Assessment of nickel geochemical fractions and availability in calcareous soils

Nasseem , M. G.[1], M. A. Hussein.[1], H. A. Zaid[1] and H. A. El-hadidi[2]

[1] Soil and Agricultural Chemistry Department, Faculty of Agriculture, Saba Basha, Alexandria University, Egypt

[2] Soil and water Department, Faculty of Agriculture, Tripoli, Tripoli University, Libya

ABSTRACT

Mehlich (Mehlich-3), Sultanpour (AB-DTPA) and Lindsay (DTPA) as multinutrients extractants have been used to determine the available Ni in soil. However, the element fraction extracted by these methods are not known. In the present study, fifteen calcareous soils, collected from the north western coast of Egypt, representing a wide range of physical and chemical properties including total Ni content, were analyzed by sequential extraction technique to isolate five fractions of nickel, which are (water soluble, exchangeable, carbonate bound, Fe-Mn oxide bound and organically bound fractions. The residual fraction of Ni was estimated by subtracting the sum of the five Ni fractions from total Ni. The amounts of total Ni in soils varied from 7.84 to 64.8 mg/kg. The available amounts of Ni were chemically extracted by Mehlich-3, AB-DTPA and DTPA extractants. The ranking of these three extractants for Ni extraction was Mehlich-3 >AB-DTPA>DTPA. The results also showed strong correlation between the carbonate bound and residual Ni and the amounts extracted by Mehlich-3 or DTPA extractant. On the other hand, the Ni extracted by AB-DTPA was highly correlated with the water soluble and residual Ni fractions. Also, the highest correlation was found between Ni extracted by DTPA and the sum of water soluble, exchangeable, carbonate bound, Fe-Mn bound and residual fractions of Ni. In the case of AB-DTPA or Mehlich-3, the highest correlation was observed with the sum of soluble, exchangeable, carbonate bound and Fe-Mn oxides bound Ni fractions. The sum of these fractions may give significant effect on the mobility of Ni in soils.

Keywords: nickel, fractionation, calcareous soils, availability.

INTRODUCTION

Nickel (Ni) is a nutrient required by plants in very small quantities, nonetheless, it is essential for plant growth and will lead to definite visual symptoms if not available in adequate amounts. In general, naturally occurring concentration of Ni in soil is lower than 100 ppm (McGrath, 1995). Heavy metals including Ni may be distributed among many components of the soil or sediment and may be associated with them in different ways (Kabala and Singh, 2001; Khairah *et al.*, 2009). The nature of the association is referred to as speciation. The general approach, for the soil speciation studies, has been to separate the element from soil using different chemical reagents into fractions and by analyzing each fraction to determine the amount of element combined or associated with each soil fraction (Yaman *et al.*, 2000). Therefore, the identification of the chemical form or phases of nickel in soil is necessary for estimating its biological availability, physico-chemical reactivity and transport in the environment and into the food chain (Yaman and Yusuf, 2002). Various sequential extraction procedures have been proposed in the past. One of the most often used method described by Tessier *et al.* (1979) has been found wide applications in pollution research and exploration, despite of its serious limitations, such as the lack of selectivity, redistribution and readsorbance (Jeng and Singh, 1993).

Uptake by plants is one of the most important mechanisms by which metals can enter the food chain. Several extractants including inorganic reagents and /or organic chelates, have been used to diagnose nutrients deficiency and toxicity in soil but many of them are condition-specific. The methods, being used for a reliable prediction of nutrients availability in soil, are intended for extracting, one single element or several elements simultaneously. In Egypt, as in other countries, the use of multi-elements extractants is important not only for reducing the costs needed for chemical laboratory supplies, but also for saving time and increasing the performance of the laboratory workers. Soltanpour and Schwab (1977) evaluated a soil test using ammonium bicarbonate-diethylenetriaminepentaacetic acid (AB-DTPA) for simultaneous extraction as multi-nutrients. Also, Lindsay and Norvell (1978) evaluated and developed DTPA soil test for four micronutrients (Fe, Mn, Zn and Cu) in soils. Mehlich-3 (Mehlich, 1984) was developed as a successful extractant for a wide pH range to measure both the macro and micro nutrients in the soil. Nasseem *et al.* (2006) tested the efficiency of AB-DTPA and Mehlich-3 methods. They indicated that the levels of the nutrients extracted by the AB-DTPA and Mehlich-3 in calcareous soils from Egypt and Libya were highly correlated to those extracted by the standard methods for these nutrients.

The objective of this study was, therefore, to: 1) evaluate the use of three multi-nutrients extractants (DTPA, AB-DTPA and Mehlich-3) for nickel extraction; 2) determine the chemical fractions of nickel in fifteen soils selected from the north western coast of Egypt; 3) study the relationship between the fractions of nickel in soils extracted by sequential extraction technique and those extracted by the three multinutrient extractants.

MATERIALS AND METHODS

Fifteen surface soil samples (0-15 cm) were collected from different sites along the transects starting at km 50 Alexandria–Matruh of the North Western Coast of Egypt (Figure . 1). These soil samples were air-dried and ground to pass through a 2-mm sieve. The main physical and chemical properties of these soils were determined according to the methods described by Jackson (1973) and the results obtained are shown in Table (1) . The amount of total Ni was determined by digestion with HNO_3, $HClO_4$, H_2SO_4 and HF acids mixture according to the method described by Page *et al.* (1982).

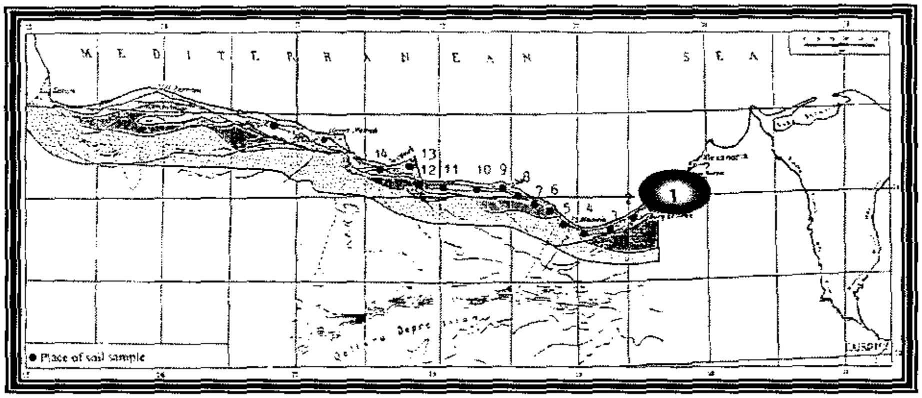

Figure (1): A map of soil samples locations along the transects start at Km 50, Alexandria-Mattruh desert road till El-Salum

The procedure used to estimate the different fractions of Ni in soils was carried out according to Tessier *et al.* (1979). This involved sequential extractions with: (1) distilled water for 2 hours to remove water soluble Ni, (2) 1M $MgCl_2$ (pH=7) for 1 hour to extract exchangeable Ni, (3) 1M sodium acetate [NaOAc] (adjusted to pH=5 with acetic acid [HOAc]) for 5 hours to extract Ni held by carbonate, (4) 0.04M NH_2OH*HCl in 25 % (v/v) HOAc at 96°C with occasional agitation for 6 hours to extract Ni held by Fe and Al oxides and (5) 0.02 M HNO_3 and 5mL of 30% H_2O_2 (adjusted to pH=2) to extract Ni held by soil organic matter. Residual form of Ni in soil was estimated by subtracting the sum of the five Ni fractions from total Ni. In addition, the amounts of available Ni in soils was determined by using three chemical extractants methods. These methods are DTPA (Lindsay and Norvell, 1978), AB-DTPA (Soltanpour and Schwab, 1977) and Mehlich-3 (acetic acid – ammonium nitrate – ammonium fluoride – nitric acid – ethylenediaminetetraacetic acid) (Mehlich, 1984) extractants were used to extract the bioavailable Ni in soils. The concentration of Ni in each extract was measured by atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

The Soils

Table (1) showed considerable variations in the main chemical and physical properties of the tested soils. The samples show wide variations in soil texture and some chemical properties. The values of soil pH varied from 7.44 to 8.37, those of ECe from 0.4 to 42.5 dS/m, organic matter from 0.21 to 1.8% total carbonate from 22.54 to 41.74%. In general, according to high percentages of total $CaCO_3$, these soils are characterized as typic Calciorthids.

Total Ni content in soils

Table (1) showed that the amounts of total nickel in soils varied between 7.84 and 64.8 mg/kg soil with an average value of 38.74 mg/kg soil compared with the range values of normal soil which are within 5 and 500 mg/kg soil (Lindsay, 1979) and these data suggest low level values of total Ni in soils of the northern western coastal zone of Egypt. The total content of Ni widely varied among soils, depending upon soil texture and total carbonate content. For all soils, however, the amounts of total Ni in soils were decreased as the soils become more coarse in texture.

The soil samples collected from El-hamam (soil No.2), El-Alamin (soil No.5), Alwoany sons (soil No.7), Ain Gazalla (soil No.8), El-Daba (soil No.9)and Baggosh (soil No.14) had the highest values of total Ni concentrations and are mostly above the tolerance limit value of 50 mg/kg (Baralkiwicz and Siepak, 1999). The highest Ni concentrations at these sampling sites are not only a problem to plant nutrition and food chain but may constitute a direct health hazard.

Table (1). Some physical and chemical properties of the tested soil samples

Soil No.	Location	pH	ECe, dS/m	O.M %	$CaCO_3$ %	Total-Ni (mg/kg soil)	Particle size distribution			Textural Class
							Sand %	Silt %	Clay %	
1	Burg El-Arab	7.69	6.00	1.21	32.62	9.65	31	40	29	CL
2	El-Hamam	7.44	4.20	1.32	39.82	51.46	71	16	13	SL
3	El-Hamam	7.66	1.60	1.26	40.78	19.15	51	18	23	SCL
4	El-Alamain	8.12	0.40	1.25	37.90	7.84	77	12	11	SL
5	El-Alamain	7.82	2.70	1.26	30.22	56.64	77	12	11	SL
6	Sidi Abdel Rahman	7.84	2.20	1.80	41.26	36.04	71	16	13	SL
7	Alowny sons	8.12	1.30	1.20	39.82	61.89	53	28	19	SL
8	Ain Gzalla	7.91	5.10	1.26	38.86	64.80	37	44	19	L
9	El-Daba	7.94	1.30	1.08	27.34	58.75	37	38	25	L
10	El-Gfyra	8.33	0.50	1.19	38.38	27.39	49	36	15	L
11	Zawaia El-Awam	7.64	6.10	1.20	41.74	13.52	69	20	11	SL
12	Rass El-hykma	7.87	42.5	0.21	35.02	44.17	29	50	21	SiL
13	Etnoh	8.28	0.60	1.29	28.78	47.45	23	52	25	SiL
14	Baggosh	8.08	1.40	1.20	35.98	51.30	51	34	15	SL
15	Matruoh	8.37	0.60	1.30	22.54	31.02	42	33	25	L

Textural Class: CL= Clay Loam, SL= Sandy Loam, SCL= Sandy Clay Loam, L= Loam, SiL= Silty Loam

Nickel fraction in soil

Assessment of the different forms of a metal determines its mobility, toxicity and behavior in the environment (Tuzen, 2003). This can be achieved by examining the form of metal by carrying on sequential extraction technique (Tessier *et al.*, 1979). The method provides the information on the differentiation of bonding strength of metals on the various solid phases in soils and their potential reactivity (Lu *et al.*, 2003). The soluble and exchangeable fractions of Ni are considered readily mobile (active Ni), while the residual fraction is relatively inactive (Li, 2001). The binding mechanism of such metal depends on the physico-chemical properties of soils, which play an important role on the rate of chemical transformation of this metal in the solid phase system (Sposito, 1989).

The concentrations of the different nickel fractions and their contributions in its total amount are shown in Tables 2 and 3, respectively. The residual Ni fraction was, by far, the most important of soil nickel. The percentage values ranged from 53.43% to 93.56% with an average of 70.74%. This result is consistent with the results obtained by many researchers who found that the greatest percentage of nickel had been occurred in the residual fraction (Tessier *et al.*, 1979; Hickey and Kittrick, 1984; Moral *et al.*, 2005; Iwegbue, 2007 & 2011 ; Chaudhary *et al.*, 2008; Ogundiran and Osibanjo, 2009; Osakwe, 2010). It has been indicated that nickel is commonly occluded by silicate during soil weathering (Moral *et al.*, 2005).

The next important fraction for nickel, in the studied soils, is the carbonate fraction which have the percentages ranged from 2.44% to 25.28 % with an average of 16.56 %. This result is consistent with previous studies (Horsfall and Spiff, 2005 and Osakwe, 2010). However, low levels of nickel bound to carbonate has been reported (Tessier *et al* ., 1979; Hickey and Kittrick, 1984). Significant percentage of nickel associated with carbonate phase has been also reported by Abeh *et al.* (2007).

Table (2). The concentration values of nickel in the different geochemical fractions

Soil No.	Location	Fraction (mg/kg soil)						M.F.
		F_1	F_2	F_3	F_4	F_5	F_6	
1	Burg El-Arab	0.15	0.04	2.44	0.05	nd	6.97	0.19
2	El-Hamam	9.32	2.52	8.32	3.80	nd	27.50	11.84
3	El-Hamam	nd	0.44	3.40	0.35	nd	14.96	0.44
4	El-Alamain	nd	nd	1.68	nd	nd	6.16	nd
5	El-Alamain	4.62	1.68	9.20	5.30	nd	35.84	6.30
6	Sidi Abdel Rahman	nd	0.60	6.84	0.95	nd	27.65	0.60
7	Alowny sons	7.82	6.96	8.56	nd	nd	38.55	14.78
8	Ain Gzalla	7.28	6.08	7.96	3.50	nd	39.98	13.36
9	El-Daba	7.32	2.68	8.64	4.00	nd	36.11	10.00
10	El-Gfyra	0.42	1.92	5.96	nd	nd	19.09	2.34
11	Zawaia El-Awam	nd	0.44	0.33	0.10	nd	12.65	0.44
12	Rass El-hykma	0.26	1.60	6.84	2.05	nd	33.42	1.86
13	Etnoh	0.47	2.28	7.84	3.45	nd	33.41	2.75
14	Baggosh	3.02	2.28	8.96	3.75	nd	33.29	5.30
15	Matruoh	nd	0.48	5.64	0.25	nd	24.65	0.48
	Average	2.71	2.00	6.17	1.84	nd	24.02	4.71

Fraction: F_1= soluble, F_2= exchangeable, F_3= bound to carbonate, F_4= bound to Fe-Mn oxides, F_5=bound to organic matter (nd= not detected) and F_6= residual.
M.F. (mobile fraction) = F_1+F_2

Table (3). The contribution of nickel fractions in the total nickel contents in soils

Soil No.	Location	Fraction (%)						M.I
		F_1	F_2	F_3	F_4	F_5	F_6	
1	Burg El-Arab	1.55	0.41	25.28	0.51	-	72.22	1.96
2	El-Hamam	18.11	4.89	16.16	7.38	-	53.43	23.00
3	El-Hamam	-	2.29	17.75	1.82	-	78.12	2.29
4	El-Alamain	-	-	21.42	-	-	78.57	-
5	El-Alamain	8.15	2.96	16.24	9.35	-	63.27	11.11
6	Sidi Abdel Rahman	0.00	1.66	18.97	2.63	-	76.72	1.66
7	Alowny sons	12.63	11.24	13.83	0.00	-	62.28	23.87
8	Ain Gzalla	11.23	9.38	12.28	5.40	-	61.69	20.61
9	El-Daba	12.45	4.56	14.70	6.80	-	61.46	17.01
10	El-Gfyra	1.53	7.00	21.75	-	-	69.69	8.53
11	Zawaia El-Awam	-	3.25	2.44	0.73	-	93.56	3.25
12	Rass El-hykma	0.58	3.62	15.48	4.64	-	75.66	4.20
13	Etnoh	0.99	4.80	16.52	7.27	-	70.15	5.79
14	Baggosh	5.88	4.44	17.46	7.30	-	64.89	10.32
15	Matruoh	-	1.54	18.18	0.80	-	79.46	1.54
	Average	4.87	4.14	16.56	3.64	-	70.74	9.00

Fraction: F_1= soluble, F_2= exchangeable, F_3= bound to carbonate, F_4= bound to Fe-Mn oxides, F_5= bound to organic matter (not detected) and F_6= residual
M.I. (mobility index) = F_1+F_2

Relatively low levels of nickel were associated with the Fe-Mn Oxides (a range from nil to 5.30 mg/kg soil) (Table 2). The percentage values of Ni fraction in Fe-Mn oxides ranged between nil to 9.35% with an average of 3.64% (Table 3). It has been suggested that the levels of nickel in Fe-Mn oxide fraction depends on how much Mn oxide is absorbed in soil because Ni^{+2} can substitute for surface manganese in mixed valence Mn oxides (Jenne, 1968 and Mckenzie, 1972).

The total percentage of nickel in the exchangeable and water soluble fractions (mobile fraction) indicates that some little amount of nickel is potentially available for plants uptake in these soils. These two fractions(F_1+F_2) accounted for only about 9.0% of the total soil Ni. The average amounts of nickel associated with the different fractions followed the trend: residual > carbonate > water soluble > exchangeable > Fe-Mn oxides > organic. It is clear from these data (Tables 3 and 4) that the carbonate fraction contained most of Ni in the non residual fractions.

The relationship between the amounts of mobile Ni (F_1+F_2) and each fraction of Ni were investigated as shown in Table (4). It is clear from these data that the mobile Ni fraction (soluble + exchangeable) was correlated with all inorganic Ni fractions. The highest significant correlations of the mobile Ni in soil were with the soluble Ni (r=0.967**), exchangeable Ni (r=0.899**), residue Ni (r=0.705**) and carbonate Ni (r=0.676**) fractions. Also, a significant correlation with total-Ni (r = 0.827**) was observed.

Table (4). Correlation coefficients between Ni fractions, mobile and total Ni contents

	M.F	F_1	F_2	F_3	F_4	F_6	Total
M.F	-	0.967^{**}	0.899^{**}	0.676^{**}	0.490^{ns}	0.705^{**}	0.827^{**}
F_1		-	0.758^{**}	0.646^{**}	0.562^{*}	0.626^{**}	0.775^{**}
F_2			-	0.620^{*}	0.288^{ns}	0.729^{**}	0.786^{**}
F_3				-	0.731^{**}	0.916^{**}	0.934^{**}
F_4					-	0.685^{**}	0.736^{**}
F_6						-	0.974^{**}
Total							-

Fraction: F_1= soluble, F_2= exchangeable, F_3= bound to carbonate, F_4= bound to Fe-Mn oxides, F_6= residual.

** significance at 1% level , * significance at 5% level, ns = non significance

The extractable Ni (Availability)

Table (5) showed the amounts of Ni extracted by the three chemical extractants (DTPA, AB-DTPA and Mehlich-3) from the tested soils. The results revealed that the order of extracability of these extractants for Ni in soils was as follows:Mehlich-3 > AB-DTPA> DTPA. It is clear that Mehlich-3 removed the highest amounts of Ni from soils.

Despite some differences in the amounts of the Ni determined in the soils by the respective methods, a significant correlation was found between their amounts extracted by DTPA and those by AB-DTPA (r = 0.894**) and Mehlich-3 method (r = 0.99**). Also, a significant correlation was observed between the amounts of Ni extracted by AB-DTPA and that of Mehilich-3 (r=0.902**).

The mathematical relationships between the amounts of Ni extracted by DTPA (X) and those by AB-DTPA or Mehlich-3 methods (Y) were established by the least squares method and found as follows:

$$\mathbf{Y_{AB\text{-}DTPA} = 0.031 + 0.335\, X_{DTPA} \qquad (R^2 = 0.799)}$$

$$\mathbf{Y_{Mehlich\text{-}3} = 0.018 + 0.111\, X_{DTPA} \qquad (R^2 = 0.980)}$$

Also ,the relationship between the amounts of Ni extracted by Mehlich-3 (Y) and that extracted by AB-DTPA (X) was established and found as follows:

$$\mathbf{Y_{Mehlich\text{-}3} = 0.129 + 3.013\, X_{AB\text{-}DTPA} \qquad (R^2 = 0.814)}$$

The comparisons between the R^2 values showed that there were fairly good relationships between DTPA and AB-DTPA or Mehlich-3 with respect to the chemical extractant in measuring the availability of Ni in calcareous soils. Also a good relationship between Mehlich-3 and AB-DTPA was observed and that Mehlich-3 method showed highly R^2 values with DTPA or AB-DTPA.

According to the regression analysis presented in Table 6 , Ni extracted by DTPA or Mehlich-3 were highly correlated with the carbonate bound and residual Ni fractions. On the other hand, the Ni extracted by AB-DTPA was highly correlated with the soluble and residual Ni fractions.

Also, the highest correlation coefficient was found between Ni extracted by DTPA and the sum of soluble, exchangeable, calcium carbonate bound, Fe-Mn bound and residual Ni fractions. Using the AB-DTPA or Mehlich-3 (Table 6), the highest correlations was observed with the sum of soluble, exchangeable, carbonate bound and Fe-Mn oxides bound Ni fractions. Similar results were observed for DTPA and mehlich-3 extractants by (Wen *et al.*, 1997).

Table (5). The amounts of extractable Nickel (mg/kg soil) from soils by three chemical extractants

Soil No.	Location	DTPA	AB-DTPA	Mehlich-3
1	Burg El-Arab	0.15	0.54	1.36
2	El-Hamam	0.59	2.67	5.93
3	El-Hamam	0.28	0.80	2.53
4	El-Alamain	0.19	0.46	1.44
5	El-Alamain	1.19	2.44	9.82
6	Sidi Abdel Rahman	0.44	1.07	3.49
7	Alowny sons	0.89	2.81	6.90
8	Ain Gzalla	0.97	2.86	8.12
9	El-Daba	0.96	2.78	8.81
10	El-Gfyra	0.32	0.90	2.56
11	Zawaia El-Awam	0.18	0.76	1.67
12	Rass El-hykma	0.45	1.17	3.58
13	Etnoh	0.47	1.39	4.54
14	Baggosh	1.08	2.16	9.70
15	Matruoh	0.42	1.05	3.37
	Average	0.57	1.59	4.92

Table (6). Linear regressions between single or multible of Ni-extracted by sequential fractionation procedure (Y) and Ni-extracted by DTPA, AB-DTPA and mehlich-3 (X).

Y	X	a	b	r
F_1	DTPA	-1.50	7.45	0.72^{**}
F_2		-0.24	3.96	0.65^{**}
F_3		2.16	7.08	0.84^{**}
F_4		-0.55	4.23	0.75^{**}
F_6		10.00	28.29	0.84^{**}
F_1+F_2		-1.74	11.42	0.74^{**}
$F_1+F_2+F_3$		0.41	18.50	0.84^{**}
$F_1+F_2+F_3+F_4$		-0.14	22.73	0.87^{**}
$F_1+F_2+F_3+F_4+F_6$		9.86	51.03	0.89^{**}
F_1	AB-DTPA	-3.08	3.64	0.94^{**}
F_2		-0.86	1.80	0.79^{**}
F_3		2.06	2.58	0.81^{**}
F_4		-0.52	1.48	0.70^{**}
F_6		9.46	10.40	0.83^{**}
F_1+F_2		-3.95	5.44	0.94^{**}
$F_1+F_2+F_3$		-1.88	8.02	0.97^{**}
$F_1+F_2+F_3+F_4$		-2.40	9.51	0.98^{**}
$F_1+F_2+F_3+F_4+F_6$		7.06	19.92	0.92^{**}
F_1	Mehlich-3	-1.50	0.85	0.73^{**}
F_2		-0.02	0.41	0.60^{*}
F_3		2.25	0.79	0.84^{**}
F_4		-0.70	0.51	0.82^{**}
F_6		10.76	3.09	0.82^{**}
F_1+F_2		-1.53	1.26	0.73^{**}
$F_1+F_2+F_3$		0.72	2.06	0.83^{**}
$F_1+F_2+F_3+F_4$		0.01	2.58	0.88^{**}
$F_1+F_2+F_3+F_4+F_6$		10.78	5.68	0.88^{**}

** ,* significance at p=1% and 5% levels respectively.

F_1,F_2,F_3,F_4, and F_6 are soluble, exchangeable, bound to carbonate, bound to Fe-Mn oxides, organically and residual from of Ni respectively.

It is clear that the sum of these fractions may give significant effect on the mobility of Ni from soil to plant. In general, the three extractants are used to give, a reliable prediction for Ni availability.

The usefulness of these extractants depends on the forms being extracted by the single extractant. The results of this work demonstrate that the major fractions of Ni that can be extracted by the three extractants are the water soluble and exchangeable Ni and carbonate Ni bound forms, followed by Fe-Mn oxides bound Ni. In the mean time, a small portion of residual Ni was also extracted by these extractants. It is clean from the obtained results that sultanpour extractant (AB-DTPA) is more effective than the other two extractants (DTPA or Mehlich- 3) in extracting the residual bound Ni fraction.

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الملخص العربي

تقدير الصورالجيوكيميائية للنيكل و تيسرها في الأراضي الجيرية

ماهر جورجي نسيم[1] ، ماجدة أبو المجد حسين[1] ، حسين أحمد زيد[1]
هدى أحمد سعيد إبراهيم الحديدي[2]

1- قسم الأراضي و الكيمياء الزراعية – كلية الزراعة (سابا باشا) جامعة اسكندرية – مصر
2- قسم التربة و المياه – كلية الزراعة – طرابلس – جامعة طرابلس – ليبيا

استخدمت مستخلصات كيميائية شملت (Mehlich-3) و (AB-DTPA) و (DTPA) كمحاليل عديدة الاستخلاص للتنبؤ بالنيكل المتاح في التربة. ومع ذلك فصور العنصر المستخلص بهذه الطرق غير معروفة .

في هذه الدراسة تم جمع 15 عينة أرض جيرية من الساحل الشمال الغربي من مصر تمثل مدى واسع من الخصائص الفيزيائية و الكيميائية بما في ذلك المحتوى الكلى للنيكل بواسطة تقنية استخلاص متتابع لفصل 5 صور من النيكل و التي هي (الذائبة في الماء – المتبادل – المرتبط بالكربونات – المرتبط بأكاسيد الحديد و المنجنيز و المرتبط بالمادة العضوية). و قدرت نسبة المتبقي residual من النيكل عن طريق طرح مجموع الخمس صور من النيكل الكلي. وقد تراوح محتوى النيكل الكلى فى هذه الأراضى ما بين 7.84 و64.8 ملجم / كجم تربة كما تم استخلاص كميات من النيكل المتاح كيميائياً بالمستخلصات Mehlich-3 ، AB-DTPA ، DTPA وكان ترتيب هذه المستخلصات الثلاث لاستخلاص النيكل كالأتي : Mehlich-3 < AB-DTPA < DTPA . وقد أظهرت النتائج أن هناك علاقة قوية بين صور النيكل المرتبط بالكربونات و المتبقية والمستخلصة بطريقة Mehlich-3 أوبطريقة DTPA . ومن ناحية أخرى كان هناك ارتباط قوي بين النيكل المستخلص بطريقة AB-DTPA مع صور النيكل الذائب في الماء و المتبقي . كما تم الحصول على أعلى علاقة بين النيكل المستخلص بطريقة DTPA ومجموع صور النيكل الذائبة في الماء، المتبادل، المرتبط بالكربونات، المرتبط بأكاسيد الحديد و المنجنيز والمتبقي. إنما في حالة استخدام طريقة AB-DTPA أو Mehlich-3 لوحظ أن هناك علاقة ارتباط عالية مع مجموع صور النيكل المتمثلة في الذائبة، المتبادل، المرتبط بالكربونات، المرتبط بأكاسيد الحديد و المنجنيز. أى أن مجموع هذه الصور قد تعطي تأثير معنوي على حركة النيكل في التربة .