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Status of Heavy Metals in Soils of Assiut as Affected by the Long-Term Use of Sewage Water in Crop Irrigation: Case Study

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CONCERNING soil pollution with heavy metals, a survey study was carried out to evaluate the present status of Cd, Ni, Pb, Fe, Mn, Zn and Cu in agricultural soils near Assiut city. Over 40-50 years, soils were either irrigated with underground, or sewage waste water at six sites, namely El-Madabegh, Mankabad, Ellwan, Bani Hussein, Bani Ghalleb and Gahdam. Thirty six soil profiles were dug and subsamples were taken to determine the status of the selected elements using standard methods.

Data of this study indicate that the concentrations of Fe, Mn, Zn, Cu, Pb, Cd and Ni are present at high levels in the soils irrigated with sewage wastewater relative to that irrigated with underground water. A survey to evaluate metals uptake by the crops under agriculture at the indicated sites is needed, but use of sewage wastewater in irrigation at the indicated sites needs to be justified.

With increasing global population, the gap between the supply and demand of water is widening and is reaching such alarming levels that in some parts of the world it is posing a threat to human existence. It is therefore of utmost decosystem services. This could release clean water purposes needing fresh water.

Sewage water is an alternative potential source of irrigation water in arid and semiarid areas where fresh water supplies are inadequate. Disposal of sewage waters on sandy soils, especially desert soils that are low in fertility may be beneficial due to its content of nutritious elements and can result in improvement of soil properties.

It is therefore of utmost importance to define new ways of conserving water such as re-use of urban wastewater in agricultural and of these soils to become good media for plant growth (Chaney, 1985, El-Desoky and Gameh, 1998, Badawy and Helal, 2002 and Yadav *et al*., 2002). However, one of the most limiting factors for land disposal and agricultural use sewage effluents is the presence of high levels of heavy metals (Cd, Ni, Zn, Cu, Co, Cr and Pb) which may be toxic to the living organisms. An excessive load of heavy metals can increase both potential phytotoxicity and ground water contamination (Sterritt

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and Lester, 1980, Emmerich *et al*., 1982 and Chaney, 1983). Although levels of heavy metals in sewage effluents are low, the long term application of wastewater on agricultural lands often results in the accumulation of elevated levels of these metals in the soils, but this depends upon the period of its application (Ratten *et al*., 2005). Badawy and Helal (2002) studied the chemical composition of the sewage effluent of Helwan drainage station. They found that the metals can be arranged in the following order: Fe > Zn > Pb > Mn > Ni > Cr> Co > Cd > Cu. They also reported that continuous irrigation with sewage effluent, with or without annual addition of sludge lead to: 1) decreasing soil pH and total carbonate content, 2) increasing organic carbon, clay and available P and K, and 3) increasing contents of heavy metals to be as big as 280-590% of the initial content after a period of four years. According to Abdel-Sabour *et al*. (1996), five heavy metals (Fe, Zn, Cu, Co and Pb) contents were investigated in Cairo sewage effluent being used in irrigation of sandy soil of El-Gabal Al-Asfar Farm. Data reveal that large amounts of Fe, Zn, Cu and Pb have accumulated over 52 years of irrigation.

The present study aims to evaluate the magnitude of soil contamination with heavy metals resulting from use of sewage wastewater in irrigation of agricultural soils near Assiut city.

Material and Methods

Study area

In Assiut City, municipal wastewater from different sources is collected at El-Madabegh village, which lies 8 km northwest of Assiut City. For many years, without any pretreatment the wastewaters have been applied, through irrigation, to a large agricultural area (8000-10000 feddan). The area has very limited natural water resources without any annual rainfall. Thirty-six soil profiles were dug at different sites in six villages El-Madabeg, Mankabad, Bani Huessein, Bani Ghaleb, Ellwan and Gahdam. The profiles were dug in agricultural areas that have been irrigated with underground, or sewage water.

From each site, several sub-samples from 0-15 and 15-30 cm depths were separately bulked to give composite samples. The soil was air-dried and sieved to ~2 mm. Particle size distribution was determined following the method described in Chapman and Pratt (1978). Soil pH and electrical conductivity (EC) were measured in 1:2.5 soil-water suspension after 1 hr end-over-end shaking at 25 °C. Soil (1.0 g) was digested with nitric and perchloric acid mixture (Baker and Amacher, 1982) for measurement of the total concentrations of Fe, Mn, Zn, Cu, Cd, Ni and Pb. Soil available Fe, Mn, Zn, Cu, Cd Ni and Pb were extracted by diethylenetriaminepenta-acetic acid following (Lindsay and Norvell, 1978). The extracted elements were determined using a flame-Atomic Absorption Spectrometer (GBC, 906AA). The total organic matter content was determined and soil $CaCO_3$ was measured using the calcimeter method as mentioned by Chapman and Pratt (1978). The soil physical and chemical properties of the soil irrigated with sewage water (SW) and underground water (UW) are presented in Table 1 and 2, respectively.

TABLE 1. Physical and chemical parameters of the surface and subsurface layers of the soils irrigated with sewage water (SW).

Site	Depth (cm)	Particle Size Distribution % Sand	Silt	Clay	Soil Texture	O.M. %	$CaCO_3$ %	$pH_{1:2.5}$	$EC_{1:2.5}$ dS m^{-1}
El-Madabegh	**0-15**	79.8	12.0	8.2	LS	3.7 ± 0.1	6.1 ± 0.2	7.38 ± 0.02	1.94 ± 0.02
	15-30	74.6	20.0	5.4	SL	3.0 ± 0.2	5.5 ± 0.1	6.60 ± 0.01	2.06 ± 0.01
	0-15	84.0	8.0	8.0	LS	4.5 ± 0.2	8.2 ± 0.2	7.81 ± 0.02	1.26 ± 0.02
	15-30	76.1	12.1	12.8	SL	3.2 ± 0.1	8.2 ± .0	8.43 ± 0.02	1.92 ± 0.01
	0-15	71.8	20.0	8.2	SL	2.3 ± 0.2	10.2 ±0.3	7.74 ± 0.01	3.38 ± 0.02
	15-30	71.8	16.0	12.2	SL	3.3 ± 0.2	7.5 ± 0.3	7.74 ± 0.02	2.73 ± 0.02
Mankabad	**0-15**	79.8	12.0	8.2	LS	3.9 ± 0.1	6.8 ± 0.4	8.00 ± 0.01	2.59 ± 0.01
	15-30	75.8	12.0	12.2	SL	3.1 ± 0.1	6.5 ± 0.2	8.14 ± 0.02	2.6 ± 0.02
	0-15	93.5	4.0	2.50	S	2.3 ± 0.2	5.9 ± 0.3	8.41 ± 0.02	1.94 ± 0.03
	15-30	79.8	12.0	8.2	LS	2.3 ± 0.3	7.9 ± 0.5	8.49 ± 0.03	1.83 ± 0.02
	0-15	40.6	36.0	23.4	SCL	4.4 ± 0.2	9.5 ± 0.2	8.43 ± 0.02	2.38 ± 0.02
	15-30	50.6	26.0	23.4	SCL	3.6 ± 0.3	8.1 ± 0.3	8.41 ± 0.02	2.38 ± 0.03
Bani Hussein	**0-15**	85.0	10.1	4.9	S	2.0 ± 0.2	7.3 ± 0.2	7.02 ± 0.01	1.65 ± 0.02
	15-30	83.8	12.0	4.2	LS	1.8 ± 0.2	6.1 ±0.2	7.02 ± 0.02	1.69 ± 0.02
	0-15	72.0	20.0	8.0	SL	3.4 ± 0.1	6.4 ± 0.1	7.45 ± 0.03	2.49 ± 0.02
	15-30	68.0	28.0	4.0	SL	2.3 ± 0.2	8.3 ± 0.4	7.45 ± 0.04	2.15 ± 0.02
	0-15	72.0	21.0	7.0	SL	3.4 ± 0.2	6.4 ± 0.2	7.63 ± 0.01	1.88 ± 0.02
	15-30	68.0	26.0	6.0	SL	2.9 ± 0.3	8.4 ± 0.1	7.72 ± 0.10	1.19 ± 0.02
Bani Ghalleb	**0-15**	60.0	28.1	11.9	LS	4.2 ± 0.2	9.2 ± 0.2	7.78 ± 0.01	2.67 ± 0.02
	15-30	63.0	16.0	21.0	LS	3.2 ± 0.1	7.4 ± 0.3	7.42 ± 0.02	2.72 ± 0.02
	0-15	13.0	50.0	37.0	SCL	3.1 ± 0.3	8.2 ± 0.1	7.88 ± 0.03	2.20 ± 0.02
	15-30	46.0	36.0	18.0	SCL	2.2 ± 0.1	6.7 ± 0.1	7.56 ± 0.03	2.29 ± 0.03
	0-15	90.0	4.1	5.9	S	4.5 ± 0.1	5.9 ± 0.0	8.21 ± 0.02	1.89 ± 0.01
	15-30	80.0	12.0	8.0	LS	4.1 ± 0.1	7.9 ± 0.3	8.39 ± 0.02	1.93 ± 0.01
Ellwan	**0-15**	46.0	32.0	22.0	SCL	3.2 ± 0.1	7.8 ± 0.1	8.00 ± 0.01	2.29 ± 0.02
	15-30	43.2	28.0	28.8	SCL	2.9 ± 0.2	7.6 ± 0.2	8.00 ± 0.02	2.41 ± 0.01
	0-15	36.2	41.3	21.5	SCL	3.5 ± 0.2	8.8 ± 0.1	8.23 ± 0.01	2.11 ± 0.01
	15-30	41.0	40.0	19.0	SCL	2.4 ± 0.1	8.6 ± 0.0	7.88 ± 0.02	2.30 ± 0.02
	0-15	38.0	42.0	20.0	SCL	4.5 ± 0.2	10. ± 0.3	8.55 ± 0.03	2.36 ± 0.01
	15-30	35.0	44.0	21.0	SCL	4.2 ± 0.2	10. ± 0.2	8.55 ± 0.02	2.29 ± 0.02
Gahdam	**0-15**	12.8	52.0	35.2	SCL	3.4 ± 0.2	8.4 ± 0.1	8.30 ± 0.01	0.95 ± 0.02
	15-30	47.2	28.0	24.8	SCL	3.2 ± 0.2	8.3 ± 0.3	8.30 ± 0.01	0.83 ± 0.02
	0-15	41.2	40.0	18.8	SCL	4.3 ± 0.2	8.6 ± 0.3	7.80 ± 0.03	1.93 ± 0.01
	15-30	46.2	34.0	20.8	SCL	2.9 ± 0.2	8.8 ± 0.2	7.93 ± 0.03	1.85 ± 0.02
	0-15	37.8	42.0	20.2	SCL	4.1 ± 0.1	7.1 ± 0.1	8.02 ± 0.02	2.10 ± 0.01
	15-30	31.0	46.0	23.0	SCL	3.3 ± 0.1	6.7 ± 0.2	8.02 ± 0.03	1.35 ± 0.03

Values are means (n=3) ± SE

TABLE 2. Physical and chemical parameters of the surface and subsurface layers of the soils irrigated with underground water (UW).

Site	Depth (cm)	Particle Size Distribution Sand	Silt (%)	Clay	Soil Texture	O.M. (%)	$CaCO_3$ (%)	$pH_{1:2.5}$	$EC_{1:2.5}$ ($dS\ m^{-1}$)
El-Madabegh	**0-15**	29.6	24.9	45.5	CL	3.2 ± 0.1	6.1 ± 0.2	7.81 ± 0.05	0.81 ± 0.02
	15-30	31.5	23.8	44.7	CL	2.1 ± 0.1	6.1 ± 0.2	7.82 ± 0.02	0.81 ± 0.03
	0-15	29.0	25.5	45.5	CL	2.8 ± 0.2	5.9 ± 0.1	7.82 ± 0.03	0.76 ± 0.01
	15-30	30.9	24.4	44.7	CL	2.6 ± 0.1	5.9 ± 0.1	7.83 ± 0.02	0.88 ± 0.01
	0-15	28.6	25.8	45.6	CL	2.5 ± 0.3	6.6 ± 0.1	7.84 ± 0.01	0.90 ± 0.05
	15-30	30.6	25.2	44.2	CL	2.4 ± 0.1	6.1 ± 0.1	7.81 ± 0.02	1.11 ± 0.01
Mankabad	**0-15**	28.4	25.3	46.3	CL	1.1 ± 0.1	5.1 ± 0.1	8.02 ± 0.01	0.57 ± 0.01
	15-30	29.5	24.8	45.7	CL	1.1 ± 0.1	5.1 ± 0.1	8.01 ± 0.02	0.64 ± 0.02
	0-15	29.0	25.0	46.0	CL	2.2 ± 0.1	5.3 ± 0.2	7.91 ± 0.05	0.50 ± 0.02
	15-30	31.0	24.0	45.0	CL	2.0 ± 0.2	5.6 ± 0.2	7.92 ± 0.02	0.60 ± 0.03
	0-15	29.0	24.0	47.0	CL	2.2 ± 0.2	6.1 ± 0.2	7.82 ± 0.04	0.80 ± 0.01
	15-30	31.4	24.6	44.0	CL	2.4 ± 0.1	6.3 ± 0.2	7.81 ± 0.06	1.12 ± 0.02
Bani Hussein	**0-15**	22.0	49.9	28.1	L	2.0 ± 0.3	6.1 ± 0.1	8.12 ± 0.01	0.61 ± 0.01
	15-30	21.0	50.0	29.0	L	1.1 ± 0.1	6.0 ± 0.1	8.03 ± 0.02	0.72 ± 0.02
	0-15	21.4	48.8	29.3	L	2.0 ± 0.3	6.1 ± 0.2	7.91 ± 0.02	0.51 ± 0.02
	15-30	21.0	49.6	29.6	L	1.6 ± 0.1	6.0 ± 0.2	7.92 ± 0.01	0.63 ± 0.03
	0-15	21.0	50.2	28.8	L	2.6 ± 0.3	6.3 ± 0.2	7.93 ± 0.03	0.71 ± 0.05
	15-30	20.0	50.0	30.0	L	2.2 ± 0.1	6.1 ± 0.1	7.91 ± 0.04	0.81 ± 0.01
Bani Ghalleb	**0-15**	28.0	34.3	37.7	CL	2.4 ± 0.2	4.0 ± 0.2	7.92 ± 0.01	2.95 ± 0.05
	15-30	11.0	45.4	43.6	L	2.0 ± 0.1	3.3 ± 0.1	7.91 ± 0.02	2.91 ± 0.01
	0-15	27.8	34.5	37.7	CL	2.1 ± 0.1	3.8 ± 0.2	7.92 ± 0.01	1.81 ± 0.02
	15-30	11.5	45.0	43.5	L	2.0 ± 0.2	3.2 ± 0.2	7.41 ± 0.03	1.93 ± 0.01
	0-15	27.0	34.8	38.2	CL	2.5 ± 0.2	4.1 ± 0.1	7.91 ± 0.01	2.81 ± 0.02
	15-30	12.0	45.1	43.9	L	2.1 ± 0.2	3.2 ± 0.2	7.92 ± 0.06	2.25 ± 0.02
Ellwan	**0-15**	25.1	35.6	39.3	L	3.1 ± 0.1	4.3 ± 0.2	8.03 ± 0.01	2.14 ± 0.01
	15-30	30.6	29.6	39.8	CL	2.6 ± 0.1	3.0 ± 0.2	8.03 ± 0.02	2.21 ± 0.02
	0-15	24.8	36.2	39.0	L	2.8 ± 0.1	4.1 ± 0.2	8.04 ± 0.01	2.01 ± 0.02
	15-30	31.0	29.0	40.0	CL	2.4 ± 0.1	3.0 ± 0.2	8.02 ± 0.02	2.11 ± 0.02
	0-15	30.5	30.6	38.9	L	3.4 ± 0.1	5.2 ± 0.2	8.11 ± 0.02	2.22 ± 0.02
	15-30	31.2	30.0	39.8	CL	3.3 ± 0.1	4.2 ± 0.1	8.02 ± 0.01	2.42 ± 0.01
Gahdam	**0-15**	20.9	50.1	29.0	L	2.8 ± 0.1	3.2 ± 0.1	7.71 ± 0.03	1.32 ± 0.03
	15-30	20.8	49.2	30.0	L	2.4 ± 0.2	2.9 ± 0.1	7.81 ± 0.01	1.12 ± 0.01
	0-15	21.0	50.0	29.0	L	2.6 ± 0.2	3.0 ± 0.1	7.82 ± 0.02	1.33 ± 0.01
	15-30	21.0	49.2	29.8	L	2.7 ± 0.2	3.0 ± 0.1	7.82 ± 0.01	1.32 ± 0.02
	0-15	20.0	50.0	30.0	L	2.9 ± 0.2	3.4 ± 0.1	7.82 ± 0.01	1.43 ± 0.01
	15-30	21.0	49.0	40.0	L	2.6 ± 0.2	3.0 ± 0.2	7.83 ± 0.03	1.11 ± 0.02

Values are means (n=3) ± SE

Water analysis

It was found necessary to complete this study, being concerned with pollution through irrigation with water to which effluents of sewage water were disposed, by analyzing the wastewater discharged from El-Madabegh sewage. EC and pH and the total concentrations of Fe, Mn, Zn, Cu, Cd, Ni and Pb were determined in the sewage water (Table 3).

Statistical analysis

Data were subjected to analysis of variance using MStat, a micro-computer program. In Tables, values are means (n=3) ± the standard error (SE). In figure, error bars represent SE.

Results and Discussion

Total metal concentrations in soils

Figure 1 shows the variation in total amounts of Fe, Mn, Zn, Cu, Cd, Ni and Pb in soils of the six locations (villages) of the study area irrigated by untreated sewage wastewater for 45-50 years.

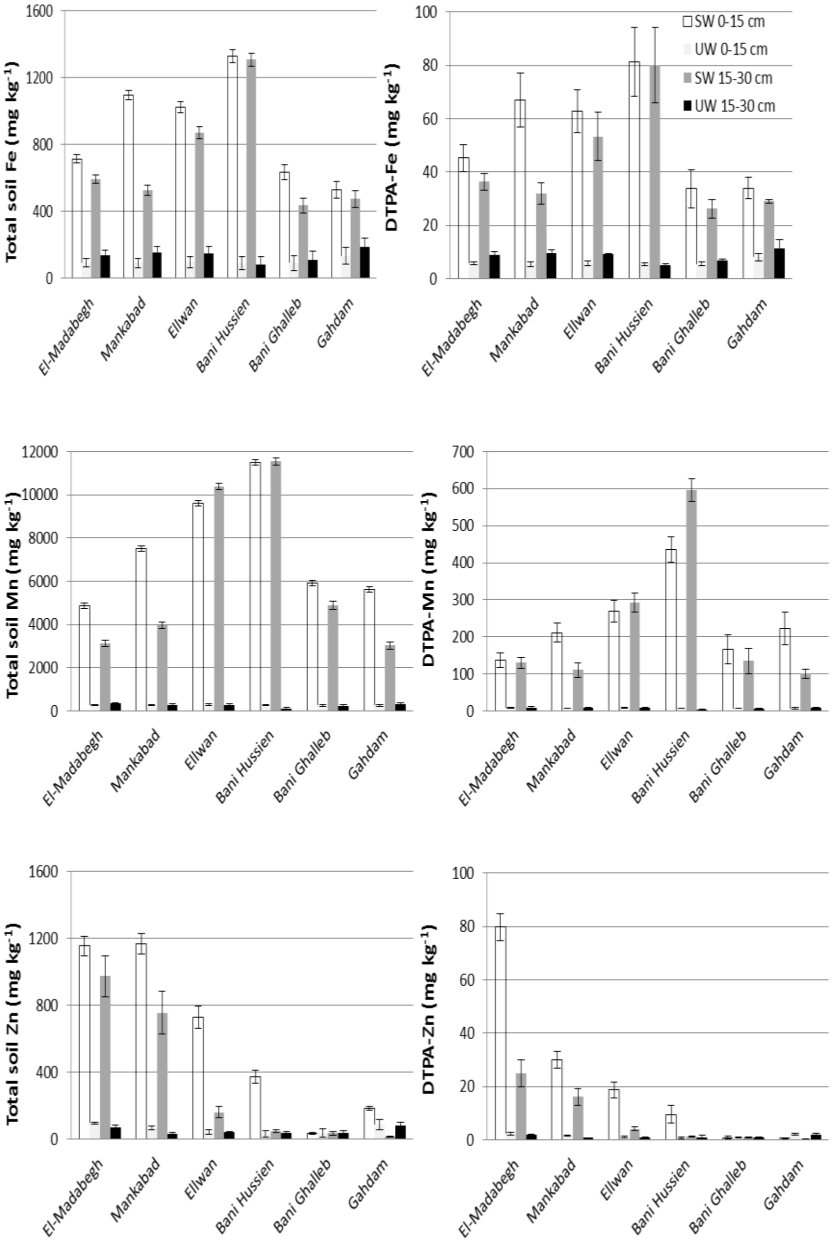
Iron (Fe): The concentrations of total Fe in soils of Bani Ghalleb and Gahdam are insignificantly different and were lower than those in the soils of El-Madabegh, Mankabad and Ellwan. The lowest Fe concentration (1316 mg kg^{-1} soil) was found in Bani Hussien area and the highest concentration (9475 mg kg^{-1} soil) was recorded in soils of Ellwan. The concentration of total Fe in soils of the Alluvial soils near Assiut city, except Bani Hussien, were extremely high compared to that reported by Elsokkary and Lag (1978). El-Demerdashe *et al*. (1991) and Abd El-Salam (2002) found that the total Fe in Alluvial soils varied from 4997 to 9375 mg kg^{-1} soil which is in agreement of data reported in this study. The accumulation of total Fe in these soils decreased in the order: Ellwan > Mankabad > El-Madabegh > Bani Ghalleb > Gahdam > Bani Hussien. It is also clear that the total Fe in all sites decreased with depth. Similar results were obtained by Shaymaa (2008).

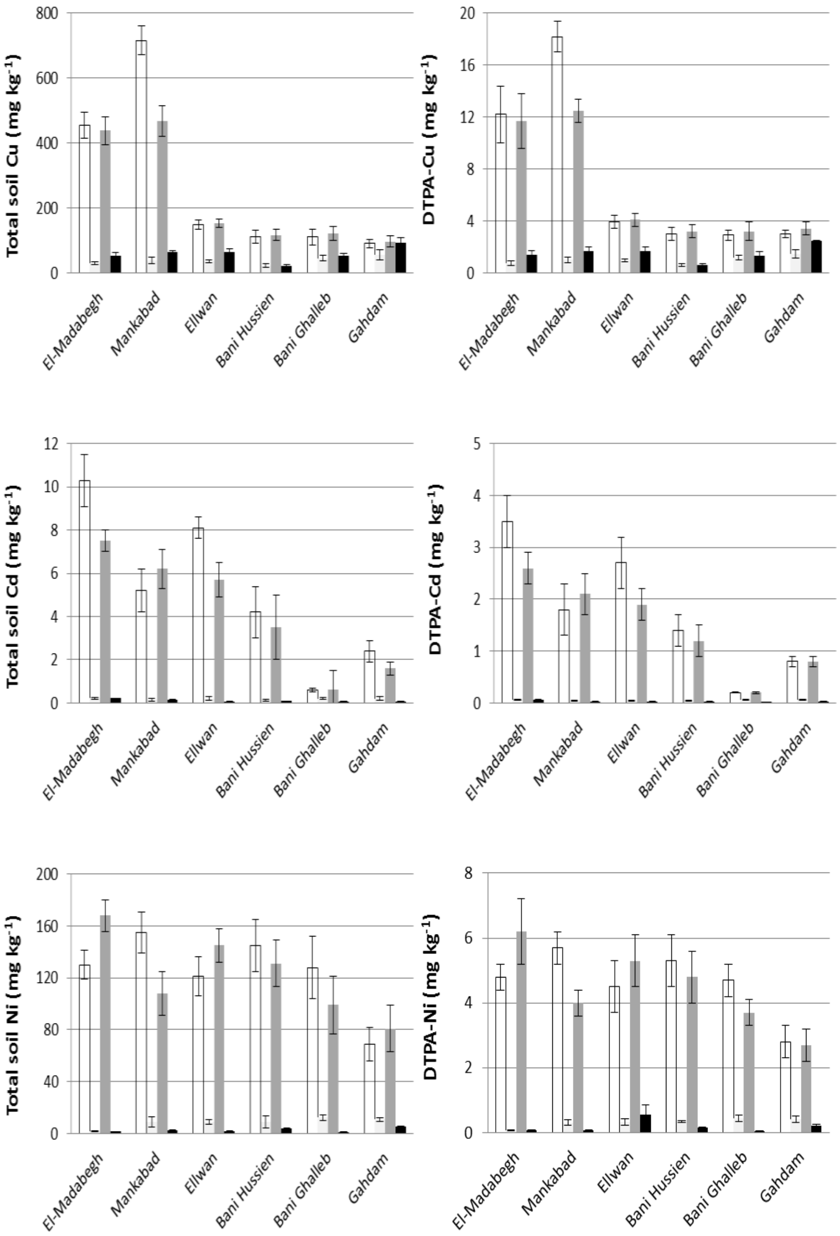
Manganese (Mn): Elsokkary and Lag (1978) reported concentrations of total Mn as 617 and 645 mg kg^{-1} soil in alluvial and lacustrine soils . El-Demerdashe *et al*. (1991) reported values of total Mn in soils of North Tahrir ranged from 90 to 350 mg kg^{-1} soil in the surface layer and Shahin and Abdel Hamid (1993) found that total Mn contents in calcareous soils of Maryout in the range 186-379 mg kg^{-1} soil. In this study, there is marked variation in the concentration of total Mn in soils of the six locations (Fig. 1). The concentration of total Mn in soil of El-Madabegh area was the lowest (3985.5 mg kg^{-1} soil), while the highest concentration of is in soils (18513 mg kg^{-1} soil) of Bani Hussien. The average values were 3985.5, 5735, 9990, 18513, 5403 and 4323 mg kg^{-1} soil in El-Madabegh, Mankabad, Ellwan, Bani Hussien, Bani Ghalleb and Gahdam, respectively. Total Mn was decreased with depth in different soil profiles of the studied areas.

TABLE 3. Chemical analysis of the sewage wastewater at different locations near Assiut city.

Location	pH	EC ($dS\ m^{-1}$)	Fe	Mn	Zn	Cu	Cd	Ni	Pb
			$Mg\ L^{-1}$						
Main station	7.61 ± 0.05	4.4 ± 0.1	2.3 ± 0.02	16.0 ± 0.05	2.1 ± 0.01	0.4 ± 0.05	0	6.2 ± 0.02	4.6 ± 0.01
Ibrahimia canal	7.82 ± 0.03	3.4 ± 0.2	2.0 ± 0.04	8.5 ± 0.02	1.1 ± 0.02	0.2 ± 0.02	0	2.0 ± 0.02	3.3 ± 0.01
Mankabad	7.80 ± 0.01	3.4 ± 0.1	21.0 ± 0.02	6.4 ± 0.01	3.6 ± 0.01	0.4 ± 0.01	1.0 ± 0.01	5.2 ± 0.04	8.0 ± 0.02
Ellwan	7.11 ± 0.05	4.0 ± 0.2	16.0 ± 0.01	30.1 ± 0.03	16.8 ± 0.02	0.4 ± 0.02	0.6 ± 0.02	0	11.0 ± 0.05
Bani Hussien	7.82 ± 0.02	3.6 ± 0.2	14.0 ± 0.02	12.0 ± 0.01	3.1 ± 0.01	1.1 ± 0.01	0	3.0 ± 0.03	2.0 ± 0.01
Bani Ghaleb	7.33 ± 0.02	3.5 ± 0.3	5.0 ± 0.02	6.0 ± 0.02	2.0 ± 0.02	0.3 ± 0.01	2.0 ± 0.02	3.0 ± 0.01	3.0 ± 0.02
Bani Ghalleb Side Canal	7.54 ± 0.03	3.5 ± 0.2	2.0 ± 0.1	5.0 ± 0.02	2.0 ± 0.01	0.3 ± 0.02	0	2.0 ± 0.02	6.0 ± 0.03
Gahdam	7.55 ± 0.03	3.9 ± 0.1	18.0 ± 0.3	19.0 ± 0.01	6.6 ± 0.01	1.3 ± 0.01	0	2.0 ± 0.02	4.0 ± 0.01

Values are means (n=3) ± SE.


Total soil Fe (mg kg-1)
DTPA-Fe (mg kg-1)
SW 0-15 cm
UW 0-15 cm
SW 15-30 cm
UW 15-30 cm
Total soil Mn (mg kg-1)
DTPA-Mn (mg kg-1)
Total soil Zn (mg kg-1)
DTPA-Zn (mg kg-1)
El-Madabegh
Mankabad
Ellwan
Bani Hussien
Bani Ghalleb
Gahdam


Total soil Cu (mg kg-1)
DTPA-Cu (mg kg-1)
Total soil Cd (mg kg-1)
DTPA-Cd (mg kg-1)
Total soil Ni (mg kg-1)
DTPA-Ni (mg kg-1)
El-Madabegh
Mankabad
Ellwan
Bani Hussien
Bani Ghalleb
Gahdam

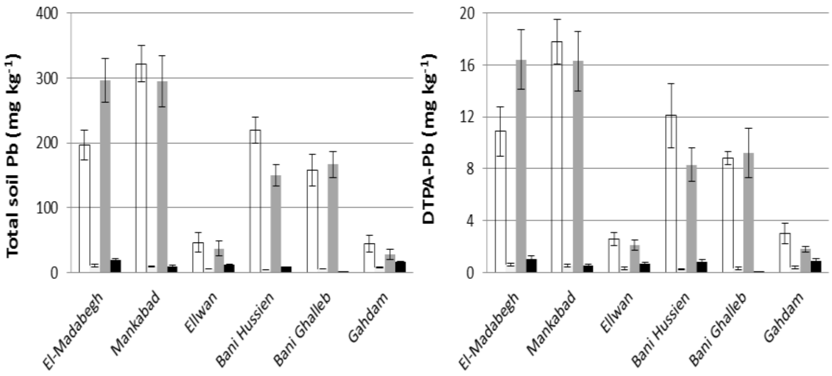


Fig. 1. Concentrations of the total and DTPA-extractable Fe, Mn, Zn, Cu, Cd, Ni and Pb (mg kg^{-1} soil) in sewage water (SW) and underground water (UW)-irrigated soils of El-Madabegh, Mankabad, Ellwan, Bani Hussein, Bani Ghalleb and Gahdam.

Comparing the above described results for the soils irrigated with sewage wastewater and those obtained for the soil irrigated with underground water in the same villages (Tables 1 and 2), data reveals marked differences due to the use of sewage wastewaters. Data reported by Shaymaa (2008) is in agreement with the data of this study.

Zinc (Zn): All soils in this study case have very high levels of total Zn. Total Zn in all soil samples collected from the studied area (polluted) ranged from 115.6 to 1063.5 mg kg^{-1} soil with an average of 489.4 mg kg^{-1} soil. Concentrations of total Zn in the soils irrigated with sewage water were 1063.5, 962.5, 444.5, 210.5, 135 and 115.6 mg kg^{-1} soil in El-Madabegh, Mankabad, Ellwan, Bani Hussien, Bani Ghalleb and Gahdam, respectively. The concentration decreased from the beginning of the irrigation canal starting at El-Madabegh and ending at Gahdam along a distance of about 25 km. This could be attributed to the possible settlement of the Zn-containing compounds held in the sewage wastewater starting from El-Madabegh with a gradual decrease in the concentrations of these compounds along the water follow over the indicated distance. Compared to the soils irrigated with underground water, total Zn concentration in the soils irrigated with sewage wastewater with higher by 1268% for Madabegh, 1980.5% for Mankabad, 1036% for Ellwan, 603.5% for Bani Hussien, 367.9 for Bani Ghalleb and 141.8% for Gahdam. Data of the studies conducted by Abdel Salam (2002), Shaymaa (2008) and Nadia (2009) is in close agreement with that of this study. Data indicate that the total Zn concentration was higher in the surface than in the subsurface layer in the soils of the 6 locations which indicate that there was no down word movement of Zn in soil.

Cupper (Cu): Data obtained for total Cu in all soil samples collected from the studied areas ranged from 93.5 to 592 mg kg^{-1} soil. Results showed higher level of total Cu in soils of Mankabad and El-Madabegh (592 and 241 mg kg^{-1} soil, respectively), than those of Ellwan (151 mg kg^{-1} soil), Bani Hyussien (114.5 mg kg^{-1} soil), Bani Ghalleb (116.5 mg kg^{-1} soil) and Gahdam (93.5 mg kg^{-1} soil). The accumulation of total Cu in these soils decreased in the order: Mankabad > El-Madabegh > Ellwan > Bani Ghalleb > Bani Hussien > Gahdan.

Cadium (Cd): Figure 1 shows higher concentrations of total Cd in soils of El-Madabegh, Mankabad and Ellwan (8.9, 5.3 and 6.4 mg kg^{-1} soil, respectively), than those of Bani Hussien (3.95 mg kg^{-1} soil), Bani Ghalleb (0.6 mg kg^{-1} soil) and Gahdam (2 mg kg^{-1} soil). The total content of Cd in the surface layer ranged from 0.6 to 10.3 mg kg^{-1} soil, and it was higher than that found (6.6 to 7.5 mg kg^{-1} soil) in the subsurface layer at all studied areas irrigated with sewage wastewater. In this study, the concentration of total Cu is higher than that (0.32 mg kg^{-1} soil) reported by Elsokkary and Lag (1978) in the alluvial soils. Alloway (1995) reported that the common concentration of total Cd in agricultural soils is in the range 0.2-1.0 mg kg^{-1} soil. Therefore, the concentrations of Cd found in these soils were significantly higher than that acceptable for the agriculture soils (Kabata-Pendias and Pendias, 1992, Abdel Salam, 2002 and Meers *et al*., 2005). The accumulation of total Cd in these soils decreased in the order: El-Madabegh > Ellwan > Mankabad > Bani Hussien > Gahdam > Bani Ghaleb.

Nickel (Ni): At all sites, total Ni in the surface layer of the soils irrigated with sewage wastewater was in the range 69-155 mg kg^{-1} soil (Fig. 1) and that in the subsurface layer was in the range 81-168 mg kg^{-1} soil. Total Ni in the soils of the six locations is higher than that (50 mg kg^{-1} soil) found in the agricultural soils (Alloway, 1995). Metwally and Rabie (1989) reported that total Ni in the alluvial and calcareous soils of Egypt ranged from 25 to 85 and from 29 to 72.2 mg kg^{-1} soil, respectively.

Lead (Pb): Total Pb in all soil samples collected from the studied areas irrigated with sewage wastewater ranged from 36 to 308.8 mg kg^{-1} soil. The surface soil layers of the various locations differed widely in their total content of Pb. The total content of Pb was higher in the surface than in the subsurface layer at the studied areas, except El-Madabegh. Data indicate that the highest Pb concentration (308.5 mg kg^{-1} soil) was found the soil of Mankabad, while the lowest (36 mg kg^{-1} soil) was recorded in soils of Gahdam. The concentration of total Pb found in these soils was significantly higher than those previously reported by Abdel Salam (2002). Alloway (1995) reported that a range of 10 and 30 mg Pb kg^{-1} soil is an acceptable concentration for agricultural soils.

It may be stated that all the soils of the six locations which were irrigated with sewage wastewater are polluted with Fe, Mn, Zn, Cu, Cd, Ni and Pb due to the use of sewage wastewater over 45-50 years.

DTPA-extractable Fe, Mn, Zn, Cu, Cd, Ni and Pb in soils near Assiut city

Figure 1 shows the concentration of the DTPA-extractable Fe, Mn, Zn, Cu, Cd, Ni and Pb from soils irrigated with wastewater at El-Madabegh, Mankabad, Ellwan, Bani Hussein, Bani Ghalleb and Gahdam.

With respect to DTPA-Fe, there is a wide variation between the studied soils. Data indicate that the concentrations of the available Fe in soils of El-Madabegh, Mankabad, Ellwan, Bani Hussien, Bani Ghalleb and Gahdam were 40.8, 49.5, 58, 80.6, 29.9 and 31.5 mg kg^{-1} soil, respectively. According to Viets and Lindsay (1973), Elgharably (1993) and Elgharably (2007) soils, at the indicated sites of this study, contain high concentrations of available Fe.

Extractable-Mn, Zn and Cu are varied between sampled sites. This variation was associated with variation in soil properties (Table 1). Compared to the soils irrigated with underground water at all sites, the concentrations of extractable Mn, Zn and Cu of the soils irrigated with sewage wastewater were higher by approximately 3058.3% for Mn, 804.4% for Zn and 412.8% for Cu. According to Viets and Lindsay (1973), all soils irrigated with sewage wastewater are polluted with Mn, Zn and Cu.

According to Kabata-Pendia and Pendia (1984) soils containing less than 0.01 mg kg^{-1} soil are Cd-deficient, and those containing 0.01-0.07 mg kg^{-1} soil are Cd-non-deficient (normal range). The soils under investigation in this study contain high concentration of DTPA-extractable Cd. Highest concentration (10.3 mg Cd kg^{-1} soil) of DTPA-extractable Cd is at El-Madabegh and the lowest (0.6 mg Cd kg^{-1} soil).

Data reported by Elsokkary and Lag (1978), Shahin and Abdel Hamid (1993), Aboulroos *et al*. (1996) and Abdel Salam (2002) suggest that the range 1.17-1.61 mg kg^{-1} soil of extractable Pb could be the background concentration of Pb in the alluvial non-polluted soils of Egypt. Concentrations of DTPA-Pb at the studied areas in this study are higher than that reported by others and therefore these lands are considered Pb-contaminated.

Evaluation of soil Lead, Nickel and Cadmium impact on the studied soil quality

Metals in soils exert a decisive impact on the quality of soil and its use in food production. Hakanson (1980) used the contamination factor (CF) and the degree of contamination (DC) to asses soil contamination by comparing the metal concentration of the surface layer to the metal background value. Four contamination categories were defined according to Liu *et al*. (2005) as follow:

Contamination Factor (CF)	**Degree of contamination (DC)**
CF < 1	Low contamination
1 $\leq$ CF > 3	Moderate contamination
3 $\leq$ CF < 6	Considerable contamination
CF $\geq$ 6	Very high contamination

Table 4 shows the contamination factor (CF) of Pb, Ni and Cd in the surface layer of the soils irrigated with underground water (UW) and sewage wastewater (SW) at different sites near Assiut City.

Data presented show that soils at the studied sites which have been SW irrigated have values of CF for Pb in the range 6.11-50.93. At the same sites, the CF of Ni at all sites is in the range 6.33-80.75 and that of Cd is in the range 2.89-46.82. Therefore, according to Hakanson (1980) and Liu *et al*. (2005) soils at all sites are considered highly contaminated with Pb, Ni and Cd.

Repeated application of sewage water resulted in accumulation of heavy metals in soils, reaching high levels for plants and other soil organisms. Metals that accumulate in the edible plants and pose the greatest threat to human and animal health are Cd, Ni, Pb, Cu and Zn (Chaney, 1983). The US environmental protection agency (US EPA, 1993) regulated nine trace elements for land-applied sewage sludge. Only six of these elements (Cu, Ni, Zn, Cd, Pb and Se) are considered to be phytotoxic (Schmidt, 1997).

Finally, it may be stated that all of the studied sites are considered Pb, Ni and Cd contaminated due to the use of untreated sewage wastewater in irrigation of certain agricultural soils near Assiut City over 45-50 years.

Conclusion

Our study proves that the agricultural soils under investigation are contaminated with Pb, Cd and Ni.

The metal concentrations in soils of the studied areas exceeded the limited values recommended by several studies; however, an Egyptian standard models need to be established to be compared with for agricultural soils.

The results will serve as a pilot study for further investigation of soil and plant species in environmental pollution. We will continue this trend of investigations in our future work.

TABLE 4. Soil contamination factor (CF) of Pb, Ni and Cd of the surface and subsurface layers of soils irrigated with sewage water (SW), or underground water (UW) near Assiut city.

Sites	Soil Depth	Pb			Ni			Cd		
		UW	SW	CF	UW	SW	CF	UW	SW	CF
	(cm)	mg kg^{-1} soil			mg kg^{-1} soil			mg kg^{-1} soil		
Madabegh	0-15	10.4	197	18.94	1.62	130	80.75	0.22	10.3	46.82
	15-30	14.65	246.5	16.83	1.62	148.0	91.36	0.22	8.9	40.45
Mankabad	0-15	9.35	322	34.44	9.18	155	16.88	0.14	5.2	37.14
	15-30	9.49	308.5	32.54	5.67	132.5	23.53	0.135	5.7	42.2
Ellwan	0-15	9.4	46	8.52	8.91	121	13.58	0.2	8.1	40.5
	15-30	8.9	41.5	4.66	5.27	133.0	25.24	0.135	6.4	47.41
Bani Hussien	0-15	4.3	219	50.93	8.91	145	16.27	0.13	4.2	30.77
	15-30	6.65	184.5	27.58	6.48	138.0	21.30	0.11	3.95	35.58
Bani Ghalleb	0-15	5.6	158	28.2	12.3	128	10.41	0.21	0.6	2.89
	15-30	3.42	162.5	47.51	6.69	113.5	16.97	0.135	0.6	4.44
Gahdam	0-15	7.2	44	6.11	10.9	69	6.33	0.2	2.4	12.0
	15-30	11.7	36.0	3.08	8.15	75.0	9.2	0.14	2.0	14.29

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حالة العناصر الثقيلة فى أراضى أسيوط نتيجة أستخدام مياه الصرف الصحى لفترات طويلة فى رى المحاصيل: دراسة حالة

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تهدف هذه الدراسة الى تقييم حالة عناصر الرصاص والنيكل والكادميوم والحديد والمنجنيز والزنك والنحاس فى الأراضى الزراعية لبعض المناطق فى أسيوط والتى يتم ريها باستخدام مياه الصرف الصحى منذ ما يقرب من 40 - 50 عام.

وقد تم حفر 36 قطاع وأخذت عينات تربة من 6 مناطق تابعة لمحافظة أسيوط وتقع فى قرى المدابغ ومنقباد وعلوان وبنى حسين وبنى غالب وجحدم يتم ريها بمياه الصرف الصحى أو المياه الجوفية لتقييم الصفات الطبيعية والكيميائية للتربة وتقدير التركيز الميسر والكلى للعناصر المذكورة. كما تم أخذ عينات من الماء المستخدم فى رى المحاصيل المختلفة فى كل منطقة.

ومن النتائج المتحصل عليها أتضح أنه مقارنة للأراضى المروية بالمياه الجوفية ونتيجة للرى بمياه الصرف الصحى فأن تركيزات العناصر فى التربة مرتفعة. وبناءا على النتائج المتحصل عليها فأنه يلزم معالجة الأراضى التى تحتوى على التركيزات المرتفعة من العناصر الثقيلة كما أنه يلزم تقدير تركيزات العناصر التى يتم أمتصاصها بالمحاصيل المزروعة فى المناطق تحت الدراسة كما أنه يوصى بجدولة أستخدام مياه الصرف الصحى فى الرى فى هذه المناطق.