Influence of Sewage Water Reuse Application on Soil and the Distribution of Heavy Metals

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Abstract: The study aims to investigate the effect of the sewage water reuse in soil and plant. The use of treated sewage water on soil has an advantage of improving soil texture in terms of organic enrichment, macro- and micronutrient elements. Remarkable increase in the level of heavy metals was observed as indicated by increasing the micronutrients available content in soil (Fe, Zn, Mn and Cu). The available content of heavy metal in soil was under the permissible levels. The longer term of irrigation is the higher accumulation of metals particularly on the top soil. While, the level of heavy metals decreases as soil depth increases. Nevertheless, accumulation of metals on the soil was still far behind the risky level. This is mainly due to the fact that the level of metals in sewage irrigation water was within the permissible level according to WHO. To eliminate the accumulation of metals on the soil, it is, therefore, recommended to use an additional treatment process such as addition of dried plant leaves or lime to decrease the level of metals in the sewage irrigation water. The use of drainage water in irrigation had the highest value of basic infiltration rate. Using sewage water or drainage water in irrigation of sugar beet led to increase the N, P and K of soils after harvesting. In addition to the dry matter content.

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1. Introduction

Egypt is located in arid region, water is becoming a very scarce resources. The planners are forced to consider any source of water which might be used economically and effectively to promote further development. With the increasing population at a high rate, the need for increasing food production is apparent.

As a consequence, the mobilization of land and water resources is proceeding fast. The development of irrigation is especially dynamic way because it is often the most important factor for increasing agricultural production.

This rapid development of irrigation translates into a sharply increasing water demand and the most accessible water resources, such as rivers and shallow aquifers are now almost entirely committed. Alternative water resources are therefore needed to satisfy further increases in demand. This is mainly a necessity in regions which are characterized by severe mismatches between water supply and demand, often associated to generally low water resources availability and asymmetries of availability and demand in a temporal and regional basis and a peculiar relationship among water and environment raise specific problems. The reuse of agricultural drainage water and treated sewage wastewater for beneficial purposes in Egypt is an attractive solution which hopefully will help considerably expansion of the irrigated agriculture or saving of fresh water for other sectors.

UN projections (UN Population Division, 1994) show that four Mediterranean countries already have less than the minimum required water availability to sustain their own food production (750 m3/inh.yr). By 2025, eight countries will be in virtually the same situation. These countries are essentially all on the Southern border of the Mediterranean (see Table 1). The crisis is already so acute in Egypt, for example, domestic water consumption exceeds 50% of the available water resources. In such places, the conventional water resources will be insufficient to even meet the domestic water demand at the beginning of the next century. On the other hand, all the Mediterranean countries of the European Union are expected to maintain themselves at or above 3000 m3/inh yr.

In the Mediterranean basin, wastewater has been used as a source of irrigation water for centuries. In addition to provide a low cost water source, the use of treated wastewater for irrigation in agriculture combines three advantages. First, using the fertilizing properties of the water (fertirrigation) eliminates part of the demand for synthetic fertilizers and contributes to decrease the level of nutrients in rivers. Second, the practice increases the available agricultural water resources and third, it may eliminate the need for expensive tertiary treatment. Irrigation with wastewater also appears to give some very interesting effects on the soil and on the crops. As a result, the use of treated wastewater for irrigation has been progressively adopted by virtually all Mediterranean countries (Marecos do Monte et al., 1996). Because irrigation is so far the largest water use in the world and the quality requirements are usually the easiest to achieve among the various types of wastewater reuse, it is by far the largest reuse application in terms of volume.

Table (1) Area, population and annual renewable fresh water availability for 1990, 2025 and 2050 in the Mediterranean countries (UN Population Division, 1994)

Country	Area (km^2)	Total renewable fresh water per year (km^3)	Fresh water availability in m3/inhabitant year					
			1990		2025		2050	
			Population (thousands)	Availability (m3/inh yr)	Population (thousands)	Availability (m3/inh yr)	Population (thousands)	Availability (m3/inh yr)
Albania	27,531	21.00	3289	6385	4668	4499	5265	3989
Algeria	2,380,000	17.20	24935	690	45475	378	55674	309
Cyprus	9,250	0.90	702	1282	927	971	1006	895
Egypt	1,000,500	58.90	56312	1046	97301	605	117398	502
France	544,000	185.00	56718	3262	61247	3021	60475	3059
Greece	132,000	69.00	10238	5763	9868	5979	8591	6868
Italy	301,300	187.00	57023	3279	52324	3574	43630	4286
Jordan	37,300	1.31	4259	308	12039	109	16874	78
Lebanon	10,360	4.98	2555	1949	4424	1126	5189	960
Libya	1,760,000	4.62	4545	1017	12885	359	19109	242
Malta	320	0.03	354	85	422	71	439	68
Morocco	445,000	28.00	24334	1151	40650	689	47858	585
Portugal	92,400	66.00	9868	6688	9685	6815	9140	7221
Spain	504,800	111.00	39272	2826	37571	2954	31765	3494
Syria	185,000	25.79	12348	2089	33505	770	47212	546
Tunisia	126,000	4.36	8080	540	13290	328	15607	279
Turkey	780,000	203.00	56098	3619	90937	2232	106284	1910
Yugoslavia	256,523	265.00	22945	11549	24582	10780	24441	10842
Total	8,612,989	1255.04						

However, wastewater is often associated with environmental and health risks. As a consequence, its acceptability to replace other water resources for irrigation is highly dependent on whether the health risks and environmental impacts entailed are acceptable. It is therefore, necessary to take precautions before reusing wastewater. As a result, although the irrigation of crops or landscapes with sewage effluents is in itself an effective wastewater treatment method, a more effective treatment is necessary for some pollutants and adequate water storage and distribution system must be provided before sewage is used for agricultural or landscape irrigation (Asano et al., 1985).

There has been an increasing interest in reuse of wastewater in agriculture over the last few decades due to increased demand for fresh water. Population growth, increased per capita use of water, the demands of industry and of the agricultural sector all put pressure on water resources. Treatment of wastewater provides an effluent of sufficient quality that it should be put to beneficial use and not wasted (Asano, 1998). The reuse of wastewater has been successful for irrigation of a wide array of crops, and increases in crop yields from 10-30% have been reported (Asano, 1998). In addition, the reuse of treated wastewater for irrigation and industrial purposes can be used as strategy to release freshwater for domestic use, and to improve the quality of river waters used for abstraction of drinking water (by reducing disposal of effluent into rivers). Wastewater is used extensively for irrigation in certain countries e.g. 67% of total effluent of Israel, 25% in India and 24% in South Africa is reused for irrigation through direct planning, though unplanned reuse is considerably greater. During the last decade, there has been growing concern that the world is moving towards a water crisis (Falkenmark, 1989)). There is increasing water scarcity in dry climate regions, for example, in Africa and South Asia, and there are major political implications of water scarcity in some regions e.g. Middle East (Murakami, 1995). Water quantity and quality issues are both of concern. Recycling of wastewater is one of the main options when looking for new sources of water in water scarce regions. The guidelines or standards required removing health risks from the use of wastewater and the amount and type of wastewater treatment needed to meet the guidelines are both contentious issues. The cost of treating wastewater to high microbiological standards can be so prohibitive that use of untreated wastewater is allowed to occur unregulated.

Blume, et al., (1980), found that the use of sewage effluent year after year in irrigation, markedly increased available P and N in the soil. El-Kholi et al., (2000) showed that using sewage effluent in irrigation for 47 years at El-Gabal El-Asfar farm, increased both total and DTPA extractable of heavy metals (Cd, Co, Cr, Cu and Pb).

El-Sayed, (1999) indicated that reuse of wastewater in irrigation for different periods relatively increased the accumulation of Zn in soil followed by Pb, Cu, Ni, and Cd in turn , most of Zn, Cu, Ni, and Cd accumulation in the soil were associated with available organic and carbonate fractions, whereas available Pb and organic fractions took an opposite trend. El-Koli et al. (2000) found that, reuse of sewage wastewater of Belbies drain over 35 years for irrigation, increased soil content of Fe, Mn, Zn, Cu, Cd, Pb, Ni, Co and Cr in comparison with those irrigated with Nile water. Whereas, this increase was 4 folds for Fe, Cu, Cd and Ni but 20 folds for Zn and 6 folds for Pb in the surface layers. El-Henawy (2000) stated that using drainage water or drainage water mixed with wastewater for irrigation caused an increase in soil content of available heavy metals (Ni, Pb, Co and Cd) in comparison with fresh water. Wafaa (2001) found that, concentration of available and total micro nutrient in soil (Cu, Zn, Mn and Fe) were increased in soil profiles irrigated with wastewater in comparison with those of fresh water depending on the nature and source of pollution. She also noticed that gradual decrease in heavy metals with increasing soil depth. However, the higher accumulation of those elements was found in the surface layer than the sup-surface one. Abo Sliman et al. (2001) studied the use of fresh, drainage and treated sewage water in irrigation the soil cultivated by sugar beet crop. They found that the contents of macro and microelements in soil decrease with fresh water while the continuous or alternative applying of sewage or drainage water with fresh water increase the elemental contents in soil especially with surface irrigation.

The objective of this work is to find out the effect of irrigation with different water qualities on soil physic-chemical properties particularly heavy metals distribution in soil and plant and the distribution of heavy metals in the soils.

2. Materials and methods

Soil samples were taken before planting and after harvesting during the two growing season 2008/2009 from the soil layer 0-30 cm and 30-60 cm. to analyze some physical and chemical properties of the soil (tables, 2 and 3a &b).

Table (2) physical properties of the soil before planting

Soil depth cm.	Particle size distribution			Texture class	F.C%	PWP%	AW%	BD gm/cm^3
	Sand%	Silt%	Clay%					
0-30	25.04	24.04	50.92	Clayey	44.31	24.13	20.23	1.22
30-60	26.52	22.71	50.77	Clayey	34.22	18.56	15.68	1.30

Where: FC=field capacity, PWP= permanent wilting point, AW= available water and BD= bulk density

Table (3a) chemical properties of soil before planting

Soil depth cm.	pH 1:2.5	EC dS/m	Cation meq/l				Anion meq/l			SAR	OM %	$CaCO_3$ %	CEC Meq/100g soil
			Na^+	K^+	Ca^{++}	Mg^{++}	HCO_3^-	Cl^-	SO_4^{--}				
0-30	7.87	4.22	19.20	0.80	15.75	8.25	3.15	20.30	20.55	5.52	0.65	1.18	34.84
30-60	8.03	3.49	14.50	0.75	14.65	7.15	3.15	13.7	20.2	4.38	0.50	1.70	30.50
mean	7.95	3.86	16.85	0.78	15.2	7.7	3.15	17.00	20.38	4.95	0.58	1.44	32.67

Table (3b) chemical properties of soil before planting

Soil depth cm.	Elemental content of soil before planting in ppm											
	N	P	K	Fe	Mn	Zn	Cu	Cd	Pb	Ni	Cr	Co
0-30	30.58	9.78	331	20.50	16.95	3.30	2.74	0.07	2.35	0.74	0.35	0.40
30-60	32.43	9.43	309	10.50	7.53	1.58	0.56	0.03	0.01	0.43	0.01	0.00
mean	31.51	9.61	320	15.25	12.24	2.44	1.65	0.05	1.18	0.59	0.18	0.20

3. Soil chemical analysis

Soil paste was carried out according the methods described by Richard, (1954). Electrical conductivity (ECe) was measured by EC meter as dS/m at 25 °C in soil extract according to Jackson, (1985). pH was determined in 1:2.5 soil : water suspension by Cottenie et al., (1982). Soluble cation (Na^+ and K^+) were determined using flame photometer while Ca and Mg were determined by titration with versenate according to Jackson, (1985). The soluble anion $CO_3^=$ and $HCO3^-$ were determined volumetrically against a standard solution of H_2SO_4 according to Black (1965). Cl^- was determined following Moher's method also SO_4^{--} was computed by the difference between both the sum of the cations and anions Jackson, (1985). Available nitrogen content was determined by modified Kjedahl method according to Cottenie et al., (1982). Available K was extracted by 1N ammonium acetate pH=7 and determined using flame photometer according to Knudsen et al. (1982). Available heavy metals "Co, Cr, Cd, Ni, Pb" and micro element" Fe, Mn, Zn, Cu" were extracted using DPTA method and estimated by ASS according to Cottenie et al., (1982).

3.1. Water analysis

Water qualities of irrigation water were subjected to chemical analysis for determination of EC, soluble anion and cations, SAR, N, P, K, micro nutrient "Fe, Mn, Zn, Cu", heavy metals "Co, Cr, Cd, Ni, Pb" as presented in tables (4 and 5).

Table (4) Chemical analysis of water samples

Water quality	pH	EC dS/m	Cation meq/l				Anion meq/l			SAR
			Na^+	K^+	Ca^{++}	Mg^{++}	HCO_3^-	Cl^-	SO_4^{--}	
Fresh water	7.4	0.55	1.8	0.2	2.0	1.5	1.45	1.4	2.56	1.36
Secondary treated	7.8	1.3	7.1	0.9	2.9	2.1	4.3	4.8	3.9	4.49

Table (5) some macro and micro nutrients (ppm) of water qualities

Water qualities	N	P	K	Fe	Mn	Zn	Cu	Cd	Pb	Ni	Cr	Co
Fresh water	1.360	0.490	7.000	0.020	0.030	0.000	0.001	0.002	0.012	0.000	0.01	0.004
Secondary treated	7.850	4.850	32.600	0.331	0.063	0.032	0.016	0.006	0.091	0.030	0.040	0.015

The design of the experiment was split-split plot with two replications in the first and second seasons located in El-Mansoura farm (middle of the Nile Delta). The plot area was 10.5 m^2 (3x3.5 m). The main plots were two different water qualities, fresh water (Nile water) and secondary treated sewage water.

Date of sowing was October 10, 2008 for the first season and October 14, 2009 in the second season. 3-4 seeds of sugar beet were sown in each hill with 25 cm distance. The plants were thinned to one plant per hill after a month from planting. The harvest date was May 26 in the first growing season and 28 of May in the second growing season. The plant subjected to the following parameters:

Root yield (ton/feddan), sucrose%, gross sugar=sucrose % x root yield (ton/feddan) and leaf area determined by leaf area meter.

4. Results and Discussions

Data in table (6) showed that, irrigation of soil by fresh water gave the lowest mean values of ECe (3.86 and 3.89 dS/m) as compared to second treated waste water (stww) (4.78 and 6.05 dS/m) throughout the first and second season respectively. While, the highest mean values of ECe 4.78 and 6.05 dS/m were obtained by stww in the first and second season. These results are in agreement with obtained by Abo Sinna et al. (1994). Regarding the SAR, the irrigation by stww increased SAR values compared to irrigation by fresh water in the first and second seasons respectively. This may be due to the high content of Na ions in stww as compared with fresh water. These results were with the coincidence of the results obtained by Omar et al. (2001).

Data in the same table showed that, Na^+ was the dominant cation followed by Ca^{++} in the two seasons, while Cl^- and $SO4^{--}$ were the dominant anions. As also indicated that all ions were increased as a result of irrigation by different water qualities, but the increase of different ions were more pronounced under irrigation by stww compared to fresh water.

Table (6) Chemical of soil paste extract after harvesting of sugar beet seasons (2008-2009)

Season no.	Water type.	pH 1:2.5	EC dS/m	Cation meq/l				Anion meq/l			SAR
				Na^+	K^+	Ca^{++}	Mg^{++}	HCO_3^-	Cl^-	SO_4^{--}	
	Before	7.95	3.86	16.85	0.78	15.20	7.70	3.15	17.00	20.38	4.95
First season	Fresh water	8.40	3.95	21.30	0.40	11.05	7.22	3.33	16.02	21.43	7.05
	Secondly treated sewage water	8.50	4.78	28.50	0.60	15.48	5.03	14.30	17.18	28.10	6. 65
Second season	Fresh water	8.95	3.89	23.00	0.40	9.40	5.80	7.50	16.10	15.00	8.31
	Secondly treated sewage water	8.27	6.05	42.40	0.60	15.10	9.00	5.00	29.60	32.40	12.21

4.1. Effect of irrigation with different water quality in the availability of some macro and micro nutrient and heavy metals content in soil after harvesting

4.1.1. Macro nutrients

Data in table (7) revealed that, the use of stww in irrigation led to increase of the N content of soil after harvesting of sugar beet. As the mean values of soil nitrogen increased from 31.51 to 39.25 and 39.75 ppm in the first and second season. This may be due to the high concentration of nitrogen in the stww.

Table (7) Available mineral content of soil after harvesting as affected by continuous irrigation with different water qualities

Season no	Water qualities	ppm											
		N	P	K	Fe	Mn	Zn	Cu	Cd	Pb	Ni	Cr	Co
	before	31.51	9.61	320	15.25	12.24	2.44	1.65	0.05	1.18	0.59	0.18	0.20
First season	Fresh water	30.50	11.00	330	16.00	15.98	2.65	2.05	0.02	1.50	0.65	0.24	0.22
	Secondary treated	39.25	13.32	373	21.32	23.45	4.21	3.22	0.12	2.80	1.05	0.33	0.36
Second season	Fresh water	30.70	11.38	339	16.94	15.05	2.84	2.11	0.08	1.60	0.71	0.25	0.25
	Secondary treated	39.75	13.54	385	22.01	24.15	4.39	3.26	0.13	2.84	1.08	0.34	0.38

Regarding the available phosphorus, data in table (7) revealed that the use of stww in irrigation led to increase of the P content of soil after harvesting of sugar beet. As the mean values of soil P increased from 9.61 to 13.32 and 13.54 ppm in the first and second season, respectively. This may be due to the high concentration of phosphorus in the stww.

In the same time the potassium availability increased significantly with irrigation by the stww. Where, values of soil K increased from 320 to 373 and 385 ppm in the first and second season. This may be due to the high concentration of potassium in the stww.

4.1.2. Micronutrient

As illustrated in table (7), the irrigation with fresh water gave the lowest mean value of Fe in the first and second season (16 and 16.94 ppm), respectively. Nevertheless, the highest value was obtained using stww in irrigation season in both seasons as the Fe value increased from 15.25 to 21.32 and 22.01ppm, respectively. These findings are in agreement with those obtained by wafaa (2001) who mentioned that irrigation by polluted water increased Fe content in soil. On the other hand, the irrigation with fresh water gave the lowest mean values of Mn in the first and second seasons (15.98 and 15.05 ppm, respectively) compared to other water qualities while the highest mean values in both seasons (23.45 and 24.15 ppm respectively). These results may be due to the high concentration of Mn in the stww. In the same time, the irrigation with fresh water gave the lowest mean values of Zn in the first and second seasons (2.65 and 2.84 ppm, respectively) compared to other water qualities while the highest mean values in both seasons (4.21 and 4.39 respectively). These results may be due to the high concentration of Zn in the stww. As regards to copper, the lowest mean values of Cu in the first and second seasons (2.65 and 2.84 ppm, respectively) was obtained with the irrigation with fresh water, while the highest mean values in both seasons (4.21 and 4.39 respectively) obtained by the irrigation with stww. These results may be due to the high concentration of Cu in the stww.

4.1.3. Heavy metals

Concerning the effect of different quality of irrigation water on cobalt content data in table (7) revealed that, the use of fresh water gave the lowest value in the first and second season (0.22-0.25 ppm, respectively). While, the use of stww gave the highest mean values where, the mean values respective to both seasons seem to be equal (0.36-0.38 ppm, respectively). Regarding the Chromium, data obtained revealed that, the use of fresh water gave the lowest value in the first and second season (0.24-0.25 ppm, respectively). While, the use of stww gave the highest mean values where, the mean values respective to both seasons seem to be equal (0.33-0.34 ppm, respectively). Concerning Nickel, data obtained exposed that, the use of fresh water gave the lowest value in the first and second season (0.65-0.71 ppm, respectively). While, the use of stww gave the highest mean values where, the mean values respective to both seasons seem to be equal (1.05-1.08 ppm, respectively). Relating to cadmium, data obtained revealed that, the use of fresh water gave the lowest value in the first and second season (0.02-0.08 ppm, respectively). While, the use of stww gave the highest mean values where, the mean values respective to both seasons seem to be equal (0.12-0.08 ppm, respectively). For the lead, data obtained revealed that, the use of fresh water gave the lowest value in the first and second season (1.5-1.6 ppm, respectively). While, the use of stww gave the highest mean values where, the mean values respective to both seasons seem to be equal (2.8-2.84 ppm, respectively).

4.2. Effect of water quality on yield and yield component of sugar beet

Data presented in table (8) revealed that, use of stww on sugar beet irrigation gave the highest significant increase in the root weight. This significant increase was achieved in the two growing seasons. This can be attributed to the adequate effect of soil moisture and enough potassium supply that is essential for translocation content of carbohydrates in plant. It has a beneficial role in calcium and potassium nutrition.

Table (8) Effect of water quality on yield and yield component of sugar beet

Season no.	Treatment	Sucrose %	Leaf area (cm^2)	Root weight (ton/fed)	Gross sugar (ton/fed)
First Season	Fresh water	18.62	822.19	32.35	6.01
	stww	19.17	856.26	34.67	6.62
Second season	Fresh water	17.97	676.87	32.61	5.99
	stww	18.14	729.37	34.14	6.19

The mean value of root weight corresponding to the first and second growing seasons were (34.67 and 34.14 ton/fed) when irrigate with stww. While, the lowest values in the growing seasons (32.35 and 32.61 ton/fed) were obtained with irrigation by fresh water. Data in table (8) illustrate also that, the sucrose percentage tended to increase due to the use of stww for sugar beet irrigation. The difference between the two seasons was highly remarkably. Where, the irrigation with stww surpassed fresh water in increasing sucrose percentage in both seasons (0.55 and 0.17%, respectively).

Regarding the gross sugar beet yield, data in table (8), revealed that, sugar yield was highly affected by irrigation with stww in both seasons (6.62 and 6.19 ton/ fed, respectively). While, the lowest values were for irrigation with fresh water in both seasons (6.01 and 5.99 ton/fed, respectively).

Data concerning the leaf area of sugar beet plant as influenced by the water qualities are presented in table (8). The obtained result showed that, the effect of water qualities on leaf area is highly significant in the two growing seasons. The high leaf area respective to first and second seasons (856.26 and 729.37 cm^2) were obtained by secondary treated wastewater. The lowest values of leaf area (822.19 and 676.87 cm^2) were recorded with irrigation with fresh water in the first and second season respectively.

5. Conclusions

From the abovementioned discussion it can be concluded that:

1. For agricultural use in future, the reuse of treated wastewater is considered as an important component of the water policies.
2. Water use efficiency can be maximized under clay soil conditions with using low quality, (sewage water) alternatively with fresh water.
3. Considerable amount of chemical fertilizers can be saved and consequently using treated

wastewater can be minimizing pollution of environment.

4. Also, the heavy metals increases, but it is in the permeable level according to WHO. To eliminate the accumulation of metals on the soil, it is, therefore, recommended to use an additional treatment process such as addition of dried plant leaves or lime to decrease the level of metals in the sewage irrigation water.

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