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RISK ASSESSMENT OF SEWAGE REUSE ON THE SANDY SOIL OF THE ABU-RAWASH DESERT, EGYPT

The arid and semi-arid countries suffer from the shortage of water resources as a result of insufficient rainfall to support agricultural activities. At present, 96.4% of Egyptian land areas are almost without any cultivation. Meanwhile, treated sewage water has been used for many decades as a source for irrigation in many countries. Recent studies consider treated sewage as a source of non-potable purposes rather than a source of environmental threat. In Egypt, sewage application in land takes place on sandy soil that suffers from an inherent lack of organic matter as well as micro- and macronutrients. One of such applications has been practised on sandy soil of Abu-Rawash Sewage Farm. The area of 105 hectares has been planned to expand to only 210 hectares. The farm receives, presently, from 4000 to 5000 m^3 of primarily treated sewage water per day. On the farm there are mainly citrus trees and some experimental fields of hardwood trees, flower plants and small experimental area intended to be used for sludge. Generally, the level of metals in sewage water is within low concentrations of mg/dm^3, yet they still have the possibility of retaining them in variable concentrated forms. This takes place when metals are the constituents of the food chain and are absorbed by plants or retained by animals. The present subject is the fate of metals in the sandy soil of an Egyptian sewage farm that has been irrigated by primarily treated sewage water since 1944. The increasing demand for the sewage water being treated in such a way raises the question of what is the impact of sewage application on the sandy soil. What is the fate of heavy metals in soil at its variable depths, which, therefore, will affect the growing plant. What are the changes that take place in the case of such sandy soil of the desert.

1. INTRODUCTION

The arid and semi-arid countries suffer from the shortage of water resources due to the fact that they have insufficient rainfall to support agricultural activities. Egypt covers an area of slightly over one million km^2 of the arid belt in Northern Africa and Western Asia [1]. At present, 96.4% of Egyptian land area are almost without any cultivation [2]. Additionally, Egypt faces today the problem of overpopulation. This

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leads to a high demand of water and land usable for food production. Egypt was self-sufficient agriculturally, and agricultural production grew by over 3% annually during the 1960's. In the 1970's and the early 1980's, the pace of growth declined to ca. 2% per year [3].

The major challenge facing Egypt now is that of developing and managing better the very limited natural resources of water to meet the needs of a population growing at a rate of 2.1% per year. Therefore, increasing the cultivated area and reclaiming parts of the desert are the challenge of near future to Egypt [4]. On the other hand, inadequately treated sewage finds its way to different water bodies, including surface as well as groundwater.

Meanwhile, treated sewage water has been used for many decades as a source for irrigation in many countries [2], [5]. Recent studies consider treated sewage as a source of water at least for non-potable purposes rather than a source of environmental threat [4]. This is particularly true for the countries that suffer from the deficiency of water resources [5].

Land sewage application in Egypt takes place on sandy soil that suffers from an inherent lack of organic matter as well as micro- and macronutrients. Sewage has been used for sandy soil of Abu-Rawash Sewage Farm [2]. It is located to the south-west of Cairo and occupies 105 hectares, which is planned to be expanded to 210 hectares only. Presently the farm receives between 4000 and 5000 m^3 of primarily treated sewage water per day from Zenien sewage treatment plant. The farm was established in 1936 and started its fully effective operation in 1944. It consists mainly of citrus trees and some experimental fields of hardwood trees, flower plants and small experimental area where the sludge is used. The eucalyptus trees surround the farm [6]. New wastewater treatment plants have recently been erected in Cairo and other urban centers. The volume of treated wastewater that could be available for agricultural activities would increase steadily during the next three decades. The total annual volume of wastewater available from Great Cairo has been increased from 0.9 billion m^3 in 1990 to 1.7 billion m^3 in 2000 and it is estimated that it will increase to about 1.93 billion m^3 by 2010 [7].

In recent years, agronomists and environmentalists have become aware of a potential hazard posed by heavy metals [2], [8]. The accumulation of such metals in soil after application of sewage has concerned researchers for two main reasons: firstly, the ability of plants to absorb and translocate certain metals that are toxic to humans and animals; secondly, the accumulation of metals in soil to levels that become toxic to plants [4], [9]. Many investigators have studied extensively the effect of heavy metals on the quality of water and soil [10], [11]. The toxicity of such metal ions to the environment is well documented [12], [13]. Although heavy metals may be discharged in highly diluted forms, yet they still can be retained in variable concentrated forms. This takes place when metals enter the food chain and are absorbed by plants or retained by animals.

The increasing demand for such treated sewage water raises the question of what is the impact of sewage application on the sandy soil. What is the fate of heavy metals in soil at various depths, which, therefore, will affect the growing plants. What are the changes that take place on such sandy soil of the desert.

2. MATERIALS AND METHODS

This study was carried out continuously for a period of 12 months. Primarily treated sewage water in the Abu-Rawash area (Giza Governorate) was used for irrigation purposes. Meanwhile, fresh canal water was also used for irrigation within another area close to this canal that is an arm of the Nile river.

2.1. WATER SAMPLES

The physical and chemical characteristics as well as the level of heavy metals of both primarily treated sewage water and fresh canal water were determined according to APHA [14]. The parameters of interest are as follows: electric conductivity (EC), pH, cation contents (Mg, Na, K), and anion contents (bicarbonates, chlorides, sulphates). Similarly, the physical characteristics of the soil (EC and pH) were investigated according to APHA [14].

In order to prepare the water samples for the determination of the heavy metal content, the collected water samples were filtered through Whatman filter paper No. 4, acidified to pH lower than 2.0 and preserved in polyethylene bottles.

2.2. SOIL SAMPLES

Various soil samples were collected throughout the period of the present study. They are as follows:

1. Non-irrigated soil (as control).
2. Soil irrigated by the treated sewage water effluent (soil has been irrigated periodically for 6 years).
3. Soil irrigated by fresh canal water for 40 years at the same location.

Soil samples were collected to a depth of 40 cm, representing four successive layers, namely 0–10 cm, 10–20 cm, 20–30 cm and 30–40 cm. The soil samples were air-dried, crushed gently, sieved through 2 mm sieve, and stored for acid digestion and metal determinations.

Particle-size distribution of known soil samples was determined as percentage distribution of sand, silt and clay according to the international pipette method described by PIPER [15], using the standard triangular diagram. Organic matter concentration was determined volumetrically based on the oxidation of organic carbon by potassium dichromate in the acidified medium as described by JACKSON [16]. Electric conductivity (EC, in mS/cm) was determined as the total soluble salts of the soil saturated extract at 25 °C described by LINDSAY and NORVELL [17] and COTTENIE et al. [18]. Calcium carbonate content expressed as per cent of soil component was determined volumetrically in the acidified solution using sulphuric acid according to the procedure described by COTTENIE et al. [18].

To study the availability of heavy metals in the different soil samples, different extraction procedures were carried out as follows:

1. *DTPA soil extract*: 0.005 M DTPA (diethylene triamine pentaacetic acid, Merck) in 0.01 M calcium chloride and 0.1 M triethanolamine (TEA) at pH 7.3 according to LINDSAY and NORVELL [17].

2. *Ammonium acetate–EDTA soil extract*: 0.01 M EDTA (ethylenediaminetetraacetic acid, Merck) in 0.1 M ammonium acetate at pH 4.65 according to COTTENIE et al. [18].

3. *0.5 M nitric acid soil extract*: according to COTTENIE et al. [18].

Heavy metals such as iron, copper, manganese, zinc, lead, cadmium and nickel were determined in both water samples and the soil extracts using Atomic Absorption Spectrophotometer, 3300 Perkin-Elmer. Additionally, manganese, sodium and potassium concentrations in both water and soil samples were determined using Flame Photometer, Perkin-Elmer.

3. RESULTS AND DISCUSSION

3.1. PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATERS USED FOR IRRIGATION

Table 1 shows that the sewage water is generally characterized by higher levels of EC, Mg^{2+}, Na^+, K^+, HCO_3^-, Cl^- and SO_4^{2-}, compared with the canal water, while the pH value of the sewage water is slightly lower than that of the canal water. It is worth noting that Na^+ and HCO_3^- were present at the highest cation and anion concentrations, respectively, in both types of water. The summer values of the physical and chemical characteristics were slightly higher than the winter values.

Tables 2 and 3 illustrate the level of heavy metals in the two types of waters that were used for irrigation during the winter and summer. It can be noticed that iron concentration was the highest, while cadmium content was the lowest in both types of water. Meanwhile, a slight variation can be observed during the successive months of the year. However, the level of metals in sewage water was generally higher than the corresponding concentration of metals in the canal water. Additionally, the level of

Table 1

Physical and chemical characteristics of sewage water and canal water used for irrigation

Season	Type of water	EC (mS/cm) at 25 °C	pH			Cation (meq/dm^3)									Anions (meq/ dm^3)								
						Mg^{++}			Na^+			K^+			HCO_3^-			Cl^-			SO_4^{2-}		
			Min	Max	Aver	Min	Max	Aver	Min	Max	Aver	Min	Max	Aver	Min	Max	Aver	Min	Max	Aver	Min	Max	Aver
Winter	Sewg water	0.98	6.5	7.5	6.9	1.88	2.75	2.29	3.54	8.79	6.16	0.40	0.89	0.65	6.18	6.24	6.21	5.40	5.45	5.42	1.74	1.83	1.78
	Canal water	0.53	7.8	8.3	8.0	0.73	1.05	0.89	1.41	4.77	3.09	0.07	0.25	0.15	2.20	3.62	3.13	0.77	3.95	2.42	0.15	1.5	0.84
Summer	Sewg water	1.31	6.5	8.7	7.8	2.41	2.73	2.56	7.83	8.66	8.25	0.92	1.26	1.09	6.01	6.07	6.04	5.19	5.25	5.22	0.42	0.47	0.44
	Canal water	0.62	8.2	8.5	8.4	1.13	1.25	1.18	2.69	4.19	3.44	0.29	0.45	.37	2.42	3.79	3.27	0.82	4.01	2.50	0.23	1.59	0.92

Sewg – sewage.

metals in summer (table 3) was slightly higher than in winter (table 2). This may be due to an input of suspended solids, fertile clay minerals coming from the Nile flood that takes place during the summer months. It also reflects an increasing rate of water consumption and contamination during such a period. Level of the metal content in the canal water during the summer can be arranged in the following descending order (table 3):

$$Fe > Zn > Ni > Mn > Pb > Cu > Cd .$$

Table 2

Level of heavy metals in sewage water and canal water at Abu-Rawash during winter season

Type of water	Months	Content of elements (mg/dm^3)						
		Fe	Cu	Mn	Zn	Pb	Cd	Ni
Sewage water	November	1.46	0.073	0.750	0.445	0.800	0.090	0.339
	December	3.30	0.106	0.855	0.541	0.436	0.053	0.361
	January	5.07	0.096	0.625	0.673	0.395	0.071	0.399
	February	5.76	0.125	0.560	0.618	0.305	0.054	0.478
	March	4.77	0.211	0.805	0.646	0.430	0.076	0.451
	Mean	4.08	0.123	0.719	0.585	0.473	0.069	0.406
Canal water	November	0.78	0.058	0.563	0.261	0.135	0.065	0.204
	December	1.83	0.085	0.481	0.263	0.210	0.025	0.193
	January	1.27	0.046	0.350	0.116	0.238	0.015	0.347
	February	2.20	0.048	0.333	0.128	0.279	0.030	0.302
	March	2.46	0.083	0.260	0.148	0.187	0.017	0.308
	Mean	1.71	0.063	0.398	0.213	0.210	0.032	0.271
LSD	5%	0.0403	0.0096	0.0085	0.0658	0.0037	0.0020	IN
Egy. law 1994 **		1.00	1.00	0.05	1.00	0.05	0.01	0.10
WHO	Min	0.10	0.05	0.05	5.00	•	•	•
	Max	1.00	1.50	0.50	15.00	0.10	0.01	•

IN – insignificant.

• – undetectable amount.

LSD – the statistical least significant difference (at 5%).

** Egyptian permitted limits for the type of sewage effluents that can be used for irrigation purposes.

WHO – World Health Organization limits for the type of effluents that can be used for irrigation purposes.

It was found that the concentrations of copper, manganese and zinc in the canal water are within the permissible limits, while those of copper, lead, cadmium and nickel exceed the permissible limits to irrigation water according to the Egyptian [19] and WHO regulations [20].

Table 3

Level of heavy metals in the sewage water and canal water at Abu-Rawash during the summer season

Type of water	Months	Content of elements (mg/dm^3)						
		Fe	Cu	Mn	Zn	Pb	Cd	Ni
Sewage water	April	6.84	0.420	0.430	1.210	0.820	0.060	0.352
	May	5.10	0.325	0.420	1.430	1.350	0.083	0.333
	June	4.86	0.348	0.383	1.766	0.963	0.056	0.362
	July	6.18	0.416	0.895	1.890	1.225	0.093	0.463
	August	5.99	0.365	0.880	1.860	1.413	0.073	0.514
	Mean	5.80	0.375	0.602	1.631	1.155	0.073	0.405
Canal water	April	1.60	0.063	0.260	0.26	0.175	0.028	0.232
	May	2.10	0.058	0.210	0.234	0.195	0.020	0.262
	June	1.30	0.051	0.218	0.311	0.171	0.022	0.239
	July	2.33	0.068	0.276	0.401	0.246	0.021	0.313
	August	2.38	0.053	0.258	0.422	0.228	0.016	0.281
	Mean	1.94	0.059	0.246	0.327	0.204	0.022	0.266
LSD	5%	0.0205	0.0137	0.0046	0.0445	0.0093	0.009	0.0014
Egy. law 1994 **		1.00	1.00	0.05	1.00	0.05	0.01	0.10
WHO	Min	0.10	0.05	0.05	5.00	•	•	•
	Max	1.00	1.50	0.50	15.00	0.10	0.01	•

• – undetectable amount.

LSD – the statistical least significant difference (at 5%).

** Egyptian permitted limits for the type of sewage effluents that can be used for irrigation purposes.

WHO – World Health Organization limits for the type of effluents that can be used for irrigation purposes.

For sewage water (tables 2 and 3), it is obvious that only copper and zinc contents remain within the permissible limits [19], [20], while the concentrations of the other metals are beyond them. Correlating the results obtained during the summer seasons (table 3) it can be concluded that the levels of iron, lead, cadmium and nickel in both canal water and sewage water are over the permissible limits to irrigation water [19], [20]. Therefore, such water should not be used for irrigation without further treatment allowing us to reach the permissible limits. In terms of heavy metals, it is well known that they can be accumulated by the soil being cultivated. Meanwhile, metals can find their way to plants and finally to the food chain.

3.2. SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOIL

The soil characteristics are given in table 4. It can be seen that in the sandy soil irrigated by the sewage water, a slight pH decrease in its surface layer was observed, while the subsoil was less affected. Meanwhile, using fresh water for similar soil did not cause any significant change in the pH value. This is in a good agreement with the results reported by ABOU-SEEDA [21] and HUSSEIN [22].

Table 4

Particle-size distribution (texture) of three different types of soil at variable depths as well as pH, electrical conductivity (EC), organic matter (OM) and $CaCO_3$ content in each soil

Period of cultivation (years)	Soil depth (cm)	Texture				Soil texture	$CaCO_3$ (%)	OM (%)	EC at 25 °C	pH
		Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)					
Non-cultivated soil	0–10	76.4	23.6	0.04	0.03	Sandy	1.3	0.04	0.52	7.65
	10–20	75.1	24.8	0.04	0.03	Sandy	1.3	0.03	0.44	7.75
	20–30	66.6	33.3	0.03	0.04	Sandy	1.2	0.02	0.33	7.84
	30–40	63.6	36.3	0.03	0.04	Sandy	1.0	0.01	0.31	7.86
	Mean	70.4	29.5	0.04	0.04	Sandy	1.2	0.03	0. 40	7.77
6 years, sewage water	0–10	63.2	22.9	1.44	12.46	L. sandy	0.69	3.20	1.17	6.25
	10–20	63.4	26.6	2.70	7.26	L. sandy	0.77	2.06	0.73	6.30
	20–30	79.2	18.1	2.13	0.60	Sandy	0.57	0.65	0.68	6.45
	30–40	80.1	17.1	2.24	0.50	Sandy	1.26	0.77	0.51	6.46
	Mean	71.5	21.2	2.13	5.20	Sandy	1.07	1.67	0.77	6.37
40 years, canal water	0–10	66.6	16.6	3.52	13.23	L. sandy	3.67	0.34	0.92	7.92
	10–20	70.9	11.4	2.86	14.87	L. sandy	4.20	0.34	0.78	7.88
	20–30	69.5	12.5	3.70	13.87	L. sandy	4.17	0.20	0.65	7.93
	30–40	67.5	14.9	3.68	13.89	L. sandy	3.51	0.27	0.60	7.93
	Mean	68.6	14.0	3.44	13.96	L. sandy	3.89	0.29	0.74	7.92

L. – loamy.
OM – organic matter.
EC – electric conductivity as mS/cm.

On the contrary, both EC and organic matter (OM) content increased after 6 years of using sewage for irrigation. However, with increasing the soil depth a noticeable decrease in these values was observed. The highest EC and OM values were characteristic of the soil enriched with sewage. Furthermore, organic matter content increased in the surface layer (0–10 cm) from 0.04% for non-cultivated soil to 3.2% for soils irrigated by sewage water. This increase can be explained by the fact that sewage water contains such amounts of OM and suspended matters that enrich the soil as a result of continuous irrigation. Organic matter content is largely dependent on the rate of decomposition of the highly polluted organic wastes and its proportion to the soil. In our case, the results prove that there is a continuous organic matter accumulation in the soil (table 4). The content of organic matter in the soil irrigated by the canal water is relatively very low compared to the soil irrigated by sewage water. This defines the role of sewage water in terms of soil enrichment with organic matter. The present finding is in a good agreement with that reported by several investigators, i.e., EL-GAMAL & ABDEL-SHAFY [23], FALTAS et al. [24], EL-GAMAL et al. [25] and ABOU-SEEDA [21]. On the other hand, the EC value decreases with the increase in the depth in all the profiles studied. This result is confirmed by ABOU-SEEDA [21] and Hussein [22].

Table 4 indicates that sewage irrigation is responsible for low level of calcium carbonate in the soil. However, such a decrease was more pronounced in its surface layer than in the subsoil. On the other hand, a slight decrease in the calcium carbonate concentration was observed in the soil irrigated by the canal water. It should be stressed that the latter soil contained the higher level of carbonates than the other two soils. The decrease in the level of $CaCO_3$ in the soil irrigated by sewage may be attributed to a low acidity of such a soil, a result of sewage irrigation. This result is consistent with these reported by ABOU-SEEDA [21] and MANSOUR [26].

3.3. PARTICLE-SIZE DISTRIBUTION IN THE SOIL BEING CULTIVATED

Particle-size distribution of the two types of cultivated soil (table 4) shows that they differ in the texture. This change depends on the period of irrigation as well as on the depth of soil. The deeper the soil, the more pronounced its texture.

In the soil irrigated by sewage, the content of clay and silt in the surface layer increased significantly compared with the non-cultivated soil. On the contrary, the per cent portion of coarse and fine sand decreased. However, the per cent of clay and fine sand decreased with depth.

In the soil irrigated by canal water (table 4), a slight variation in general texture with increase in a depth was observed.

In the non-cultivated soil, the per cent of coarse sand and silt increases with the increase in the soil depth, while the per cent of fine sand decreases.

The above results prove that the use of sewage water increases significantly the clay and silt content in soil. Such a change is mainly attributed to the suspended and organic matter in the sewage water, especially before the modernisation of a local treatment plant. This improves the water capacity of such a soil which is capable of retaining water much better than non-cultivated soil. Similar improvement of the soil irrigated by canal water may be due to the annual addition of farmyard manure or fertilizers. These results are consistent with those reported by EL-GAMAL & ABDEL-SHAFY [23], EL-GAMAL et al. [25] and MANSOUR [26]. It can, therefore, be concluded that the use of either sewage water or fresh water for the irrigation of sandy soil changes the texture of such soil from sandy to loam sandy (table 4).

3.4. LEVEL OF METALS IN CULTIVATED SOIL EXTRACTED BY DTPA, EDTA OR HNO_3

Usually the DTPA procedure is used for determining the available soluble metals that can be taken by plants from the soil. However, the manganese concentrations determined by such a procedure are usually much lower than those obtained by the other two methods. On the other hand, the EDTA procedure can be applicable when the soil is rich in organic matter, which usually results from sewage irrigation. According to ABOU-SEEDA [21] nitric acid extraction gives usually higher metal concentration due to dissolving the total metals.

Table 5

Contents of metals (mg/kg of soil) extracted with DTPA from soils irrigated by sewage water for six years and irrigated with canal water for 40 years (non-cultivated soil as reference sample)

Period of cultivation (years)	Soil depth (cm)	Contents of metals extracted with DTPA (mg/kg of soil)								
		Fe	Cu	Mn	Zn	Pb	Cd	Ni	K	Mg
Non-cultivated soil	0–10	3.90	1.17	1.33	1.09	0.92	0.02	1.18	35.70	79.99
	10–20	3.70	0.81	0.62	0.60	0.91	0.02	1.10	33.25	70.67
	20–30	3.20	0.68	0.45	0.50	0.31	0.02	1.08	28.92	64.15
	30–40	3.10	0.38	0.30	0.30	0.18	0.01	1.08	28.10	54.22
	Mean	3.48	0.76	0.68	0.62	0.58	0.02	1.11	31.49	67.26
6 years, sewage water	0–10	28.3	2.84	10.56	13.53	2.30	0.040	1.81	113.9	107.6
	10–20	27.6	2.82	7.43	13.28	2.29	0.037	1.78	92.1	102.5
	20–30	25.6	2.62	7.36	12.66	2.28	0.032	1.77	82.0	98.0
	30–40	24.3	2.42	6.06	11.75	2.22	0.027	1.68	69.5	88.5
	Mean	26.45	2.68	7.85	12.81	2.27	0.034	1.76	89.4	99.1
40 years, canal water	0–10	7.20	2.76	7.50	2.76	4.36	0.100	1.70	69.23	151.0
	10–20	6.40	2.38	6.34	2.30	3.94	0.097	1.66	58.37	145.2
	20–30	5.10	2.16	6.11	2.06	3.31	0.084	1.62	46.59	139.2
	30–40	3.90	1.53	4.49	1.76	2.41	0.072	1.53	37.64	128.9
	Mean	5.65	2.21	6.11	2.22	3.51	0.088	1.63	52.96	141.1

The non-cultivated soil was used as control or reference for the correlation purposes. The results obtained (tables 5, 6 and 7) indicate that in general the metal concentrations decrease with the depth. This fact was confirmed by the study of three soils. However, such a decrease was clearly marked in the soil irrigated by sewage water. The results also indicate that in this soil the level of metals is the highest compared to all the soils studied. It can be arranged according to the following descending order:

soil irrigated by sewage for 6 years > soil irrigated
by fresh water for 40 years > non-cultivated soil.

Table 6

Contents of metals (mg/kg of soil) extracted with EDTA from soils irrigated by sewage water for six years and irrigated with canal water for 40 years (non-cultivated soil as reference sample)

Period of cultivation (years)	Soil depth (cm)	Contents of metals extracted with EDTA (mg/kg of soil)								
		Fe	Cu	Mn	Zn	Pb	Cd	Ni	K	Mg
Non-cultivated soil	0–10	30.8	1.3	34.62	1.80	1.30	0.13	1.7	110.4	153.4
	10–20	26.7	1.3	42.92	2.41	1.40	0.10	1.6	140.7	160.1
	20–30	23.4	1.1	34.43	1.79	0.70	0.10	1.6	132.9	130.3
	30–40	20.3	0.8	29.52	1.50	0.30	0.08	1.5	85.6	110.2
	Mean	25.3	1.13	35.37	1.88	0.93	0.10	1.6	47.4	138.5
6 years, sewage water	0–10	87.2	6.41	139.7	11.39	6.78	0.15	2.00	102.5	375.5
	10–20	70.6	6.11	139.7	9.73	6.17	0.12	2.17	90.3	311.4
	20–30	66.1	5.80	130.6	8.75	6.77	0.13	2.34	102.5	317.7
	30–40	54.1	5.07	110.1	6.78	5.81	0.11	2.50	69.0	261.2
	Mean	55.6	5.85	130.0	9.16	6.38	0.13	2.25	91.1	316.5
40 years, canal water	0–10	54.2	5.92	116.5	9.21	4.03	0.19	2.37	86.24	227.3
	10–20	56.7	5.16	105.3	5.96	4.18	0.22	2.64	73.26	187.4
	20–30	38.4	4.12	87.8	3.99	4.51	0.19	2.50	55.76	221.7
	30–40	32.1	3.45	83.3	3.49	2.31	0.15	2.16	42.97	206.5
	Mean	45.35	4.66	98.23	5.66	3.76	0.19	2.42	64.56	210.7

Table 7

Contents of metals (mg/kg of soil) extracted with 0.5 M HNO_3 from soils irrigated by sewage water for six years and by canal water for 40 years (non-cultivated soil as reference sample)

Period of cultivation (years)	Soil depth (cm)	Contents of metals extracted with 0.5 M HNO_3 (mg/kg of soil)								
		Fe	Cu	Mn	Zn	Pb	Cd	Ni	K	Mg
Non-cultivated soil	0–10	185.4	2.89	47.33	3.88	5.8	0.07	3.8	96.1	239.3
	10–20	154.4	2.10	59.85	4.19	6.1	0.06	3.7	178.4	234.0
	20–30	139.1	1.92	42.15	3.65	5.5	0.05	2.5	99.1	193.9
	30–40	125.8	1.28	32.09	2.52	4.8	0.04	2.2	58.1	182.4
	Mean	151.2	2.05	45.36	3.56	5.55	0.06	3.1	107.9	212.4
6 years, sewage water	0–10	346.8	7.94	197.8	117.5	7.35	0.179	7.54	257.8	831.1
	10–20	262.1	7.57	175.9	115.0	6.99	0.166	7.26	209.2	812.9
	20–30	325.3	7.38	170.9	114.1	7.20	0.192	8.28	252.5	907.1
	30–40	272.8	6.25	133.2	109.5	5.90	0.070	7.36	172.5	823.7
	Mean	301.8	7.29	169.5	114.0	6.86	0.151	7.61	223.0	843.7
40 years, canal water	0–10	223.1	7.31	160.7	16.26	9.90	0.126	7.80	573.3	219.0
	10–20	205.9	6.42	151.5	13.84	9.37	0.138	8.18	413.5	180.3
	20–30	178.3	5.52	127.9	8.98	9.10	0.123	8.38	281.3	129.4
	30–40	161.2	4.56	113.0	10.53	6.70	0.104	8.23	186.5	115.1
	Mean	192.1	5.95	138.3	12.40	8.76	0.122	8.14	363.6	161.0

Finally the decrease in metal content with the depth increase was shown clearly for such elements as potassium and magnesium followed by manganese, lead and cadmium.

In the case of the soil irrigated by sewage, the increase in metal content was caused by their high level in the sewage water (tables 2 and 3). Of the metals investigated zinc exhibited the highest increase in metal concentration which was followed by the increase of manganese and iron concentrations. Similarly the increase in the level of metal in the soil irrigated by fresh water was exhibited by manganese followed by zinc and copper.

The present results indicated that the soil irrigated by sewage water or fresh water was characterized by an increased level of metals. Furthermore, sewage enhanced the increase of metal content in comparison with fresh water. Such a finding was more pronounced in the case of iron, zinc and potassium, which are all considered indispensable nutrients to plants. On the contrary, a slight increase in the concentration of hazardous metals, including cadmium and lead, was proved. Although such a level of metals in soil is considered high, it is not excessive nor toxic [5], [18], [19]. This is consistent with the results reported by ABDOU and EL-NENNAH [27], EL-LEITHI [28] and MANSOUR [26].

4. CONCLUSIONS

The results obtained reveal that the levels of iron, copper, manganese, lead, cadmium and nickel in sewage water, often primarily treated, are over the permissible limits. Similarly, the levels of iron, lead, cadmium and nickel in canal fresh water also exceed the permissible limits. Nevertheless, the levels of metals in the sewage water are relatively higher than those in the fresh water. Therefore, metals can be accumulated by the soil being cultivated, taken by plants and finally find their way to the food chain. Such water should not be used for irrigation without its further treatment to reach the permissible limits of heavy metals.

Further investigation showed that using sewage water for sandy soil irrigation increased the soil acidity. The use of fresh water for irrigation slightly decreased the pH (i.e., pH of the surface layer of non-cultivated soil was 7.7 and decreased to 6.3 in the soil irrigated by sewage water for 6 years).

The EC value increased due to irrigation, but decreased by increasing depth in all the profiles studied. The $CaCO_3$ content decreased from 1.2% in the surface layer (0–40 cm) of non-cultivated soil to 1.0% in the soil irrigated by sewage water for 6 years. This decrease can be attributed to the ability of $CaCO_3$ to dissolve in the organic acid present in the sewage water.

Enrichment of soil with organic matter was clearly observed when sewage water was used for irrigation. The content of organic matter in the soil irrigated by sewage water for 6 years was always higher than that in the soil irrigated by fresh water (40 years). Such higher levels of organic matter are mainly referred to the fact that sewage water contain appreciable amounts of suspended matter, which deposit in the irrigated soil. This also explains the improvement of the texture of sandy soil.

Irrigation of sandy soil by various types of water increases the level of metals in soil to reasonable limits. Soil irrigated by sewage contained higher amounts of metals in comparison to soil irrigated by fresh water. Such a finding was more pronounced in the case of iron, zinc and potassium which are all considered nutrients of plants. A slight increase in the concentrations of hazardous metals, including cadmium and lead, was shown. Such a level of metals in soil is considered high, but not excessive nor toxic. This increase reflects both the level of metals in the type of the water used and the irrigation period. The sandy soil texture was changed beneficially to loamy sand in the surface layers after 6 years of irrigating the soil by sewage water or 40 years of using fresh water. Thus, an improvement in the soil characteristics in terms of its water capacity can certainly be expected.

Some metals (manganese, zinc, iron, copper, potassium, etc.) in wastes may supplement the plants with deficient macro- and microelements. Excessive application of the sewage wastes induces changes in the soil pH. The unwise use of untreated sewage water could result in the accumulation of metals in the soil in the levels toxic to plants. The metals non-essential for plants (cadmium, lead and nickel) present in some wastes are of concern to environmentalists because of their hazard effect to human and animal health. These elements are accumulated mainly in surface layers of soil. However, a relatively low percentage of toxic metals (cadmium, lead and nickel) in total element content reflects their low availability to both soil and plants. Consequently, these elements were not accumulated yet in toxic levels even after long periods of sewage irrigation.

REFERENCES

[1] SAID R., *The Nile, Geology, Hydro-geology and Utilization*, Pergamon Press, 1993, p. 615.

[2] ABDEL-SHAFY H.I., TROEGER U., HANSEN P.D., Report 1998, Bilateral Egypt–Germany Scientific & Technological Cooperation, National Research Center and International Research Center, 1998, Juelich GMBH, 86 pages.

[3] ABU ZEID M., *Water Resources Assessment in Egypt*, Planning for Groundwater Development in Arid & Semi-Arid Regions, RIGW/IWACO: Cairo/Rotterdam, 1991, 15–34.

[4] ABDEL-SHAFY H.I., HASSAN S.A., EL-AWAMRY Z.K., *Short-term evaluation of dessert soil as affected by sewage water irrigation in Egypt*, Al-Azhar J. Agric. Res., 1998, Vol. 28, 183–194.

[5] MAHIDA H.N., *Water pollution & disposal of wastewater on land*, Tata McGraw-Hill Publ., New Delhi, 1983.

[6] HALL J.E., L'HERMITE P., NEWMAN P.J., *Treatment and use of sewage sludge and liquid agricultural wastes*, Review of Cost Program-Commission of the European Communities, EUR 14330 EN, 1992.

[7] ABDEL-SHAFY H.I., ALY R.O., *Nile water sources, pollution and endeavors of protection*, in publication.
[8] BAKKEN T.H., DAGESTAD K., IWA 2ND WORLD WATER CONGRESS; Efficient water management-making it happen, Berlin, 15–19 Oct., 2001, page 9.
[9] GERMAN J., SVENSSON G., IWA 2ND WORLD WATER CONGRESS; Efficient water management-making it happen, Berlin, 15–19 Oct., 2001, page 14.
[10] ABDEL-SHAFY H.I., HEGEMANN W., TEINER A., *Accumulation of metals by vascular plants*, Environmental Management and Health, 1994, 5 (2), 21–24.
[11] EL-GAMAL I.M., ABDEL-SHAFY H.I., *Role of land irrigation by liquid sewage on the uptake of metals and nutrient elements by citrus plants*, Biomass and Bioenergy, An International Journal, 1992, 1 (5), 275–280.
[12] ABDEL-SHAFY H.I., HASSAN S.A., ALY R.O., AL-AWAMRY N.M., AL-AZHAR J., Agriculture Researches, 1998, 28, 171–182.
[13] FORSTNER U., WITTMANN G.I., *Metals Pollution in the Aquatic Environment*, Springer-Verlag, Berlin–Heidelberg–N.Y., 1983, page 485.
[14] American Public Health Association (APHA), *Standard Method for the Examination of Water & Wastewater*, APHA, AWWA, WPCF, Washington, D.C., 1995, page 385.
[15] PIPER C.S., *Soil and Plant Analysis*, Interscience Publishers, Inc. New York, 1966.
[16] JACKSON M.L., *Soil Chemical Analysis*, Prentice Hall, Inc. Englewood Cliffs, 1967, N.J. Laboratory of the Congress, M.A.S.
[17] LINDSAY W.L., NORVELL W.A., *Development of a DTPA soil test for Zinc, Iron, Manganese and Copper*, Soil Sci. Soc. Am. J., 1978, 42, 421–428.
[18] COTTENIE A., VERLOO M., KIEKENS L., VELGHE G., CAMERLYNCK R., *Chemical Analysis of Plants and Soils*, Laboratory of Analytical and Agrochemistry State University, Ghent, 1982, Belgium.
[19] Egyptian Environmental Protection Agency, Law 4/1994: legislation-controlling disposal of wastewater, 1994.
[20] WHO: World Health Organization, Geneva, 1978.
[21] ABOU-SEEDA M.A., *Chemical and environmental aspects of sewage sludge application on Egyptian soils*, Ph.D. Thesis, Fac. of Agriculture, Van de load bouwenten-schappen, Holland, 1988, pages 189.
[22] HUSSEIN L.A., ABD EL-AZIZ S.M., ABD EL-MOTTALEB M.A., Environmental Studies and Research, Cairo, Jan. 31–Feb. 4, 1988, 2, 481–497; *Chemical composition of plants grown on soil ammended with sewage effluent*, Annals of Agric. Sci. Mostohor, 26 (4), 2753–2761.
[23] EL-GAMAL I.M., ABDEL-SHAFY H.I., *Role of land irrigation by liquid sewage on the uptake of metals and nutrient elements by citrus plants*, Biomass & Bioenergy, 1991, Vol. 1, No. 5, pp. 275–280.
[24] FALTAS R.L., EL-AWADY R.M., SELEM M.M., ABD EL-REHEEM A., *Changes in physical properties of sandy soil due to sewage water utilization cultivation for five successive years*, Annals of Agric. Sci. Mostohor, 1986, 24 (3).
[25] EL-GAMAL I.M., ABDEL-SHAFY H.I., ABO-EL-WAFA O., *Influence of prolonged use of sewage effluents on the soil of Abu-Rawash*, First National Conf. on Envir. Studies & Research, Cairo, Jan. 31–Feb. 4, 1988, Vol. 2, 481–497.
[26] MANSOUR S.F., *Development of sandy soils under sewage water irrigation*, M.Sc. Thesis, Faculty of Agric., Cairo Univ., 1996.
[27] ABDOU F.M., EL-NENNAH M., *Effect of irrigating loamy sand soil by liquid sewage sludge on its contents of some micronutrients*, Plant and Soil, 1980, 56, 53–57.
[28] EL-LETHI A.A.E., *Pedological status of heavy metals in vicinity of some industrial and high way areas in soils of the Nile-Delta*, Ph.D. Thesis, Fac. of Agric. Alex. Univ., 1986, Egypt.

OCENA UŻYCIA ŚCIEKÓW DO NAWADNIANIA PIASZCZYSTEJ GLEBY NA PUSTYNI ABU-RAWASH W EGIPCIE

W krajach o suchym i pustynnym klimacie odczuwa się deficyt wody spowodowany skąpymi opadami deszczu koniecznego w uprawie roli. Obecnie aż 96,4% obszaru Egiptu nie jest wcale uprawianych. Oczyszczonych ścieków od dziesięcioleci używa się w wielu krajach do nawadniania gleby. Zgodnie z najnowszymi badaniami oczyszczone ścieki uważa się raczej za źródło wody nienadającej się do picia niż za zagrożenie dla środowiska. W Egipcie ścieki stosuje się do nawadniania piaszczystej gleby pozbawionej substancji organicznych, a także makro- i mikroelementów. Jednym z przykładów takiego postępowania jest farma Abu-Rawash. Jej obszar 105 ha ma zostać powiększony do 210 ha. Na farmę tę w ciągu jednego dnia dostarcza się obecnie od 4000 do 5000 m^3 wstępnie oczyszczonych ścieków. Hoduje się na niej głównie cytrusy i, eksperymentalnie, drzewa liściaste i kwiaty. Stężenie metali w ściekach jest niewielkie, a rośliny mogą je gromadzić w różnych stężeniach. Tak dzieje się, gdy metale są w łańcuchu pokarmowym i pobierają je rośliny i zwierzęta.

Przedmiotem tego artykułu jest los metali w piaszczystej glebie egipskiej farmy nawadnianej wstępnie oczyszczonymi ściekami od 1944 r. Wzrastające zapotrzebowanie na wodę ze ścieków używaną w ten sposób rodzi pytanie o jej wpływ na piaszczystą glebę. Chcemy znać los metali ciężkich w glebie w zależności od jej głębokości, co z kolei wpływa na rosnące rośliny. Chcemy wiedzieć, jakie zmiany zachodzą w tak nawadnianej glebie pustynnej.