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Impacts of Irrigation with Sewage Effluent on Physical and Chemical Parameters of Egyptian Soil

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ABSTRACT

Egypt may soon suffer from water problems due to many factors, including the intransigence of upstream countries in addition to climate change and various pollution factors. Under these circumstances, many farmers are forced to use sewage water for irrigation, which may eventually lead to deterioration of soil and environmental quality. Therefore, the present investigation aims to study the influences of sewage water application for varied extended periods on some physical and chemical parameters of Abu-Rawash soil and to compare between the general properties of sewage effluent water and Nile water. In sewage effluent, Na^+ was the dominant cation and EC, SAR, pH, and NH_4^+ values below the Permissible Maximum Level while nitrate content exceeds the safe level. The total N content in sewaged water was more than 13 folds that of Nile water. In sewage effluent irrigated soils, there are appreciable increases in clay fraction by 8.02 and 12.0 folds compared with the virgin soil. $CaCO_3$ content of soil continuously irrigated with sewage water reduced as increasing period of application while there are an increasing in soil pH and EC. Only remarkably increase in ESP was occurred in the top soil layers of sewage irrigated soils. Bulk density and Hydraulic conductivity of sewaged soil decreases with increasing period of application and total porosity and available water capacity increased. The results reflect deficiency of nutritional status of uncultivated sandy soils in an arid zone, especially in N content.

Keywords: sewage water, irrigation, water scarcity, soil properties.

INTRODUCTION

The world faces enormous environmental challenges, resulting from human activities, such as fast and an unbalanced way growing population, water crises, undernourishment, unplanned urbanization, adverse land usage, dangerous and harmful wastes, unconscious energy consumption and pollution hazards (Alloway, 1995). With increasing global population, the gap between the supply and demand for water is widening and is reaching such alarming levels that in some parts of the world it is posing a threat to human existence. Shortage of irrigation water sources in Egypt bring out the issue of using non-conventional water resources. Non-conventional water resources include agricultural drainage water, desalinization of sea water or brackish groundwater and use of municipal wastewater. Many farmers around the world are even compelled to use sewage effluent water to irrigate their crops, due to paucity of fresh water (absence of alternatives). Despite that water contains high levels of organic materials and plant nutrients. It also contains numerous pathogenic microorganisms, toxic compounds and heavy metals (Katbata-Pendias, 1993; Alloway, 1995).

Wastewater has been considered as low price fertilizer because of its high nitrogen (N), phosphorus (P) and potassium (K) content (Abdel Hady, 2001). Although of wide variation in nutrient concentrations, sewage effluents contain respectively; 48.3, 7.6, 72.4 and 34.6 mgL^{-1} of N, P, K and sulphur (S) besides their micro-nutrient fustigation value (0.34 mg Zn L^{-1}, 10.8 mg Fe L^{-1}, 0.2 mg Cu L^{-1} and 0.36 mg Mn L^{-1}). El-Hady (2007) revealed that total N content in El-Khashab canal (sewage water) was more than double that of Nile water. He attributed that to the fact that El-Khashab canal water is mixed with sewage water. He also added that P and K values of waste samples collected exceeded that Nile water. Hayssam *et al* (2012) mentioned that irrigation with primary sewage effluent decreased the CaCO3 content from 32.26 to 31.04 and 29.15% for primary sewage effluent treatments after 8, 16 and 24 months, respectively, of irrigation stage. They attributed that to the influence of organic acids presented in sewage effluent on dissolving CaCO3. Unlike fresh plant and animal residues that have been incorporated into the soil, most sewage sludges have been through a biological treatment, where partial decomposition and stabilization have occurred. Therefore, the rate of decomposition in soil may be slower than most fresh organic residues, resulting in longer lasting increases in the levels of soil organic matter. Sara *et al.* (1994) reported that soil pH reduced from pH 5.9 to 4.6 by the addition in the sludge. Probably this is due to the high rates of nitrification. Also, slight reduction in pH values (from 8.37 to 8.0) in soil amended with primary – treated and secondary- treated sewage effluent water, respectively was reported by Hayssam *et al.* (2012). Sewage sludge contains large quantities of salts (Mtshali *et al.*, 2014), which might increase the soil solution electrical conductivity (EC).

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Increasing the EC increases the osmotic potential of the soil solution, which may reduce the ability of plants to absorb water at high water suctions. Several studies concluded that the application of sewage sludge led to decrease in bulk density (BD). In general, soil BD values decreased as the rate of sewage sludge application increased (EL-Nennah *et al*., 1982). Khaleel *et al*. (1981) mentioned that reduction in soil BD was probably due not only to the dilutional effect of adding less dense organic matter to the more dense mineral matter, but also to increased soil aggregation. Maximum rate of water movement through soils, or saturated hydraulic conductivity (sat. K), increased significantly by the addition of sewage sludge (Khaleel *et al*., 1981). They also added that the Increases in sat. K was generally greater for finer textured soil; when moderate rates of sewage sludge were added to a loamy clay soil, sat. K remained twice that of the untreated soil. The organic matter in biosolids and compost increases the soil's ability to retain water. It improves the structure and increases its organic content, which makes it possible to have agricultural activities in soils with high clay content and decreasing soil erosion (Scott and Ahlstrom, 1985). The addition of sewage sludge to soil increases water retention at both field capacity (-33 kPa) and wilting point (-1500 kPa).The increase in water retention (weight basis) at various matric potentials of sludge-treated soils is probably due to the increase in total porosity, storage pores space (50µm diameter), and the water absorption capacity of organic matter (Epstein, 1975).

He added that the greatest percentage increases in water retention at both field capacity (FC) and wilting point (WP), were for treatments on coarser textured soils or using higher application rates. Plant-available water holding capacity (AWC), or the difference between moisture retained at FC and WP (weight basis), increased with increasing sludge application rates for medium and fine-textured soils (Bargezar *et al*, 2002). Several studies (Epstein *et al*., 1976; Pratt *et al*., 1973) decaled that sewage sludge may supply a large portion of the N required for crop growth for several years after application. The N content of sewage sludge depends on the degree and type of processing, and can range from less than 1 to greater than 170 g/kg. The primary inorganic form is NH_4, representing approximately 30% of the total N contained in anaerobic sludge. These findings confirmed by the results obtained by EL-Nennah *et al*. (1982) who found that use of sewage effluent in irrigation resulted in remarkable change of organic matter, available P and total and soluble N.

The main objective of the present study is to evaluate the influence of using sewage water effluent in irrigation consecutively for up to 100 years on soil physical and chemical properties with the characterization of the general properties of sewage effluent water and Nile water.

MATERIALS AND METHODS

The selected site was at Abu–Rawash area which located, east of Giza Governorate, Egypt; at 25Km north - east of Cairo. This study area is located between latitude 30° 1′ 33″ N and Longitude 31° 4′ 18″ E. This farm has been irrigated consequently with sewage water effluent for more than 100 years and thereby, this location provides a possible model of the potential long-term effects of sewage sludge on terrestrial ecosystem.

Water sampling: The sewage effluent water sample (4 separately liters) were carefully taken from the farm, mixed and were stored at less than 4°C until the following analysis carried.

Soil samples: Three soil profiles were dug to the depth 120 cm; the first site reflected non cultivated soils (control), while the second and third profiles representing soils irrigated continuously with sewage effluent water for 50 and 100 years, respectively and denoted as WWS-0yrs, WWS-50yrs, and WWS-100yrs soil, respectively. Each soil profile was sampled at 30 cm increments. At each depth, three disturbed sub-soil samples were collected to make a composite soil samples for (chemical analysis) and triplicate undisturbed soil samples were also collected for (physical analysis).

Sewage effluent water analysis: The following analyses were carried on the collected sewage effluent water sample and the results are listed in Table (1): pH was measured by pH meter, electrical conductivity (EC) was measured by EC meter and soluble cations and anions: carried as described by (Page *et al*., 1982). Sodium adsorption ratio (SAR) of the used water was calculated according the following equations:

$$\mathrm{SAR} = \frac{Na}{\sqrt[2]{\frac{(Ca+Mg)}{2}}}$$

Soil physical analysis*:* The following analyses were carried out on the selected soil samples and the results are listed in Tables (2 and 3); Soil particle size distribution was carried out by pipette method as described by Piper (1950), Soil bulk density (BD) was determined according to Klute (1986), Soil moisture characteristic curve was carried out using the pressure cocker apparatus, at tensions ranging from 0.01 to 15.00 atm., the calculation of pore-size distribution was obtained according to the equivalent pore-diameter, at the different soil moisture contents versus soil tension, in atm., (Topp *et al*., 1993), Hydraulic conductivity was determined by using undisturbed soil samples according to Klute (1986). Values of hydraulic conductivity were calculated by using Darcys law:

$$\frac{Q}{Axt} = Kx\frac{\Delta H}{L}$$

Where: Q = the volume (cm^3) of water passing through the soil column attime t, and A is the cross-sectional area of the soil column, L= the length of soil column (cm), $\Delta H/L$ = hydraulic gradient, K= the hydraulic conductivity (cm/hr).

Total porosity was calculated as percentage from the obtained values of real and bulk densities, Klute (1986).

Soil chemical analysis: *Soluble ions concentrations*: In saturated soil- paste extracts carried out according to (page *et al*., 1982). *Cation exchange capacity (CEC):* by (Black, 1965). *Total and available nitrogen:* NO_3 and NH_4 of the soil determined according to page *et al*. (1982). *Calcium carbonate* was determined using Collin's calcemeter according to Jackson (1984). *Organic matter* was determined using the method of walkely and Blank as described by Jackson (1984). *Soil reaction (pH)* was measured in soil paste using combined electrode pH meter (page *et al*., 1982). *Soil salinity (EC)* was measured by electrical conductivity meter in saturated soil extract, dSm^{-1} (Jackson, 1984).

RESULTS AND DISCUSSION

1. Water Salinity and related parameters

Data reported in Table (1) show that the EC values of sewage effluent water sample (1.51 dsm^{-1}) was higher than that of Nile water (0.39 dsm^{-1}), However, is still lower than the permissible maximum level (PML) for using water for irrigation, which set (2 dsm^{-1}) by FAO (1976). The high EC value of sewage effluent water may be attributed to the high content of soluble alkali elements in that water compared with Nile water. On the other side, the obtained data show that in sewage effluent water sodium was the dominant cation (6.43meq/l) followed by calcium (4.3meq/l), and magnesium (3.1meq/L); while the sequence of the soluble cations (in meq/L) in Nile water were; calcium (2.095) > magnesium (0.68) and sodium (0.64). The obtained results are in accordance with those obtained by Ibrahim *et al*. (1992) and Abd El-Hady (2001). They observed the same sequence in water samples collected from El-Gabal El-Asfer sewage station and El-Saff canal. With regards to soluble anions, chloride was the dominant anions followed by bicarbonate, while sulphate contributed small portion in the effluent water sample. There concentrations (in meq/L) were (13, 1.2, and 0.8, respectively), whereas the sequence in Nile water sample (in meq/L) was; SO_4^{-2}(2.17) > $HCO3^{-}$(1.29)> Cl^{-}(0.4). On the same manner; the calculated sodium adsorption ratio (SAR) of the sewaged water was higher than that of Nile water. It was 0.935 and 5.46 for Nile water and the sewaged water, respectively. However SAR of the sewaged water is classified as, from slightly to moderately sodium hazard, it still lower than the permissible maximum limit (PML) reported for SAR by (FAO, 1976), which cited as 6, for agriculture purposes. On the other side, the data indicated that pH value in sewaged water was also higher than that in the Nile water, it increased by 0.4 units. This may be attributed to the high concentration of Na^+ in that water, but its value was lower than PML reported by FAO (1976) for using water for irrigation, which cited as (pH=5-9).

Table 1. General properties of sewage effluent water and Nile water

Parameter	Sewage water	Nile water
EC (ds/m)	1.51	0.39
pH	7.7	7.3
TSS(mg/L)	699.4	249.6
TN(ppm)	62.35	4.5
NH_4 (mg/L)	2.21	0.54
NO_3(mg/L)	54.6	1.43
P (mg/L)	1.781	0.17
Ca^{2+} (meq/l)	4.3	2.095
K^+ (meq/l)	1.27	0.46
Na^+ (meq/l)	6.43	0.64
Cl^- (meq/l)	13	0.4
HCO_3^- (meq/l)	1.2	1.29
SO_4^{2-} (meq/l)	0.8	2.17
SAR	3.343	0.935

Macronutrient Concentrations: Also, data shown in Table (1) reveal that total N content in sewaged water was more than 13 folds that of Nile water. This is expected since this water enriched with organic matter, which considered the main source of nitrogen. Moreover, it appears from the Table that amounts of water nitrate content (54.6ppm) is considered higher than the safe level (15 ppm), (FAO, 1976), this results agrees with the findings of (Abd El-Hady, 2001). Also, the concentrations of NH_4 in sewaged water as shown from the Table exceeded than that in Nile water sample by more than 4 folds, however, it still lower than PML (5 ppm), which proposed by (FAO, 1976). P and K concentrations of sewaged water exceeded that of Nile water by (10.47 and 2.76 folds, respectively), confirmed that this water considered as a cheap source of macronutrients in soils (Katbata-Pendias, 1993 and Alloway, 1995).

2. Soil physical properties

Bulk Density: Bulk density (BD), is defined as the weight of oven-dry soil per unit volume, it is an indicator of the soil's physical conditions. BD is usually related to a soil's porosity, texture, hydraulic conductivity, aggregation, compaction, and organic matter content. Table (2) show that, soil BD values in the top soil depth (0-30cm) of (WWS-100, WWS-50, and WWS-0yrs soil) were, (1.44, 1.5and1.81 g/cm^3), respectively. It is obvious from these data that as period of sewage water application increases, soil BD values decreased. (Bozkurt *et al*., 2010; and Gabriella *et al*., 2018) attributed that to dilutional effect of adding OM as well as to its influence on soil aggregation. The present results also showing that soil BD progressively increased with increasing soil depths, that is because of less of organic matter content with depth, in addition to the high content of coarse soil particles.

Total soil Porosity: As shown from Table (2) that total porosity of the investigated soil sample flocculated between (31.6 to 36.98%), (38.4 to 43.3%), and (43.01 to 45.6%) in WWS-0yrs, WWS-50yrs, and WWS-100yrs soil samples, respectively. It is clearly obvious from the present data that total porosity increase with increasing period of sewage effluent water application particularly in the upper layer of sewaged soils. These results may be ascribed to increasing of fine particles and organic debris in that soil layers.

Table 2. The hydro-physical properties of the investigated soil profiles

Years of application	Depth (cm)	BD (g/cm^3)	Porosity (%)	HD (cm/hr)	AWC (v/v %)
WWS- 0yrs	0-30	1.81	31.6	28.44	4.65
	30-60	1.80	32.07	30.24	4.22
	60-90	1.71	35.47	31.68	3.12
	90-120	1.67	36.98	34.2	2.00
	mean	1.74	34.05	31.14	3.49
WWS-50yrs.	0-30	1.5	43.3	22.68	10.26
	30-60	1.5	43.3	24.84	8.88
	60-90	1.61	39.2	23.04	5.87
	90-120	1.63	38.4	24.12	5.20
	mean	1.56	41.13	23.67	7.55
WWS-100yrs.	0-30	1.44	45.6	18.00	13.79
	30-60	1.47	44.5	19.08	11.08
	60-90	1.58	40.37	19.44	8.83
	90-120	1.51	43.01	23.04	8.10
	mean	1.50	43.39	19.89	10.45

Hydraulic conductivity: The influences of sewage water irrigation on hydraulic conductivity (HC) in the tested soils are listed in Table (2). It is obvious from the data that HC values of WWS-100yrs ($\bar{x}$=19.89cm/hr.) is less than that in WWS-50yrs ($\bar{x}$=23.67cm/hr.) and WWS-0yrs soil ($\bar{x}$ =31.14cm/sec), especially in the surface layers, where its data are (18, 22.68, and 28.44cm/hr.), respectively, reflecting the effects of disposal of sewage water onto soils. Similar conclusions were also reported by Malla *et al*., (2007); and Karsten and Marschner, (2015).They attributed the HC reduction in sewage disposal soils as results of the organic suspended solids may impede water transmission initially by temporarily plugging soil surface and by clogging of pores; however, the effect of organic matter addition through sewage on aggregation improves soil structure and enhances water transmission.

Soil Moisture characteristic Curve (Available Water): Results of available water capacity (AWC) of the tested soils are presented in Figs (1 through 3). The Figs refer that continuous application with sewage effluent greatly influenced on AWC, especially in the surface soil layers. The means of AWC are (10.45, 7.55, 3.49 V/v%) in (WWS-100yrs, WWS-50yrs,and WWS-0yrs), respectively. It's clearly shown from the previous results that organic debris, clay and fine particles exist in sewage water have an important role in retaining water, owing to their high adsorption capacity. These results are in consistent with results of (Gu *et al*., 2013; and Burducea *et al*., 2016).

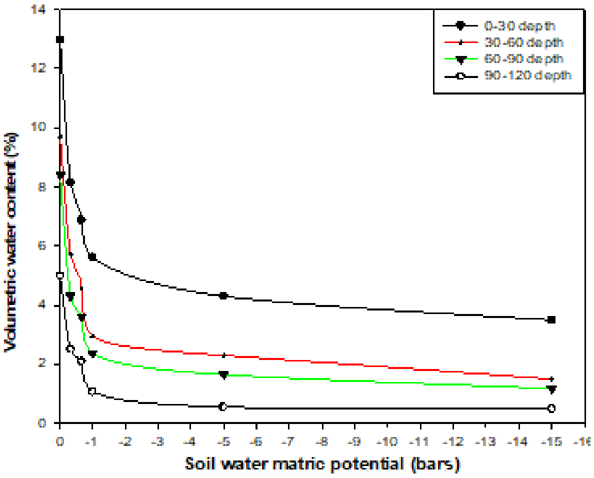

Figure (1): Diagrammatic representation of the water retention curve of WWS-0yrs soil

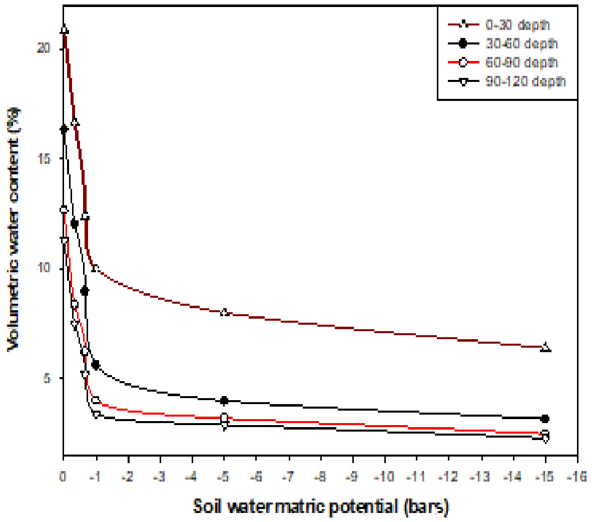

Figure (2): Diagrammatic representation of the water retention curve for WWS-50yrs soils.

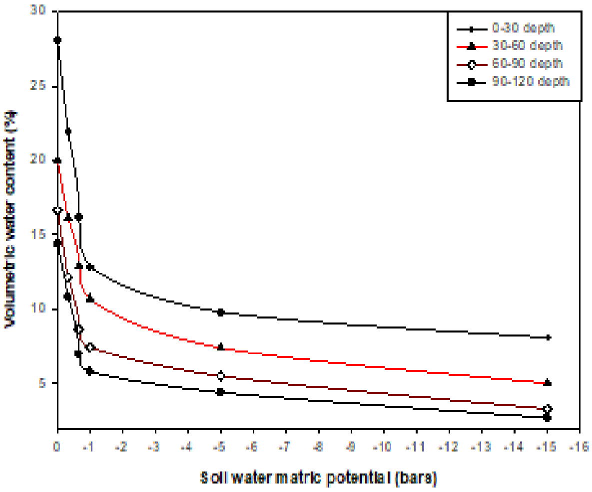

Figure (3): Diagrammatic representation of the water retention curve for WWS-100yrs soils.

Texture Characteristics: The results of particle size distribution and textural class of the studied soils are given in Table (3). As shown from the table that the texture class in all soil depths of WWS-0yrs (control) soil was sandy in texture. Sand percentage was ranged from (90.8 to 94.51%, $\bar{x}$ = 93.20%), followed by silt (4.69 to 7.57%, $\bar{x}$ = 5.63%), while clay fraction accounted small portion (0.8 to 1.63%, $\bar{x}$ = 1.17%).

Meanwhile, in sewage effluent irrigated soils, there are appreciable increases in clay fraction compared with the virgin soil (the Table). Clay fraction increased by 8.02 and 12.0 folds compared with its content in the WWS-0yrs. Furthermore, the distribution of clay fraction along the sewaged soil profiles show that clay existed in high percentages in the upper soil layers compared with the last soil layers. The texture grades of tested soil samples were (SCL, SL, S, and S), for the successive tested soil depths, respectively. These results ascribed to accumulation of fine particles carried by the disposal wastewater.

In WWS-100yrs, the texture grades of the successive soil depth are clay loam (CL), sandy loam (SL), loamy sand (LS) and sand (S), respectively. In the top soil layer, clay fraction accounted (29.5%) due to the disposal of fine particles present in wastewater; whereas its value decreased to (13.51%) in the sub-layer (30-60cm), which reflecting migration of such fine particles with the percolating irrigation water following the agricultural practices. These results indicated that the wastewater disposal practice for long period had important effect on the soil texture grade. These results are in contrast with the results of El-Wakeel and Abd El-Naim (1986); Bayoumi *et al*. (1993) and Ibrahim *et al*. (2010). They concluded that no marked change in soil texture as a result of disposal of sewage water onto soils.

3. Soil chemical Properties

$CaCO_3$ content of Soils: As shown from Table (3) that $CaCO_3$ content of soil continuously irrigated with sewage wastewater reduced as increasing period of application. $CaCO_3$ content ranged from (2.38 to 2.59%), (1.16 to 1.36%) and (0.83 to 1.3%) in WWS-0yrs, WWS-50yrs, and WWS-100yrs Soil samples, respectively. The present results were confirmed with the results of Hayssam *et al*. (2012). They concluded that the reduction in $CaCO_3$ content of sewaged soil may be attributed to production of organic acids through anaerobic decomposition process of OM, which had led to the solublization of $CaCO_3$. On the other hand, this result comes in contradiction with El-Hady (2007) who reported slight increase in the CaCO3 content as the soil treated by wastewater.

Table 3. Some of the characteristics of the investigated soil samples

Irrigation years	Depth (cm)	Sand %	Clay %	Silt %	USDA Texture	$CaCO_3$ (%)	OM (%)	pH	EC (ds/m)	ESP (%)
WWS-0yrs	0-30	90.8	1.63	7.57	S	2.38	0.62	7.51	0.77	2.92
	30-60	93.2	1.15	5.65	S	2.47	0.59	7.43	0.66	2.34
	60-90	94.3	1.09	4.61	S	2.55	0.41	7.44	0.61	2.45
	90-120	94.51	0.8	4.69	S	2.59	0.20	7.42	0.57	2.14
	mean	93.20	1.17	5.63	-	2.49	0.45	7.45	0.65	2.46
WWS-50yrs.	0-30	50.2	22.31	27.49	SCL	1.16	2.04	7.71	1.96	4.53
	30-60	77.8	10.26	11.94	SL	1.27	1.92	7.71	1.83	4.94
	60-90	91.05	2.5	6.45	S	1.2	1.08	7.63	1.48	3.88
	90-120	91.35	2.5	6.15	S	1.36	0.75	7.56	1.62	3.10
	mean	77.60	9.39	13.01	-	1.24	1.44	7.65	1.72	4.11
WWS-100yrs.	0-30	40.2	29.5	30.3	CL	0.83	3.16	7.83	2.54	6.73
	30-60	70.35	13.51	16.14	SL	0.95	3.05	7.82	1.96	6.11
	60-90	82.2	7.81	9.99	LS	1.12	2.15	7.69	1.82	5.90
	90-120	87.8	5.35	6.85	S	1.3	1.90	7.64	1.09	3.68
	mean	70.13	14.04	15.82	-	1.05	2.56	7.74	1.85	3.61

Organic Matter Content (OM): As shown from Table (3) that the highest OM was recorded in WWS-100yrs soil (ranged from 1.9 to 3.16) followed by WWS-50yrs soil (ranged from 0.75 to 2.04). Also in the (control soil), the Table reveals that soil OM content was extremely depleted throughout soil profile layers, where it was 0.62% and 0.2%, in the upper and deepest soil layer, respectively. These results are reflecting poorly nutritional status of sandy soils in arid zone conditions in addition to that soil was uncultivated (control soil), consequently didn't supplement to any organic amending through agricultural practices. Furthermore, it is obvious from the data that long-term use of sewage effluent water in irrigation results in increased in soil OM , particularly, in the upper soil layer which receiving sewage water, compared with soil sub-layers (Evangelou *et al*., 2017).

Soil pH: Data presented in Table (3) show that the pH values of control soil sample (WWS-0yrs) are neutral to slightly alkaline in nature with an average pH value (7.45). The results confirmed that long–term application of sewage effluent water caused increasing in soil pH. Such effect may be attributed to the high content of basic cations *viz.* Na^+, $Ca^{2+}$and Mg^{2+} in that water. These results are agreed with the findings of Rusan *et al.* (2007), and Adjia (2008). The distribution of pH within soil profile in WWS-100yrs soil, referred that the top soil (0-30 cm) had the highest pH value (7.83) followed by the sub layers (7.82), then it gradually decreased with soil depths. Similar pattern was also observed in WWS-50yrs soil (Figure 4). Also it is cleared from the data that the high pH values in the upper layers in the sewaged soils was mainly associated with period of sewage water application as well as the depth of wetting zone of sewage effluent water.

On the other side, in the control soil samples (WWS-0yrs), the highest pH was recorded in topsoil (7.51), and then gradually decreased in the lower depths. The high soil alkalinity may be related to high salinity in that layer compared with the lower soil layers prevented in that area (as will be discuss below) as well as due to evaporation process prevailing in our area.

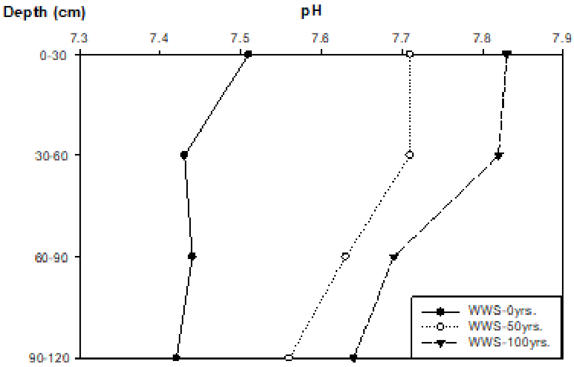

Figure (4): Effect of different period of sewage effluent application on pH of successive soil depths

Soil Salinity and sodicity: As shown from Table (3), WWS-100yrs soil has the highest EC value ($x^- = 1.852$ dSm^{-1}), followed by WWS-50yrs soil samples ($x^-=1.722$ dSm^{-1}), and WWS-0yrs (control soil), ($x^-= 0.652$ dSm^{-1}). In sewaged soil samples the data show that soil salinity increased with increasing period of using sewage effluent water in irrigation. This means that, this water plays an important role in the salinization of soils which irrigated continuously with sewage effluent water (Mtshali *et al*., 2014) These results are consistent with Evangelou *et al.* (2017) who attributed the increase in EC values to the high soluble salts content in applied sludge as well as, due to elevated concentration of soil NO_3-N. Moreover, Mohammad and Mazahreh (2003) attributed the increased salt concentration of soil receiving WW to the original level of TDS of WW. In the disposal wastewater soils, the distribution of soil salinity along soil profiles (Table 3) show that surface layer (0-30 cm) in the tested soils has a relatively high EC value compared with subsoil layers. That is because the upper soil layer directly exposed to the disposal saline water. These results are consistent with Ibrahim *et al* (2010), who mentioned that soil salinity progressively decreased with the increase in soil depth in sewage amending soils. Meanwhile remarkably higher accumulation of soluble salts in the deeper soil layers (20-40 and 40-60 cm) than surface (0-20 cm) soil layer has

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been ascribed to the leaching effect with irrigate water was reported by Rusan *et al*. (2007). On the other side, the high EC in the top soil depth of control soil compared with subsoil layers may be due to evaporation of water from soil surface and accumulation of salts.

Exchangeable sodium percentage (ESP): The calculated Exchangeable sodium percentage (ESP) of the studied soils (Table 3) referred that only remarkably increase in ESP was occurred in the top soil layers of WWS-50yrs and WWS-100yrs soil compared with the lower soil layers (Fig 5), that is may be due to relative high clay contents of these soil layers which create more adsorption sites to the soils as well as the presence of alkali cations in appreciable concentration in sewage effluent water. Similar observations were also reported by Ibrahim *et al* (2010).

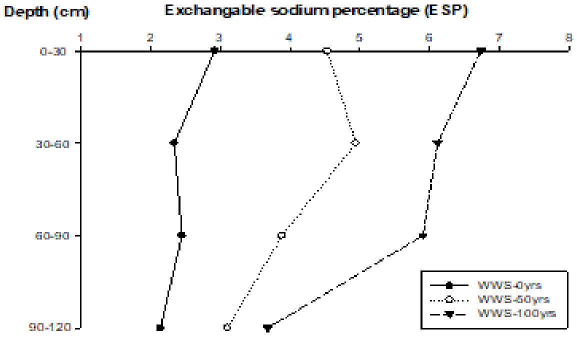

Figure (5): Effect of different period of sewage water irrigation on ESP of successive soil depths.

Soil Macronutrient concentrations in the tested soils:

Total-N: Data of Total soil N in the studied soils are listed in Table (4). The data showed that TN% in the studied soils accounted (0.0024, 0.0277, and 0.0531%) in WWS-0yrs, WWS-50yrs, and WWS-100yrs soil, respectively. On the same concern, Lindsay (1979) mentioned that TN% in world soils ranged between (800 to 4000, x^{-}=1400 ppm). In control (WWS-0yrs) soil total nitrogen range between (21.63x10^{-4} to 27.64x10^{-4} %). Moreover, on mean basis, available N values (NH$_4^-$ and NO$_3^+$) represent (22.8 and 54.2%) from its total. These results reflect deficiency of nutritional status of uncultivated sandy soils in an arid zone, especially in N content. With continuous use of sewage water, as shown from the Table, total nitrogen increased with increasing period of sewage water application. It ranged from (176x10^{-4} to 392x10^{-4} %) and (297x10^{-4} to 1109x10^{-4} %) in WWS-50yrs and WWS-100yrs, respectively. Moreover, the available N (NO$_3^-$ and NH$_4^+$) represent (61.9 and 30.32%) and (69.7 and 22.7%) in WWS-50yrs and WWS-100yrs, from its corresponding totals. respectively. As clearly from the Table that the upper soil layers of the two sewage water disposal soils have the highest total N values (392x10^{-4} and 1109 x10^{-4} %), respectively, while the deepest layers showed the lowest values (176x10^{-4} and 297x10^{-4} %). These results are in consistent with (Nennah *et al*., 1982). Also, Ibrahim *et al.* (2010) added that the different values of total N depend on many factors, such as soil O.M. content, soluble N added annually from sewage water irrigation, years of sewage effluent application.

Available-P: Data of available P for tested soils are presented in Table (4). From the Table we can show that the available P accounted, on mean basis, (0.72, 6.44, and 8.78 ppm) in WWS-0yrs, WWS-50yrs, and WWS-100yrs soil, respectively. As shown from the Table, in control soil (WWS-0yrs) available P throughout soil profile was low. It ranged between (0.82 and 0.59 ppm), in top soil and deepest soil depth, respectively. In the sewaged soil samples, the data revealed that the highest values of available P was observed in the surface layers and declined with soil depth and was associated with years of application. For instance, P content ranged from (5.58 to 7.2 ppm) and from (8.01 to 9.56 ppm) in WWS-50yrs and WWS-100yrs, respectively. These results come in agreements with that of Evangelou *et al.* (2017). Moreover, Esteller *et al.* (2009) mentioned that with Increasing the soil organic matter ability of the soil to sorb P decreased, consequently, P availability decreased.

Soluble-K: Data of soluble K for the investigated soil profiles are given in Table (4). On mean basis, the results showed that soluble K (meq/l) accounted (0.64, 1.09, and 1.28) in WWS-0yrs, WWS-50yrs, and WWS-100yrs soil, respectively. In control (WWS-0yrs) soil, k concentrations in the (0-30,-60,-90.-120 cm) soil depth were (0.71, 0.65, 0.62, and 0.61meq/l), respectively. While in WWS-50yrs and WWS-100yrs; the values were (1.4, 1.2, 0.84, and 0.92 meq/l) and (2.17, 1.3, 1.44, and 0.22 meq/l), respectively. It is clearly shown from the Table that sewage disposal soils exhibit the highest values of available k, especially in the surface soil depths. These results are consistent with (Zhang *et al*., 2008; and Hayssam *et al*., 2012).

Table 4. Some of chemical analysis of the investigated soil samples

Years of application	depth (cm)	TN(%)x10^{-4}	NO$_3$ ppm	NH$_4$ ppm	Av. P ppm	Soluble K$^+$(me/l)
WWS-0yrs	0-30	27.64	15.7	6.83	0.82	0.71
	30-60	25.91	13.79	6.14	0.76	0.65
	60-90	24.76	13.11	5.78	0.71	0.62
	90-120	21.63	11.66	4.05	0.59	0.61
	mean	24.98	13.56	5.70	0.72	0.64
WWS-50yrs.	0-30	392	84	70	7.2	1.4
	30-60	283	266	98	6.9	1.2
	60-90	257	154	84	6.09	0.84
	90-120	176	182	84	5.58	0.92
	mean	277	171.5	84	6.44	1.09
WWS-100yrs.	0-30	1109	896	126	9.56	2.17
	30-60	410	168	126	9.09	1.3
	60-90	311	196	98	8.47	1.44
	90-120	297	154	112	8.01	0.22
	mean	531.75	353.5	115.5	8.78	1.28

CONCLUSION

This study aims to evaluate the effects of using sewage water in irrigation consecutively for up to 100 years on soil physical and chemical properties with the comparison between sewage effluent water and Nile water. The results show that continual use of sewage water in irrigation improves soil nutrients status, but at the same time increases the possibility of nitrate. Also, the physicochemical parameters of the waters were still appropriate for soil irrigation. The calculated SAR value was classified as slightly to moderate hazard however and it was still lower than the permissible maximum limit (PML). Meanwhile, NO_3 was above the PML. Prolonged use of sewage water irrigation over 100-yerars led to detectable increases in all the tested soil parameters, except for $CaCO_3$ content, Also the continuous application of sewage effluent greatly influenced on available water capacity (AWC).

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آثار الري بمياه الصرف الصحي على المعايير الفيزيائية والكيميائية للتربة المصرية

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الهدف الرئيسي من هذه الدراسة هو تقييم تأثير استخدام مياه الصرف الصحي في الري على التوالي لمدة تصل إلى 100 عام على الخصائص الفيزيائية والكيميائية للتربة مع تحديد الخصائص العامة لمياه الصرف الصحي ومقارنتها بمياه النيل. وقد أظهرت النتائج أن الاستخدام المستمر لمياه الصرف الصحي في الري يحسن حالة مغذيات التربة ، ولكنه في نفس الوقت يزيد من نسبة النترات. كما أن الخواص الفيزيائية والكيميائية للمياه كانت لا تزال مناسبة لري التربة. تم تصنيف قيمة معدل الامتصاص النوعي (SAR) المحسوبة على أنها مخاطر طفيفة إلى متوسطة ولكنها لا تزال أقل من الحد الأقصى المسموح به (PML). وفي الوقت نفسه ، كانت النترات أعلى من الحد المسموح به . أدى الاستخدام المطول للري بمياه الصرف الصحي على مدى مائة عام إلى زيادات ملحوظة في جميع معايير التربة المختبرة ، باستثناء محتوى كربونات الكالسيوم ، كما أثر التطبيق المستمر لمياه الصرف الصحي بشكل كبير على سعة المياه المتاحة (AWC).