Egyptian Sugar Journal (2022), 19: 1-11
https:// doi.org/10.21608/ESUGJ. 2022.150163.1015

RESEARCH ARTICLE

Environmental negative and positive impacts of treated sewage water on the soil: A case study from Sohag governorate, Egypt

Shaimaa M. Mostafa[1], Mohsen A. Gameh[2], Mohamed M. Abd ElWahab[3], Mohamed A. EL Desoky[2], Osama Ibrahim Negim[4]

Received: 17 July / Revised 28 August 2022/Accepted 4 September / Published online: 11 September 2022

Abstract

This study aims to investigate the environmental negative and positive impacts of treated sewage water on the soil at two sites (El Cola and El-Deir), Sohag Governorate, Egypt. The changes in soil properties and nutrient contents due to prolonged treated sewage water irrigation were also studied compared to non-irrigated soils on the subsurface layers. The results indicate that most of the soil samples in El Cola and El Deir area - Sohag governorate have a sandy texture. soil pH values of the studied area varied between 7.1 and 8.23 In most cases, pH of the surface layers was lower than that of the subsurface ones, especially for those irrigated by sewage water for a long time (20, 19, 29 and 21 years). The ECe values of the soils (El Cola and El Deir) ranged from 0.7 to 1.4 ds/m with an average value of 1.1 dS/m. Most of the cultivated soil samples had low salinity (ECe < 4dS/m). In most of the sewage water irrigated soils, the surface layers showed higher ECe values than the subsurface ones due to the salt accumulation of this sewage water. Moreover, soil organic matter content tended to decrease with depth and soil prolonged irrigated with sewage water increased the soil organic matter compared to the short time irrigated soil. In general, the results also showed that increases in the total N, available phosphorus and available K 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 were higher than those under short-term use. A positive significant correlation between nutrients (total N and available K) and soil organic matter was found and it suggests that sewage irrigation helps to increase levels of soil organic matter and hence improve the fertility status of the soil.,Regarding to heavy metals, the soil contents of all investigated heavy metals (Cd, Zn, Cu, Pb and Ni) are lower than their corresponding values of the common range, background and average concentrations for world soils. However, in term of contamination factor (CF), the soil samples have CF values ranged from 1 to 48 in El-Cola and from 0.6 to 19 in El-Deir, indicating the pollution levels are in the range of low or moderate to very high levels Among all metals, Pb showed the highest values of CF (48 mg per kg).

Keywords: Toxic trace metals; Soils; Sewage wastewater; Contamination.

Introduction

Irrigation forests with sewage water for energy and timber production in Egypt is an approach that helps to overcome health hazards associated with sewage farming. Hopefully, sewage water will help in the expansion of the irrigated agriculture or save 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 Sohag governorates, samples of sewage water, soil irrigated with these water sources were collected and analyzed.

However, such wastewater exerts most of the nutrient load and could be used as irrigation water for certain crops, trees and plants which may lead to an increase in agricultural produce and plantation. It has the potential to supply (organic) carbon nutrients (NPK) and (inorganic micronutrients to support crop/plant growth. In agriculture practices, the irrigation water quality is believed to have an effect on the soil characteristics, crop production and management of water (Gregory 2000; Sheinberg 1987). Water results in a reduction in crop yield and deterioration of the physical/chemical properties of soil Therefore, it has more concern to the people/ farmers when being used as an irrigate, which may contain constituents capable of creating adverse effects on the soil media and the agriculture produce. The use of primary and secondary effluents in irrigation can improve the quality of the soil and plant growth because they are considered as an organic matter-rich source, however, direct application of wastewater on agricultural

[1*] Department of Environmental Science and Pollution Treatment, Faculty of Sugar and Integrated Industries Technology, Assiut University, Egypt.
[2]Soil and Water Department, Faculty of Agricultural., Assiut University, Egypt.
[3]Chemistry Department, Faculty of Science, Assiut University, Egypt.
[4]Soil and Water Department, Faculty of Agricultural, Sohag University, Egypt.
***Corresponding author:** Shaimaa mostafa829@yahoo.com

land is limited by the extent of contamination with heavy metals, toxic organic chemicals and pathogens (Ali et al. 2012).

A wide range of new projects has been fulfilled in Egypt aiming at expanding the green stretch in the desert by introducing forest plantations using treated sewage waters to produce timber trees of a high economic value. The use of treated wastewater for irrigation in agriculture achieves three advantages: 1) Using the fertilizing properties of the water (Fertirrigation) eliminates a part of the demand for synthetic fertilizer, 2) The practice increases the available agricultural water resource, and 3) It may eliminate the need for expensive tertiary treatment. Poor water quality degrades the soil quality that results from the accumulation of heavy metals and alteration of the soil physical and chemical properties. it also influences the soil health that affects human health to a great extent (Yerasi 2013) The prolonged reuse of sewage wastewater for irrigated agriculture increases the soil heavy metals content in comparison with using Nile water (El koli 2000) Heavy metals are accumulated in sewage and wastewater treated soil in excessive amounts enough to cause health problems for animals and human beings which consume a plant that grows on this soil (Yadav 2002) Since these sewage effluents carry low levels of heavy metals, buildup of these Review 4 metals in the soil that are irrigated with these waters depends also upon the application time period (El-Desoky 1998). The present study deals with the application of domestic wastewater for irrigation and its effect on soil properties, crop yield and quality. Effect of irrigation water on yield and quality of crops, the use of sewage has favorably influenced the crop production; its continuous application for number of years may result in enrichment in top soils (Anderson 1972). This study aims to investigate the Environmental negative and positive impacts of treated sewage water on the soil. changes in soil properties and nutrient contents due to irrigation with prolonged treated sewage water compared to non-irrigated soils.

Materials and methods

Study area

This study was conducted in Sohag Governorate, in the Upper Egypt north of Assuit Governorate and south of Qena Governorate ,to evaluate the properties and nutrient status of soils prolonged, shortly irrigated with sewage water as compared to the non-irrigated.

Soil sampling and analyses

Study sites were selected based on differences in the period of irrigation (from 7 to 21 years) On El Cola, and (from 9 to 29 years) on El Deir. The samples were taken from each location at 3 depths (0 - 30 ,30 - 60 and 60-90 cm). Moreover, other soil samples were taken at the same depths from the non-irrigated locations where the soil was not ever irrigated.

Analytical methods

The particle-size distribution: was carried out by the pipette method (Richards 1954; Jackson 1973), the corresponding textural class was determined from the USDA textural class triangle. The soil organic matter (OM): content was determined using the dichromate oxidation method described by (Jackson 1973). The calcium carbonate: content of the soil samples was estimated by a Collins calciminer according to (Jackson 1973) and (US-EPA 1996). The soil pH: was measured by means of a digital pH meter in a 1:1 ratio of the soil to water suspension by PH meter, HANNA instrument according to (Taylor et al. 1985). The electrical conductivity: tile saturated soil paste extract (ECc) was estimated using an electrical conductivity meter (Jackson 1973). Soluble Cations and anions (Na^+, K^+, Ca+2and Mg) and soluble anions (C_l^- and HCO_3^-, SO_4^-): were volumetrically determined by the titration methods according to Jackson 1973) Using electrical conductivity meter- Orion Model 1950. Sodium and potassium in the extract were measured by flame photometer, sulphates were determined using the turbidimeter method (Jackson 1973) using flame photometer (CL378-ELICO) N,P,K (Jackson1973). determined by ICP – OES (Optima8300). Heavy metals determined by ICP – OES (Optima8300) according to (USEPA, 1996).

Result and discussion

Assessment of soil characteristics

Soil texture

The texture or the particle size distribution is one of the most important measures of the soil because it affects most chemical reactions release of nutrient elements and retention of soil moisture. Also, soil texture as abiotic factor, influences the distribution of minerals, organic matter, retention, microbial biomass and other soil properties. It represents one of the most important factors influencing the structure of microbial communities as well as PH, cation exchange, capacity, and organic matter content (Girvan 2003). Most of the soil samples in El Cola and El Deir region have a sandy texture. The texture of most soil samples does not obviously change with depth. in most soils irrigated with sewage water for a long time (20,19,21 and 19 years). Clay and silt contents in the surface layers are lower than in the subsurface one., on the other hand, most soils irrigated with sewage water for a short time (7,9,10,11 and 12 years) clay and silt contents in the surface layer are higher than in the subsurface one., the soil samples does not obviously change with depth.

Organic matter

The organic matter (OM) content of the studied soil in El Cola varies between 0.1 to 0.8% with an average value 0.45%, the soil irrigated for a long time (20 and 19 years)., the lowest organic matter content is found in the surface layers on the non-irrigated soil which show scarcity in the plant and animal life., for the same reason, the results also show that the organic matter content decrease with depth ,the long-term use (20 and 19 years) of sewage irrigation results in increases in the soil organic matter content compared to the short – term use (7, 10, 11 and 12 years).

On El Deir (OM) content of the studied soil in El Deir varies between with an average value 1.0 to 1.6 % with in average range 1.3 %, the soil irrigated for a long time (19 and 21years).

Organic matter content decreases with depth. soil prolonged irrigated with sewage water have increases in the soil organic matter compared to the short time irrigated soil. these results coincide with those (Rattan 2005; Khurana 2012; Molla Hosseini 2013).

The irrigation system has a significant effect on the soil organic matter., under the surface irrigation system, the soil organic matter increases more in the surface irrigation compared to the dripping irrigation. this may be due to the increased amount of water that added to the soil under the surface irrigation system that gave an opportunity to accumulate more organic matter than under the drip irrigation.

Table 1. Effect of sewage water, irrigation period on the soil texture, organic matter, calcium carbonate ($CaCo_3$).

period	Depth meter	Particle size distribution %				OM%	$CaCo_3$ %
		Sand	Silt	Clay	Soil texture		
				El Cola			
Not irrigated	0-30	95.5	1.3	3.2	Sand	0.2	6.1
7 years	0-30	68.4	15.5	16.1	Sand	0.8	4.98
	30-60	77.2	13.5	9.3	Sand	0.7	4.0
	60-90	87.5	9.1	3.4	Sand	0.6	2.89
10 years	0-30	66.3	22.9	10.8	Sand	0.3	5.52
	30-60	72.6	17.5	9.9	Sand	0.2	5.57
	60-90	62.5	23.8	13.7	Sand	0.2	5.90
	0-30	81.8	7.2	11	Sand	0.4	5.9
11years	30-60	97.1	2.5	0.4	Sand	0.1	5.2
	60-90	80.3	12.3	7.4	Sand	0.1	4.3
	0-30	69.7	23	7.3	Sand	0.5	5.89
12 years	30-60	88.2	8.3	3.5	Sand	0.3	5.12
	60-90	87.3	9.7	3	Sand	0.2	4.57
	0-30	95.5	2.3	2.2	Sand	0.4	4.9
19 years	30-60	80.8	12.3	7.4	Sand	0.3	4.8
	60-90	79	13	8	Sand	0.3	4.8
	0-30	90.5	5.3	4.2	Sand	0. 6	5.0
20 years	30-60	88.8	6.9	4.3	Sand	0.1	5.0
	60-90	85.2	7.8	7.0	Sand	0.1	4.2
				El Deir			
Not irrigated	0-30	83.6	12.7	3.7	Sand	0.2	6.52
9 years	0-30	88.5	8.9	2.6	Sand	0.4	4.8
	30-60	73.4	18.9	7.7	Sand	0.4	4.4
	60-90	71.6	16.2	12.2	Sand	0.4	4.0
19 years	0-30	87.2	10.3	2.5	Sand	1.6	5.7
	30-60	78.5	18.3	3.2	Sand	1.4	5.90
	60-90	71.6	16.2	12.2	Sand	1.0	5.70
21 years	0-30	80.9	10.8	1.3	Sand	1.7	5.0
	30-60	73.4	18.9	7.7	Sand	1.6	5.0
	60-90	91.3	3.2	5.5	Sand	1.2	5.2

EKB

Calcium carbonate.

Calcium carbonate as shown in table 1 content varies between with an average 4.8 % El Deir, 2.8 El Cola, lowest calcium carbonate in this location is found in the surface layers of the irrigated soils by sewage water for (20, 19, 19 and 21 years). on the other hand, the highest content of calcium carbonate is shown in short-term irrigation especially (10 years of irrigation) than the long-term irrigation, which may be attributed to the increase in organic matter and the decrease in the soil PH due to the production of organic acids as a result of the anaerobic decomposition of organic materials that leads to solubilization of $CaCo_3$ in the sewage irrigated with sewage water for a long time compared to those irrigated with sewage water for a short-time in addition, most soil samples, calcium carbonate decreases with depth, Non-irrigated soil records the highest content of calcium carbonate (McClean 2003; El-Arby 2006).

Soil pH

Table 2 indicates that soil pH values of the studied area varied between 7.1 and 8.23 In most cases, pH of the surface layers was lower than that of the subsurface ones, especially for those irrigated by sewage water for a long time (20, 19 and 21 years). The results also showed that the long-term use (20, 19, 19 and 21 years) of sewage water in irrigation resulted in decreasing the soil reaction (pH) more than short-term (7, 9, 11 and 12 years) of this water, 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, also indicated that the pH of the soil (Rattan 2005; Narwal 1993; Yao 2013).

A decrease 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., 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, 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 wastewater (Dheri 2007).

Soil Salinity

The electrical conductivity of the saturated soil paste extract (ECe) of the studied soils is shown in Table 2., The EC_e values of the soils (El Cola and El Deir) ranged from 0.7 to 1.4 ds/m with an average value of 1.1 dS/m. Most of the cultivated soil samples had low salinity (ECe < 4dS/m). In most of the sewage water irrigated soils, the surface layers showed higher ECe values than the subsurface ones due to the salt accumulation of this sewage water, the sustained use of sewage water in irrigation caused increases in the salinity of the soils, especially in the surface layers., 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 (19, 20, 21 and 19 years) of sewage water in irrigation had higher ECe values than short-erm use of this water (7, 9, 10, 11 and 12 years). On the other hand, under the drip irrigation systems, long-term use of sewage water showed lower ECe values than short-term use. Moreover, the long-term use of sewage water in irrigation under the surface irrigation system resulted in higher ECe 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, infiltration rate and an increase in the salt accumulation under the surface irrigation system more than under the drip irrigation one (Roshdy and Nadia 2009; Abedi-Koupai and Sohrab 2004).

Soluble cation and anions

The soluble Na^+ of the studied soils in El Cola location is shown in table 2 in generally varies from 7 to 17 m mole/kg with an average of 12 m mole/kg on El Cola and El Deir region.

The highest level of soluble sodium found in the non-irrigated soil., on the other hand, the lowest level of soluble sodium is found in soils prolonged irrigation with sewage water (19, 20, 21 and 29 years), in most of the investigated soil, soluble Na^+ concentration decreases with depth. in addition, its concentration in the soil prolonged irrigation with sewage water (19, 20, 21 and 29 years) is lower than in these shortly irrigated with sewer water (7, 9, 10, 11 and 12 years), especially in the surface soil layers, soils irrigated with sewage water for a short time, have higher soluble sodium concentration than those irrigated with sewage water for a long time.

The range of soluble mg^{2+} in El Cola studied soil is generally from 2.8 to 6.0 m mole/ kg with an average value of 4.4 mmole / kg, The soluble mg^{2+} concentration decrease with depth, soil prolonged irrigated (19, 20, 21 and 29 years) contain lower soluble mg^{2+} values than those shortly irrigated especially in the surface soil layers. most of these soils contain levels of soluble mg^{2+} less than those of soluble Ca^{2+}., The distribution of soluble Ca^{+2} with depth does not have a systematic variation in most of this soil., however, some soils show a decrease in the soluble Ca^{2+} with depth., also there are no constant distribution trends for soluble Ca^{2+} , soil shortly irrigated with sewage water contain lower amount of soluble Ca^{+2} and mg^{+2} than those prolonged irrigated with this water especially in the surface soil layer.

The soluble CL^- concentration in the investigated soils of El Cola generally range from 0.5 to 29.2 m mole / kg with an average value of 14.8 mmole/kg/kg. The highest level of soluble CL^- is in the non-irrigated soil, but the lowest one is found in sewage water prolonged irrigated soil. in most of these soils, the soluble CL^- concentration decreases with depth and the soils shortly irrigated with sewage water contain higher soluble CL^- levels than those prolonged irrigated, the height level of CL^- in the non-irrigated soil and in the prolonged irrigated soil., CL^- on El Deir set as the same character, generally range from 3.2 to 31.1 m mole / kg with an average value of 17.1 m mole/kg, height level of CL^- in the non-irrigated soil.

The soluble bicarbonates in the studied soil of El Cola and El Deir vary from 0.1 to 0.5 m mole/kg with an average value of 0.3 mmole/kg/ kg. the surface layers in most of these soils contain much higher amounts of soluble $HCO3^-$ than the sub surface ones that it may be attributed to the CO3 evolution from the plant root , the organic matter decomposition and the solubilization of CaCO3 in the surface layer, soil shortly irrigated with sewage water have higher soluble $HCO3^-$ than those prolonged one, that it may be attributed to CO_2 evolution from the plant root and organic matter decomposition , surface layer in most studies contain higher amount of soluble HCO_3^- than the sub surface ones.

The soluble SO_4^{2-} concentration in the investigated soil of El Cola and El Deir generally in the range of 1.1 to 6.2 m mole / kg with an average value 3.6 m mole / kg., The soluble SO_4^{2-} in these soils decreases with depth, in addition, most soils prolonged irrigated with sewage water decrease SO_4^{2-} with depth, most of soils that shortly irrigated with sewage water have higher soluble SO_4^{2-} levels than those prolonged irrigated with this water.

Table 2. Effect of sewage water, irrigation period on the soil PH, salinity ECS, soluble cation Na^+, Ca^+, Mg^+, soluble anion Cl^-, HCO_3^-, SO_4^-

period	Depth	pH	EC ds/m	Soluble cations (m mole/ kg)			Soluble anions (m mole /kg)		
				Na^+	Ca^{2+}	Mg+	Cl^-	$HCO3^-$	$SO4^-$
El Cola									
Not irrigated	0-30	7.63	0.88	17	2.82	2.8	23.5	0.5	6.0
7 years	0-30	7.51	1.4	16	3.63	6.2	14.4	0.2	5.9
	30-60	7.13	0.98	12	3.13	4.2	31	0.2	3.3
	60-90	7.22	0.88	10	2.90	3.2	10.5	0.1	1.2
10 years	0-30	7.09	0.98	15	5.02	6.8	29.2	0.4	4.5
	30-60	7.34	0.96	12	4.34	4.6	12	0.4	3.8
	60-90	7.41	0.92	10	3.90	3.8	3	0	1.1
11year	0-30	7.99	1.0	11	4.46	5.6	0.6	0.1	5.2
	30-60	7.42	0.9	10	3.50	5.0	0.7	0.2	3.8
	60-90	7.14	0.9	8	3.13	2.8	0.8	0.2	1.6
12 years	0-30	8.23	1.0	14	7.12	6.8	0.5	0.5	5.6
	30-60	7.47	0.7	10	4.85	4.0	1	0.2	1.8
	60-90	7.32	0.7	9	3.80	2.8	1.1	0.2	0.5
19 years	0-30	7.24	1.2	10	8.50	6.0	1	0.4	4.4
	30-60	7.33	1.0	9	8.0	5.8	1	0.2	4.2
	60-90	7.34	0.9	8	8.0	5.8	0.8	0.2	4.0
20 years	0-30	7.07	1.0	12	1.20	5.5	1	0.3	4.4
	30-60	7.71	0.8	10	5.80	5.0	0.5	0.2	3.2
	60-90	7.17	0.8	10	4.04	3.2	1.2	0	1.5
El Deir									
Not irrigated	0-30	8.13	0.86	17	2.70	2.8	31.1	0.3	6.2
9 years	0-30	8.09	0.90	10	5.08	6.0	6.4	0.2	5.1
	30-60	8.1	0.90	9	5.06	5.8	6.0	0.1	5.0
	60-90	8.2	0.83	8	5.02	5.7	5.5	0.1	4.1
19 years	0-30	7.55	1.2	12	6.60	6.0	18.4	0.5	3.6
	30-60	7.84	1.0	10	5.60	5.0	5.6	0.2	2.8
	60-90	7.83	1.0	9	4.92	4.2	3.2	0.2	2.2
21 years	0-30	7.29	1.2	12	6.10	6.4	55	0.5	4.0
	30-60	7.47	0.9	10	5.60	5.8	28.2	0.3	3.2
	60-90	7.86	0.8	8	4.60	4.0	9.2	0.3	2.2

Assessment of nutrients status.

Total nitrogen

The total nitrogen in the studied soils as mentioned in table 3 varied from 24 to 295 mg/kg with an average value of 159 mg/kg., 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 (19, 20, 21 and 29 years) with sewage water under the surface irrigation system showed higher values of the total nitrogen than those shortly irrigated. sewage water contained organic and inorganic compounds, and nutrients like nitrogen. 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. This may be attributed to the increased amount of water added to the soils under the surface irrigation system which 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 (19,20,21 and 19 years) irrigated with sewage water was higher than those irrigated with sewage water for a short period (7, 9, 10 and 11 years). The results also showed in most soil samples, total nitrogen decreased with depth (Hussain et al. 2002; Afifi 2011).

Available phosphorus

Record the available phosphorus of the studied soils ranged from 6 to18 mg/kg. with an average value of 12 mg/kg., 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 (19, 20, 21 and 29 years) were higher than those under the short-term use (7, 9, 10 and 11 years) of sewage water., 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. The use of domestic wastewater in irrigation can provide essential nutrients to the crops and improves the fertility level of soils., the sewage irrigated soils recorded high available P levels indicating their significant additions through sewage water as low-grade cheap fertilizers (Ladwani et al. 2012; Kharche et al. 2011).

Available potassium.

The available potassium in the studied soils ranged from 160 to 240 mg/kg with an average value of 200 mg/kg., 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., The soils prolonged (19, 20, 21 and 29 years) irrigated with sewage water contained higher available potassium values than those irrigated with sewage water for a short period (7, 9, 10 and 11 years). irrigation with sewage water increased the total potassium and the yield of rabi crops compared to the irrigation with well water or fresh water., irrigation with wastewater increased the soil potassium contents. In addition, the amounts of water added to the soils under the surface irrigation system cause potassium to leach from the surface layers to the subsurface ones (Ghafoor 1999).

Table 3. Effect of sewage water, irrigation period on the soil total N, available P and available K.

period	Depth meter	Total N mg/ kg	Available P mg/ kg	Available K mg/kg
		El Cola		
Not irrigated	0-30	30	7	160
7 years	0-30	114	16	240
	30-60	100	14	180
	60-90	67	9	160
10 years	0-30	141	16	240
	30-60	85	12	220
	60-90	31	8	190
11years	0-30	212	15	230
	30-60	200	12	226
	60-90	190	8	218
12 years	0-30	118	16	220
	30-60	112	12	200
	60-90	60	10	200
19 years	0-30	104	16	222
	30-60	100	12	202
	60-90	87	7	185
20 years	0-30	132	18	236
	30-60	100	12	230
	60-90	80	8	190
		El Deir		
Not irrigated	0-30	24	6	175
9 years	0-30	143	8	228
	30-60	140	6	200
	60-90	100	6	192
21 years	0-30	218	16	252
	30-60	179	12	230
	60-90	109	6	222
29 years	0-30	295	12	230
	30-60	97	10	220
	60-90	80	6	205

Table (4) Characteristics of water resources used in the irrigation of studied soil, and maximum permissible limits (MPL), according to Ayers and westcot (1985) and Pescod (1992).

Soil texture	Sewage water average	MPL
Soil texture	Sandy	__
OM	El Cola 0.45% El Deir 1.3 %	<5
$CaCo_3$	El Cola 2.8 % El Deir 4.8 %	6.5-8.4
PH	7.6	<3
EC_W	1.1	__
Na	12	__
Ca	4.4	__
Mg	14.8	__
Cl	El Cola 14.8 El Deir 17.1	<4
HCO3	0.3	__
SO4	3.6	__
N	159	__
P	12	__
K	200	__

The correlation study showed that significant positive correlations among various nutrients in soil samples of study area table 5.

According to Pearson's coefficient, total N showed a positive and significant correlation with E_C (r= 0.394) and OM (r= 0.466*). Soil available P showed a negative and significant correlation with pH (-0.383) but it showed a positive and significant correlation with E_C (0.559). For soil available K, it showed a positive and significant correlation with E_C (0.42), OM (0.396) and total N (0.678) and soil available P (0.616).

In the current study, the positive significant correlation between nutrients (total N and available K) and soil organic matter suggests that sewage irrigation helps to increase levels of soil organic matter and hence, improves the fertility status of the soil (Singh et al. 2012). The negative relation between soil available P and pH could be explained by precipitation of soil P due to increase soil pH Soil P is generally most available to crops at a soil pH of 6 and 7 (Ara et al. 2018). In alkaline soils, P retention is dominated by precipitation reactions, and it can be adsorbed on the surface of Ca carbonate, and clay minerals and thus, become unavailable to plants.

Table 5. Corelations between soil properties and nutrients in soils irrigated with sewage wastewater.

Variables	Sand	Silt	Clay	pH	EC	OM	$CaCO_3$	Total N	Available P	Available K
Sand	**1**	**-0.943***	**-0.818***	-0.128	-0.223	-0.103	-0.105	0.099	-0.018	-0.080
Silt		**1**	**0.613***	0.167	0.129	0.127	0.140	-0.091	-0.009	0.056
Clay			**1**	0.074	0.209	-0.107	0.025	-0.186	-0.026	-0.011
pH				**1**	-0.126	0.063	0.355	-0.049	**-0.383***	-0.038
EC					**1**	**0.456***	0.173	**0.394***	**0.559***	**0.482***
OM						**1**	0.096	**0.466***	0.174	**0.396***
CaCO3							**1**	-0.006	0.087	0.232
Total N								**1**	**0.402**	**0.678***
Available P									**1**	**0.616***
Available K										**1**

Values in bold are different from 0 with a significance level alpha=0.05

Assessment of soil toxic trace metals.

Data in Table 6 show the aqua regia concentrations of toxic trace metals (Cd, Zn, Cu, Pb, and Ni) at a soil sampling depth of 0–30 cm, 30 – 60 cm and 60-90 cm. It was observed that the concentrations of all investigated heavy metals are lower than their corresponding values of the common range, background shales and average concentrations for world soils in soil according to (Lindsay 1979; Turekian and Wedepohl 1961; Huang et al. 2009).

Generally, an increase in the aqua regia-extractable (metals) level of the sewage water irrigated soils exists, especially in the prolonged irrigated ones, compared to that of the non-irrigated soils. Moreover, soils prolonged irrigated with sewage water contain higher aqua regia-extractable metals levels than those irrigated with sewage water for a short period. The long-term use of wastewater in irrigated a agricultural land causes the soil to be contaminated with heavy metals (Masona 2011) Additionally, it was found that the high value recorded with aqua regia-extractable metal in the long-term irrigation sites and tended to decrease with depth.

Table 6. Aqua regia concentrations of toxic heavy metals in the investigated soils.

Irrigation period	Depth, cm	Cd	Zn	Cu	Pb	Ni
		El Cola				
20 years	0-30	0.09	1.90	14.3	0.48	0.82
	30-60	0.07	1.58	8.3	0.26	0.76
	60-90	0.07	0.34	2.8	0.08	0.54
19 years	0-30	0.08	1.58	12.5	0.08	0.9
	30-60	0.06	1.02	11.0	0.07	0.88
	60-90	0.04	0.8	9.0	0.06	0.52
12 years	0-30	0.06	1.64	12.0	0.12	0.76
	30-60	0.06	0.54	10.0	0.12	0.54
	60-90	0.05	0.48	6.2	0.1	0.43
11year	0-30	0.06	1.94	10.8	0.44	0.82
	30-60	0.06	1.02	8.4	0.12	0.76
	60-90	0.06	0.96	4.8	0.06	0.54
10 years	0-30	0.06	1.68	4.4	0.32	0.56
	30-60	0.04	0.94	3.0	0.22	0.45
	60-90	0.02	0.71	2.1	0.06	0.38
7 years	0-30	0.06	1.94	4.2	0.27	0.66
	30-60	0. 04	1.08	3.8	0.28	0.51
	60-90	0.04	0.74	2.8	0.02	0.45
Not irrigated	0-30	0.02	0.2	2.0	0.01	0.10
		El Deir				
21 years	0-30	0.06	1.72	12.8	0.24	0.67
	30-60	0.04	1.3	8.2	0.2	0.55
	60-90	0.03	1.1	4.1	0.08	0.81
19 years	0-30	0.12	1.36	6.8	0.38	0.87
	30-60	0.07	1.16	3.8	0.28	0.66
	60-90	0.06	1.14	2.2	0.06	0.08
9 years	0-30	0.05	1.52	10.8	0.24	0.64
	30-60	0.04	1.43	8.2	0.21	0.54
	60-90	0.03	1.03	6.8	0.11	0.44
Not irrigated	0-30	0.01	0.32	4	0.02	0.52
		Cd	Zn	Cu	Pb	Ni
Common range	Max	0.7	300	100	200	500
	Min	0.01	10	2	2	5
	Av	0.06	50	30	10	40
Shale background		0.3	95	45	20	68
World (av)[c]		1.10	62	14	25	18

The “contamination” term is often mixed with “polluted” one, although clear difference in the definition indicate that these terms are not interchangeable. the polluted terms refer to a situation in which the concentration of a substance is higher than it would naturally occur but also it indicates that a substance is causing harm of some type. on the other hand, the contamination term also implies that the concentration of a substance is higher than it would naturally occur but it does not necessarily denote that the substance is causing any harm (Roshdy and Nadia 2009).

The assessment of the contamination in the studied soils was carried out using the Cf, the Cf can be used to differentiate between the metals originating from anthropogenic activities and those from natural processes., to assess the degree of anthropogenic influence., it compares the average metal concentration in the surface layers to the average metal concentration background one (Hakanson 1980).

The calculated data of CF of soil samples are presented in table 8. The results showed that the soil samples collected at El Cola have CF values ranged from 1 to 48, indicating the pollution levels are in the range of moderate to very high levels. Among all metals, Pb showed the highest values of CF. Meanwhile, at El-Deir, the values of CF ranged from 0.6 (low contamination level) to 19 (very high contamination level). Generally, it was found that the higher pollution levels recorded in the long-term irrigation sites than those at short-term irrigation sites.

Table 7. The defined four contamination categories.

Cf (Cf)	Degree of contamination (DC)
$c_f^i < 1$	Low Cf
$1 \leq c_f^i < 3$	Moderate Cf
$3 \leq c_f^i < 6$	Considerable Cf
$6 \leq c_f^i$	Very high Cf

Table 8. The values of contamination factor (CF) of the investigated soils

Period of irrigation	Depth	Cd	Zn	Cu	Pb	Ni
		EL COLA				
20 y	0-30	4.5	9.5	7.2	48.0	8.2
	30-60	3.5	7.9	4.2	26.0	7.6
	60-90	3.5	1.7	1.4	8.0	5.4
19 y	0-30	4.0	7.9	6.3	8.0	9.0
	30-60	3.0	5.1	5.5	7.0	8.8
	60-90	2.0	4.0	4.5	6.0	5.2
12 y	0-30	3.0	8.2	6.0	12.0	7.6
	30-60	3.0	2.7	5.0	12.0	5.4
	60-90	2.5	2.4	3.1	10.0	4.3
11 y	0-30	3.0	9.7	5.4	44.0	8.2
	30-60	3.0	5.1	4.2	12.0	7.6
	60-90	3.0	4.8	2.4	6.0	5.4
10 y	0-30	3.0	8.4	2.2	32.0	5.6
	30-60	2.0	4.7	1.5	22.0	4.5
	60-90	1.0	3.6	1.1	6.0	3.8
7 y	0-30	3.0	9.7	2.1	27.0	6.6
	30-60	2.0	5.4	1.9	28.0	5.1
	60-90	2.0	3.7	1.4	2.0	4.5
		El Deir				
21 y	0-30	12.0	4.3	1.7	19.0	1.7
	30-60	7.0	3.6	1.0	14.0	1.3
	60-90	6.0	3.6	0.6	3.0	0.2
19 y	0-30	6.0	5.4	3.2	12.0	1.3
	30-60	4.0	4.1	2.1	10.0	1.1
	60-90	3.0	3.4	1.0	4.0	1.6
9 y	0-30	5.0	4.8	2.7	12.0	1.2
	30-60	4.0	4.5	2.1	10.5	1.0
	60-90	3.0	3.2	1.7	5.5	0.8

The correlation study showed that significant positive correlations among soil properties and heavy metals in soil samples of the study area as mentioned in table 9. According to Pearson’s coefficient, Cd showed a significant positive correlation with EC. Additionally, Zn showed a significant positive correlation with EC and Cd. Cu showed a significant positive correlation with Cd and Zn. Pb showed a significant positive correlation with EC, Cd and Zn. Ni showed a significant positive correlation with Cd, Zn, Cu and Pb. An obtained correlation among investigated heavy metals might be an indicator for the same source, mainly anthropogenic source.

Table 9. Correlation between heavy metals and soil properties.

Variables	Cd	Zn	Cu	Pb	Ni
Sand	0.240	-0.201	0.269	-0.084	0.287
Silt	-0.198	0.133	-0.229	0.056	-0.246
Clay	-0.257	0.181	-0.352	0.070	-0.291
pH	-0.276	0.098	0.060	-0.047	-0.026
EC	0.438	0.630	0.185	0.399	0.337
OM	0.288	0.359	0.075	0.333	0.174
CaCO3	-0.012	0.053	-0.025	0.141	0.003
Cd	1	0.498	0.422	0.558	0.567
Zn		1	0.555	0.733	0.578
Cu			1	0.363	0.654
Pb				1	0.466
Ni					1

Conclusions

The present research was done in order to study the effects of the treated sewage water on some soil chemical properties as well as toxic metals, 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.

Regarding to heavy metals, the soil contents of all investigated heavy metals (Cd, Zn, Cu, Pb and Ni) are lower than their corresponding values of the common range, background shales and average concentrations for world soils. 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.

Reference

Abedi-Koupai J , Sohrab F (2004) Evaluating the application of superabsorbent polymers on soil water capacity and potential on three soil textures. Iran J. of Polymer Sci. and Technology 17, 163-17.

Afifi AA, Abd El-Rheem, Kh M, Youssef R (2011) Influence of Sewage Water Reuse Application on Soil and the Distribution of Heavy Metals Nature and Science 9 (4), 8288.

Ali H, Naseer M, Sajed MA (2012) Phytoremediation of heavy metals by Trifoliumalexandrinum, Int. J. Environ. Sci. 2, 1459–1469.

Anderson A, Nilsson KO (1972) Standard Methods for the Examination of water and waste water, 21st ed. Washington, USA.

Ara I, Islam M, Kashem M, Osman KT (2018) A comparative study of phosphorus availability in an acidic soil and an alkaline soil amended with organic and inorganic phosphorus sources. Journal of Soil Science and Plant Nutrition, 18(2), 466–478. https://doi.org/10. 4067/S0718-95162018005001402.

Dheri GS, Brar MS, Malhi SS (2007) Comparative Phytoremediation of Chromium-Contaminated Soils by Fenugreek, Spinach, and Raya Communications in Soil Science and Plant Analysis, 38: 1655-1672.

El-Arby A M, Elbordiny MM (2006) Impact of reused wastewater for irrigation on availability of heavy metals in sandy soils and their uptake by plants., J. Applied Sci. Res., 2, 106111.

El-Desoky MA, Gameh MA (1998) Heavy metals mobility and changes in properties of sandy soils irrigated with untreated sewage water at Assiut. J. Agric. Sci., Mansoura Univ. 23: 4705-4719.

El koli MA, Abou el Defan TA, Allah AE, Kandel NF (2000) Environmental impact of irrigation with waste water effluent on some soil properties, j.agric. sci. Mansoura univ., 25(9):5955-5962.

Ghafoor A (1999) Concentration of Ca2+ in irrigation water for reclaiming saline-sodic soils. Pakistan J. Agri. Sci. 36(3-4):145-148.

Gregory A (2000) Strategic direction of water recycling in Sydney: Australia, Proceedings of the 1st Symposium on Water Recycling.

Girvan MS, Bullimore J, Pretty JN, Osborn AM, Ball AS (2003) Soil type is the primary determinant of the composition of the total and active bacterial communities in arable soils. Appl. Environ. Microbial., 69: 1800–1809.

Hakanson L (1980) An Ecological Risk Index for Aquatic Pollution Control: A Sedimentological Approach, Water Res, 14, 975–1001, doi:10.1016/0043-1354(80)90143.

Huang S, Tu j, Liu H, Liao Q, Feng j , Weng Z (2009) Multivariate analysis of trace element concentrations in atmospheric deposition in the Yangtze River Delta, East China. Atmos. Environ. 43(36), 5781–5790.

Hussain I, Raschid L, Hanjra MA, Marikar F , van der Hoek W (2002) Wastewater Use in Agriculture: Review of Impacts and ethodological Issues in Valuing Impacts. Working Paper 37. International Water Management Institute, Colombo, Sri Lanka.

Jackson M L (1973) Soil chemical analysis - Prentice Hall Inc.Eng-Cliffs by Unitited American State.

Kharche V K, Desai V N, Pharande AL (2011) Effect of sewage irrigation on soil properties, essential nutrient and pollutant element status of soils and plants in a vegetable growing area around Ahmednagar city in Maharashtra. J. Ind. Soc. Soil Sci. 59 (2), 177184.

Khurana M P S, Singh P (2012) Waste Water Use in Crop Production: A Review. Resources and Environment, 2(4): 116-131.

Ladwani K D, Manik V , D S Ramteke (2012) Impact of domestic waste water irrigation on soil properties and crop yield. International J of Scientific and Research Publications2(10):1-7.

Lindsay W (1979) Chemical equilibria in soils. 1st edition. A WileyInterscience Publication. John Wiley and Sons, New York.

Masona C, Mayfair L, Mapurazi S, Makanda R (2011). Assessment of heavy metal accumulation in wastewater irrigated soil and uptake by maize plants (Zea Mays L) at Firle REFRENCE 21 Farm in Harare, Journal of Sustainable Development, 4(6), 132-137.

Mc Clean CJ, Cresser MS, Smart RP, Aydin alp C , Karkat AV (2003) Unsuitable irrigation practices in the Bursa plain, Turkey. In: Diffuse Pollution and Basin Management: M. Bruen, (Ed.). Proceedings of the 7th International Specialized IWA Conference, International Water Association, August 1721 -st , 2003, Dublin, Ireland, 2003. p. 60 - 65.

Molla Hosseini H (2013) Long term effects of municipal wastewater irrigation on some properties of a semiarid region soil of Iran.

Narwal RP, Gupta AP, Singh A, Karwasra S P S (1993) Composition of some city waste waters and their effect on soil characteristics. Annals of Biology, 9, 239245.

Rattan R K, Datta S P, Chhonkar P K, Suribabua K, Singh AK (2005) Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater-A case study., Agriculture, Eco-systems & Environ., 109, 310-32.

Richards LA ed (1954) Diagnosis and improvement of saline and alkali soils U.S.D.A. Handbook 60.

Rushdy , Nadia MK (2009) Distribution and forms of some heavy metals in a contaminated soil at Assuit Ph. D Thesis, Fac. of Agric., Assiut, Univ., Egypt.

Sheinberg I , Oster J D (1978) Quality of Irrigation Water, London; Pergamon Press – agriculture on sewage water.

Singh PK, Deshbhratar PB, Ramteke DS (2012) Effects of sewage wastewater irrigation on soil properties, crop yield and environment. Agricultural Water Management, 103, 100–104. doi: 10.1016/j.agwat.2011.10.022

Taylor SR, Mc Lennan S M (1985) The Continental Crust, Composition and Evolution; An Examination of the Geochemical Record Preserved in Sedimentary Rocks. Blackwell, Oxford, UK.

Turekian KK, Weephole KH (1961) Distribution of the elements in some major units of the Earth's Crust. Geol Soc Am Bull 72:175–192

US-EPA (United States, Department of Agriculture) (1996) Soil Survey Investigations. Soil Survey Laboratory Methods Manual. Report No.42, V.3, Washington, D. C.

Yadav RK B, Goyal RK, Sharma S K, Dubey, PS Minhas (2002) Post-irrigation impact of domestic sewage effluent on composition of soils, crops and ground water, India, A case study.

Yao H, Zhang Sh, Xue X, Yang J, hu K, yu X (2013) Influence of the sewage irrigation on the agricultural soil properties in Tong Liao City, China. Front. Environ. Sci. Eng. 7(2), 273–280.

Yerasi PKR , Reddy YK , Reddy GK , Prasad MR (2013) Sewage irrigation can sustain the soil health A review. International Journal of Agricultural Sciences, 3: 470.