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Long-term Impact of Treated Sewage Water on Some Soil Properties and Nutrients Status in Luxor Governorate, Egypt

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IRRIGATION of forests with sewage water for fuel and timber production in Egypt is an approach which helps to overcome health hazards associated with sewage farming. Hopefully, sewage water will help in the expansion of the irrigated agriculture or save the fresh water for other sectors. This study was carried out to investigate the impact of irrigation with treated sewage water on the properties and nutrients status of soils in Luxor Governorate. samples of sewage water, ground water and Nile water as well as samples of soil irrigated with these water sources were collected and analyzed.

The results showed that sewage water and groundwater are considered moderately saline with an EC_w of 0.88 and 1.20 dS/m, respectively, while the Nile water is slightly saline (EC_w 0.27 dS/m). With respect of their SAR, RSC and Cl values, all investigated water sources are of a high quality and can be used in the irrigation without limitations. Moreover, sewage water contained higher amount of organic matter, N, P and K compared to groundwater and Nile water.

On the other hand, most of the soils that were irrigated with sewage water were of low levels of salinity (EC_e < 4dS/m) and sodocity (SAR_e <13), indicating no threat to soil quality. Use of sewage water in irrigation also improved the chemical properties and fertility status of the soils. It increased OM, N, K and P levels in the soils while pH and $CaCO_3$ values decreased. The irrigation system showed effects of treated sewage water on the soil properties. The soils irrigated with sewage water under the surface irrigation system had higher values of OM, EC_e, total nitrogen and available phosphorus but lower SAR_e and available K levels than those under the drip irrigation systems. Moreover, prolonged irrigated (15 years) with sewage water had a higher values of saturation percentage, organic matter, total nitrogen, available phosphorus, and available K but the lower ones of pH, SAR_e and calcium carbonate than those under the short term (4 years) use of sewage water.

Keywords: Long-term, Sewage water irrigation, Chemical soil properties, Drip irrigation; Surface irrigation

Egypt is located in the arid region, where fresh water resources are very scarce. The planners are forced to consider any source of water which might be used economically and effectively to promote further development. The reuse of agricultural drainage water and treated sewage water for beneficial purposes in Egypt is an attractive solution which hopefully may considerably help the expansion of the irrigated agriculture or save the fresh water for other sectors (Afifi *et al*., 2011). New projects are carried out now in Egypt aiming at expanding the green stretch in the desert by introducing forest plantations irrigated by treated sewage water, to produce timber trees of a high economic value (Salem *et al*., 2000). Poor water quality degrades soil quality, results in an alteration in soil physical and chemical properties and influences the soil health to a great extent. (Yerasi *et al*., 2013).

The irrigation with waste water of a high concentration of Na and K led to an increase in the salinity as well as the exchangeable Na and K of the irrigated soils (Khai *et al*., 2008).) Narwal *et al*. (1993) and Rana *et al*. (2010) reported that the soil pH decreased by a 0.38 to one unit as a result of sewage water irrigation . Moreover, Mollahoseini (2013) indicated that the soil organic carbon

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increased with using wastewater in the irrigation from the year of 1981 to 2010. Using wastewater in irrigation for 5060- years in soils of Calcutta (India), Friedel *et al*. (2000) found an increase in the soil organic carbon from 0.19 to 0.37% and from 1.24 to 1.73% after 25 years in soils of Kurukshetra (Haryana, India). In addition, long-term wastewater irrigation can be a good means of carbon sequestration in soils and can thus be referred as a soil quality sustaining practice (Dheri *et al*., 2007). About 1.42% decrease in the surface soil $CaCO_3$ content was reported with the use of waste water for irrigation purpose over the ground water irrigation (McClean *et al*., 2003; El-Arby *et al*., 2006; El-Hady, 2007).

The irrigation with municipal wastewater could change soil properties that play an important role in the availability of nutrients present in the applied wastewater (Magesan *et al*. 1998 ; Mollahoseini, 2013). The wastewater irrigation provides water, nitrogen and phosphorus as well as organic matter to the soil (Siebe, 1998 ; Mollahoseini, 2013). Ghafoor *et al*. (1999) showed that the irrigation with sewage water increased the yield of rabi crops compared to the irrigation with well water; it also increased the total N, P and K as well as the organic carbon content of soil. The sewage water can be used as alternative to fresh water irrigation and as a source of fertilizers, since it has high contents of both organic matter and nutrients (Weggler- Beaton *et al*., 2000). It has a high nutrient load, suspended solids and dissolved nitrates. It adds available N, P and K, to the soil, suggesting using sewage water as a low grade cheap fertilizer in agriculture which can markedly reduce the cost due to substitution of chemical fertilizers. (Kharche *et al*., 2011; Singh *et al*., 2012). Prolonged wastewater irrigation was reported to produce a significant increase in the total soil nitrogen and phosphorus (Yao *et al*., 2013).

This study aims to investigate the quality of treated sewage water used in the irrigation and its long term influence on some soil properties and nutrient content. The changes in soil properties and nutrient contents due to prolonged treated sewage water irrigation will be also studied compared to those irrigated with both tube well and Nile waters under forest plantation.

Materials and Methods

Study area:-

This study was conducted in Luxor Governorate, that lies in the upper Egypt between Qena Governorate in the north and Aswan Governorate in the south, to evaluate the properties and nutrient status of soils prolonged irrigated with sewage water compared to those irrigated with ground water and Nile water. Location study is considered a part of sewage water management station that is located southeast of Luxor city. The study area approximately lies between latitude of 2522.82'38° " to 2526.28'36°" N and longitude of 3236.01′40°" to 32° 4305.75′" E (Figure 1).

Soil sampling and analyses:-

Four study sites were selected on the basis of differences in the irrigation system (surface and drip irrigation) and the period of irrigation (4 and 15 years). In each site, soil samples were collected from five locations. The samples were taken from each location at 3 depths (0-30 ,30-60 and 6090- cm). In addition, other soil samples were collected at the same depths from two other locations in the study area where the soils were irrigated with ground and Nile waters. Moreover, other soil samples were taken at the same depths from another location where the soil was not ever irrigated (a virgin soil).

Particle- size distribution was carried out by the pipette method and the corresponding textural class was determined from the USDA textural class triangle. Carbonate content of the soil samples was estimated by a Collins calcimeter. The soil organic carbon content was determined according to the modified Walkely and Black method **.** The soil pH was measured by means of a digital pH meter in 1: 1 ratio of soil to water suspension. The Electrical conductivity of the saturated soil paste extract (EC_e) was estimated using an electrical conductivity meter **.** Calcium and magnesium in the soil extract were determined volumetrically by EDTA method, while sodium and potassium were measured by the flame photometer **.** The soil sodium adsorption ratio (SAR_e) was calculated using the equation: $SA\,R_e$ =

Na^{+}

Ca^{2+} $+Mg^{2+}$

2

The available Phosphorus in the soil samples was extracted by 0.5 M $NaHCO_3$ at pH 8.5 and determined spectrophotometrically . The available

potassium in the soil samples was extracted with 1 N ammonium acetate at pH 7.0 and determined using the flame photometer . The total nitrogen in the soil samples was determined using the microkjeldahl method (Page *et al*, 1982, klute, 1986 and USDA, 1996).

Water sampling and analysis:-

Water samples were collected from the three types of water resources (sewage water, groundwater and Nile water). Parameter analysis included pH, total soluble salts, sodium adsorption ratio, residual sodium carbonate, soluble cations and anions, organic matter, total nitrogen, phosphorous and potassium.

The total soluble salts were determined by measuring the electrical conductivity of the water samples (EC_w); the pH of the water samples was measured using a glass electrode**.** Carbonate and bicarbonate, chloride, calcium and magnesium ions in water samples were volumetrically determined by the titration methods**.** Sodium and potassium ions were measured by flame photometer and the sulphate ions were measured using the turbidmetery method **.** The SAR in the water samples was calculated as in the soil samples and the residual sodium carbonates (RSC) were calculated from the equation**:**

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$$

The organic matter content (O.M) of the water samples were done where 250 ml of these samples were evaporated and the organic matter was determined in the evaporates using Walkley and Black method . Other water samples of 250 ml were also evaporated and the evaporaters were then digested using H_2SO_4 and $HCLO_4$ acids. In the digests, the total nitrogen was determined using the microkjeldahl method, the total phosphorus was determined calorimetrically using the chlorostanous phosphomolybdic acid method and the total potassium was estimated using the flame photometer (Page *et al*, 1982).

Results and Discussion

Irrigation water quality

The characterization of the irrigation waters (sewage water, groundwater and Nile water) is present in Table 1. The pH value of the investigated water sources is in the order of sewage water > Nile water > groundwater. Sewage water has a lower pH value compared to Nile water and ground water. Its contains organic acids that may reduce the pH of this water (Mollahoseini, 2013). According to Pescod (1992) the pH of the irrigation waters used in the area under study is considered within the permissible limit. The electrical conductivity (EC_w) of sewage water and groundwater is 0.88 and 1.20 dS/m, respectively. These two water sources are considered moderately saline, while the EC_w value of the Nile water is 0.27 dS/m that is considered slightly saline, according to the guidelines of the US soil salinity laboratory (Ayers and westocot, 1985).

The sodium adsorption ratio (SAR) of all investigated water resources is below 9 that means their sodicity is negligible. Therefore according to EC_w and SAR values, these water sources are of a reasonable quality that can be used for irrigation with few restrictions. Moreover, the residual sodium carbonate (RSC) values of these water sources are below 1.25 meq/l (Table 1). This means that these water sources are safe for irrigation with respect of the RSC (Eaton., 1950 and CAS, 2002).

The concentration of chlorides (Cl) in sewage water and Nile water is less than 4 mmol/l (Table 1). According to Ayers and Westocot (1985), these water sources are considered of a good quality and they can be safely used with respect of Cl concentration. However, the Cl concentration in the groundwater (5.50 mmol/l) is higher than 4 mmol/l, and according to Ayers and westocot (1985), its source is considered slight to moderate concerning its use in irrigation. The organic matter content of the irrigation water sources decreased in the order of sewage water > groundwater >Nile water. This may be due to the high amounts of organic materials in sewage water. The results in Table 1 also show that the concentration of the total nitrogen (N), total phosphorus (P) and total Potassium (K) in the irrigation water sources decreases in the order of sewage water > groundwater >Nile water. Sewage water contains high amounts of organic materials as well as soluble and insoluble phosphate and potassium compounds (Afifi *et al*., 2011).

Long-term effect of irrigation with sewage water .on some soil properties

Soil texture

The results in Table 2 indicate that most of the soil samples had a sandy texture (78.26%), some soil samples accounted by 14.5% had a loamy sand texture and few of them (7.24%) showed sandy loam texture. However the texture of most soil samples does not obviously change with depth.

Under the surface irrigation, all soils that were irrigated with sewage water for 4 years had a sandy texture while some soils that were irrigated with this water for 15 years showed a loamy sand texture, especially in the surface layers. In other wards under their conditions, the soils irrigated for 4 years recorded a higher percentage of sand and lower percentages of both silt and clay compared to those soils that were irrigated for 15 years. The same trend was found in the soils irrigated with sewage water using the drip irrigation system. The soil irrigated with ground water for 15 years still had a sandy texture while those irrigated with Nile water for that period of time showed a loamy sand texture, especially in upper layers. Nile water may carry some suspended silt and clay particles to the surface layers when it is used in irrigating these soils.

Saturation percentage

The saturation percentage (SP) values of the studied soils ranged between 18.64 and 57.44% This parameter reflects the coarse texture of the studied soils (Table2) Most of the soil samples, especially those irrigated with sewage water for 4 years, had lower saturation values than those irrigated for 15 years. In general, the saturation percentage of the studied soil seems to increase with increasing the clay and silt content

Organic matter

The organic matter (O.M) content of the studied soils varied from 0.0 to 1.84% with an average value of 0.23 % (Table 2). The lowest organic matter content was found in the subsurface layers of the non irrigated soil. It showed a scarcity in the plant and animal life. For the same reason, the results also showed that the organic matter content decreased with depth. The soils prolonged irrigated with sewage water resulted in increases in the soil organic matter compared to those irrigated with groundwater and Nile water. This indicates that the irrigation with sewage water helps to improve the fertility status of there soil. These results coincided with those of Khurana and Singh (2012) and Mollahoseini (2013).

Moreover, the soils irrigated with sewage water for 15 years showed a higher organic matter content than those irrigated with this water for 4 years. The irrigation system had a significant effect on the soil organic matter. Under the surface irrigation system, the soil organic matter increased more than under the drip irrigation one. This may be due to the increased amount of water that added to the soil under the surface irrigation system that gives an opportunity to accumulate more organic matter than under the drip irrigation.

Calcium carbonate

The calcium carbonate content of the investigation soils ranged between 0.2 and 11.51% with an average value of 5.64% (Table 2). The lowest calcium carbonate content was recorded for the soil that has been irrigated by sewage water for 15 years under the surface irrigation system. On the other hand, the highest content of calcium carbonate was found in the soil that has been irrigated by groundwater and in the non irrigated soil. Moreover, the results showed that, the long-term use (15 years) of sewage water in irrigation resulted more decreases in the soil calcium carbonate content compared to the short -term use (4 years). This may be related to the decrease in the soil pH due to the production of organic acids as a result of the anaerobic decomposition of organic materials leading to the solubilization of $CaCO_3$ (McClean *et al*., 2003 ; El-Arby *et al*., 2006). The irrigation system did not show a clear effect on the calcium carbonate content of the soils.

Soil reaction (pH)

The soil pH values of the studied area varied between 6.82 and 8.88 (Table 3). In most cases, the pH of the surface layers was lower than that of the subsurface ones, especially for those irrigated by sewage water for long time (15 years). The results also showed that the long-term use (15 years) of sewage water in irrigation resulted in decreases in the soil reaction (pH) more than the short -term use (4 years) of this water. In addition that, use of sewage water in irrigation showed more decrease in the soil (pH) than using Nile water or groundwater in irrigation. The irrigation system also did not show a clear effect on the soil (pH). Rattan *et al*. (2005) reported that the long-term use (20 years) of sewage water in irrigating crops revealed a decrease in the soil pH by 0.4 unit below the initial pH value. Narwal *et al*. (1993) also indicated that the pH of the soil

decreased with sewage water irrigation at all studied locations; a soil pH decrease of about one unit was observed in the soils that were irrigated by sewage water. Yao *et al*. (2013) showed that, the soil pH values of the wastewater-irrigated sites were slightly lower than those of the controlled sites at the same depths. Wastewater-irrigated soils contained higher organic carbon and nitrogen contents, which could promote microorganism activity to break up organic nitrogen molecules into inorganic nitrogen and H^+. Meanwhile, wastewater itself may carry H+ into irrigated soils too. These two aspects could result in lower pH values in wastewater-irrigated soils. Moreover, Dheri *et al*. (2007) indicated that the production of organic acids due to the anaerobic decomposition of organic matter was a principal cause for the reduced pH in the soil irrigated with waste water.

Soil salinity

The electrical conductivity of the saturated soil paste extract (EC_e) of the studied soils is shown in Table 3. The EC_e values of the soils ranged from 0.41 to146.70 dS/m with an average value of 5.21 dS/m. Most of the cultivated soil samples had low salinity (EC_e < 4dS/m). In most of the sewage water irrigated soils, the surface layers showed higher EC_e values than the subsurface ones due to the salt accumulation of this sewage water, El-Desoky and Gameh (1998) found that the sustained use of sewage water in irrigation caused increases in the salinity of the soils, especially in the surface layers. Roshdy (2009) indicated that the use of sewage water in irrigation could result in a salt accumulation in soils which may limit its use under arid and semi-arid conditions.

The results also showed that under the surface irrigation system, the long-term use (15 years) of sewage water in irrigation had higher EC_e values than the short -term use (4 years) of this water. On the other hand, under the drip irrigation systems, the long-term use of sewage water showed lower EC_e values than the short -term use. Moreover, the long-term use of sewage water in irrigation under the surface irrigation system resulted in higher EC_e values than under the drip irrigation system. The long-term use of sewage water in irrigation reduces the infiltration rate and soil porosity with less possibility of a soil structure change under the surface irrigation system more than under the drip irrigation system. This could be related to the low production of suspended materials in the drip irrigation system and thus low possibility of soil porosity clogging. However, under the surface irrigation system, the soil aggregates are dispersed and more fine particles are produced and moved to clog soil voids. This leads to a reduction in the soil porosity and infiltration rate and an increase in the salt accumulation under the surface irrigation system more than under the drip irrigation one. This result is in an agreement with that of Abedi-Koupai *et al*. (2006). On the other hand, the short -term use of sewage water in irrigation under the drip irrigation system showed higher EC_e values than under the surface irrigation system. This may be due to the higher amount of water added to the soil under the surface irrigation system giving an opportunity to leach the accumulated salts more than the drip irrigation one.

The soil sodium adsorption ratio (SAR_e)

The soil sodium adsorption ratio (SAR_e) of the studied soils ranged from 0.28 to 13 with an average value of 1.53 (Table 3). Most of studied soils according to Abegunrin *et al*. (2013) were non alkaline (SAR <13). Most of the sewage water irrigated soils had lower SAR_e values than the groundwater irrigated one. On the other hand, the sewage water irrigated soils showed higher SAR_e values than Nile water irrigated one. In most soils under the long-term use (15 years) of sewage water in irrigation, the SAR_e values of the surface soil layers were lower than those of the subsurface ones. However, in most soils under the short -term use (4 years) of sewage water, the SAR_e values of the surface soil layers were higher than those of the subsurface ones. The results also showed that, in most cases, the soils under the surface irrigation system contained lower SAR_e values than those under drip irrigation one.

Long-term effect of sewage water on some soil nutrients

Table 3 shows the irrigation impact of sewage water on the total nitrogen, available phosphorus and available potassium of the studied soils compared to those irrigated with Nile and ground waters.

TABLE1. Characteristics of water resources used in the irrigation of the studied soils and their maximum permissible limits (MPL) according to Ayers and westcot (19 85) and Pescod (1992).

Parameter	Water resource			MPL
	Sewage water	Groundwater	Nile water	
pH	6.88	7.72	7.15	6.5 – 8.4
EC_w (dS/m)	0.88	1.20	0.27	< 3
SAR	1.47	2.37	0.68	< 9
RSC (meq/l)	- 4.22	- 5.52	- 0.93	< 1.25
Na^+ (mmol/l)	3.33	5.18	0.95	-
K^+ (mmol/l)	0.53	0.58	0.05	-
Ca^{+2} (mmol/l)	2.75	1.25	0.65	-
Mg^{+2} (mmol/l)	2.42	3.52	0.62	-
Cl^- (mmol/l)	2.52	5.50	0.90	< 4
HCO_3^- (mmol/l)	6.12	4.00	0.55	-
SO_4^{-2} (mmol/l)	0.19	2.9	1.05	-
O.M (mg/l)	40	30	20	-
N (mg/l)	3.64	3.36	1.12	-
P (mg/l)	13.87	1.88	1.99	-
K (mg/l)	24.26	22.68	1.96	-

TABLE 2. Effect of water source, irrigation system, and irrigation use period on the soil texture, saturation percentage (SP), organic matter (OM) and calcium carbonate ($CaCO_3$) of the studied soils

Water Source and Irrigation System	Period	ample No.	Depth (cm)	Particle-size distribution (%)			Soil texture	SP (%)	OM (%)	CaCO3 (%)
				Sand	Silt	clay				
Sewage water Surface irrigation	4 years	1	0 – 30	90.87	6.69	2.44	sand	25.67	0.11	8.96
			30 – 60	90.35	7.68	1.97	sand	25.70	0.10	8.16
			60 – 90	91.01	4.34	4.65	sand	23.81	0.03	8.96
		2	0 – 30	94.36	2.61	3.04	sand	23.83	0.20	7.31
			30 – 60	93.12	4.39	2.49	sand	24.82	0.17	7.49
			60 – 90	89.94	5.89	4.18	sand	26.91	0.00	10.54
		3	0 – 30	85.48	11.45	3.07	sand	25.44	0.20	8.88
			30 – 60	94.16	4.39	1.45	sand	24.50	0.07	6.41
			60 – 90	93.89	3.16	2.95	sand	28.04	0.01	5.74
		4	0 – 30	85.48	11.45	3.07	sand	25.31	0.13	11.51
			30 – 60	91.42	6.13	2.45	sand	26.38	0.12	8.02
			60 – 90	89.76	7.39	2.86	sand	26.42	0.11	11.30
		5	0 – 30	89.76	7.39	2.86	sand	27.92	0.34	10.13
			30 – 60	89.03	9.05	1.92	sand	25.67	0.19	8.92
			60 – 90	92.17	5.39	2.44	sand	25.70	0.01	8.57
	15 years	1	0 – 30	82.44	14.30	3.25	Loamy sand	33.62	1.84	4.58
			30 – 60	87.09	9.60	3.31	Sand	23.35	0.06	5.73
			60 – 90	87.06	9.19	3.76	Sand	22.86	0.00	5.06
		2	0 – 30	88.42	1.89	9.69	Loamy sand	26.80	0.62	0.20
			30 – 60	95.37	1.22	3.42	sand	23.19	0.03	6.16
			60 – 90	81.25	11.80	6.95	Loamy sand	20.72	0.07	6.68
		3	0 – 30	88.82	5.47	5.71	Sand	29.72	0.81	4.84
			30 – 60	90.36	6.10	3.55	Sand	20.05	0.10	5.12
			60 – 90	94.51	1.66	3.84	sand	19.29	0.10	5.57
		4	0 – 30	91.60	4.86	3.54	Sand	27.01	0.94	2.18
			30 – 60	94.61	3.96	1.42	Sand	25.03	0.26	5.58
			60 – 90	90.60	5.09	4.32	sand	23.37	0.10	6.38
		5	0 – 30	89.51	6.88	3.61	Sand	33.47	1.14	2.15
			30 – 60	94.61	3.96	1.42	Sand	25.22	0.10	5.85
			60 – 90	92.19	7.60	0.22	sand	26.91	0.14	5.84
Sewage water Drip irrigation	4 years	1	0 – 30	93.97	3.03	3.00	sand	24.89	0.16	6.52
			30 – 60	92.06	4.46	3.48	sand	22.60	0.04	5.36
			60 – 90	94.88	1.88	3.24	sand	21.64	0.05	5.97
		2	0 – 30	95.00	2.98	2.03	sand	22.52	0.14	5.37
			30 – 60	92.57	4.34	3.09	sand	25.37	0.04	6.24
			60 – 90	91.78	7.51	0.71	sand	18.64	0.04	3.98
		3	0 – 30	54.10	42.76	3.14	sand	23.19	0.16	5.62
			30 – 60	93.95	4.06	1.99	sand	21.57	0.08	4.96
			60 – 90	91.58	5.35	3.07	sand	22.10	0.10	7.15
		4	0 – 30	91.96	4.25	3.80	sand	20.28	0.04	5.77
			30 – 60	92.88	4.13	2.98	sand	22.84	0.06	5.29
			60 – 90	94.76	2.29	2.95	sand	20.27	0.01	5.71
		5	0 – 30	95.00	2.98	2.03	sand	21.69	0.07	5.52
			30 – 60	94.51	2.56	2.93	sand	20.83	0.00	5.26
			60 – 90	94.58	1.34	4.08	sand	23.76	0.03	4.36

Water Source and Irrigation System	Period	ample No.	Depth (cm)	Particle-size distribution (%) Sand	Silt	clay	Soil texture	SP (%)	OM (%)	CaCO3 (%)
Sewage water Drip irrigation	15 years	1	0 – 30	88.19	7.55	4.26	Sand	22.41	1.03	6.00
			30 – 60	87.12	10.69	2.19	Sand	20.08	0.21	8.02
			60 – 90	86.44	12.14	1.42	sand	22.13	0.01	7.94
		2	0 – 30	77.82	18.93	3.26	Loamy sand	24.41	0.51	2.43
			30 – 60	94.25	3.63	2.12	sand	23.06	0.11	0.20
			60 – 90	72.54	16.65	10.81	Sandy loam	40.39	0.06	1.26
		3	0 – 30	77.83	18.94	3.27	Loamy sand	24.69	0.32	4.90
			30 – 60	77.17	17.81	5.02	Loamy sand	43.90	0.17	1.60
			60 – 90	80.32	16.75	2.94	Loamy sand	39.71	0.06	0.67
		4	0 – 30	87.80	8.35	3.86	Sand	26.93	0.82	4.19
			30 – 60	72.36	24.05	3.59	Sandy loam	50.25	0.08	2.17
			60 – 90	71.71	25.69	2.60	Sandy loam	43.82	0.01	1.23
		5	0 – 30	87.58	8.06	4.36	Sand	29.19	0.78	4.49
			30 – 60	65.47	31.42	3.12	Sandy loam	54.08	0.10	1.39
			60 – 90	65.04	31.68	3.28	Sandy loam	57.44	0.06	0.61
Groundwater Surface irrigation		15 years	0 – 30	87.24	11.01	1.75	sand	21.57	0.48	4.89
			30 – 60	89.85	7.40	2.76	sand	33.98	0.08	9.66
			60 – 90	87.39	11.77	0.84	sand	36.98	0.07	10.70
Nile water surface irrigation		15 years	0 – 30	84.60	9.35	6.05	Loamy sand	21.44	0.22	0.75
			30 – 60	84.22	7.95	7.84	Loamy sand	23.34	0.11	1.81
			60 – 90	90.30	2.94	6.76	sand	23.17	0.16	5.23
Non irrigated soil			0 – 30	94.95	1.03	4.02	sand	22.73	0.04	8.19
			30 – 60	82.21	14.42	3.37	Loamy sand	24.31	0.03	7.25
			60 – 90	93.67	2.30	4.03	sand	23.24	0.12	7.51

TABLE 3. **Effect of water source, irrigation system, and irrigation use period on the (pH), salinity (EC_e), sodium adsorption ratio (SAR_e), total nitrogen (N), available phosphorus (P) and available potassium (K) of the studied soils**

Water Source and Irrigation System	Period	Sample No.	Depth (cm)	pH (1:1)	EC_e (dS/m)	SAR_e	N (mg/kg)	P (mg/ kg)	K (mg/kg)
Sewage water Surface irrigation	4 years	1	0 – 30	7.68	1.48	1.03	36.44	36.58	165.89
			30 – 60	7.66	1.28	0.28	31.54	42.51	217.62
			60 – 90	8.27	1.73	0.34	30.56	23.60	155.61
		2	0 – 30	8.10	1.24	0.54	62.63	21.54	156.38
			30 – 60	8.46	0.66	0.50	55.26	92.70	227.10
			60 – 90	8.19	0.59	0.44	31.56	163.48	175.93
		3	0 – 30	7.55	0.90	0.99	63.41	36.70	165.50
			30 – 60	7.95	2.19	1.64	22.20	23.41	135.32
			60 – 90	8.19	1.23	1.15	18.56	22.60	115.06
		4	0 – 30	7.70	2.53	1.94	39.96	36.58	335.51
			30 – 60	7.94	1.40	0.69	35.42	65.92	134.99
			60 – 90	7.87	1.52	0.71	36.56	70.41	207.46
		5	0 – 30	8.05	1.58	0.39	108.02	51.50	297.55
			30 – 60	7.96	0.76	0.89	59.47	10.86	156.66
			60 – 90	8.19	0.77	0.89	36.46	8.86	126.03
	15 years	1	0 – 30	7.45	3.44	0.61	156.87	108.43	489.58
			30 – 60	8.33	0.71	1.15	70.34	70.70	328.52
			60 – 90	8.09	0.45	0.93	33.11	8.24	236.10
		2	0 – 30	7.15	1.44	0.52	198.21	96.44	166.16
			30 – 60	8.12	0.98	0.81	69.81	32.21	365.48
			60 – 90	7.86	0.56	0.65	33.11	35.21	358.64
		3	0 – 30	7.37	0.82	0.29	128.94	27.72	245.94
			30 – 60	7.86	1.76	0.57	81.93	24.16	146.50
			60 – 90	7.65	1.39	0.51	33.11	42.51	144.97
		4	0 – 30	7.39	3.42	1.05	157.50	72.10	267.65
			30 – 60	7.89	1.84	0.85	69.81	131.84	176.62
			60 – 90	8.12	1.76	0.86	25.57	79.78	173.99
		5	0 – 30	6.82	3.37	0.76	156.60	29.42	196.05
			30 – 60	8.18	1.71	0.89	32.47	31.65	64.97
			60 – 90	7.59	2.56	1.05	44.25	40.82	133.51
Sewage water Drip irrigation	4 years	1	0 – 30	7.79	2.04	0.53	50.64	53.52	264.91
			30 – 60	8.32	0.61	0.94	13.54	20.04	144.08
			60 – 90	7.99	0.68	1.01	14.53	11.24	166.24
		2	0 – 30	7.63	3.94	1.47	45.74	47.00	237.89
			30 – 60	8.23	0.78	0.56	13.75	20.04	124.76
			60 – 90	8.50	0.88	0.70	14.03	37.76	185.58
		3	0 – 30	7.37	10.49	5.15	50.05	29.03	257.49
			30 – 60	8.22	0.88	1.64	25.56	21.04	94.56
			60 – 90	8.21	1.35	2.00	30.51	38.76	104.86
		4	0 – 30	7.53	15.56	4.61	14.13	28.09	325.92
			30 – 60	8.27	1.93	1.18	15.77	29.78	93.34
			60 – 90	8.19	1.53	1.11	11.42	11.24	95.36
		5	0 – 30	7.86	7.78	1.11	20.82	46.44	267.35
			30 – 60	7.82	1.40	1.48	14.13	72.66	54.51
			60 – 90	7.79	2.04	1.09	12.93	39.76	135.10

Water Source and Irrigation System	Period	Sample No.	Depth (cm)	pH (1:1)	EC_e (dS/m)	SAR_e	N (mg/kg)	P (mg/ kg)	K (mg/kg)
Sewage water Drip irrigation system	15 years	1	0 - 30	7.86	2.11	0.67	141.67	79.78	327.09
			30 - 60	8.05	1.03	0.57	65.51	35.77	227.05
			60 - 90	8.07	0.73	0.45	10.96	15.02	224.70
		2	0 - 30	7.45	1.41	1.04	58.68	93.07	328.78
			30 - 60	8.18	1.29	3.28	33.55	82.02	205.98
			60 - 90	7.40	2.33	3.36	18.90	93.26	528.97
		3	0 - 30	8.02	1.40	1.03	101.14	50.56	268.47
			30 - 60	8.10	0.65	1.68	52.73	43.26	639.59
			60 - 90	7.77	0.68	1.83	19.63	16.12	488.80
		4	0 - 30	7.52	1.90	0.85	64.64	55.84	358.56
			30 - 60	7.75	0.77	1.28	26.05	35.06	674.48
			60 - 90	7.69	0.54	1.14	10.96	15.12	525.74
		5	0 - 30	7.35	4.25	2.08	107.23	55.81	377.76
			30 - 60	7.24	7.70	2.82	31.43	14.23	661.73
			60 - 90	7.09	0.65	0.80	18.94	36.52	632.27
Groundwater Surface irrigation		15 years	0 - 30	8.42	3.35	3.07	70.48	29.59	309.74
			30 - 60	8.88	2.30	2.02	78.31	57.87	187.07
			60 - 90	8.81	2.32	1.95	22.26	37.45	216.94
Nile water Surface irrigation		15 years	0 - 30	7.82	0.47	0.47	69.52	23.78	429.13
			30 - 60	8.06	0.75	0.51	59.02	53.37	512.25
			60 - 90	8.16	0.41	0.37	50.68	19.66	24.32
Non irrigated soil			0 - 30	8.08	15.81	4.73	0.00	0.00	672.11
			30 - 60	7.67	63.50	8.37	0.00	0.00	337.44
			60 - 90	7.46	146.70	13.01	0.00	12.55	337.71

Total Nitrogen

The total nitrogen in the studied soils varied from 0.0 to 198.21 mg/kg with an average value of 50.98 mg/kg (Table 3). Generally, increases in the total N of all studied soils occurred as a result of the irrigation with sewage water compared to the non irrigated soil. The soils prolonged irrigated (15 years) with sewage water under the surface irrigation system showed higher values of the total nitrogen than those irrigated with Nile water or groundwater . Hussain *et al.* (2002) found that the sewage water contained organic and inorganic compounds that included nutrients like nitrogen. Afifi *et al*. (2011) revealed that the use of sewage water in irrigation led to an increase in the total nitrogen contents of the soil after harvesting. This may be due to the high concentration of nitrogen in the sewage water. The irrigation system had an effect on the total nitrogen contents of the soil. In most cases, the soils under the surface irrigation system showed higher values of the total nitrogen than the soils under the drip irrigation system. This may be attributed to the increased amount of water added to the soils under the surface irrigation system that gives an opportunity to accumulate more organic matter and inorganic compounds including nutrients like nitrogen (N) than under the drip irrigation system. In most cases, the total nitrogen of the soils prolonged (15 years) irrigated with sewage water were higher than those irrigated with sewage water for a short period (4 years). The results also showed that, in most soil samples, the total nitrogen decreased with depth.

Available phosphorus

The available phosphorus of the studied soils ranged from 0.0 to 131.34 mg/kg with an average value of 42.51 mg/kg (Table 3). In general, increases in the available phosphorus of all studied soils irrigated with sewage water occurred compared to those of the non irrigated soil. The soils irrigated with sewage water for a long time (15 years) under the surface irrigation system had higher available phosphorus values than those irrigated with Nile water or groundwater.

In most cases, the available phosphorus values of the soils under the long-term (15 years) irrigation with sewage water were higher than those under the short term use (4 years) of sewage water. El-Khateeb et al. (2012) indicated that the available phosphorus of the forest soils clearly increased as a result of the irrigation with sewage water; their results varied due to the period of irrigation. Use of domestic wastewater in irrigation can provides essential nutrients to the crops and improves the fertility level of soils (Ladwani *et al*., 2012).

In addition, Kharche *et al*. (2011) and Singh *et al*. (2012) found that the sewage irrigated soils recorded high available P levels indicating their significant additions through sewage water as low grade cheap fertilizers. Moreover in most cases, the soils under the surface irrigation system showed higher available phosphorus contents than those under the drip irrigation system. The increased amount of sewage water added to the soil under the surface irrigation system gives an opportunity for organic matter and inorganic compounds that include nutrients like phosphorus to accumulate more than under the drip irrigation system.

Available potassium

The available potassium in the studied soils ranged from 24.32 to 674.48 mg/kg with an average value of 271.35mg/kg (Table 3). Generally, the available potassium in most studied soils increased as a result of the long-term irrigation with sewage water, especially in the surface soil layers compared to that in the soils irrigated with Nile water or groundwater. The soils prolonged (15 years) irrigated with sewage water contained higher available potassium values than those irrigated with sewage water for a short period (4 years). Ghafoor (1999) reported that the irrigation with sewage water increased the total potassium and the yield of rabi crops compared to the irrigation with well water. Saffari and Saffari (2013) also indicated that the irrigation with waste water increased the soil potassium contents. In addition, the long-term use of sewage water

in irrigation under the drip irrigation system showed higher soil available potassium values than its use under the surface irrigation system, This may be attributed to the increased amounts of water added to the soils under the surface irrigation system that cause the potassium to leach from the surface layers to the subsurface ones.

Conclusions

The present research was done in order to study the effects of the treated sewage water on some soil chemical properties. On the basis of currently available data, the soil salinity level remained normal and the sodium level indicated by the soil sodium adsorption ratio (SAR_e) was below the critical level of 13, indicating no threat to the soil quality. Hence the soils could be suitable for crop production. The irrigation with sewage water also improved the chemical properties and fertility status of the studied soils. It increased levels of OM, N, K, and P in the soils while it decreased the pH and $CaCO_3$ of the soils. The use of sewage water for irrigating crops has nutritional benefits in using a water resource that would otherwise be discarded. Sewage water irrigation also reduces the use of other water sources espeasally fresh water that can be used elsewhere such as for drinking. Other factors have to be considered and studied with using sewage water in irrigation including the presence of pathogens and chemical contaminants as well as salinity impacts on the soil structure. These can be controlled through sewage water treatment and effective farm management practices. Future research and development must focus on the use of wastewater in agriculture because fresh water sources for agriculture are diminishing while the amounts of wastewater from cities are rapidly increasing due to rapid population explosions and industrialization.

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"التاثير طويل الامد لمياه الصرف الصحى المعالجة على بعض الخواص والحالة الغذائية للتربة فى محافظة الاقصر- مصر "

حسنى مبارك فراج[1] محمد علي الدسوقي[2] ، أبو بكر عبد المنعم أبوبكر باشا[1] و ناديه محمد كمال رشدى [2]

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هذه الدراسةِ نُفّذتْ فى محافظة الاقصر – جنوب مصر لدراسة تأثيرِ استخدام مياه الصرف الصحى المعالجة فى رى الغابات الشجريه على بعض الخواص وحالة بعض العناصر الغذائية للتربه , حيث تم جمع عينات من مياه المجارى والمياه الجوفيه و مياه النيل بالاضافة الى عينات من التربة المرويه بهذه المياه , وتم تحليل هذه العينات واسفرت نتائج التحليل على الاتى :-

تعتبر مياه الصرف الصحى المعالجة والمياه الجوفيه متوسطة الملوحه حيث قيمة التوصيل الكهربى لها (EC_w) (0.88 و 1.20 دى سيمنز/متر على التوالى فى حين ان مياه النيل تعتبر منخفضة الملوحه حيث قيمة EC_w لها 0.271 دى سيمنز/ متر . وتعبر جميع مصادر المياه عاليه الجوده ويمكن استعمالها فى الرى بدون اى قيود وذلك فيما يتعلق بقيمة كل من SAR و RSC و تركيز الكلوريد. كما تحتوى مياه الصرف الصحى المعالجة على كميه كبيرة من الماده العضويه, النيتروجين , الفوسفور والبوتاسيوم مقارنة بالمياه الجوفيه ومياه النيل.

ومن ناحية أخرى أظهرت النتائج ان معظم عينات التربة التى تروى بمياه الصرف الصحى منخفضة الملوحة ($EC_e < 4$ dS/m) ونسبة الصوديوم المدمص (SAR_e) اقل من المستوى الحرج (13) وهذا يدل على عدم وجود اى خطر على جودة التربة عند استخدام مياه الصرف الصحى المعالج فى الرى . وقد ادى استخدام مياه الصرف الصحى فى الرى الى تحسين بعض خواص التربة الكيميائية وحالة خصوبة التربة, حيث زاد محتوى التربة من الماده العضويه والنيتروجين الكلى والكميه الميسره من كل من الفوسفور والبوتاسيوم فى حين حدث انخفاض فى كل من قيمة ال pH و محتوى التربة من كربونات الكالسيوم. كما اظهرت النتائج ان لنظام الرى بمياه الصرف الصحى تاثيرا على خواص التربة , حيث وجد ان التربة المروية بمياه الصرف الصحى تحت نظام الرى السطحى اظهرت قيم اعلى من التوصيل الكهربى , الماده العضويه , النيتروجين الكلى و الفوسفور الميسر بينما كانت قيمة نسبة الصوديوم المدمص والبوتاسيوم الميسر اقل بالمقارنة مع التربة تحت نظام الرى بالتنقيط . كما ان رى التربة لفتره طويله (15 سنه) باستخدام مياه الصرف الصحى ادى الى زيادة السعة التشبعيه , المادة العضويه , النيتروجين الكلى والكمية الميسره من كل من الفوسفور والبوتاسيوم للتربة بينما قلت قيمة pH , ونسبة الصوديوم المدمص و محتوى التربه من كربونات الكالسيوم بالمقارنة بالاستخدام قصير الامد (4 سنوات) لمياه الصرف الصحى فى الرى .