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Sewage effluent as an alternative source for irrigation: Impact on soil properties and heavy metal status

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Abstract

Sewage irrigation may provide an alternative resource due to scarcity of fresh water in Egypt, thus such a practice should be evaluated. A number of 36 pairs of soil samples were collected; each pair consisted of one sample irrigated with fresh water and another irrigated with sewage water from two different sites in Al-Qalyubia Governorate, Egypt. Sewage water-irrigated soils showed higher pH, EC, N, P, K, Fe Mn, Zn, Cd, Pb and Ni than fresh water-irrigated soils. Positive changes in soil properties occurred with sewage irrigation. Bulk density decreased field capacity, organic carbon and nutrients increased by sewage water irrigation. There was build-upin Cd, Pb, Ni and Zn. Single pollution index (SPI) and pollution load index (PLI) indicated no pollution in fresh water irrigated soils as both parameters did not exceed 1.0. Sewage irrigated soils were moderately polluted. The contamination factor (CF) revealed aconsidered contamination with Pb and high for Cd, Ni and Zn. The contamination degree was very high. Food crops cultivation in such soils should be practiced under precautions with a change in the cropping pattern.

Keyword: Sewage effluent, Soil properties, Heavy metals, Soil pollution

Introduction

Water shortage is one of the most serious issues in the Mediterranean region. The relatively uneven distribution of precipitation, high temperatures and increased demands for irrigation water are the main factors which contribute to this situation (Loutfy, 2011). Waste water irrigation is becoming a global phenomenon (Abaidoo *et al.*, 2010)and is adapted increasingly in areas near to urban cities of developing countries (Sou/Dakouré *et al.*, 2013). Sources of waste water are domestic sewage effluent (municipal wastewater), agricultural effluents, industrial effluents, and storm water (Kunhikrishnan *et al.*, 2012).

Irrigation with sewage effluent have advantages such as providing economic and effective alternative sources of water (Ali *et al.*, 2013) and saving fertilizer costs due to nutrients contents in water(Minhas *et al.*, 2015). Different implications on soil properties were reported due to irrigation with sewage water (Lado and Ben-Hur, 2009). It adds large amounts of organic matter, macro and micro-nutrients (Yadav *et al.*, 2002), increases salts (Mohammad Rusan *et al.*, 2007) and decreases soil pH(Rattan *et al.*, 2005).It may increase clay content and improve soil fertility (Masto *et al.*, 2009).

Sewage water carries nutrients contains medium to high content of heavy metals (Butt *et al.*, 2005). Thus, using it for irrigation could lead to accumulation of such metals in soil and foodstuff (Surdyk *et al.*, 2010). Prolonged irrigation of sewage water could be a potential environmental risk(Mapanda *et al.*, 2005). It releases organic contaminants into soil and water(Wang *et al.*, 2015), leaches metals into underlying aquifers, affecting the quality of drinking water (Lottermoser, 2012) and cause health risks due to pathogenic infestation (Ahmad *et al.*, 2011; Chopra and Pathak, 2012; Minhas *et al.*, 2015).

Many farmers in developing countries irrigate crops using raw urban and industrial effluents. Therefore, soils, crops and groundwater would have to be assessed (Yadav *et al.*, 2015). Some studies showed that heavy metals in long-term sewage irrigated soils may still be below the maximum permissible limit (Bao *et al.*, 2014; Salakinkop and Hunshal, 2014). The present study aimed at assessing the effect of sewage water on soil properties and heavy metal contents in some areas in Qalubiya, Egypt.

2. Materials and methods

2.1. The area of study

The study was conducted during August to September 2014 at Tukh District, Al-Qalubiya Governorate, Egypt, located between latitude 30° 18' 28″ to 30° 23' 28″ N and longitude 31° 11' 55″ to 31° 14' 49 ″ E, lying at 15 meters above sea level The climate of the area is characterized by hot rainless summer, short rainy mild winter, high evaporation and low relative humidity. Soil of the areais Typic Haplotorrerts.

2.2. Collection of samples

Soils irrigated with sewage effluents lies on the banks of the main drain of Al- Qalubiya Governorate (Fig. 1), while soils irrigated with fresh Nile receive their water from Al-Kawm Battin canal. Water samples were collected along with soil sample. At each site, a number of 36 soil samples (0-30 cm layer) were collected separately from different site.

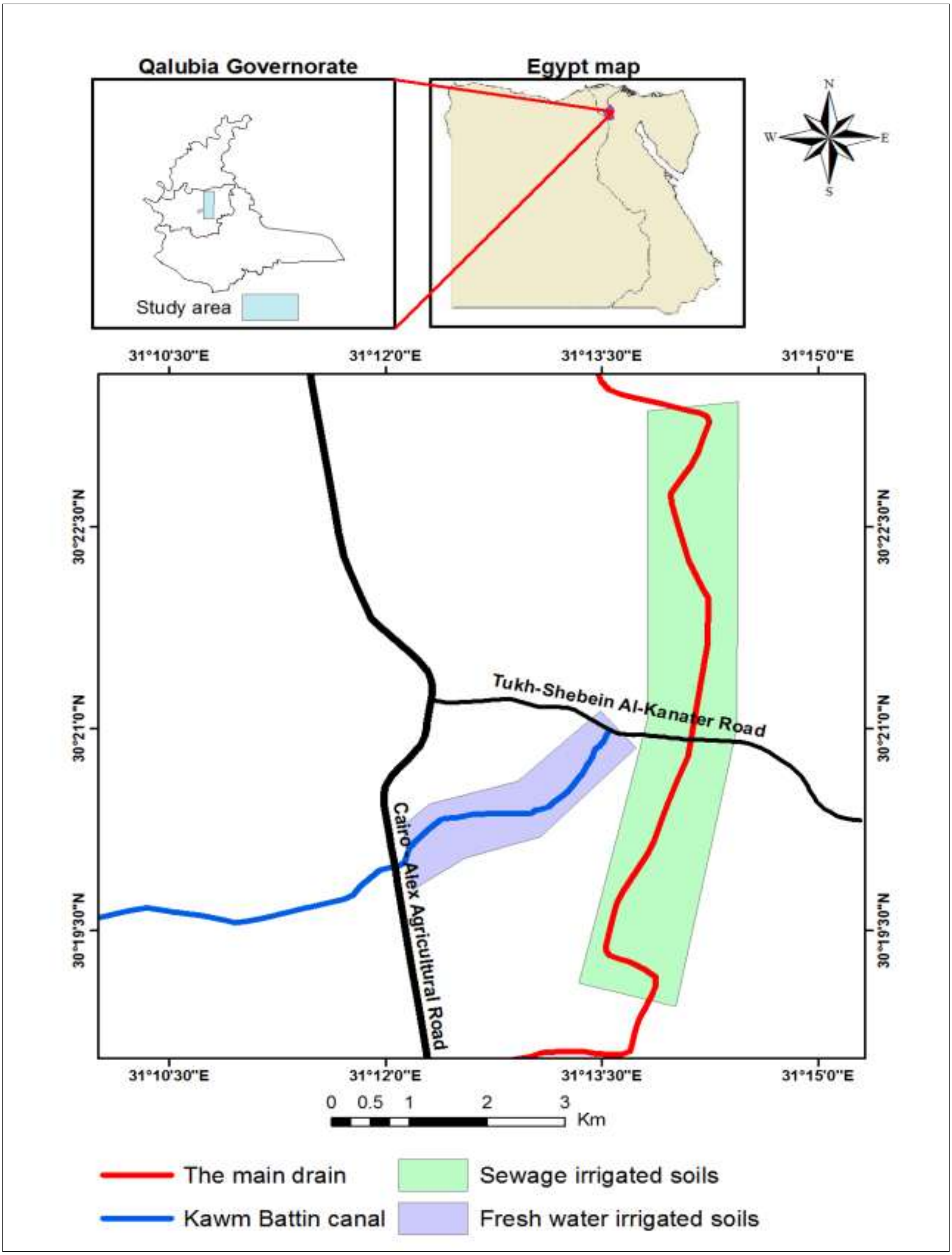


Fig. 1. Location map of the studied area

2.3. Analyses

2.3.1. Water analysis

Analyses of samples were done according to methods cited by APHA (1999) and USDA (1954). The following parameters were calculated for water:

Residual sodium carbonate (RSC) = $[CO_3^{2-} + HCO_3^-] - [Ca^{2+} + Mg^{2+}]$

Sodium Adsorption Ratio (SAR) = $Na^+ / \sqrt{[Ca^{2+} + Mg^{2+}]/2}$

Mg-ratio = $Mg^{2+} / [Ca^{2+} + Mg^{2+}]$

Total Hardness(TH) = $[Ca^{2+} + Mg^{2+}] \times 50$, where, 50 is the equivalent weight of $CaCO_3$

2.3.2. Soil analysis

Air-dried soil samples were crushed and passed through 2 mm sieve and analysed for chemical and physical properties according methods cited to Page *et al.* (1982), Klute (1986) and Soltanpour and Schwab (1977). Total contents of Cd, Pb, Ni and Zn were determined using aqua regia for digestion (ISO, 1995) and measured using HG-AAS Perkin Elmer 2380.

2.3.3. Assessment of heavy metal contamination

Monitoring heavy metal in soilhelps to avoid health risk and further deterioration of the environment(Al-Musharafi *et al.*, 2013). Indices in the study were as follows:

(1). Single pollution index (SPI)

This index identifies metal toxicity induced by single element contamination (Saha *et al.*, 2015). The equation is; SPI = Ci / Cp, where; Ci is metal content in soil; Cp, the permissible concentration of the metals (0.4, 27, 29 and 70 mg $kg^{-1}$for Cd, Pb, Ni and Zn, respectively as mentioned by "Kabata-Pendias, 2010"). According to Chen *et al.*(2005) andLee *et al.*(2006)soil pollutionconcerningthe based on SPI are: low (≤ 1), moderate (1 ≤ 3) or high (> 3).

(2). Pollution load index (PLI)

This index shows a simple comparative means for level of multi-element pollution(Bhuiyan *et al.*, 2010). This parameter is calculated according to Lu *et al.*(2014)as follows:

$$PLI = \sqrt[n]{SPI_1 \times SPI_2 \ldots\ldots \times SPI_n}$$

Soil pollution occurs when PLI surpasses 1.0 (Tomlinson *et al.*, 1980). The soils are considered background when PLI = 0, while more values categorize soils in other six classes; i.e. ≤ 1, unpolluted; 1 : ≤ 2, unpolluted to moderately polluted; 2 : ≤ 3, moderately polluted; 3 : ≤ 4, moderately to highly polluted; 4 : ≤ 5, highly polluted; or > 5, very highly polluted(Zhang *et al.*, 2011).

(3). Contamination Factor (CF)

This parameter is used to identify soil contamination of the single heavy metal. It is calculated as follows: CF = Ci / Co, where Ci is the metal content in soil, Cois the metal concent in the unpolluted (background) soil(Ferati *et al.*, 2015). Soil contamination could be classified based on CF values as mentioned by Hakanson(1980)and Ghannem *et al.*(2016)into four classes: low (<1), moderate (1- 3), considerable (3-6), or high (>6)

(4). The contamination degree (CD)

The total of contamination factors represents the degree of contamination (Saha *et al.*, 2016). The calculated values of CD arrange soil in four contamination categories, low (below 8), moderate (8 : ≤ 16), considerable (16 :≤ 32) and very high (≥32)(Hakanson, 1980; Krishna and Mohan, 2016)

3. Results and discussion

3.1. Water quality for irrigation (Table 1)

Water samples of the sewage effluent had a relatively high pH value compared with Nile water. Thus, they were within the safe limit for irrigation (Ayers and We stcot, 1994). This increase may be related to the relatively high content of both sodium and bicarbonate ions in sewage effluent (Chapman, 1996). Values of EC and total dissolved solids (TDS) were 0.37 dSm^{-1} and 350 mgL^{-1}, respectively for fresh water, while the corresponding values for the sewage water were1.10 dSm^{-1} and 800 mgL^{-1}, respectively. The higher values of the sewage water maybe associated with discharge of brackish industrial effluents.

Basedon Ayers and Westcot (1994), there is no salinity hazardsfor the fresh water. Values of total suspended solids (TSS) were 50 and 110 mgL^{-1} in the fresh and sewage water, respectively. Therefore, fresh water hadlow suspended solids, while sewage water had medium solids (Pescod, 1992). Values of total hardness (TH) were 140 and 315 mgL^{-1} for the fresh and the sewage water, respectively. The existence of soluble calcium and magnesium salts in waters is the main cause of water hardness (Chapman, 1996). According to Twort *et al.* (1994) the fresh water is slightly hard, while the sewage water is very hard. Values of SAR were 0.31 and 3.23 for the fresh and the sewage water, respectively. To assess potential infiltration problem, values of EC and SAR were used together (Ayers and Westcot, 1994). The fresh water had no restriction in use, while the sewage water had slight to moderate restrictions. According to USDA (1954), the fresh water is safe in use since it had no positive RSC.

Table 1. Analyses of fresh and sewage water

Parameters	Unit	Fresh water	Sewage water	Standard level for irrigation
pH	- log [H^+]	7.23 [1]	7.39 [1]	6.5 - 8.4 [a]
EC	dSm^{-1}	0.37 [1]	1.10 [2]	< 3 [a]
TDS	mgL^{-1}	350 [1]	800 [2]	< 2000 [a]
TSS	mgL^{-1}	50 [w]	110 [m]	< 350 [b]
Ca	mmolc L^{-1}	1.50	3.50	nm
Mg	mmolc L^{-1}	1.30	2.80	nm
Na	mmolc L^{-1}	0.37	5.71	nm
K	mmolc L^{-1}	0.22	0.84	nm
Cl	mmolc L^{-1}	1.10 [1]	4.10 [2]	< 10 [a]
CO_3	mmolc L^{-1}	0.00	0.00	nm
HCO_3	mmolc L^{-1}	2.20 [1]	8.40 [2]	< 8.5 [a]
SO_4	mmolc L^{-1}	0.15	0.35	nm
SAR	mmolc L^{-1}	0.31 [1]	3.23 [2]	< 9 [a]
RSC	mmolc L^{-1}	- 0.6 [*]	2.10 [**]	< 2.5 [c]
Mg-Ratio	mmolc L^{-1}	46.43	44.44	< 50 [d]
TH	mg L^{-1}	140 [sh]	315 [vh]	< 300 [e]
NH_4-N	mg L^{-1}	4.10	11.20	nm
NO_3-N	mg L^{-1}	3.90 [1]	19.40 [2]	< 30 [a]
P	mg L^{-1}	0.51	3.65	nm
Fe	mg L^{-1}	0.03	4.44	5.00 [a]
Mn	mg L^{-1}	0.02	0.15	0.20 [a]
Zn	mg L^{-1}	0.01	3.56	2.00 [a]
Cd	mg L^{-1}	n.d	0.03	0.01 [a]
Pb	mg L^{-1}	0.01	6.11	5.00 [a]
Co	mg L^{-1}	n.d	n.d	0.05 [a]
Ni	mg L^{-1}	0.01	0.62	0.20 [a]
B	mg L^{-1}	0.01	0.02	< 3 [a]

[a] Ayers and Westcot (1994); [b] Pescod (1992); [c] USDA (1954); [d] FAO/UNESCO (1973); [e] Twort *et al.* (1994); nm = not mentioned in references; [1] none restriction; [2] slight to moderate restrictions; [3] severe restrictions; [*] probably save; [**] marginally suitable; [w] weak; [m] medium, [sh] slightly hard; [vh] very hard.

The sewage water, with an RSC value of 2.10 $mmolcL^{-1}$ is marginally suitable (1.25 to 2.5 $mmolcL^{-1}$).Excessive concentration of magnesium in irrigation water may cause deterioration in soil structure due to increasing ESP (Rahman and Rowell, 1979). Potential harmful effect occurs when Mg ratio surpasses 50% i.e. when Mg^{2+}exceeds Ca^{2+} (FAO-UNESCO, 1973). Accordingly, no Mg harmful effect is expected for irrigation as Mg is <50 % for both waters. Values of Clwere1.10 and 4.10 $mmolcL^{-1}$for the fresh and sewage water, respectively. Values of B were 0.01 and 0.02 mgL^{-1}, for same waters. Both SAR and chloride imposed slight to moderate restrictions in using sewage water, while no restriction concerning B (Ayers and Westcott, 1994).Content of metals did not surpass the maximum acceptable concentration suggested by Ayers and Westcot (1994), except Zn (3.56), Cd (0.03), Pb (6.11) and Ni (0.62) in sewage water that exceeded the permissible levels of 2.0, 0.01, 5.0 and 0.20 mgL^{-1}, respectively. Contents of NH_4-N and NO_3-N were 4.10 and 3.90 mgL^{-1}, respectively for fresh water and 11.20 and 19.40 mgL^{-1}, respectively for sewage water. No restriction in using the fresh water, while a slight to moderate restriction is imposed when using sewage water (Ayers and Westcot, 1994). P content was 0.51 and 6.65 mgL^{-1}in fresh and sewage water, respectively.

3.2. Effect of water quality on soil properties

Results in Table 2 show that soil pH varied from 7.39 to 7.81 in the fresh water-irrigated soils and from 7.45 to 7.99 in the sewage water irrigated soils. The pH of soils irrigated with fresh water was lower than those irrigated with sewage water.

There was 56.72% increase in EC in soils irrigated with sewage water compared with those irrigated with fresh water. EC values for the fresh water-irrigated soils ranged from 0.64 to 1.75 dSm^{-1} with an average of 0.87 dSm^{-1}, while the corresponding values for sewage-irrigated soils ranged from 0.56 to 5.77 dSm^{-1} with an average of 2.01 dSm^{-1}. These results agree with those of Gwenzi and Munondo (2008) and Ghosh *et al.*(2012) who recorded increased values of pH and EC in soils irrigated with wastewater.

Table 2. Properties of the studied soils

Parameter	Unit	Fresh water-irrigated soil				Sewage water-irrigated soils			
		Min.	Max.	Mean	S.D	Min.	Max.	Mean	S.D
WHC	%	34.70	36.67	35.55	0.50	33.33	38.00	36.07	1.50
Bd	Mgm^{-3}	1.18	1.34	1.25	0.05	1.11	1.28	1.20	0.06
O.C	gkg^{-1}	7.65	12.75	10.77	1.51	8.55	15.60	11.98	1.98
pH	- log [H^+]	7.39	7.81	7.57	0.13	7.45	7.99	7.62	0.21
ECe	$dS\ m^{-1}$	0.64	1.75	0.87	0.35	0.56	5.77	2.01	1.69
Ca^{2+}	mmolc L^{-1}	2.60	7.60	3.88	1.47	3.70	23.00	8.72	8.09
Mg^{2+}	mmolc L^{-1}	2.80	4.10	3.42	0.41	2.40	26.40	8.00	7.90
Na^+	mmolc L^{-1}	0.64	1.45	0.92	0.26	0.66	9.25	2.21	2.67
K^+	mmolc L^{-1}	0.20	1.24	0.65	0.33	0.23	0.91	0.49	0.22
Cl^-	mmolc L^{-1}	2.40	5.70	3.36	0.97	2.00	52.80	11.00	15.81
$CO_3^=$	mmolc L^{-1}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3^-	mmolc L^{-1}	2.80	4.40	3.62	0.56	2.60	4.00	3.29	0.50
$SO_4^=$	mmolc L^{-1}	0.40	5.49	1.89	1.53	0.51	27.83	5.14	8.58
SAR	mmolc L^{-1}	0.36	0.64	0.48	0.11	0.37	1.87	0.72	0.46
Total N	g kg^{-1}	2.80	5.95	3.62	1.11	2.45	52.50	18.08	15.83
AB-DTPA - P	mg kg^{-1}	1.42	9.94	4.26	2.78	3.25	13.19	7.85	3.80
AB-DTPA - K	mg kg^{-1}	197.43	679.82	474.68	74.33	298.01	722.67	502.62	39.69
AB-DTPA - Fe	mg kg^{-1}	2.14	8.32	4.15	2.21	3.80	43.14	10.09	12.47
AB-DTPA - Mn	mg kg^{-1}	8.22	20.94	13.50	4.64	6.16	76.68	22.04	21.82

On the other hand, Yao *et al.*(2013) mentioned that wastewater irrigation has not had any significant effect on pH or EC.Soil organic carbon ranged from 7.65 to 12.75 in the fresh water-irrigated soils and from 8.55 to 15.60 gkg^{-1} in the sewage water-irrigated soils. Average of soils irrigated with fresh water was 10.77 $gkg^{-1}$and for the sewage-irrigated soils it was 11.98 gkg^{-1}. Thus, the sewage-irrigated soils had 10.10% more organic carbon than the fresh water-irrigated soils. These results agree with Yao *et al.*(2013)Yang *et al.*(2015) who found an increase in soil organic carbon in sites irrigated with sewage water compared to those receive fresh water. Moreover Al-Omran *et al.*(2012) reported significantincrease in soil organic carbon in sewage-irrigated soils as compared to well water-irrigated ones. Values of the water holding capacity ranged between 34.70 and 36.67% with an average of 35.55% in soils irrigated with fresh water and between 33.33 and 38.00% with an average of 36.07% in soils irrigated with sewage water. These results indicatea slight increase of 1.5% in soil water holding capacity. Values of soil bulk density varied from1.18 to 1.34 Mgm^{-3} with an average of 1.25 Mgm^{-3} in fresh water-irrigated soils; while the corresponding values of sewage water- irrigated soils were 1.11 and 1.28 Mgm^{-3} with an average of 1.20 Mgm^{-3}. Thus, sewage water had bulk density lower by 4.0% than fresh water-irrigated soils. These results agree with Mathan(1994) who stated that sewage irrigation decreased soil bulk density. Contents of N, P,K, Fe and Mn in sewage-irrigated soils increased by 5, 1.8, 5.9, 2.4 and 1.6timesabovethose which received fresh water. Total N rangedfrom 2.80 to 5.95 gkg^{-1}(average of 3.62 gkg^{-1}) in fresh water-irrigated soils and from 2.45 to 52.50 gkg^{-1}(average of 18.08 gkg^{-1})insewage water-irrigated soils. P in fresh water irrigated soils ranged from 1.42 to 9.94 $mgkg^{-1}$(average of 4.26$mgkg^{-1}$), while those of soils which received sewage water ranged between 3.25 and 13.19 $mgkg^{-1}$ (average of 7.75 $mgkg^{-1}$). Available K in fresh water irrigated soils ranged from 197.43 to 679.82 $mgkg^{-1}$with (average of474.68 $mgkg^{-1}$) and from 289.01 to 722.67 $mgkg^{-1}$in sewage irrigated soils (average of 502.62 $mgkg^{-1}$). Available Fe ranged from 2.14 to 8.32 $mgkg^{-1}$in fresh water-irrigated soils and from 3.80 to 43.14 $mgkg^{-1}$ in sewage water-irrigated soils. Available Mn ranged from 8.22 to 20.94 $mgkg^{-1}$in fresh water irrigated soils; and 6.16 to 76.68 $mgkg^{-1}$ in sewage water-irrigated soils. These results are in agreement withthose reported by Angin *et al.*(2005) and Xu *et al.*(2010)who found a considerable increase in nutrient load in soils irrigated with effluent over those received fresh water

3.3. Heavy metal contents in soils

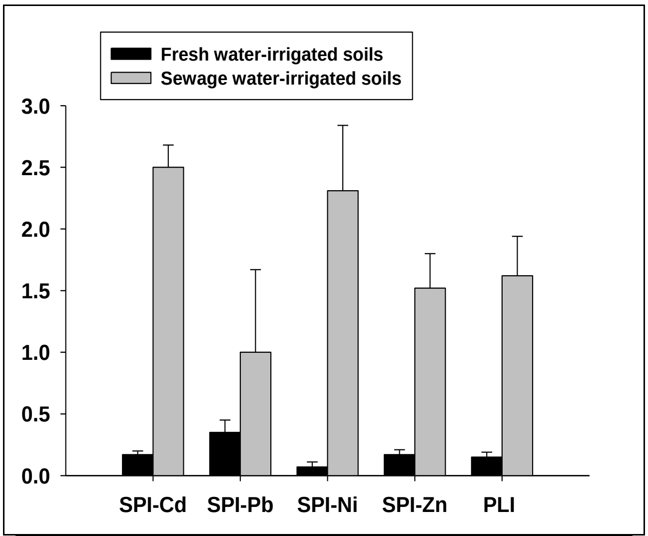
The total content of heavy metals (Table 3)indicatesa build-up of Cd, Pb, Ni and Zn in the sewage water-irrigated soils. Contents of Cd, Pb, Ni and Zn were greater by 14.3, 2.9, 35.3 and 9.1folds, respectively in the sewage-irrigated soils over the fresh water-irrigated soils. This agrees with Bao *et al.*(2014) and Meng *et al.*(2016) who noteda considerable accumulation of heavy metals in soils after long-term sewage water irrigation. Chung *et al.*(2011) reported a slight increase of heavy metal contents in soils after long-term irrigation with sewage water.

Table 3. Total heavy metal contents (mg kg^{-1}) in the studied soils

Metal	Fresh water-irrigated soils				Sewage water-irrigated soils			
	Min.	Max.	Mean	S.D	Min.	Max.	Mean	S.D
Cd	0.05	0.09	0.07	0.01	0.89	1.12	1.03	0.08
Pb	3.17	13.17	9.42	4.38	4.38	58.75	26.88	9.4
Ni	0.64	3.63	1.91	1.11	34.3	86.24	67.06	7.9
Zn	3.96	17.08	11.64	4.05	80.39	129.41	106.32	9.8

3.4. Heavy metals status

As shown in Fig. 2, no metal pollution occurred in the fresh water-irrigated soils since the mean values of SPI and PLI did not exceed 1.0. On the other hand, values of SPI for the sewage-irrigated soils were 2.5, 1.0, 2.3 and 1.5 for Cd, Pb, Ni and Zn respectively. Soil pollution with heavy metals was low for Pb and moderate for Cd, Ni and Zn. Regarding the overall pollution, the PLI was1.6 and hence, the soils maybe considered unpolluted to moderately polluted. These results agree with those of Liu *et al.*(2005), Sun *et al.*(2013), Hu *et al.*(2014)who reported that sewage irrigation caused pollution of soils with heavy metals. The mean values of CF as shown in Fig.3 were 15.3, 3.3, 51.7 and 11.3 for Cd, Pb, Ni and Zn, respectively. These results indicate contamination caused by anthropogenic activitiesas mentioned by Moore *et al.*(2011)since CF values exceeded 1.0. Thus, the soils could be classed into two contamination classes; considerable for Pb and high for Cd, Ni and Zn. Regarding the contamination degree, the soils are of high degree of contamination since CD exceeded 32. These results agree with Liu *et al.*(2005)and Balkhair and Ashraf (2016)who reported hazards of heavy metal contamination in agricultural fields due to irrigation with sewage water.



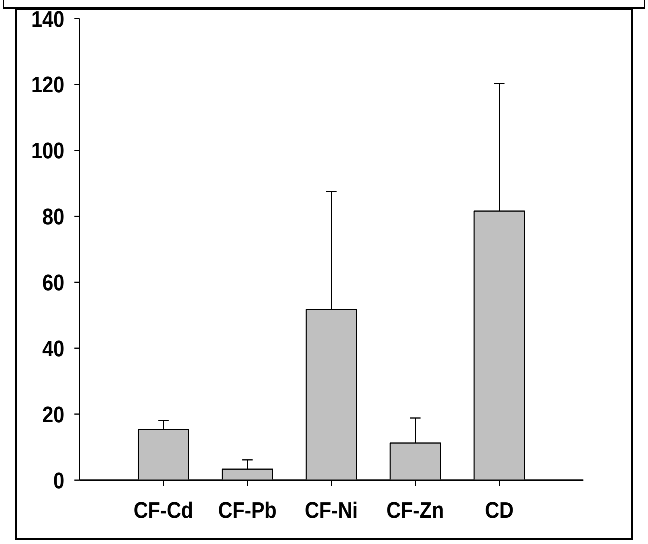


Fig. 2. Pollution indices for the studied soilsFig. 3. Contamination indices for the sewage Water-irrigated soils

5. Conclusion

Water shortage has been a serious issue which preoccupies the public opinion in Egypt. Accordingly, the use of unconventional resources should be considered for agriculture proposes. Sewage effluent may providea source of irrigation but its use must be well evaluated. A comparison between soils irrigated with sewage effluent and those which receive Nile fresh water was done. Sewage irrigation resulted in some positive effects such as providing organic matter and nutrientsto soil. On the other hand, there was a build-up in EC, pH and heavy metals in sewage-irrigated soils. Single pollution index (SPI) and pollution load index (PLI) indicate a moderate pollution in sewage irrigated soils. The contamination factor (CF) indicates contamination with Pb, Cd, Ni and Zn. Therefore, one or more scenario for remediation should be performed. An alternative possible solution for such problem could be achieved by changing land usepattern from food crops cultivation to others such as fibers.

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مياه الصرف الصحي كمصدر بديل للري : التأثير على خواص التربة وحالة الفلزات الثقيلة

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الملخص العربي

على الرغم من أن الري بمياه الصرف الصحي هو البديل للماء العذب في مصر، إلا أنه يجب تقييم هذه الممارسة جيداً. تم أخذ عدد 36 عينة تربة في موقعين مختلفين في محافظة القليوبية بمصر أحدهما يروي بمياه الصرف الصحي، والآخر يروى بمياه النيل. أظهرت النتائج زيادة قيم رقم الحموضة، الأملاح الكلية الذائبة، النيتروجين، الفسفور، البوتاسيوم، الحديد، المنجنيز، الزنك، البورون، الكادميوم، الرصاص، والنيكل في مياه الصرف الصحي عن المياه العذبة. كان للري بمياه الصرف الصحي تأثير إيجابي على خواص التربة ظهر من خلال خفض الكثافة الظاهرية، زيادة حفظ التربة للماء، إثراء التربة بالمادة العضوية ، والمغذيات. أما بالنسبة للتأثيرات السلبية فكانت زيادة رقم حموضة التربة، الأملاح الذائبة، والفلزات الثقيلة مثل الكادميوم، الرصاص، النيكل ، والزنك. أظهرت قيم كل من مؤشر التلوث الفردي (SPI) و مؤشر حمل التلوث (PLI)عدم وجود أي تلوث في الأراضي المروية بالماء العذب، في حين أن تلك المروية بمياه الصرف الصحي كانت معتدلة التلوث. أظهرت قيم معامل التلوث (CF) وجود تلوث محسوس بالنسبة لعنصر الرصاص وعالي جداً بالنسبة للكادميوم، النيكل، والزنك، وكانت درجة التلوث بهذه المعادن عالية جداً. يمكن إستنتاج أن زراعة المحاصيل الغذائية في مثل هذه الأراضي يجب أن يتم تحت تدابير وقائية، والإ تغيير التركيب المحصولي بمحاصيل غير غذائية.