3 mg kg (FW). The concentration of all the toxic metals in alfalfa was almost identical for TMWW and FW irrigated plots. In general, the concentration of toxic metals showed increasing trends in TMWW treatment relative to FW but the difference was not significant at 5% level of significance. The results were similar to those of Johnson *et al.* (1982), Abdou and El-Nennah (1980), El-Mashhady and ElNennah (1982) who observed increased contents of trace metals in plants irrigated with waste waters.

Soil properties
Soil salinity
The soil salinity increased with depth and ranged from 2.0 to 6.5 dS/m in S1, 2.0 to 3.9 dS m^{-1} in S2 and 2.6 to 4.1 dS/m in S3 in FW irrigated plots. Soil salinity did not show significant changes with time and ranged between 1.8 to 4.9 dS/m in S1, 2.9 to 4.0 dS/m in S2 and 2.6 to 3.5 dS/m in S3 in TMWW irrigated plots. Soil salinity did not increase to harmful limits with FW and TMWW irrigation (USDA 1954). Al-Shanghiti and Shammas (1985) reported similar results and found a decrease in soil salinity with waste water irrigation

Chemical composition of soils
Nitrogen (N)
The weighted mean N contents of soils were 36.1 mg/kg and 68.5 mg/kg in FW and TMWW irrigated plots respectively. The N contents of soils were significantly low in FW than TMWW irrigated plots ($LSD_{0.50}$ = 20.2). This showed that N present in TMWW increased the N concentration of soils above the levels in the soil receiving FW water and the same amount of pre-plant inorganic fertilizer.

Phosphorus (P)
The weighted mean values of available P in soils were 19.7 mg/g and 24.9 mg/g in FW and TMWW irrigated plots, respectively. The difference in P contents of soils between FW and TMWW treatments was not significant at 5% level of significance ($LSD_{0.05}$ = 19.6). The results showed that P contents for TMWW did not increase the P contents of soils significantly when compared to FW treatment.

Potassium (K)
The weighted mean values of water soluble K in soils were 40.9 mg/kg and 47.4 mg/kg in FW and TMWW irrigated plots, respectively. The difference in K contents between FW and TMWW treatments was not significant at 5% level of significance ($LSD_{0.05}$) = 20.4). The slightly higher contents of soil in TMWW treatment than FW treatment could be attributed to higher levels of K in TMWW.

Iron (Fe)
The weighted mean values of Fe were 2.27, 2.23 and 3.53 mg/kg in *S1, S2* and S3- respectively under FW irrigation. The Fe contents of soils increased significantly with time ($LSD_{0.05}$ = 0.53). Similarly, the mean values of Fe were 2.27, 2.27 and 3.70 mg kg^{-1} in Ap. 89, *Nov.* 89 and June *1990,* respectively under TMWW irrigation. The Fe contents of soils were significantly higher in the last year than the previous two years ($LSD_{0.05}$ = 0.73).

Zinc (Zn)
The weighted mean values of Zn were 2.23 mg/kg in S1, 1.27 mg/kg in S2 and 1.73 mg/kg in S3 in FW irrigated plots. The Zn contents decreased with time and were significantly lower in the second year as compared to the first year. The difference in Zn contents of soils was not significant between the first

and the last year ($LSD_{0.05}$= 0.76). Overall, the Zn contents were slightly higher in TMWW than FW irrigated plots. This could be attributed to low levels of Zn in FW as compared to TMWW treatment. The weighted mean values of Zn in soils were 2.60 mg/kg in S1, *2.30* mg/kg in S2 and 1.97 mg/kg in S3 in the TMWW irrigated plots. The Zn contents showed decreasing trend with time but the difference was not significant at the 5% level of significance. Although, the TMWW contained appreciably higher amount of Zn than FW the effect on Zn status of soil was not significant.

Copper (Cu)
The weighted mean values of Cu in soils were 0.47 mg/kg in S1, 0.40 mg/kg in S2 and 0.53 mg/kg in S3 in FW irrigated plots. There was no significant difference in Cu contents of soil with time at 5% level of significance. The weighted mean values of Cu in soil were 0.47 mg/kg in S1, 0.30 mg/kg in S2 and 0.67 mg/kg in S3 in TMWW irrigated plots. The Cu contents of soil increased significantly in the last year as compared to the first year. The Cu contents were significantly lower in the second year than in the first year and the last year ($LSD_{0.05}$ = 0.12). The results showed that Cu present in TMWW increased the Cu content of soil.

Conclusion
Nutrients present in treated waste water increased dry matter and grain yield appreciably as compared to yields obtained using fresh water irrigation. Irrigation with TMWW did not influence the chemical composition of soil and plants to hazardous limits. Hence irrigation with TMWW is safe and is a potential source of supplemental irrigation not only to meet growing crop water needs but also for increased agricultural production.

References

Abdou FM, El-Nennah M (1980) Effect of irrigation loamy sand soil by liquid sewage sludge on its content of some micronutrients. *Plant Soil* **56**, *53-57.*

Al-Shanghiti A, Shammas AT (1985) Results of two years monitoring study on irrigation with treated sewage water. In '8th Symposium Saudi Biological.SocietyAbstract'. pp. 257-258.

Cordonnier MJ, Johnston TJ (1983) Effects of waste water irrigation and plant and row spacing on soybean yield and development- *Agronomy Journal* **75**, 908-913.

Crites RW (1984) Land use of waste water and sludge, *Environmental Science Technology* **18**, 140A-147A.

Demirjian YA, Westman TR, Joshi AM, Rope DJ, Buhl RV, Clark WR (1984) Land treatment of contaminated sludge with waste water irrigation. *Journal WPCF* **56**, 370-377.

El-Mashhady A, El-Nennah M (1982) Some quality aspects of the use of sewage effluent in agriculture. *Ain Shams University, Faculty of Agriculture, Research Bulletin* **1903**, 1-16.

Johnson RD, Jones RL, Hinesly TD, David DJ (1982) 'Selected chemical characteristics of soil, forages and drainage water from the sewage farm serving'. Melbourne, Australia. Corps Engineers, Washington, DC. Environmental Protection Agency 43019-75:54.

Saenz R (1987) Use of waste water treated in stabilization ponds for irrigation evaluation of microbiological aspects. *Water Quality Bulletin* **12**, 84-89.

USDA, Salinity Laboratory Staff (1954) 'Diagnosis and Improvement of Saline and Alkali Soils'. (United States Department of Agriculture Handbook No. 60: Washington D.C.)