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DISTRIBUTION OF SOME HEAVY METALS IN THE NEWLY RECLAIMED SOILS OF EL-KHATTARA AS AFFECTED BY THE LANDUSE PERIOD

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Eight soil profiles representing the newly reclaimed soils of the El-Khattara, El-Sharkia Governorate were selected to study the effect of land use period on both the total and DTPA-extractable contents of *Zn*, Mn, Co and Ni. These profiles were evaluated from the physical and chemical standpoints. The selected profiles covered a wide range of land use periods, i.e., virgin soil and cultivated for 7, 10 and 14 years.

The results indicate that the acid extracted (AE) content of the heavy metals in the different soils follows the order: Mn > *Zn* > Co > Ni, while the DTPA-extractable content follows the order: Mn > Co > *Zn* > Ni. All the studied metals increased by the increasing period of land-use and decreased with depth in the profiles.

Statistical measures indicated that the weighted mean variations may be ascribed to the parent material itself rather than soil formation or local conditions. The trend values of AE and DTPA-extractable Mn and Ni were found highly symmetrical, whereas *Zn* and Co were determined less symmetrical in distribution. The specific range variations were mainly attributed to pedogenic processes, sedimentation regime and local conditions.

Keywords: DTPA-extractable elements, El-Khattara area, El-Sharkia Governorate, acid extracted (AE) heavy metals, Zn, Mn, Co and Ni, weighted mean, trend and specific range.

According to the studies conducted within the framework of the Land Master plan; the total area suitable for reclamation was about 2.8 million feddan. Out of which the desert sandy soils represent 34%. The El-Khattara area represents one of the promising areas for reclamation and agricultural use. A number of man's activities in such area may contribute to raising soil heavy metal levels. The agricultural practices, i.e. mineral fertilizers, pesticides, organic wastes, together with industrial effluents, fallout dust, traffic and fuel exhausts, all may act as soil pollutants.

This investigation is mainly carried out to throw light on the effect of land use on the distribution of some heavy metals in the soils of El-Khattara area as affected by the period of landuse.

MATERIALS AND METHODS

Eight soil profiles representing the newly reclaimed sandy soils at El-Khattara area of El-Sharkia Governorate were selected for the present study. The selected profiles covered relatively wide ranges of land use periods, i.e., virgin soil, soil cultivated for 7, 10 and 14 years. The soil samples were air-dried, ground, sieved and subjected to the following analyses:

1. Particle size distribution was carried out by dry sieving (Piper, 1950).
2. Total salinity, cation and anion contents were determined in soil extracts (1:1) according to Black (1965).
3. pH was determined in 1:1 soil extracts (Richards, 1954).
4. $CaCO_3$ was determined volumetrically using the Collin's calcimeter according to Jackson (1958)
5. The organic matter content of soils was determined as described by Walkley (1947) and Jackson (1958).
6. The acid-extractable (AE) contents of Zn, Mn, Co and Ni were determined after digestion in a mixture of Conc. HNO_3 + Conc. H_2SO_4 + 62% perchloric acid as recommended by Hesse (1971). Available soil Zn, Mn, Co and Ni were determined after extraction with DTPA-TEA according to Lindsay and Norvell (1978). Analysis of heavy metals was carried out by an atomic-absorption spectrophotometer (Unicam 929) with a graphite furnace.

RESULTS AND DISCUSSION

Physical and Chemical Properties

Physical and chemical properties of the studied profiles are presented in tables (1 and 2). Data showed that soil texture is sandy. The soils are non-saline to moderately saline as indicated by the EC values which ranged from 0.76 to 3.10 dS/cm. Soil salinity decreased with depth in most of the studied soils. The pH of the soils is neutral to alkaline (7.6 to 8.6) with calcium carbonate contents ranging from 0.35 to 9.44% (highest at the 0-20 cm depth of profile 5, and lowest at 90-120 cm depth of profile 3). The soluble cations and anions of the studied soils were dominated by Na^+, Ca^{2+}, Cl^- and HCO_3^-.

TABLE (1). Particle size distribution of the studied soils at different periods of land use

Profile No.	Depth, cm	Particle sizes (mm)					
		2.0-1.0	1.0-0.5	0.5-0.25	0.25-0.125	0.125-0.063	< 0.063
Virgin Soil							
1	0-40	6.0	56.0	24.5	9.0	3.5	1.0
	40-75	5.5	56.0	24.0	9.5	3.0	1.5
7 years							
2	0-20	2.0	26.0	47.0	18.0	5.5	1.5
	20-50	4.0	60.5	23.0	8.0	3.5	1.0
	50-100	10.5	30.5	38.0	14.5	5.5	1.0
	100-120	18.0	38.0	32.0	8.5	3.0	0.5
10 years							
3	0-30	24.0	41.0	28.0	4.0	2.0	1.0
	30-60	24.5	42.0	28.5	3.0	1.5	0.5
	60-90	28.0	48.0	21.0	2.0	0.5	0.5
	90-120	27.5	44.0	26.0	2.0	0.5	0.0
4	0-25	30.5	38.0	25.5	4.0	1.0	1.0
	25-70	21.0	37.5	31.0	7.5	2.0	1.0
	70-100	18.0	49.0	30.0	2.0	0.5	0.5
	100-120	24.0	42.0	31.5	2.0	0.5	0.0
5	0-20	12.5	23.0	44.5	13.0	5.5	1.5
	20-50	27.0	31.5	30.5	8.5	2.0	0.5
	50-80	27.0	26.5	39.0	5.5	1.5	0.5
14 years							
6	0-30	11.5	26.0	40.0	17.0	4.5	1.0
	30-70	14.0	26.0	41.5	16.0	2.0	0.5
	70-100	20.0	35.0	35.0	8.0	1.5	0.5
7	0-20	19.0	31.5	34.5	10.0	4.5	0.5
	20-50	25.0	34.0	31.0	8.0	1.5	0.5
	50-75	16.0	27.0	47.0	8.5	1.0	0.5
8	0-15	24.0	30.5	32.0	9.0	4.0	0.5
	15-60	13.0	30.5	45.0	8.0	3.0	0.5
	60-90	17.5	32.0	39.0	8.5	2.0	1.0
	90-110	14.0	37.0	41.0	6.0	1.5	0.5

Acid Extracted Heavy Metals

Zinc

Table (3) illustrates that the AE-Zn ranged from 13.50 to 124.90 mg/kg. The highest content was determined in the surface layer (0-30 cm) of profile 6 of the soil cultivated for 14 years where the soil contains moderate amounts of $CaCO_3$ and organic matter and moderate salinity, while the lowest content is recorded in the deepest layer (70-100 cm) of profile 6 of the soil cultivated for 14 years where soil $CaCO_3$ and O.M. contents are quite low with moderate soil reaction. Moussa *et al.* (1990) and Abdel-Hamid *et al*. (1991) found similar results to this study with total Zn contents varying widely from 68 to 122 ppm, in some sandy soils of Egypt.

In general, the surface layers, conatin higher AE-Zn than the subsurface layer in most of the studied profiles. This may be attributed to the different soil management practices which include the addition of organic matter, mineral fertilizers and plant residues. These results are in agreement with those of El- Demerdashe *et al*. (1995).

Data in table (3) revealed that the land use period leads to the increase of the content of AE-Zn compared with the virgin soil, this increase was 1.92, 22.02 and 29.57% in the soil cultivated for 7, 10 and 14 years, respectively. These results are in agreement with those of Rabie *et al*. (1989) and Kabata-Pendias and Pendias (1992).

Manganese

Data in table (3) showed that the AE-Mn content varied widely from 35.50 to 299.50 mg/kg. The lowest content was observed in the deepest layer (90-120 cm) of profile 3 of the soil cultivated for 10 years where contents of both $CaCO_3$ and organic matter content are very low. The highest Mn content was found in the surface layer (0-30 cm) of profile 6 of the soil cultivated for 14 years revealing the common characteristic of Mn accumulating mainly in the top layer. Manganese accumulation in the surface soils reflects the biogenic character of the accumulation of the metal and also the recent anthropogenic source of the element. These data are in agreement with the statements of El-Gala *et al*. (1990), and Abdel-Kariem (1994) revealing that the total Mn contents of some sandy soils of Egypt ranged widely from 60 to 328 ppm.

Data also showed that the increasing land use periods led to the increase of AE-Mn contents compared to the virgin soil. This increase was 21.71, 18.48 and 68.42 % in the soil cultivated for 7, 10 and 14 years, respectively.

The depthwise distribution of the AE-Mn revealed that the contents decreased with depth in all profiles with the exception of profile 2 cultivated for 7 years, where the highest content was observed in the 50-100 cm layer.

TABLE (2). Some chemical properties of the studied soils at different periods of land use

Profile No.	Depth, cm	pH (1:1)	EC dSm^{-1}	$CaCO_3$ %	O.M %	Soluble Cations (me/l)				Soluble Anions (me/l)		
						Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
Virgin Soil												
1	0-40	7.6	3.10	0.77	0.08	8.9	10.5	10.3	1.36	10.5	13.8	7.3
	40-100	7.6	3.10	0.91	0.08	9.1	10.1	10.5	1.37	10.5	13.0	7.2
7 years												
2	0-20	7.7	1.93	1.12	0.41	4.6	3.2	11.2	0.44	7.8	9.2	2.4
	20-50	7.9	1.47	1.03	0.18	4.2	3.1	7.2	0.33	5.4	7.4	2.1
	50-100	8.1	1.27	4.22	0.11	3.6	2.8	6.3	0.24	3.6	7.0	2.3
	100-150	8.2	1.16	1.36	0.08	3.1	2.3	6.1	0.23	3.6	5.6	2.5
10 years												
3	0-30	8.2	1.56	0.98	0.79	3.7	4.1	7.8	0.13	7.4	5.8	2.5
	30-60	8.4	1.08	0.59	0.21	2.3	2.7	5.7	0.27	5.3	3.8	2.3
	60-90	8.5	0.76	0.68	0.09	2.2	2.8	2.6	0.15	4.2	2.6	1.0
	90-120	8.4	0.87	0.35	0.09	2.5	2.1	4.1	0.13	4.2	3.4	1.2
4	0-25	8.0	1.34	0.92	1.40	3.1	3.0	7.1	0.39	6.5	4.6	2.5
	25-70	8.3	1.06	5.28	0.28	2.6	2.4	5.6	0.26	4.6	4.2	2.1
	70-100	8.6	0.84	0.53	0.12	2.3	2.1	3.9	0.26	4.9	3.6	1.1
	100-150	8.4	0.93	0.68	0.08	2.5	2.5	4.2	0.22	8.0	4.0	1.6
5	0-20	7.8	1.84	9.44	0.89	3.5	3.8	10.6	0.69	7.2	8.1	3.3
	20-50	8.2	1.36	3.98	0.36	3.6	3.2	6.3	0.39	5.6	5.2	2.7
	50-100	8.3	1.30	3.04	0.14	3.	3.2	6.0	0.49	5.9	6.2	1.1
14 years												
6	0-30	7.7	1.68	4.51	1.78	3.5	2.6	10.2	0.54	7.6	6.4	2.9
	30-70	8.2	1.37	7.52	0.31	4.3	4.2	5.1	0.24	7.1	4.2	2.5
	70-120	8.3	1.16	2.89	0.12	3.2	3.5	4.9	0.11	6.2	4.1	1.4
7	0-20	8.1	1.38	5.99	1.24	2.3	2.5	8.6	0.44	7.1	5.2	1.6
	20-50	8.3	1.31	0.36	0.27	2.7	3.0	7.4	0.27	7.4	4.8	1.2
	50-120	8.6	0.96	0.59	0.11	2.1	2.3	5.2	0.21	5.4	3.5	0.9
8	0-15	7.9	1.44	2.66	0.96	3.2	4.0	7.2	0.27	7.2	5.6	1.7
	15-60	8.1	1.21	9.06	0.29	3.3	2.6	6.2	0.15	6.3	4.4	1.6
	60-90	8.2	0.96	0.56	0.11	2.2	2.3	5.1	0.13	5.4	3.2	1.2
	90-150	8.2	0.93	1.03	0.08	2.1	2.2	4.9	0.26	3.1	5.2	1.2

TABLE (3). Acid extracted heavy metals in the studied soils (mg /kg) at different periods of land use

Profile No.	Depth, cm	Zn	Mn	Co	Ni
		mg/kg			
Virgin Soil					
1	0-40	57.20	86.40	5.90	1.08
	40-75	59.10	66.88	7.50	0.75
7 years					
2	0-20	54.43	67.70	10.90	2.15
	20-50	50.50	83.30	22.70	1.48
	50-100	54.20	122.40	26.80	6.50
	100-120	69.20	99.70	19.80	5.60
10 years					
3	0-30	56.20	88.60	11.60	4.90
	30-60	100.90	44.10	15.50	3.10
	60-90	113.20	45.30	16.90	3.70
	90-120	57.80	35.50	26.40	2.50
4	0-25	103.50	178.90	38.30	11.40
	25-70	55.40	126.50	8.50	8.10
	70-100	58.40	43.20	5.90	3.80
	100-120	45.60	42.90	18.10	3.60
5	0-20	59.20	164.80	22.50	9.53
	20-50	64.10	131.60	10.90	7.76
	50-80	66.90	97.40	13.90	8.31
14 years					
6	0-30	124.90	299.50	22.70	17.90
	30-70	58.80	118.50	9.50	6.10
	70-100	13.50	69.10	3.30	4.50
7	0-20	97.10	277.50	17.10	15.30
	20-50	49.50	93.50	7.20	6.60
	50-75	35.20	50.20	19.90	4.10
8	0-15	101.20	211.70	42.90	10.80
	15-60	103.40	70.30	36.30	3.50
	60-90	47.70	40.90	20.20	3.20
	90-110	122.80	59.60	27.90	4.50

Cobalt

Data in table (3) revealed that the AE-Co content ranged from 3.30 to 42.90 mg/kg in the studied soils. The lowest content was observed in the deepest layer (70-100 cm) of profile 6 of the soil cultivated for 14 years with very low $CaCO_3$ and organic matter. The highest Co content was found in the surface layer (0-15 cm) of profile 8 of the soil cultivated for 14 years where the contents of both organic matter and $CaCO_3$ were relatively high with moderate salinity. This may be attributed to the intensive application of farmyard manure and phosphate fertilizers. The increase of Co caused by the use of manure and P fertilizers is in agreement with the average 14ppm Co contents determined earlier in the sandy soils of Egypt by El-Demerdashe *et al.* (1971).

Table (3) illustrates that the land use period leads to an increase of the AE-Co content in the cultivated soils compared to the virgin one, where the increases were 199, 155 and 208% in the soil cultivated for 7, 10 and 14 years, respectively. This could be attributed to the continuous additions of the chemical fertilizers, sewage sludge, pesticides and plant residues.

Data revealed that the total Co content tends to increase with depth in both the virgin soil and the soil cultivated for 7 years, while there was a decrease with depth in the soil cultivated for 10 and 14 years with the exception of profile 3, where the Co content increased with depth. The results given above are in agreement with those of Kabata-Pendias and Pendias (1992).

Nickel

Data in table (3) illustrates that AE-Ni content ranged from 0.75 to 17.9 mg/kg in the studied soils. The lowest content was observed in the deepest layer (40-75 cm) of profile 1 of the virgin soil where its content of both $CaCO_3$ and organic matter was very low and the salinity was moderate. The highest Ni content was found in the surface layer (0-30 cm) of profile 6 of the soil cultivated for 14 years, where the soil has moderate salinity and high content of organic matter. These results are in agreement with the data obtained by Kabata-Pendias and Pendias (1992) and Abdel-Kariem (1994) who found total Ni contents ranged from 8.3-22.6 mg/kg in the sandy soils of Egypt.

Results revealed that the land use of different periods lead to the increase of AE-Ni contents compared to the virgin soil. The increases were 327, 558 and 731% in the soils cultivated for 7, 10 and 14 years, respectively. This trend is attributed to the continuous additions of the chemical fertilizers, sewage sludge, pesticides and plant residues.

Data showed that the AE-Ni contents decreased with depth in all the studied profiles with the exception of profile 2 cultivated for 7 years, where the highest contents were observed in the deepest layers.

DTPA-Extractable Heavy Metals

The maximum, minimum and average of DTPA-extractable heavy metals contents as well as their percentage of total contents are given in table 4. For each metal there was a wide variation in its chemically extractable content. These variations were observed within all the studied soils with one exceptional case in the virgin soil where the variation for its chemically extractable contents was relatively narrow.

Moreover, the DTPA-extractable fractions as the percent of the total contents are very low (1.2-1.7 and 1.8-2.56 %) in the case of Zn and Ni, respectively, while being somewhat higher (5.2-12.6 and 10.3-27.33 %) for Mn and Co, respectively.

Data in table (4) revealed that in the virgin soil the DTPA- extractable content of the studied metals relative to their total content was relatively high compared to the cultivated soils with two exceptional cases in Mn and Ni where this ratio was higher in the cultivated soil. This could be attributed to soil pH, which was neutral in the virgin soils, considering that the chemically extractable content would be low under alkali conditions. On the other hand, the increase in the ratio between DTPA-extractable Mn and Ni and their total contents in the soil cultivated for 14 years may be due to the extensive use of superphosphate as a fertilizer. The results obtained are in agreement with that of Abdel-Kariem (1999) who found that DTPA-extractable contents of Zn, and Mn ranged from 0.20 to 0.56, and from 0.19 to 3.39 ppm, with the averages of 0.295, and 1.330 ppm, respectively for El-Khatatba sandy soils.

Statistical Measures of AE and DTPA-Extractable Heavy Metals in the Studied Soils

To work out the relationship between the distribution of elements (Zn, Mn, Co and Ni) and locality of the studied soil profiles, the three statistical measures suggested by Oertel and Giles (1965) namely, the weighted mean (W), trend (T) and specific range (R) were applied. Data in tables (5 and 6) showed that the weighted means of AE-Zn, Mn, Co and Ni contents ranged from 49.10 to 120.80, from 53.40 to 134.20, from 6.87 to 30.38 and from 0.88 to 8.34 mg/kg, respectively, while the weighted mean for DTPA-extractable content of these respective elements ranged from 0.71 to 1.02, 4.19 to 23.20, 1.43-to 3.03 and 0.034 to 0.160 mg/kg.

Comparing the weighted means of the AE and DTPA-extractable elements in the soils showed that the former can be expressed in the order: Mn > Zn > Co > Ni, while the latter can be expressed in the order: Mn > Co > Zn > Ni. The minute variations between the groups of profiles may be ascribed to the variations in the parent material rather than to soil formation or local conditions prevailing in each site. This may also be associated with the geomorphological conditions which may have coincided with the sedimentation regime that has prevailed during soil formation.

TABLE(4). Maximum , minimum and average values of the DTPA-extractable heavy metals in the studied soils at different periods of land use

	Zn	Mn	Co	Ni
	mg/kg			
Virgin Soil				
Maximum	1.07	4.30	2.62	0.038
Minimum	0.90	4.17	2.42	0.032
Average	0.99	4.24	2.52	0.035
% of the total	1.67	5.24	27.33	1.880
7 years				
Maximum	0.86	13.99	2.59	0.235
Minimum	0.72	1.25	1.63	0.028
Average	0.77	5.55	2.29	0.103
% of the total	1.33	5.62	10.25	2.560
10 years				
Maximum	1.51	35.90	4.72	0.354
Minimum	0.69	0.44	1.67	0.027
Average	0.96	8.77	2.57	0.117
% of the total	1.34	9.66	13.04	1.890
14 years				
Maximum	1.55	56.30	3.33	0.502
Minimum	0.66	0.68	0.71	0.032
Average	0.92	16.79	2.52	0.139
% of the total	1.21	12.59	10.85	1.830

TABLE (5). Weighted mean (W), Trend (T), and specific range (R) for the AE contents (ppm) of the studied elements

Profile No.	Zinc			Manganese			Cobalt			Nickel		
	W	T	R	W	T	R	W	T	R	W	T	R
1	58.3	0.021	0.035	74.7	-0.140	0.26	6.87	0.130	0.222	0.88	-0.190	0.38
2	56.5	-0.548	1.97	134.2	-0.520	1.62	10.26	-0.550	1.90	8.29	-0.540	1.63
3	49.1	-0494	1.26	98.9	-0.640	2.30	16.27	-0.051	0.78	6.52	-0.570	1.73
4	120.8	0.163	1.04	74.1	-0.651	2.31	30.38	-0.290	0.75	4.51	-0.580	1.73
5	107.0	0.475	1.47	53.4	-0.400	1.01	17.60	0.340	0.84	3.52	-0.280	0.68
6	60.7	-0.414	0.96	90.7	-0.490	1.50	16.14	-0.580	2.01	6.25	-0.500	1.25
7	117.1	0.495	1.55	121.1	-0.270	0.56	14.67	-0.350	0.79	8.34	-0.130	0.22
8	58.5	0.069	0.32	99.7	0.320	0.55	21.52	0.500	0.74	4.62	0.540	1.09

TABLE (6).Weighted mean (W), Trend (T), and specific range (R) for DTPA-extractable content (ppm) of the studied elements

Profile No.	Zinc			Manganese			Cobalt			Nickel		
	W	T	R	W	T	R	W	T	R	W	T	R
1	1.00	0.100	0.170	4.25	0.019	0.031	2.54	0.051	0.102	0.344	-0.095	0.174
2	0.98	-0.368	0.898	23.20	-0.690	3.13	1.43	-0.570	2.28	0.160	-0.680	2.91
3	0.71	-0.454	0.900	9.26	-0.810	5.15	1.53	-0.460	1.26	0.102	-0.700	2.98
4	0.81	-0.206	0.410	5.55	-0.870	7.46	2.65	-0.210	0.60	0.048	-0.830	5.13
5	1.02	-0.064	0.730	4.19	-0.681	3.01	1.88	-0.090	0.21	0.097	-0.700	2.94
6	0.92	-0.391	0.870	6.33	-0.780	4.44	2.41	-0.350	0.78	0.080	-0.630	4.08
7	0.79	-0.240	0.440	10.58	-0.761	4.07	3.03	-0.190	0.30	0.092	-0.710	3.17
8	0.79	0.013	0.180	4.29	-0.693	2.97	2.23	-0.090	0.43	0.088	-0.630	2.35

Concerning the trend (T), data showed a symmetry of AE-Mn and Ni among the studied soils as revealed by the small T values, while Zn and Co display relatively less symmetrical distribution and relatively high T values. Likewise, data also showed a symmetry of DTPA-extractable Mn. and Ni among the studied soils as revealed by the small T values, while Zn and Co display relatively less symmetrical distribution and relatively high T values.

The specific range (R) for the AE contents of the elements Zn, Mn, Co and Ni are generally widely variable, ranging from 0.035 to 1.970, from 0.260 to 2.310, from 0.222 to 2.010 and from 0.220 to 1.730 ppm, respectively. For the DTPA- extractable elements the specific range varies from 0.170 to 0.900, from 0.031 to 7.460, from 0.102 to 2.280 and from 0.174 to 5.130 ppm, respectively. The variations in the values of specific range are mainly attributed to inherited characteristics modified by pedogenic processes, the soil sedimentation regime as well as conditions and practices applied for each soil.

The relationship between AE contents of the studied elements and the factors affecting it was assessed through evaluating the correlation coefficients which were computed and tabulated in table (7). The coefficients revealed significant correlations between the AE-Mn and organic matter, whereas zinc and cobalt contents were significantly correlated only to organic matter. Mn was significantly correlated to organic matter and $CaCO_3$ but revealed a negative correlation with pH.

TABLE(7). Correlation coefficients between acid extracted elements and some soil variables

Elements	pH	O.M	$CaCO_3$
Zn		0.5666**	-0.7729**
Mn	- 0.4952*	0.8801**	0.5134**
Co		0.4927*	
Ni			0.4983*

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توزيع بعض المعادن الثقيلة في الأراضي المستصلحة حديثا بمنطقة الخطارة كنتيجة لفترة الاستزراع

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تم اختيار ثمانية قطاعات أرضية تمثل الأراضي المستصلحة حديثا بمنطقة الخطارة بمحافظة الشرقية لدراسة تأثير استخدام الأرض على كل من المحتوى الكلى والميسر لكل من الزنك والمنجنيز والكوبالت والنيكل ، ولتحقيق ذلك تم اختيار القطاعات بحيث تمثل الأراضي تحت الاستخدام لفترات متباينة (أرض بكر ،٧، ١٠، ١٤ سنة استخدام).

وقد أوضحت النتائج المتحصل عليها ما يلي:

١- متوسط المحتوى الكلى من العناصر يختلف باختلاف فترات الاستخدام وقد أخذ الاتجاه التالي: المنجنيز > الزنك > الكوبالت > النيكل ، بينما أخذ المحتوي الميسر الاتجاه التالي: المنجنيز > الكوبالت > الزنك > النيكل

٢- بتطبيق المقاييس الإحصائية تبين أن اختلاف المتوسط الوزني للعناصر المدروسة يرجع أساسا لمادة الأصل ، وقيم الاتجاه تعبر عن توزيع متماثل للمنجنيز والنيكل الكلى والمنجنيز والنيكل المستخلصين كيميائيا مع توزيع أقل تماثلا للعناصر الأخرى، كما أن اختلاف النطاق النوعي يرجع أساسا للعمليات البيدولوجية ونظام الترسيب والظروف المحلية للقطاعات.

٣- بإجراء التحليل الإحصائي وجد أنة توجد علاقة معنوية موجبة عالية بين الزنك والمادة العضوية وسالبة مع كل من كربونات الكالسيوم والصوديوم الذائب • كما توجد علاقة معنوية موجبة عالية بين المنجنيز وكل من المادة العضوية وكربونات الكالسيوم والصوديوم الذائب وسالبة مع رقم الحموضة. أيضا توجد علاقة معنوية موجبة بين الكوبالت والمادة العضوية وسالبة مع درجة التوصيل الكهربي، كما توجد علاقة معنوية موجبة بين النيكل وكربونات الكالسيوم وسالبة مع كل من الكالسيوم والمغنيسيوم الذائبين.