Current Status of Some Micro-Nutrients and Heavy Metals of Al-Hawawer Valley Soils of Marsa Matrouh – Egypt

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ABSTRACT

The present study was focused on the current status of some micro-nutrients such as (Fe, Mn, Zn, and Cu) and some heavy metals such as (Pb, Co, and Ni) representing Wadi Al-Hawawer area that located at Marsa Matrouh Governorate, Egypt. The obtained results illustrated that the vertical distribution of total concentrations of Fe were decreased with increasing profile depth. However, the available concentrations of Fe were oscillated in different soil profiles. Also, the released percentage of Fe tended to decrease with depth. The released percentages of Mn in different soil profile were found to be between 0.66% and 1.66 %, respectively. The distribution of total concentrations of Mn in different soil profiles tended to be osculated with depth. The available concentrations of Zn in different soil profiles were between 2.15 mg/kg and 3.95 mg/kg in the deepest layer of profile No. 3 and in the second and last layer of profile No. 1, respectively. Generally, micro-nutrients concentrations in the studied soil profile were found to take the following sequence Fe > Mn > Zn > Cu, and the available concentrations of micro-nutrients in the studied soil profile were found to take the same tendency. However, the released percentages of micro- nutrients took the following order Cu > Fe > Mn > Zn. The released percentages of Pb in different soil profiles were between 2.98% to 6.67 % in the deepest layer of soil profiles No. 4 and 6 and the top surface of soil profile No. 3, respectively. The vertical distribution of available concentration of Co tended to osculate with increasing depth. The released percentages of Co were between 0.07% to 0.89% in the surface layer of soil profile No. 1 and 3, respectively. The vertical distribution of total concentration of Ni tended to increase with increasing soil depth in soil profiles No. 3, 4, and 5 respectively and vice versa with soil profiles numbers 1, 2, and 6, respectively.

Keywords: Heavy metals; Trace Elements; Micro-Nutrients; Soil Properties; Al-Hawawer Valley

INTRODUCTION

The Egyptian soils may be classified into two groups including the transported alluvial origin and desert sandy and calcareous soils. In general, the alluvial soils have already received continuous supply of heavy metals and micro-nutrients owing to either intensive agriculture and excessive fertilization or wastewater reuse. In contrast, the desert sandy and calcareous soils have represented usually a very low content of either heavy metals or micro-nutrients (Abd Elrahman, 2005; Khalil et al., 2009; Hegab et al., 2016; Abou-Shady, 2016; Abou-Shady, 2017; Abou-Shady et al., 2018 A, B, and C; Eissa ei al., 2018; Khalfa et al., 2018).

Most of Egyptian soils represent a comparatively high concentration of total Fe compared with other elements. On the other hand, the soluble and exchangeable Fe are found to exist in a relatively low concentrations particularly in well-drained soils (Abd Elrahman, 2005). The concentrations of Mn in different soils located at El-Fayoum Governorate, Egypt, were ranged between 280-840 mg kg^{-1}, however the available Mn was found to be between 2.0-12.9 mg kg^{-1}. On the other hand, the concentration of Zn was found to be between 20.7-55.1 mg kg^{-1}. The highest average concentrations of total Zn were depended on soil texture and took the following order clay > loam > clay loam > sandy clay loam > sandy clay > sandy loam. This is because the fine particles soil contains the higher content of organic matter. At the same area of El-Fayoum governorate the total content of Cu was found to be between 58-104 mg kg^{-1}, however the extractable Cu was found between 1.6 mg kg^{-1} and 8.4 mg kg^{-1}. The total or available Cu in different soils was correlated basically on soil texture, $CaCO_3$ concentrations, and organic matter content. Also, it was reported that the critical concentrations of Fe, Mn, and Zn in different soils were found to be (5.6 mg kg^{-1}, 3.4 mg kg^{-1}, and 3.8 mg kg^{-1}) for alluvial, sandy, and calcareous soils, and (1.4 ug g^{-1} and 1.2 ug g^{-1}) for sandy and calcareous soils, and (0.9 ug g^{-1} and 0.7 ug g^{-1}) for alluvial and calcareous soils, respectively (Elgala et al., 1986; Abd Elrahman, 2005).

The total content of Ni in different alluvial soils located at El-Fayoum Governorate, Egypt was found to be between 33.5-77 mg kg^{-1}, however the lower concentrations of Ni were found in the available extraction to be between (0.44-1.34 mg kg^{-1}). In El-Gabal El-Asfar area, the available concentrations of Pb that were extracted by DTPA were found to be between 0.26 to 37.4 mg kg^{-1}. The relatively high concentrations of Pb in this area may be because of the intensive

irrigation with sewerage water for a long period. Also, in some top soil surface that was under intensive irrigation for 10 years the available Pb content was found to be approximately 11.8 mg kg^{-1}. The total concentration of Co was evaluated in different soils (from Delta, Egypt) differ in its pollution degree as follows non-polluted, moderately, and highly polluted soils. The results showed that Co concentration was found to be between (13.12-23.20 mg kg^{-1}) and (26.5-30.0 mg kg^{-1}) for the non-polluted and moderately polluted soils, respectively. The highest values of Co were found to be between (36-64.69 mg kg^{-1}) (Abd Elrahman, 2005).

The present study was focused on the current statues of some micro-nutrients including (Fe, Mn, Zn, and Cu) in addition to some heavy metals including (Pb, Co, and Ni) in some soils profiles representing Wadi Al-Hawawer area that located at Marsa Matrouh Governorate, Egypt.

MATERIALS AND METHODS

Soil profiles were collected from Wadi Al-Hawawer area that located in Western part of Marsa Matrouh governorate, Egypt as it depicted in Fig. 1. Wadi Al-Hawawer area consisted of three main parts including Eastern branch with approximately total area (833 m^2), Medium branch with approximately total area (1500 m^2), and Western branch with approximately total area (1025 m^2) as it presented in Fig. 2. Soil analysis was carried out according to (Jackson, 1973). Micro-nutrients and heavy metals were detected using Inductivity Coupled Argon Plasma (ICAP) (Abou-Shady, 2017).

Soil profiles description

The first soil profile located in the Eastern branch within longitudes (26° 50ˉ 26.3ˉˉ E) and latitudes (31° 25ˉ 22.1ˉˉ N). The common vegetation was desert shrubs, and topography was undulating with gently sloping. The first layer (0-25 cm) was very pale brown (10YR7/4, dry & moist) Sand, massive, non-sticky, non-plastic, few soft lime segregations, common fine gravels, strong effervescence, and clear wavy boundary. The second layer (25-50 cm) was very pale brown (10YR7/3, dry) to pale brown (10YR6/3, moist), sandy loam, massive, soft, slightly sticky, slightly plastic, many fine to coarse pores, few gypsum spots, moderate effervescence, and clear smooth boundary. However, the third layer (50-90 cm) was very pale brown (10YR7/3, dry) to light yellowish brown (10YR6/4, moist), loamy sand, massive, soft, non-sticky, non-plastic, common fine pores, common fine soft lime segregations, few gypsum mycelium, and strong effervescence.

The second soil profile located in the Eastern branch within longitudes (26° 50ˉ 26ˉˉ E) and latitudes (31° 25ˉ

9.9ˉˉ N). The most common vegetation was desert shrubs, and the topography was slightly with gently sloping. The first layer (0-15 cm) was very pale brown (10YR7/3, dry) to light yellowish brown (10YR6/4, moist), sand, single grains, loose, non-sticky, non-plastic, few fine dead roots, few gypsum spots, few fine gravels, moderate effervescence, and clear smooth boundary. The second layer (15-50 cm) was characterized as very pale brown (10YR7/3, dry) to light yellowish brown (10YR6/4, moist), gravelly sand, single grains, loose, non-sticky, non-plastic, varisized gravels, and moderate effervescence.

The third profile was located in the Medium branch within longitudes (26° 50ˉ 7ˉˉ E) and latitudes (31° 25ˉ 40.3ˉˉ N). The common vegetation was desert shrubs, and the topography was almost flat with flat slope. The first layer (0-30 cm) was characterized by very pale brown (10YR7/4, dry) to light yellowish brown (10YR6/4, moist), sandy loam massive, slightly hard, sticky, plastic;, common fine to medium pores, few fine dead roots, few gypsum spots, common soft lime segregations, few very fine gravels, moderate effervescence, and clear smooth boundary. The second layer (0-80 cm) was characterized by very pale brown (10YR7/4, dry) to light yellowish brown (10YR6/4, moist), sandy loam, massive, soft, slightly sticky, slightly plastic, many fine to coarse pores, few fine to medium dead roots, few gypsum spots, many soft lime concretions, common fine and medium gravels, moderate effervescence, and clear smooth boundary. However, the third layer (80-120 cm) was characterized by pale yellow (2.5Y8/4, dry & moist), sand, massive, soft, non-sticky, non-plastic, common medium, coarse pores, few soft lime segregations, common fine gravels, and slight effervescence.

The forth profile was located in the Medium branch within longitudes (26° 50ˉ 12.5ˉˉ E) and Latitudes (31° 25ˉ 10.5ˉˉ N). The most common vegetation was desert shrubs and the topography was slightly undulating with gently sloping. The first layer (0-45 cm) was characterized by very pale brown (10YR7/4, dry) to light yellowish brown (10YR6/4, moist), sandy loam, massive, soft, slightly sticky, slightly plastic, many few gypsum spots, few fine gravels, strong effervescence, and clear smooth boundary. The second layer was (45-90 cm) characterized by very pale brown (10YR7/3, dry) to light yellowish brown (10YR6/4, moist), sandy loam, massive, soft, slightly sticky, slightly plastic, many common fine and coarse gravels, strong effervescence, and gradually smooth boundary. However, the third layer (90-120 cm) was characterized by very pale brown (10YR7/3, dry) to light yellowish brown (10YR6/4, moist) gravelly sand, single grains, loose, non-sticky, non-plastic, common fine and coarse gravels, and moderate effervescence.

The fifth profile was located in the Western branch within longitudes (26º 49ˊ 50.9ˊˊ E) and latitudes (31º 25ˊ 34.3ˊˊ N). The common vegetation was desert shrubs, and the topography was slightly undulating with gently sloping. The first layer (0-30 cm) was characterized by very pale brown (10YR8/3, dry & moist), sand, single grains, loose, non-sticky, non-plastic, common fine pores, few gypsum spots, few fine gravels, moderate effervescence, and diffuse smooth boundary. The second layer (30-70 cm) was characterized by very pale brown (10YR8/3, dry) to light yellowish brown (10YR6/4, moist), sand, single grains, loose, non-sticky, non-plastic, few fine pores, few gypsum spots, few fine gravels, few fine to medium dead roots, strong effervescence, and diffuse smooth boundary. However, the third layer (70-110 cm) was characterized by very pale brown (10YR7/4, dry) to light yellowish brown (10YR6/4, moist), sand, single grains, loose, non-sticky, non-plastic, few gypsum, few fine gravels, and moderate effervescence.

The sixth profile was located in the Western branch within longitudes (26º 49ˊ 50.4ˊˊ E) and latitudes (31º 25ˊ 22ˊˊ N). The common vegetation was desert shrubs, and the topography was almost flat and the slope was also flat. The first layer (0-20 cm) was characterized by very pale brown (10YR8/4, dry & moist), sandy loam to loamy sand , massive, soft, slightly sticky, non-plastic, many fine to coarse pores, few gypsum spots, few fine gravels, few fine dead roots, moderate effervescence, and gradual smooth boundary. The second layer (20-50 cm) was characterized by very pale brown (10YR8/3, dry & moist), loamy sandy, massive, soft, slightly sticky, non-plastic, common fine pores, few gypsum spots, few fine gravels, strong effervescence, and abrupt smooth boundary. However, the third layer (50-120 cm) was characterized very pale brown (10YR8/4, dry & moist), gravelly sand, single grain, loose, non-sticky, non-plastic, common fine and coarse gravels, few fine to medium dead roots, strong effervescence, and diffuse smooth boundary.

Fig. 1. Map showing the North Western part of Egypt in which the studied area is located

Fig. 2. Map showing the exact locations of soil profiles for the studied area (Al-Hawawer Valley)

Chemical and Physical Properties

Soil texture

The texture classes of studied soils are listed in Table.1 and ranged from sandy to sandy loam in Wadi Al-Hawawer area. Some locations had high sand content in the surface layers such as profiles No. 1, 4, and 6 which may be due to accumulation of wind-blown sand. It was found that, the changes in textural class with depth are not significant in most of all the Wadi Hawawer soil profiles.

Total and active CaCO₃ contents

The calcium carbonate content of the studied soils profile plays a great role in their formation, consequently, and the physicochemical characteristics. The total $CaCO_3$ percentages presented in (Table, 2) ranged between 27.3 and 4.41% in profile No. (6 and 2), respectively in Wadi Al-Hawawer soils. The highest contents were found in the deepest layer (50-120 cm) of profile No. (6), whereas the lowest contents were found in the surface layer (0-15 cm) of profile No. (2). The active fraction of $CaCO_3$ content varied widely from 0.15 to 6.40% in profile No. (1 and 4), respectively

Organic matter content of soils

Table No. (2) showed that organic matter (OM) content was ranged from 0.10% to 0.71% in different soil profile of Wadi Al-Hawawer area. The highest content of OM was recorded in the surface layer (0-20 cm) of profile No. (6), while the lowest content was found in the deepest layer (50-90 cm) of profile No. (1).

The distribution of organic matter in different soil profiles indicates that the organic matter percentage reached the maximum concentrations in the top layers and decreased progressively with the bottom of different soil profiles.

Saturation percentage

Data in Table (1) showed that the saturation percentage (SP) ranged from 16.50% to 32.00 %. The highest levels were found in surface layer (0-20 cm) of profile No. (6). The lowest content of SP was associated with the deepest layer (70-110 cm) of profile No. (5).

Soil reaction (pH)

Table (2) showed that the studied soils are generally neutral to strongly alkaline, as indicated by their pH values which varied between 7.02 and 8.58. The highest pH values were found in the deepest layer (80-120 cm) of profile No. (3), while the lowest pH values were associated with the surface layer (0-25 cm) of profile No. (1).

Gypsum content

Data in Table (2) showed that gypsum content was ranged from 1.05 to 6.75% in Wadi Al-Hawawer soils profiles. The highest levels were obtained in the deepest layer (50-120 cm) of profile No. (6), however the lowest levels were represented in the surface layer (0-25 cm) of profile No. (1).

Table 1. Textural classes of the studied soils

Profile No.	Depth (Cm)	SP (%)	Vcs	C.S	Ms	F.S	Vfs	Total sand	(Silt + Clay)	Silt	Clay	Texture class
						Particle size distribution (%)						
1	0-25	17.00	3.62	28.20	53.86	8.72	3.56	97.96	2.04	-	-	S
	25-50	24.00	4.20	7.90	11.90	37.80	12.00	73.8	26.2	8.10	18.10	S.L
	50-90	27.60		1.07		87.17		88.24	11.76	1.50	10.26	S.L
2	0-15	16.60	4.13	11.28	32.70	30.29	15.40	94.80	6.20			S
	15-50	16.00	9.30	1.64	10.26	41.14	33.90	96.24	3.76			S
3	0-30	24.00	3.25	9.95	13.05	36.65	13.05	75.95	24.05	7.05	17.00	S.L
	30-80	27.00	5.15	8.80	10.70	35.80	11.00	71.45	28.55	11.30	17.25	S.L
	80-120	17.60	29.75	21.8	19.72	19.05	7.06	97.38	2.62			S
4	0-45	25.60	5.60	220	17.20	30.00	6.7	79.50	20.5	5.5	15.0	S.L-L.S
	45-90	27.00	3.25	9.95	13.05	36.65	13.05	75.95	24.05	5.05	19.00	S.L
	90-120	20.00	16.99	38.30	33.23	9.22	1.60	99.34	0.66			S
5	0-30	20.00	10.51	11.87	27.58	35.93	11.67	97.56	2.44			S
	30-70	18.30	9.44	14.82	43.75	28.18	3.26	99.45	0.55			S
	70-110	16.50	10.40	16.70	38.89	25.52	6.06	97.57	2.43			S
6	0-20	30.00		48.10		33.40		81.50		3.50	15.00	S.L-L.S
	20-50	25.00		23.40		63.60		87.00		2.50	10.00	L.S
	50-120	19.00	26.83	33.66	23.47	10.61	3.43	98.00	2.00			S

Vcs	Very Coarse Sand	2 - 1 mm	Vfs	Very Fine Sand	0.125 - 0.063 mm
Cs	Coarse Sand	1 - 0.5 mm	Silt + Clay		< 0.063 mm
Ms	Medium Sand	0.5 - 0.25 mm	S	Sandy	
Fs	Fine Sand	0.25 - 0.125 mm	S.L	Sandy Loam	

Table 2. Some chemical characteristics of the studied soils

Profile No	Depth (Cm)	CaCO$_3$ (%) T	CaCO$_3$ (%) A.C	O.M (%)	Gypsum (%)	pH	EC dS/m	Na$^+$	K$^+$	Ca^{++}	Mg^{++}	CO$_3^{--}$	HCO$_3^-$	CL$^-$	SO$_4^{--}$
								Soluble Cations (meq/l)				Soluble Anions (meq/l)			
1	0-25	25.60	1.22	0.33	1.05	7.02	0.76	3.91	0.34	2.20	1.15	-	1.50	3.70	2.40
	25-50	18.27	0.75	0.27	1.85	8.17	0.80	4.50	0.45	1.75	1.30	-	1.50	3.80	2.70
	50-90	9.05	0.15	0.10	4.15	8.10	1.32	7.50	0.65	3.50	1.55		2.25	6.35	4.60
2	0-15	4.41	0.55	0.47	0.75	7.22	0.85	3.95	0.35	2.75	1.45	-	1.5	4.50	2.50
	15-50	6.82	1.15	0.37	1.15	8.19	0.88	4.30	0.45	2.80	1.25	-	1.55	4.60	2.65
3	0-30	11.62	1.75	0.45	1.29	8.33	0.85	4.40	0.35	2.70	1.05	-	1.40	4.35	2.75
	30-80	12.02	3.18	0.35	2.25	8.49	0.92	4.55	0.45	2.90	1.30	-	1.50	4.55	3.15
	80-120	14.82	3.20	0.27	3.29	8.58	1.25	7.10	0.65	3.60	1.15	-	1.65	6.80	4.05
4	0-45	22.63	5.40	0.49	1.50	8.22	0.75	3.95	0.35	2.25	0.95	-	1.50	3.25	2.75
	45-90	23.87	3.22	0.40	1.30	8.47	0.86	4.80	0.45	2.50	0.85	-	1.60	4.10	2.90
	90-120	19.50	6.40	0.39	3.05	8.55	1.30	8.15	0.55	3.05	1.25	-	1.75	7.15	4.10
5	0-30	2.41	0.35	0.52	1.60	8.24	0.95	5.00	0.65	2.90	0.95	-	1.60	4.65	3.25
	30-70	1.65	0.30	0.45	1.25	8.42	1.15	6.30	0.75	3.15	1.30	-	1.80	5.80	3.90
	70-110	3.22	0.55	0.20	4.05	8.47	1.37	8.15	0.80	3.50	1.25	-	2.05	7.45	4.20
6	0-20	11.20	2.20	0.71	1.20	8.09	1.15	7.00	0.65	2.90	0.95	-	1.75	6.75	3.00
	20-50	12.60	3.15	0.40	1.30	8.29	1.50	9.70	0.70	3.15	1.45	-	1.75	8.55	4.70
	50-120	27.30	3.75	0.33	6.75	8.17	2.05	13.0	0.90	4.30	2.30	-	2.50	11.0	7.00

* T = Total Calcium Carbonate.
* A.C = Active Calcium Carbonate.

Soil Salinity

Data presented in Table (2) showed that the studied soils profiles are classified among non-saline to moderate saline, as indicated by ECe values which range from 0.76 to 2.05 dS/m. The highest ECe values was observed in the deepest layer (50-120 cm) of profile No. (6), while the lowest values were recorded in the surface layer (0-25 cm) of profile No. (1). The distribution of soil salinity showed that ECe values were increased with depth in all soil profiles. Data presented in Table (2) showed that the cations distribution in the studied soil profiles follow this order $Na^+ > Ca^{+2} > Mg^{+2} > K^+$, however the distribution of anions follow this order $Cl^- > SO_4^{--} > HCO_3^- > CO_3^{--}$.

RESULTS AND DISCUSSION

Distribution of micro – nutrients in Wadi Al-Hawawer soil profiles

Data presented in Table 3 shows that the total concentrations of Fe in the studied soil profiles were ranged from 1020 mg/kg to 7000 mg/kg in first layer of profile No. 2 and in deepest layer of profile No. 5, respectively. The available concentrations of Fe were ranged between 4.15 to 8.30 mg/kg in the first layer of profile No. 4 and second layer of profile No. 1, respectively. The released percentages [(the available concentrations/ Total concentrations)*1000] of Fe in the studied soil profiles were ranged between 0.07% to 0.54% in the deepest layer of profile No. 5 and first layer of profile No. 2, respectively. The vertical distribution of total concentration of Fe were decreased with increasing profile depth. However, the available concentrations of Fe were oscillated in different soil profiles. Also, the released percentages of Fe tended to decrease with depth.

On the other hand, the studied total concentrations of Mn in different soil profiles were ranged between 220.20 to 460.20 mg/kg in the first layer of profile No. 4 and in the deepest layer of profile No. 5, respectively. The available concentrations of Mn were found between 2.70 to 4.50 mg/kg in the deepest layers of profiles No. 3 and 5, respectively. The released percentages of Mn in different soil profile were found to be between 0.66**%** and 1.66 %, respectively. The total concentrations of Mn tended to increase with increasing profile depth, and the same tendency was observed with the available concentrations of Mn in different soil profiles except for profiles No. 2 and 6, respectively. The released percentages of Mn in different soil profile tended to decrease with depth similar to what was observed with the released percentages of Fe.

The total concentrations of Zn in the studies soil profiles were ranged between 80.50 to 160.20 mg/kg in top surface layer of profile No. 1 and in the deepest layer of profile No. 6, respectively. The distribution of total concentration of Mn in different soil profiles tended to be osculated with depth. The available concentrations of Zn in different soil profiles were ranged between 2.15 to 3.95 mg/kg in the deepest layer of profile No. 3 and in the second and last layer of profile No. 1, respectively. The vertical distribution of available Zn in different soil profiles tended to osculate with increasing soil profile depth. The released percentages of Zn in different soil profile were ranged between 1.78% to 4.84% in the second layer of profile No. 4 and in the surface layer of profile No. 1, respectively. The same tendency that was observed with the released percentages of Fe and Mn also was observed with Zn.

The vertical distribution of total Cu in the studied soil profile were also studied and presented in Table 3. The total concentrations of Cu were ranged from 33.90 to and 80.15 mg/kg in the surface layer of profile No. 6 and second layer of profile No. 3, respectively. The available concentrations of Cu in the studied soil profiles were ranged between 2.20 to 2.77 mg/kg in the surface layer of profiles No. 5 and 6 and deepest layer of profile No. 1, respectively. The available concentrations of Cu tended to increase with depth except for profile No. 2. The released percentages of Cu in the studied soil profile were ranged between 3.12% to 6.49% in the second layer of profile No. 3 and in the surface layer of profile No. 6, respectively. The vertical distribution of the released percentages of Cu in the studied soil profiles tended to osculate with depth. Generally, the highest concentrations of micro-nutrients in the studied soil profile were found to take the following sequence Fe > Mn > Zn > Cu, and the available concentrations of micro-nutrients in the studied soil profile were found to take the same tendency. However, the released percentages of micro-nutrients took the following order Cu > Fe > Mn > Zn.

Table 3. Micro-nutrients (Fe, Mn, Zn, and Cu) distribution in different soil profiles

Profile (No)	Depth (cm)	Fe Total (mg/kg)	Fe Available (mg/kg)	Fe Release (%)	Mn Total (mg/kg)	Mn Available (mg/kg)	Mn Release (%)	Zn Total (mg/kg)	Zn Available (mg/kg)	Zn Release (%)	Cu Total (mg/kg)	Cu Available (mg/kg)	Cu Release (%)
1	0-25	2540	8.20	0.32	250.15	4.15	1.66	80.50	3.90	4.84	47.20	2.70	5.72
	25-50	3550	8.30	0.23	260.20	4.20	1.61	85.20	3.95	4.64	45.50	2.75	6.04
	50-90	4640	7.70	0.17	270.15	4.30	1.59	90.15	3.95	4.38	50.20	2.77	5.52
2	0-15	1020	5.50	0.54	302.15	3.90	1.29	120.20	3.70	3.08	52.20	2.60	4.98
	15-50	1050	5.20	0.50	305.20	3.70	1.21	130.50	3.50	2.68	55.15	2.50	4.53
3	0-30	2050	5.40	0.26	330.15	3.20	0.97	140.15	2.95	2.10	73.20	2.40	3.28
	30-80	2070	5.13	0.25	402.20	3.50	0.87	90.20	2.95	3.27	80.15	2.50	3.12
	80-120	3050	6.20	0.20	407.50	2.70	0.66	95.20	2.15	2.26	65.50	2.55	3.89
4	0-45	3500	4.15	0.12	220.20	2.75	1.25	124.20	2.80	2.25	75.15	2.60	3.46
	45-90	4050	4.30	0.11	260.15	2.90	1.11	160.11	2.85	1.78	55.15	2.65	4.81
	90-120	6000	4.50	0.08	270.20	2.95	1.09	130.12	2.80	2.15	40.20	2.40	5.97
5	0-30	6050	6.20	0.10	415.50	4.15	1.00	105.50	3.05	2.89	39.20	2.20	5.61
	30-70	6500	6.30	0.10	450.30	4.20	0.93	107.20	3.15	2.94	41.20	2.25	5.46
	70-110	7000	5.15	0.07	460.20	4.50	0.98	150.50	3.30	2.19	45.50	2.30	5.05
6	0-20	5050	7.30	0.14	350.20	3.90	1.11	155.50	3.70	2.38	33.90	2.20	6.49
	20-50	5060	7.20	0.14	360.50	3.70	1.03	160.20	3.60	2.25	35.70	2.30	6.44

Distribution of heavy metals in Wadi Al-Hawawer soil profiles

Data listed in Table 4 showed the vertical distribution of some heavy metals including Pb, Co, and Ni and its total and available forms in Wadi Al-Hawawer soil profiles. The total concentrations of total Pb were ranged between 2.70 to 5.20 mg/kg in the surface layer of soil profile No. 3 and in the deepest layer of soil profile No. 5, respectively. Generally, the total concentrations of Pb were decreased with depth except for soil profile No 6. The available concentrations of Pb in different soil profiles were found between 0.14 to 0.22 mg/kg in the deepest layer of soil profile No. 6 and middle layer of soil profile No. 5, respectively. The vertical distribution of available concentrations of Pb tended to decrease with decreasing depth except for soil profiles No. 1 and 5, in which the available concentrations of Pb were increased with increasing soil profile depth. The released percentages of Pb in different soil profiles were between 2.98% to 6.67 % in the deepest layer of soil profiles No 4 and 6 and the top surface of soil profile No. 3, respectively. The vertical distribution of the released percentage of Pb was found to take the same tendency of available concentrations of Pb.

The vertical distribution of total, available, and released percentages of Co is presented in Table 4. The total concentrations of Co were found between 1.15 to 2.70 mg/kg in the surface layer of soil profile No. 2 and middle layer of soil profile No. 3, respectively. The total concentrations of Co tended to increase in the deepest layers compared with what was found in the top surface layers. The available concentrations of Co were found to be within range 0.001 mg/kg to 0.20 mg/kg in the surface layer of soil profile No. 1 and also with top layer of soil profile No. 3, respectively. The vertical distribution of available concentration of Co tended to osculate with increasing depth. The released percentages of Co were between 0.07% to 0.89% in the surface layer of soil profile No. 1 and 3, respectively following the same tendency that was found with the vertical distribution of available Co.

The total concentrations of Ni were found between1.50 to 2.70 mg/kg (in the deepest layer of soil profiles No. 2 and 6 as well as surface layer of soil profile No. 5) and deepest layer of soil profile No. 4, respectively. The vertical distribution of total concentration of Ni tended to increase with increasing soil depth in soil profiles No. 3, 4, and 5 respectively and vice versa with soil profiles No. 1, 2, and 6, respectively. The vertical distribution of available concentrations of Ni were found between 0.01 to 0.04 mg/kg (in surface layer of soil profiles No. 2 and 6 as well as in the deepest layer of soil profile No. 5) and in the deepest layer of soil profile No. 4, respectively. The vertical distribution of available concentration of Ni tended to osculate with increasing soil depth. The released percentages of Ni were between 0.59% and 3.48% in the surface layer of soil profile No. 2 and 5, respectively.

Table 4. Heavy metals (Pb, Co, and Ni) distribution in different soil profiles

Profile (No)	Depth (cm)	Pb Total (mg/kg)	Pb Available (mg/kg)	Pb Release (%)	Co Total (mg/kg)	Co Available (mg/kg)	Co Release (%)	Ni Total (mg/kg)	Ni Available (mg/kg)	Ni Release (%)
	0-25	3.85	0.15	3.90	1.50	0.001	0.07	2.20	0.02	0.91
	25-50	4.15	0.16	3.86	1.55	0.002	0.13	2.05	0.02	1.07
1	50-90	4.20	0.17	4.05	1.60	0.003	0.19	2.40	0.02	0.83
	0-15	3.70	0.22	5.95	1.15	0.004	0.35	1.70	0.01	0.59
2	15-50	3.90	0.20	5.13	2.20	0.002	0.09	1.15	0.02	1.74
	0-30	2.70	0.18	6.67	2.25	0.020	0.89	2.05	0.03	1.46
	30-80	3.25	0.17	5.23	2.70	0.003	0.11	2.30	0.03	1.30
3	80-120	3.50	0.16	4.57	2.60	0.004	0.15	2.40	0.02	0.83
	0-45	4.05	0.15	3.70	2.40	0.002	0.08	2.50	0.02	0.80
	45-90	4.15	0.14	3.37	2.30	0.003	0.13	2.60	0.03	1.15
4	90-120	4.70	0.14	2.98	2.60	0.003	0.12	2.70	0.04	1.48
	0-30	4.80	0.15	3.13	2.55	0.004	0.16	1.15	0.04	3.48
	30-70	5.05	0.22	4.36	2.15	0.002	0.09	1.60	0.02	1.25
5	70-110	5.20	0.23	4.42	2.40	0.003	0.13	1.65	0.01	0.61
	0-20	4.90	0.17	3.47	2.45	0.004	0.16	1.70	0.01	0.59
6	20-50	4.70	0.14	2.98	2.50	0.002	0.08	1.15	0.02	1.74

The vertical change of the released percentages of Ni tended to osculate with increasing soil depth. The released percentage of the studied heavy metals took the following sequence Pb > Ni > Co. The highest concentrations of heavy metals were found with Pb and the lowest concentrations were found with Co and Ni. The higher concentrations of heavy metals took the following order Pb > Ni > Co.

Correlation between micro - nutrients and different soil properties

The correlation between micro – nutrients concentrations and soil physical and chemical properties is listed in Tables 5 and 6. Table 5 shows the correlation between soil physics properties including (saturation percent, very coarse sand percent, coarse sand percent, medium sand percent, fine sand percent, very fine sand percent, total sand percent, silt and clay percent, silt percent, and clay percent) and (total concentrations, available concentrations, and released percentage of Fe, Mn, Zn, and Cu, respectively. The saturation percentages were positively correlated with total concentrations of the studied micro-nutrients except for the total and available concentrations of Mn. The same tendency was also observed with the correction between available concentrations of micro-nutrients and saturation percentages. However, for the released percentages of micro-nutrients of Fe and Zn were presented negatively correlation and vice versa with Mn and Cu. The highest values of correlation were observed with the total concentration of Zn and Cu,

however the lowest values were observed with the released percentages of Fe and the total concentration of Zn.

The effect of very coarse sand percentage were correlated negatively with almost all micro-nutrients (total and available concentration and released percentage) except for the total concentrations of Fe and Mn. The highest values of correlations were observed with the total concentration of Mn, however the lowest values of correlation were observed with the released percentages of Cu. The effect of course sand tended to osculate among different micro-nutrients, in which it was positively correlated with (total concentrations of Fe, Zn, and Cu), (available concentration of Cu), and (released percentages of Mn).The highest values of correlation were observed with the total concentrations of Cu, however the lowest values were observed with the available concentration of Mn.

The effect of medium sand (%) was found to be in positively correlation with (total concentrations of Fe and Mn), (available concentrations of Fe, Mn, and Zn), and (the released percentages of Mn, Zn, and Cu). The highest values of correlation were found with the released percentages of Cu, however the lowest values were observed with the total concentration of Cu. The effect of find sand was only negatively correlated with the total concentrations of Mn and Cu as well as the released percentages of Fe.

Table 5. Correlation between micro – nutrients and soil physical properties

	Saturation Percent (%)				Very Coarse Sand (%)				Coarse Sand (%)			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
Total (mg/kg)	0.08	-0.27	0.21	0.13	0.26	0.39	-0.13	-0.09	0.03	-0.37	0.11	0.31
Available (mg/kg)	0.10	-0.19	0.09	0.07	-0.06	-0.34	-0.64	-0.26	-0.33	-0.43	-0.25	0.06
Release (%)	-0.38	0.09	-0.05	0.01	-0.25	-0.59	-0.33	0.00	-0.25	0.06	-0.23	-0.26

	Medium Sand (%)				Fine Sand (%)				Very Fine Sand (%)			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
Total (mg/kg)	0.43	0.20	-0.18	-0.60	0.02	-0.07	0.07	-0.06	-0.59	-0.13	0.21	0.17
Available (mg/kg)	0.34	0.50	0.30	-0.25	0.29	0.27	0.41	0.16	-0.13	0.04	0.25	0.13
Release (%)	-0.13	0.20	0.30	0.57	-0.02	0.23	0.17	0.13	0.67	0.09	-0.06	-0.21

	Total Sand (%)				Silt and Clay (%)				Silt (%)			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
Total (mg/kg)	0.30	0.31	-0.11	-0.48	-0.36	-0.34	0.04	0.64	-0.86	0.28	-0.44	0.66
Available (mg/kg)	0.05	0.26	-0.03	-0.28	-0.11	-0.29	-0.01	0.42	-0.34	-0.23	-0.44	0.11
Release (%)	0.06	-0.09	0.00	0.33	-0.02	0.11	0.03	-0.49	0.68	-0.33	0.12	-0.62

	Clay (%)			
	Fe	Mn	Zn	Cu
Total (mg/kg)	-0.60	-0.11	-0.05	0.42
Available (mg/kg)	-0.44	-0.41	-0.49	0.17
Release (%)	0.31	-0.19	-0.14	-0.43

The highest values of correlations were observed with the available concentrations of Zn, however the lowest values were observed with the total concentration of Mn. The effect of very fine sand was negatively correlated with (total concentration of Fe and Mn), (available concentration of Fe), and (the released percentages of Zn). The highest values of correlation were observed with the released percentages of Fe, however the lowest levels were found with the total concentration of Fe. The effect of total sand was found to correlate negatively only with (total and available concentrations of Zn and Cu) and the released percentages of Mn. The highest values of correlation were observed with the released percentages of Cu, however the lowest values were observed with the total concentrations of Cu.

The effects of slit and clay percentages were correlated positively with (total concentrations of Zn and Cu), (available concentration of Cu), and (the released percentages of Mn, Zn, and Cu). The highest values of correlation were observed with the total concentrations of Cu, however the lowest values were found with the total concentrations of Fe. The effects of

silt percentages were correlated positively only with total and available concentrations of Cu, and the released percentages of Fe and Zn. The highest values of correlation were observed with the released percentages of Fe, however the lowest values were observed with the total and available concentrations of Cu. The effect of clay was found to be positively correlated with total and available concentrations of Cu and the released percentages of Fe. The highest values of correlation were observed with the total concentrations of Cu, however the lowest values were observed with the total concentrations of Fe.

The correlation between the studied micro-nutrients and soil chemical properties is presented in Table. 6. The effects of total active carbonate (%) were positively correlated with total, available concentrations, and released percentages of Cu, Zn, and Mn. The highest values of correlation were found with the available concentrations of Cu, however the lowest values were found with the total concentrations of Mn. On the other hand, the effects of active carbonate (%) were positively correlated with (the total concentrations of Fe, Zn, and Cu) and the available concentrations of Cu. The highest

values of correlation were found with the available concentrations of Cu, however the lowest values were found with the available concentration of Mn. The effect of organic matter (%) were found to be positively correlated with (total concentrations of Mn and Zn) and the released percentages of Fe and Cu. The highest values of correlation were found with the total concentrations of Zn, however the lowest values were found with the total concentrations of Fe.

The effects of gypsum (%) were found to be osculated among the positively and negatively values, for example the influence was positively correlated with total concentrations of Fe, Mn, and Cu as well as the released percentages of Zn. The highest values of correlation were found with the total concentrations of Fe, however the lowest values were found with the released percentages of Fe. The effects of soil reaction (pH) were positively correlated only with the total concentrations of Fe, Mn, Zn, and Cu. The highest values of correlation were observed with the total concentrations of Fe, however the lowest values were observed with the released percentages of Mn. The effects of electrical conductivity (EC) were negatively correlated with total concentrations of Fe, Mn, Zn, and Cu as well as the available concentrations of Cu. The highest values of correlation were observed with the available concentrations of Fe, however the lowest values were found with the total concentrations of Cu.

The effects of Na^+ concentrations (meq/l) were found to be osculated among the positively and negatively correlated values, for example it was correlated positively with the total concentrations of Fe, Mn, and Zn as well as the released percentages of Cu. The highest values were observed with the total concentrations of Fe, However the lowest values were observed with the released percentages of Fe. The effects of K^+ concentrations (meq/l) were found to be osculated among the positively and negatively correlated values, for example it was correlated positively with the total concentrations of Fe, Mn, and Zn as well as the available concentrations of Fe and Mn. The highest values were observed with the total concentrations of Fe, however the lowest values were observed with the available concentrations of Cu and the released percentages of Fe. The effects of Ca^{2+} concentrations (meq/l) were found to be osculated among the positively and negatively correlated values, for example it was correlated positively with (the total concentrations of Fe, Mn, and Zn), (the available concentrations of Mn), and the released percentages of either Zn or Cu. The highest values were observed with the total concentrations of Mn, however the lowest values were observed with the released percentages of Mn and the released percentages.

The effects of Mg^{2+} concentrations (meq/l) were found to be negatively correlated only with total concentrations of Fe, Zn, and Cu. The highest values were observed with the available concentrations of Zn, however the lowest values were observed with the total concentrations of Zn. The effects of H_2CO_3 concentrations (meq/l) were found to be osculated among the positively and negatively correlated values, for example it was correlated positively with (the total concentrations of Fe, Mn, and Zn), (the available concentrations of Fe and Mn), and (the released percentages of Cu). The highest values were observed with the total concentrations of Fe, however the lowest values were observed with the available concentrations of Cu and the released percentages of Fe. The effects of Cl^- concentrations (meq/l) were found to be osculated among the positively and negatively correlated values, for example it was correlated positively with (the total concentrations of Fe, Mn, and Zn), (the available concentrations of Mn and Zn), and (the released percentages of Cu). The highest values were observed with the total concentrations of Mn, however the lowest values were observed with the released percentages of Mn. Finally, the effects of SO_4 concentrations (meq/l) were found to be osculated among the positively and negatively correlated values, for example it was correlated positively with (the total concentrations of Fe, Mn, and Zn), (the available concentrations of Fe and Mn), and (the released percentages of Cu). The highest values were observed with the total concentrations of Fe, however the lowest values were observed with the released percentages of Fe.

Correlation between heavy metals and different soil properties

The correlation between heavy metals in total and available forms as well as released percentages and soil physical and chemical properties is listed in Tables 7 and 8. Table 7 shows the correlation between soil physics properties including (saturation percent, very coarse sand percent, coarse sand percent, medium sand percent, fine sand percent, very fine sand percent, total sand percent, silt and clay percent, silt percent, and clay percent) and (total concentrations, available concentrations, and released percentage of Pb, Co, Ni, respectively.

The saturation percentages were positively correlated with total and available concentrations as well as the released percentages of Co. Also, the total and available concentrations of Ni were found to be correlated positively with saturation percentage. The highest values of correlation were observed with the available concentration of Ni, however the lowest values were observed with the total concentrations of Pb.

Table 6. Correlation between micro – nutrients and soil chemical properties

	Total CaCO₃ (%)				Total Active CaCO₃ (%)				Organic matter (%)			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
Total (mg/kg)	-0.22	-0.72	-0.06	0.24	0.02	-0.33	0.27	0.28	-0.002	0.03	0.42	-0.15
Available (mg/kg)	-0.01	-0.55	-0.12	0.56	-0.52	-0.82	-0.57	0.001	-0.18	-0.20	-0.10	-0.56
Release (%)	-0.12	0.34	0.10	-0.06	-0.32	-0.28	-0.50	-0.22	0.00	-0.25	-0.41	0.10

	Gypsum (%)				pH				EC (dS/m)			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
Total (mg/kg)	0.41	0.22	-0.18	0.03	0.44	0.40	0.29	0.16	-0.05	-0.10	-0.14	-0.24
Available (mg/kg)	-0.02	0.07	-0.19	0.11	-0.42	-0.38	-0.63	-0.37	0.35	0.29	0.33	-0.05
Release (%)	-0.42	-0.11	0.04	-0.04	-0.62	-0.66	-0.58	-0.24	0.17	0.33	0.31	0.26

	Na (meq/l)				K (meq/l)				Ca (meq/l)			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
Total (mg/kg)	0.67	0.38	0.36	-0.52	0.80	0.71	0.19	-0.56	0.39	0.64	0.17	-0.13
Available (mg/kg)	0.15	0.10	-0.03	-0.42	0.19	0.37	-0.06	-0.59	-0.12	0.05	-0.30	-0.42
Release (%)	-0.55	-0.31	-0.29	0.48	-0.59	-0.41	-0.21	0.44	-0.26	-0.57	-0.36	0.00

	Mg (meq/l)				H₂CO₃ (meq/l)				Cl (meq/l)			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
Total (mg/kg)	-0.07	0.09	-0.30	-0.16	0.80	0.71	0.19	-0.56	0.39	0.64	0.17	-0.13
Available (mg/kg)	0.35	0.44	0.46	0.22	0.19	0.37	-0.06	-0.59	-0.12	0.05	-0.30	-0.42
Release (%)	0.31	0.24	0.44	0.22	-0.59	-0.41	-0.21	0.44	-0.26	-0.57	-0.36	0.00

	SO₄ (meq/l)			
	Fe	Mn	Zn	Cu
Total (mg/kg)	0.65	0.43	0.13	-0.33
Available (mg/kg)	0.10	0.10	-0.14	-0.29
Release (%)	-0.57	-0.33	-0.19	0.29

The effects of very coarse sand percentages were correlated negatively with available concentration and released percentages of Pb and Co. The highest values of correlations were observed with the available concentration of Co, however the lowest values of correlation were observed with the released percentages of Co. The effect of course sand tended to correlated positively only with the available concentrations of Pb, Co, and Ni. The highest values of correlation were observed with the total concentrations of Ni, however the lowest values were observed with the released percentages of Pb.

The effect of medium sand (%) was found to be in positively correlation with only Pb in its total and available concentrations. The highest values of correlation were found with the total concentrations of Pb, however the lowest values were observed with the total concentrations of Co. The effect of find sand (%) was only negatively correlated with (the total available concentrations of Pb), (available concentrations and released percentages of Co), (and released percentages of Ni). The highest values of correlations were observed with the released percentages of Ni, however the lowest values were observed with the total concentration of Ni. The effect of very fine sand (%) was negatively correlated with (the available concentration of Pb. Co, and Ni as well as the total concentrations of Ni. The highest values of correlation were observed with the released percentages of Pb, however the lowest levels were found with the total concentration of Ni. The effect

of total sand (%) was found to correlate positively only with total and available concentrations of Pb and the released percentages of Ni. The highest values of correlation were observed with the total concentrations of Pb, however the lowest values were observed with the total concentration of Ni.

The effects of slit and clay (%) were found to be correlated negatively only with (total and available concentrations of Pb and with the released percentages of Ni. The highest values of correlation were observed with the total concentrations of Ni, however the lowest values were found with the total concentrations of Pb. The effects of silt (%) were correlated negatively only with total concentrations of Pb. The highest values of correlation were observed with the available concentrations of Ni, however the lowest values were observed with the total and available concentrations of Pb. The effect of clay was found to be positively correlated with total and available concentrations of Pb and the released percentages of Ni. The highest values of correlation were observed with the total concentrations of Pb, however the lowest values were observed with the available concentrations of Co.

The correlation between the studied heavy metals and soil chemical properties is presented in Table. 8. The effects of total active carbonate (%) were positively correlated with only total and available concentrations of Ni. The highest values of correlation were found with the total concentrations of Ni, however the lowest values were found with the available concentrations of Pb. On the other hand, the effects of active carbonate (%) were positively correlated with the total concentrations of either Co or Ni, in addition to the available concentrations of Ni. The highest values of correlation were found with the total concentrations of Co and Ni, however the lowest values were found with the available concentration of Pb. The effects of organic matter (%) were found to be negatively correlated with the available concentrations and the released percentages of Pb as well as the total concentrations of Ni. The highest values of correlation were found with the total concentrations of Co, however the lowest values were found with the total concentrations of Ni.

The effects of gypsum (%) were found to be osculated among the positively and negatively values, for example the influence of gypsum (%) was negatively correlated with the released percentages of Pb, Co, and Ni as well as the available concentrations of Co. The highest values of correlation were found with the total concentrations of Ni, however the lowest values were found with the released percentages of Ni.

Table 7. Correlation between some heavy metals and soil physical properties

	Saturation Percent (%)			Very Coarse Sand (%)			Coarse Sand (%)		
	Pb	Co	Ni	Pb	Co	Ni	Pb	Co	Ni
Total (mg/kg)	-0.06	0.21	0.31	0.15	0.48	0.11	0.04	0.19	0.29
Available (mg/kg)	-0.48	0.13	0.11	-0.09	-0.14	0.08	-0.26	-0.14	-0.10
Release (%)	-0.25	0.08	-0.10	-0.20	-0.22	0.04	-0.24	-0.17	-0.21

	Medium Sand (%)			Fine Sand (%)			Very Fine Sand (%)		
	Pb	Co	Ni	Pb	Co	Ni	Pb	Co	Ni
Total (mg/kg)	0.51	-0.32	-0.13	0.02	-0.15	-0.22	-0.32	-0.13	-0.53
Available (mg/kg)	0.25	-0.29	-0.25	-0.04	0.03	-0.11	0.23	0.09	-0.11
Release (%)	-0.23	-0.24	-0.14	-0.03	0.07	0.10	0.41	0.14	0.23

	Total Sand (%)			Silt and Clay (%)			Silt (%)		
	Pb	Co	Ni	Pb	Co	Ni	Pb	Co	Ni
Total (mg/kg)	0.43	-0.08	-0.32	-0.54	0.03	0.40	-0.66	0.24	0.30
Available (mg/kg)	0.31	-0.30	-0.09	-0.31	0.31	0.16	0.29	0.17	0.59
Release (%)	-0.13	-0.27	0.16	0.21	0.30	-0.14	0.55	0.14	0.21

	Clay (%)		
	Pb	Co	Ni
Total (mg/kg)	0.43	-0.08	-0.32
Available (mg/kg)	0.31	-0.30	-0.09
Release (%)	-0.13	-0.27	0.16

Table 8. Correlation between some heavy metals and soil chemical properties

	Total CaCO₃ (%)			Total Active CaCO3 (%)			Organic Matter (%)		
	Pb	Co	Ni	Pb	Co	Ni	Pb	Co	Ni
Total (mg/kg)	-0.28	-0.02	0.70	-0.09	0.55	0.55	0.12	0.25	-0.29
Available (mg/kg)	-0.73	-0.11	0.22	-0.59	-0.05	0.37	-0.09	0.17	0.04
Release (%)	-0.33	-0.15	-0.27	-0.33	-0.15	-0.08	-0.08	0.14	0.21

	Gypsum (%)			pH			EC (dS/m)		
	Pb	Co	Ni	Pb	Co	Ni	Pb	Co	Ni
Total (mg/kg)	0.18	0.20	0.36	0.17	0.79	0.12	0.11	-0.29	-0.17
Available (mg/kg)	0.06	-0.10	0.02	-0.11	0.13	0.39	-0.06	-0.19	-0.28
Release (%)	-0.12	-0.15	-0.20	-0.17	-0.03	0.22	-0.15	-0.15	-0.07

	Na (meq/l)			K (meq/l)			Ca (meq/l)		
	Pb	Co	Ni	Pb	Co	Ni	Pb	Co	Ni
Total (mg/kg)	0.57	0.38	-0.12	0.73	0.39	-0.36	0.25	0.38	-0.15
Available (mg/kg)	-0.06	-0.17	-0.10	0.21	-0.26	-0.14	0.30	0.02	-0.11
Release (%)	-0.45	-0.24	-0.05	-0.40	-0.34	0.13	0.04	-0.03	0.00

	Mg (meq/l)			H₂CO₃ (meq/l)			Cl (meq/l)		
	Pb	Co	Ni	Pb	Co	Ni	Pb	Co	Ni
Total (mg/kg)	0.18	0.20	0.36	0.17	0.79	0.12	0.11	-0.29	-0.17
Available (mg/kg)	0.06	-0.10	0.02	-0.11	0.13	0.39	-0.06	-0.19	-0.28
Release (%)	-0.12	-0.15	-0.20	-0.17	-0.03	0.22	-0.15	-0.15	-0.07

	SO₄ (meq/l)		
	Pb	Co	Ni
Total (mg/kg)	0.47	0.35	-0.03
Available (mg/kg)	-0.02	-0.17	0.02
Release (%)	-0.36	-0.24	0.04

The effects of soil reaction (pH) were negatively correlated only with the available concentrations and released percentages of Pb.

The highest values of correlation were observed with the total concentrations of Co, however the lowest values were observed with the released percentages of Pb. The effects of electrical conductivity (EC) were negatively correlated with the studied heavy metals in different forms except for the total concentrations of Pb. The highest values of correlation were observed with the total concentrations of Pb, however the lowest values were found with the total concentrations of Co.

The effects of Na⁺ concentrations (meq/l) were found to be positively correlated with the total concentrations of Pb, and Co. The highest values were observed with the total concentrations of Pb, however the lowest values were observed with the released percentages of Pb. The effects of K⁺ concentrations (meq/l) were found to be osculated among the positively and negatively correlated values, for example it was correlated positively with the total concentrations of Pb and Co as well as the available concentrations of Pb and the released percentages of Ni. The highest values were observed with the total concentrations of Pb, however the lowest values were observed with the released percentages of Pb. The effects of Ca^{2+} concentrations (meq/l) were found to be negatively correlated with the total and available concentrations of Ni as well as the released percentages of Co. The highest values were observed with the total concentrations of Co, however the lowest values were observed with the total concentrations of Ni.

The effects of Mg^{2+} concentrations (meq/l) were found to be negatively correlated only with the released percentages of Pb, Co, and Ni, in addition to the available concentrations of Co. The highest values were observed with the total concentrations of Ni, however the lowest values were observed with the released percentages of Ni. The effects of H_2CO_3 concentrations (meq/l) were found to be negatively correlated with the released percentages of either Pb or Co as well as the available concentrations of Pb. The highest values were observed with the total concentrations of Co, however the lowest values were observed with the available and the released percentages of Pb. The effects of Cl⁻

concentrations (meq/l) were found to be correlated positively only with the total concentrations of Pb. The highest values were observed with the total concentrations of Pb, however the lowest values were observed with the total concentrations of Co. Finally, the effects of SO_4 concentrations (meq/l) were found to be osculated among the positively and negatively correlated values, for example it was correlated positively with (the total concentrations of Fe and Co), (the available concentrations of Ni), and (the released percentages of Ni). The highest values were observed with the total concentrations of Pb, however the lowest values were observed with the released percentages of Pb.

CONCLUSION

The present study was focused on the current status of some micro-nutrients including (Fe, Mn, Zn, and Cu) in addition to the current statues of some heavy metals including (Pb, Co, and Ni) in some soils profiles representing Wadi Al-Hawawer area that located at Marsa Matrouh Governorate, Egypt. The results showed that, the vertical distribution of total concentrations of Fe were decreased with increasing profile depth. However, the available concentrations of Fe were oscillated in different soil profiles. Also, the released percentages of Fe tended to decrease with depth. The released percentages of Mn in different soil profile were ranged between 0.66 and 1.66 %, respectively. The released percentages of Mn in different soil profile tended to decrease with depth similar to what was observed with the released percentages of Fe. The distribution of total concentrations of Mn in different soil profiles tended to be osculated with depth. The available concentrations of Zn in different soil profiles were between 2.15 mg/kg and 3.95 mg/kg in the deepest layer of profile No. 3 and in the second and last layer of profile No. 1, respectively. The same tendency that was observed with the released percentages of Fe and Mn also was observed with Zn. The available concentrations of Cu tended to increase with depth except for profile No. 2. The released percentages of Cu in the studied soil profile were between 3.12% and 6.49% in the second layer of profile No. 3 and in the surface layer of profile No. 6, respectively. Generally, the highest concentrations of micro-nutrients in the studied soil profile were found to take the following sequence Fe > Mn > Zn > Cu, and the available concentrations of micro-nutrients in the studied soil profile were found to take the same tendency. However, the released percentages of micro- nutrients took the following order Cu > Fe > Mn > Zn. The released percentages of Pb in different soil profiles were between 2.98% to 6.67 % in the deepest layer of soil profiles No. 4 and 6 and the top surface of soil profile

No. 3, respectively. The vertical distribution of available concentration of Co tended to osculate with increasing depth. The released percentages of Co were between 0.07% to 0.89% in the surface layer of soil profile No. 1 and 3, respectively following the same tendency that was found with the vertical distribution of available Co. The vertical distribution of total concentration of Ni tended to increase with increasing soil depth in soil profiles No. 3, 4, and 5 respectively and vice versa with soil profiles No. 1, 2, and 6, respectively. The released percentage of the studied heavy metals took the following sequence Pb > Ni > Co. The highest concentration of heavy metals were found with Pb and the lowest concentrations were found with Co and Ni. The higher concentrations of heavy metals took the following order Pb > Ni > Co.

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الملخص العربي

الوضع الحالى لبعض العناصر الغذائية والفلزات الثقيلة بمنطقة وادى الهوارير – مرسى مطروح – مصر

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هذة الدراسة ركزت على الوضع الحالى لبعض المغذيات الارضية الضرورية للنباتات مثل الحديد والمنجنيز والزنك والنحاس وكذلك بعض الفلزات الثقيلة والممثلة فى الرصاص والكوبلت والنيكل بمطنقة وادى الهوارير – مرسى مطروح – مصر. أظهرت النتائج المتحصل عليها ان التوزيع الراسى للحديد الكلى قل مع زيادة عمق القطاع الارضى، بينما أوضحت النتائج أيضا ان الحديد المتواجد فى الصورة الذائبة تذبذبت صورة التوزيع الرئسى لة ما بين الزيادة والنقصان. كما ان نسبة انطلاق الحديد من الصورة الكلية الى الصورة الذائبة اخذ نفس طريقة التوزيع الراسى للحديد الكلى فى الارض. كما وجد ان معدل أنطلاق المنجنيز فى طبقات القطاعات المختلفة كان ما بين 0.66% الى 1.66% على التوالى. كما وجد أن توزيع المنجنيز الكلى فى القطاعات الارضية المختلفة تذبذب ما بين الزيادة والنقصان مع زيادة عمق القطاع الارضى. كما وجد أن توزيع الزنك الذائب بالقطاعات الارضية المختلفة كان فى حدود 2.15 الى 3.95 ملجرام/كليوجرام وذلك فى أعمق الطبقات بالقطاع رقم 3 والطبقة الثانية للقطاع رقم 1 على التوالى. وبصفة عامة

فان أعلى القيم المتحصل عليها من الصور الكلية للمعذيات الارضية تحت الدراسة وجد انها تاخذ التسلسل الاتى: حديد > منجنيز > زنك > نحاس، كما وجد انا الصور الذائبة من المعذيات الارضية اخذت نفس التسلسل السابق للصورة الكلية. بينما وجد أن معدل أنطلاق المغذيات الارضية محل الدراسة أخذت التسلسل الاتى: نحاس > حديد > منجنيز > زنك. كما وجد أن معدل انطلاق الرصاص فى طبقات القطاعات الارضية المختلفة كان فى حدود 2.98% الى 6.67% وذلك فى أعمق الطبقات بالقطاعات الارضية رقم 4 و 6 وكذلك الطبقة السطحية للقطاع الارضى رقم 3 على التوالى. كما وجد ان التوزيع الرئسى للكوبلت الذائب تذبذب ما بين الزيادة والنقصان مع زيادة عمق القطاع الارضى. كما وجد أن معدل انطلاق الكوبلت تارجح ما بين 0.07% الى 0.89% فى الطبقات السطحية للقطاعات رقم 1 و 3 على التوالى. كما وجد أن التوزيع الرئسى للصور الكلية من النيكل زاد مع زيادة عمق القطاع الارضى فى القطاعات الارضية رقم 3 و 4 و 5 على التوالى والعكس بالعكس مع القطاعات الارضية رقم 1 و 2 و 6.