ASSESSMENT AND SPATIAL DISTRIBUTION OF NIKLE WITHIN SOILS OF IBSHWAY DISTRICT AREA, FAYOUM GOVERNORATE, EGYPT.

Mahmoud Abd-Elgawad [1*], Abdel-Naser A.A. Hafeez[1], Hamdy A. Abdurrahman[1], Mohammed Hamed El-Sayed Saleh[2],

[1]Dep.Of soils and water, Fac. of Agric, Fayoum Univ., Egypt.

[2] Faculty of Agriculture , FayoumUniversity

ABSTRACT

Spatial distribution of Ni has been studied in soils of Ibshway district area, Fayoum governorate, Egypt using grid system- log distance of 2 km.

Levels and Spatial distribution of Ni(total and extractable) contents were identified and mapped using "ILWIS application" Geographic Information System (on basis of their Ni contents) throughout the studied area.

It was found that the mean concentrations of total Ni within the top 60 cm of soils were 40.02 mg kg^{-1}, i.e higher than the general means in some soils of the world.

The general mean concentrations of total Ni within the top 60 cm in Ibshway District soils mostly higher than the maximum allowable limits applied in some countries such as Denmark , Netherlands , Germany , Ireland and Canada the total Ni values are similar to the permissible limits applied in some developed countries such as Finland and below the allowed maximum limits applied in some developed countries such as Switzerland, Czech Republic and Eastern Europe (Russia, Ukraine, Moldavia and Belarus)

The maps generated through GIS are useful for decision makers for land use planning, conservation and evaluating the degree of environmental contamination with hazardous heavy metals.

Key Words: Ni Total content, DTPA extractable, Ibshway District, soil layer

INTRODUCTION

Heavy metals occur naturally in all soils in minute quantities, but can accumulate in agricultural soils from various sources, such as fertilizers, organic supplements atmospheric deposition and urban and industrial activities.

Some of these metals such Ni is not essential nutrients for plants and animals. However, sufficiently high concentration can become toxic and constitute serious health problems whenever they enter into the human food chain.

Inorganic fertilizers are the main chemicals used by the agricultural sector In all Governorates of Egypt. It is well known that most growers of Fayoum Governorate commonly use excessive rates of inorganic fertilizers in order to get the maximum possible profit per unit area of land.

Igneous rocks are the primary source of the Ni found in soils. In soils the total concentration of a trace element such as Ni is related directly to the concentration in the parent material and to the weathering processes **(Mitchell, 1964).** The losses of Ni from soil occur in solution either by leaching or in run off, in eroded material and in harvested goods. Gain of Ni to soil occurs naturally through the accession of soil eroded from elsewhere and addition in agricultural chemicals.

Rural and urban soils in both industrial parks and near small factories outside the parks are affected by a wide verity of contaminants. The most serious sources of soil contamination are: (i) Heavy metals in hazardous waste, including materials from chemical production dyeing, electroplating and heat treatment. The production of batteries, metal treatment, mining and extractive industries, scrap yards, service stations and tinning. (ii) Hazardous organic waste materials, including those from medical centers, oil production and storage, paint , pesticide production and (iii) Corrosive metal waste materials, including those from acid/alkali plants and chemical engineering works **(EPA/ROC, 1994).**

The present work was conducted to assessment of total and EDTPA extractable contents of Nikle and to generate geographical distribution maps for them within soils of Ibshway District, Fayoum Governorate, Egypt.

MATERIALS AND METHODS

One hundred and seventeen soil samples were collected from thirty-nine sites representing Ibshway District area following the grid system at distances of 2 kilometers during November 2015. Locations of the studied sites were identified using a "GPS" (Model German).

Three soil samples were taken from each site, i.e, from (0 –10) cm, (10 –30) cm, (30 –60) cm.

The collected soil samples were air-dried, crushed with wooden hummer, passed through a 2 mm sieve and stored in plastic bottles. The collected soil samples were analyzed for total and DTPA- extractable nickel

- Available forms of Nickel (Ni) in soil were extracted using diethylenetriaminepenta acetic acid (DTPA) at pH 7.3 and determined with **Inductively Coupled Plasma (ICP),** according to **USDA, Soil Survey Lab Manual (2004).**
- Total content of Nickel (Ni) in soil samples (0.5 g each) were digested with 9.0 mL (HNO3) and 3.0 mL hydrochloric (HCl) acids using Teflon flasks and determined with **Inductively Coupled Plasma (ICP), according to USDA, Soil Survey Lab Manual (2004).**

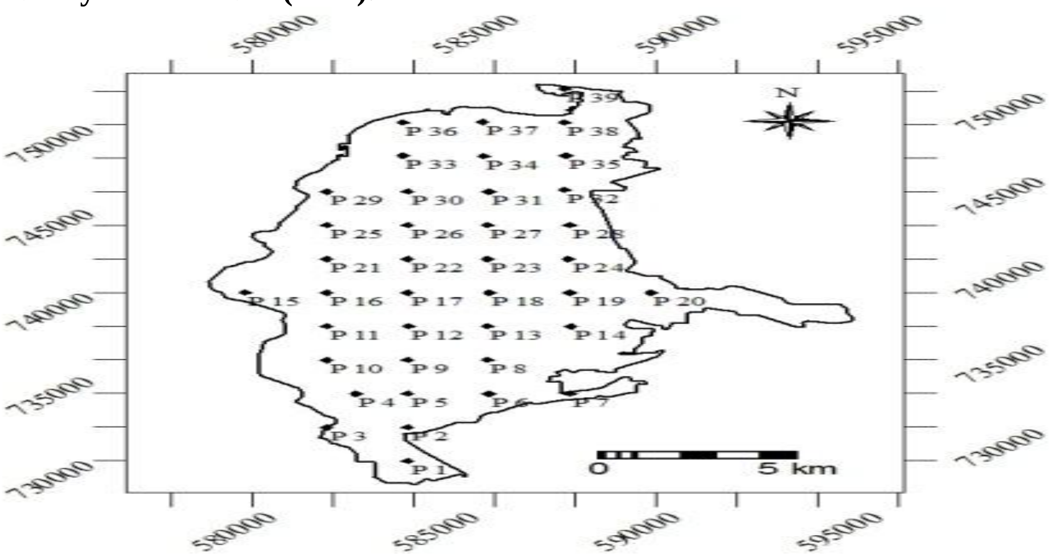


Figure (1) Location map of the investigated area and sites of the collected samples from Ibshway District.

RESULTS AND DISCUSSIONS

3.1. Distribution of nickel content.in Ibshway District soils.

3.1.1. Total nickel content.

The concentrations and spatial distribution of Ni levels in the studied layers of Ibshway District soils are given in Table (1and 2) and Figures (2, 3 and 4). Total Ni concentrations in the upper layers of soils ranged from 15.540 to 58.320 with a mean value of 39.224 mg kg-1 soil. Corresponding values for the subsurface layers ranged from 14.440 to 74.300 with an average value of 40.038 mg kg^{-1}. While in layer (30 – 60 cm) Values ranged from 16.360 to 64.880 with a mean value of 40.796 mg kg^{-1} soil. The overall mean content within the (0 – 60 cm) layers were 40.02 mg kg-1 soil. In her work on Sinnuris District, Fayoum Governorate, **Howaida (2016),** found that total Ni content ranged from 20.32 to 53.28 mg kg-1 with a mean of 40.31mg kg^{-1}. While **Amany (2019)** found that in Youssef El-Seddik district, Fayoum Governorate the total Ni content ranged from 16.667 to 55.860 mg kg^{-1} with a mean of 54.68 mg kg^{-1}.

In comparison with data of the present investigation, it could be observed that Ibshway District soils generally contain less total Ni than those of Youssef El-Seddik District, and almost the same with soils of Sinnuris District.

Data presented indicate greater mean values of total Ni for the (10 – 60 cm) soil layer in comparison with the upper 10 cm. This may be caused by leaching and moving processes from the upper layers to the lower layers of the soil. However some sites showed greater Ni concentrations within the upper 10 cm in comparison with the subsurface layer, this may be due to using contaminated water with sewage drainage water in irrigation.

For the assessment and evaluation of Ni status in Ibshway district soils, the obtained results of the total metal concentrations were compared with recommended international standards and allowable limits according to the regulations of some countries, since Egypt did not yet developed specific standards in this respect.

The concentrations of total Ni in the earth crust is 100 mg kg-1 by **Lindsay (1979)** and ranged between 5 to 500 with a general mean of 40 mg kg-1 in world soils. Data of the present study indicate that the mean Ni concentration in Ibshway soils is the same those of world soils. **Chen et al., (1999)** reported that the mean total concentrations of nickel in rural soils of some countries in mg kg-1 soil were 15 mg kg-1, South Africa; 20 mg kg-1 for China; 30 mg kg-1 for Sweden and Denmark; 30 mg kg-1 and 80 mg kg-1 for Norway before and after using sewage sludge; 50 mg kg^{-1} for France; 60 mg kg^{-1} for Australia; 75 mg kg^{-1} for Italy; 100 mg kg^{-1} for Belgium; 120 mg kg^{-1} for Taiwan; 150 mg kg-1 for Canada; 200 mg kg^{-1} for Germany; 300 mg kg^{-1} for U.K; 210 mg kg^{-1} and 420 mg kg^{-1} for USA. Concentrations values of total Nikle through the studied layers of Ibshway soils are greater than the mean values of some of the above mentioned countries (South Africa, China, Sweden, Denmark, before using sewage sludge) and lower than those of the others.

Table 1. concentrations of total and DTPA-extractable nickel in soils of Ibshway District.

Site NO.	Soil depth (cm)	Conc.(mg kg^{-1}) on dry weight basis)		Site NO.	Soil depth (cm)	Conc.(mg kg^{-1}) on dry weight basis)	
		Ni				Ni	
		Ext.*	Total			Ext.*	Total
1	0-10	0.437	49.000	13	0-10	0.289	34.680
	10-30	0.536	74.300		10-30	0.251	38.380
	30-60	0.414	52.020		30-60	0.213	41.660
2	0-10	0.882	38.240	14	0-10	0.598	26.620
	10-30	0.619	38.140		10-30	1.139	34.240
	30-60	0.609	37.520		30-60	1.454	26.260
3	0-10	0.666	52.200	15	0-10	0.356	21.660
	10-30	0.636	48.880		10-30	0.500	14.440
	30-60	0.703	50.020		30-60	0.517	16.360
4	0-10	0.393	49.400	16	0-10	0.604	25.280
	10-30	0.353	47.280		10-30	0.573	25.000
	30-60	0.317	49.260		30-60	0.489	23.200
5	0-10	1.054	46.700	17	0-10	1.143	31.300
	10-30	1.258	45.120		10-30	1.135	35.700
	30-60	1.796	53.540		30-60	1.059	36.520
6	0-10	1.527	39.620	18	0-10	1.760	43.340
	10-30	1.253	40.380		10-30	1.588	36.060
	30-60	0.810	31.260		30-60	1.509	49.560
7	0-10	0.657	36.580	19	0-10	0.648	37.680
	10-30	0.557	33.520		10-30	0.971	33.680
	30-60	0.793	36.280		30-60	0.818	37.460
8	0-10	0.520	43.900	20	0-10	0.535	44.220
	10-30	1.033	43.340		10-30	1.819	44.880
	30-60	1.221	30.880		30-60	2.859	51.740
9	0-10	0.579	29.520	21	0-10	0.320	38.100
	10-30	0.367	26.580		10-30	0.259	39.640
	30-60	0.507	26.700		30-60	0.142	33.680
10	0-10	0.730	49.680	22	0-10	1.001	45.400
	10-30	0.592	56.060		10-30	1.227	45.740
	30-60	0.571	64.880		30-60	0.694	42.640
11	0-10	1.028	32.240	23	0-10	1.776	58.320
	10-30	1.003	34.580		10-30	2.129	44.380
	30-60	0.420	45.960		30-60	2.459	51.520
12	0-10	0.380	52.060	24	0-10	1.165	26.320
	10-30	0.369	52.160		10-30	1.290	24.060
	30-60	0.305	60.900		30-60	2.107	29.500

Table 1. continued:

Site NO.	Soil depth (cm)	Conc.(mg kg^{-1}) on dry weight basis)		Site NO.	Soil depth (cm)	Conc.(mg kg^{-1})(on dry weight basis)	
		Ni				Ni	
		Ext.*	Total			Ext.*	Total
25	0-10	2.073	42. 280	33	0-10	0.874	37.140
	10-30	2.301	44.440		10-30	1.052	38.320
	30-60	2.975	46.560		30-60	1.013	39.180
26	0-10	0.557	50.000	34	0-10	1.163	47.020
	10-30	0.774	44.720		10-30	0.920	35.120
	30-60	1.393	53.200		30-60	1.163	42.760
27	0-10	1.880	52.380	35	0-10	0.398	30.220
	10-30	1.866	40.820		10-30	0.941	33.720
	30-60	1.873	47.820		30-60	1.313	25.800
28	0-10	1.661	34.840	36	0-10	1.286	28.300
	10-30	1.895	39.320		10-30	1.419	38.520
	30-60	2.499	48.540		30-60	1.660	39.420
29	0-10	0.448	40.420	37	0-10	1.020	36.840
	10-30	0.456	45.540		10-30	0.901	34.480
	30-60	0.481	40.500		30-60	0.779	31.740
30	0-10	1.417	15.540	38	0-10	0.938	31.080
	10-30	1.419	32.220		10-30	1.055	34.140
	30-60	1.937	21.300		30-60	1.528	37.200
31	0-10	1.317	43.620	39	0-10	0.482	39.140
	10-30	1.432	41.700		10-30	0.556	50.580
	30-60	1.531	44.080		30-60	0.713	42.460
32	0-10	1.106	48.860				
	10-30	1.011	51.320				
	30-60	1.097	51.160				

Ext*= Extracted with DTPA

Table 2. Spatial distribution of Ibshway district areas according to <u>thier</u> total Nikle ranges.

Heavy metal	Soil depth (cm)	Distribution level, mg kg^{-1}	Area (ha)	% of District area
Total **Ni**	(0-10)	15.54-20.00	1.79	0.02
		20.01-30.00	384.92	2.41
		30.01-35.00	1749.79	10.95
		35.01-40.00	7077.15	44.30
		40.01-50.00	6719.36	42.06
		> 50.00	41.65	0.26
	10-30	14.44-20.00	39.40	0.25
		20.01-30.00	411.47	2.58
		30.01-35.00	842.33	5.27
		35.01-40.00	7828.54	49.01
		40.01-50.00	6826.08	42.73
		> 50.00	26.01	0.16
	30-60	16.36-20.00	13.41	0.08
		20.01-30.00	378.41	2.37
		30.01-35.00	1403.39	8.79
		35.01 –40.00	5178.39	32.42
		40.01-50.00	8397.33	52.57
		50.01-60.00	597.58	3.74
		> 60.00	6.03	0.03

De Vries and Bakker (1998) reported that the maximum allowable soil total contents of Ni according to environmental standards of several countries all over the world are 10 mg kg-1 in Denmark; 15 for clay soils and 70 mg kg-1 for sandy soils in Germany; 20 mg kg-1 in Canada; 30 mg kg-1 in Ireland; 35 mg kg-1 in Netherlands; 40 mg kg-1 in Finland; 50 mg kg-1 in Switzerland; 60 mg kg-1 in both Taiwan and Czech Republic; and 85 mg kg-1 in Eastern Europe.

According to the developed Dutch standards as reported **by Chen et al., (2000),** two parameters are used for the assessment of soil contamination with Ni: the first is the target level (35 mg kg-1) or "A-value" which represents the natural or normal value above which the soil is considered contaminated with Ni and the second is the cleanup level or "C-value" (210 mg kg-1) at which the soil is considered polluted and should be remediated. On this basis 86.62% ,91.9% and 88.77% of Ibshway District soils are considered contaminated (not polluted) with Ni within the upper 10 cm, (10-30 cm) and (30-60 cm) layers, respectively. **Chen et al., (2000)** stated also that the developed Taiwan system depends on three parameters for assessing the degree of soil contamination with Nickel: A-value (the normal limit), B-value (the marginal level) and C-value at which the soil should be remediated. These values for total Ni contents of soil are 30, 60 and 200 mg kg-1 soil respectively. In comparison with Taiwan standards more than 97% of soils contain more total Ni than the normal limit within the all layers, and about 0.04 % of

Ibshway District soils have total Ni concentrations above the marginal level within the (30 – 60 cm) layers.

According to environmental standards of Denmark all soils of Ibshway District area contain greater total Ni than the maximum allowable limits within the upper 60 cm and all soils are considered Ni contaminated. However all soils of the District are considered Ni non- contaminated within 60 cm are considered Ni- none contaminated (contain > 85 mg kg-1) with respect to environmental standards of Eastern Europe countries (Russia, Ukraine, Moldavia and Belarus).

The author emphasizes the importance and real need for Egypt to develop Specific environmental standards identifying maximum allowable limits for all heavy metals concentrations in soil on basis of the country soil nature and chemical characteristic.

Data presented show that the mean total Ni concentration within the subsurface (10 – 30 cm) soil layer is greater than that of the upper 10 cm, however the opposite was true in some of the studied sites which showed greater concentrations within the upper layer probably due to the existence of in point contaminates in such areas.

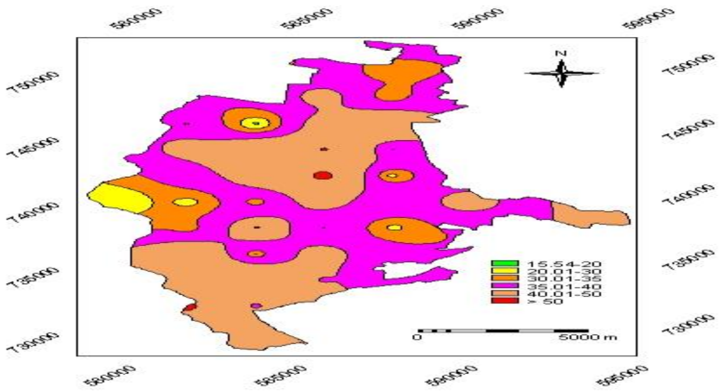


Fig. (2) Spatial Distribution Map areas of different total Nikle ranges (mg kg^{-1}) within the 0 - 10 cm layer of Ibshway District soils.

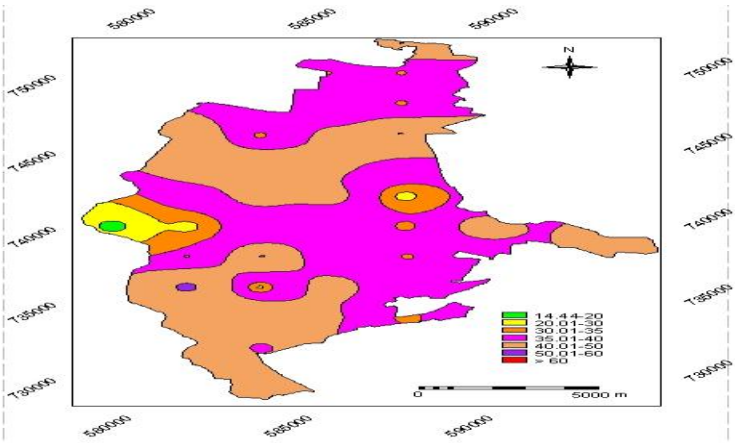


Fig. (3) Spatial Distribution Map areas of different total Nikle ranges (mg kg^{-1}) within the 10 - 30 cm layer of Ibshway District soils.

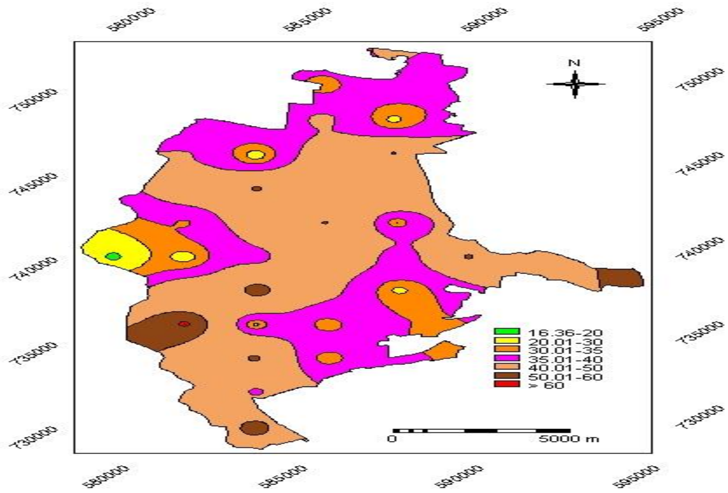


Fig. (4) Spatial Distribution Map areas of different total Nikle ranges (mg kg^{-1}) within the 30 - 60 cm layer of Ibshway District soils.

3.1.2. DTPA-extractable Nickel

Table 3. Spatial distribution of Ibshway district areas according to thier DTPA extractable Nikle ranges.

Heavy metal	Soil depth (cm)	Distribution level, mg kg^{-1}	Area (ha)	% of District area
DTPA Extractable **Ni**	0-10	0.28-1.00	11253.72	70.44
		1.01-1.50	4573.22	28.63
		> 1.50	147.98	0.93
	10-30	0.25-1.00	8754.05	54.80
		1.01-1.50	5829.66	36.49
		> 1.50	1391.29	8.71
	30-60	0.14-1.00	6974.82	43.66
		1.01-1.50	5307.56	33.23
		1.51-2.00	2659.37	16.65
		> 2.00	1023.28	6.46

The concentrations and spatial distribution of DTPA-extractable Ni levels in soils of Ibshway District are given in Table (1 and 3) and Figures (5, 6 and 7). DTPA extractable values of Ni ranged between 0.289 and 2.073 mg kg-1 soil in the top 10 cm layer with a mean of 0.915 mg kg-1. Values in (10 – 30 cm) layers ranged from 0.0251 to 2.301 with an average of 1.012 mg kg-1. Values of (30 – 60 cm) layers ranged from 0.142 to 2.975 with an average of 1.147 mg kg-1 soil. The overall mean value of the top 60 cm layer was 1.025 mg kg-1 soil.

In his studies on Fayoum District, Fayoum Governorate, Egypt. **Abdulrahman (2007)** found that DTPA-extractable Ni ranged between 0.03 and 1.48 mg kg-1 with a general mean of 0.47 mg kg-1**. Howaida (2016**), found a range of 0.40 to 2.50 mg kg-1 with a mean of 1.13 mg kg-1 in Sinnuris District soils, Fayoum Governorate. In her studies on Youssef El-Seddik District, Fayoum Governorate, Egypt**. Amany (2019**), found that DTPA- extractable values of Ni ranged between 0.98 and 3.26 mg kg-1 soil in the top 10 cm layer with a mean of 1.74 mg kg-1. Values in subsoil (10–50 cm) ranged from 1.00 to 3.16 with an average of 1.71 mg kg-1 soil. The overall mean value of the top 50 cm layer was 1.74 mg kg-1 soil.

Rashad et al., (1995) showed that DTPA extractable soil Ni contents ranged from 0.38 to 1.04 mg kg-1 with an average of 0.66 mg kg-1 in recent Nile alluvial soils, while values in coastal barrier plain soils (sandy soils) ranged from 0.2 to 0.4 with an average of 0.31 mg kg-1.Very little information is available in the literature concerning maximum permitted limits in terms of soil DTPA- extractable Ni. Studies of **Abdulrahman (2012)** showed that the critical soil DTPA- extractable limit of Ni at which 10% and say reduction of grown barley dry matter occurred and the limit associated with 50% reduction are 7.70 and 13.64 mg kg-1 soil, respectively.

The geographic distribution of DTPA-extractable Ni levels within the top soil (0 – 10 cm) , the (10 – 30 cm) and the (30 – 60 cm) soil layers throughout Ibshway District are illustrated by in Figures (5,6 and 8) and summarized in Table (2).

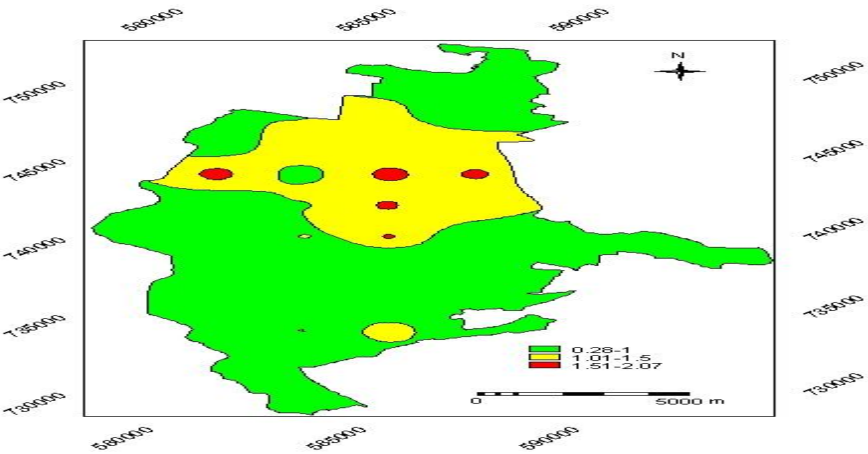
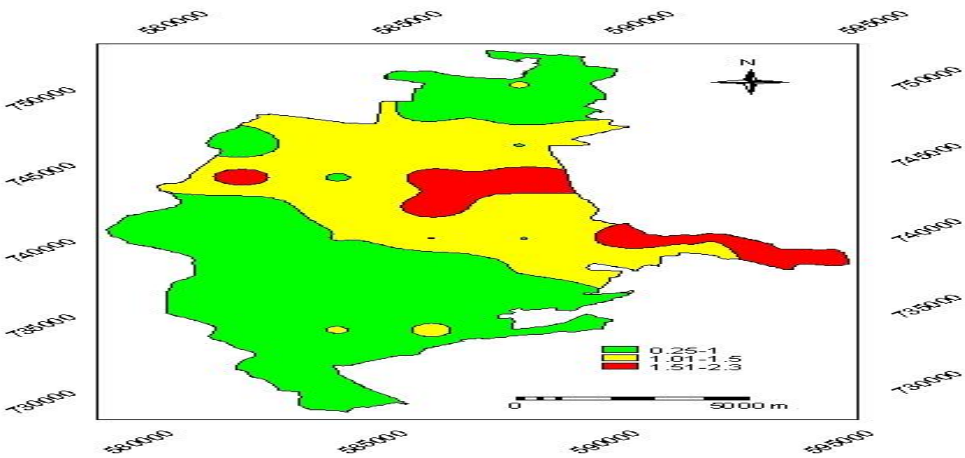


Fig. (5): spatial Distribution map areas of different DTPA-extractable Nikle ranges (mg kg-1) within the 0-10 cm layer of Ibshway District soils.



ig.(6): spatial Distribution map areas of different DTPA-extractable Nikle ranges (mg kg^{-1}) within the 10-30 cm layer of Ibshway District soils.

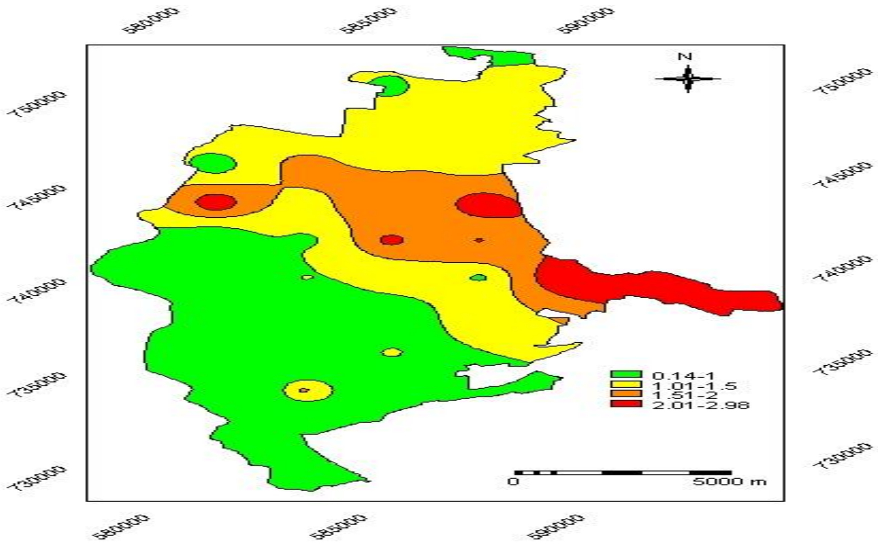


Fig. (7): spatial Distribution map areas of different DTPA-extractable Nikle ranges (mg kg^{-1}) within the 30-60 cm layer of Ibshway District soils.

CONCLUSIONS

The mean total Ni concentration within the subsurface (10 – 60 cm) soil layer was greater than that of the upper 10 cm, however the opposite trend was observed in other sites this may be due to the existence of in point contaminants in such areas or down movement of some soil colloids.

DTPA extractable values of Ni ranged between 0.289 and 2.073 mg kg-1 soil in the top 10 cm layer with a mean of 0.915 mg kg-1. Values in subsoil (10 – 30 cm) ranged from 0.0251 to 2.301 with an average of 1.012 mg kg-1. Values in subsoil (30 – 60 cm) ranged from 0.142 to 2.975 with an average of 1.147 mg kg-1 soil. The overall mean value of the top 60 cm layer was 1.025 mg kg-1 Soil. That may be originated from atmospheric deposition, high levels of applied commercial chemical fertilizers (superphosphate in particular) and/or irrigation using Nile water mixed with drainage water. It could be also concluded that soils of Ibshway District area, Fayoum Governorate in Egypt are mostly naturally Ni contaminated since subsoil had greater Ni content than the upper layer and both contained more total Ni than limits of most world countries standards. Further research work should be carried out to identify the dominant Ni minerals in Ibshway District soils. The authors emphasize the real need of Egypt to develop specific standards for the assessment of soil contamination or pollution with heavy metals on basis of the nature and properties of country soils.

REFERENCES

Abdulrahman, H.A. (2012). Effective of some remediation methods in cadmium and nickel contaminated soils of Fayoum. Ph.D. Thesis Soil and Water Department, Fayoum University, Egypt.

Abdurrahman, H.A. (2007). Status of heavy metals and nitrate in some soils and water resources in Fayoum Governorate Ms.C. thesis. Fac.Of Agric. Fayoum Univ.

Ahmed, A.A-N. (2019). Status of Heavy Metals and Soil Properties in Youssef El-Seddik District Area, Fayoum Governorate, Egypt. M.Sc. thesis. Fac. of Agric., Fayoum Univ., Egypt.
Ahmed, H.S. (2016). Status of cadmium, nickel, and lead in soils, water resources and applied chemical fertilizers at Sinnuris District, Fayoum Governorate, M.Sc. thesis, Faculty of Agriculture, Fayoum Univ., Fayoum , Egypt.
Analysis, 24: 961-972.
Chen, Z.S. (2000). Relationship between heavy metal concentrations of Taiwan and uptake by crops. Taipei: Food& Fertilizer Technology Center, ASPAC Technical Bulletin 149. http://www.agnet.org/library/tb/149/
Chen, Z.S., Tsai, C.C. and Tsui, C.C. (1999). Proposed regulation of soil pollutants in Taiwan soils. Proceedings of 6th workshop on Soil pollution and prevention: Soil remediation techniques on soils contaminated by Organic Pollutants. Taipei, Taiwan, pp. 169- 207.
De Vries and Bakker, (1998) Manual for calculating critical loads of heavy metals for terrestrial ecosystem: Guidelines for critical limits, calculation methods and input data TNO Institute of Environmental Sciences, Energy Research and Process Innovation. Den Helder, The Netherlands. 144pp.
EPA/ROC, (1994). Control tendency of hazardous waste materials in Taiwan. In: Proceedings of conference on Hazard Waste Treatment Technology. Environment Protection Agency (EPA), Taiwan ROC, pp. 1-27.
Lindsay, W.L. (1979). Chemical equilibria in soil. John Wiley and Sons, New York. 449p.
Mitchell, R.L. (1964). ‘Trace Elements in Soils’, in F.E. Bear (ed.), Chemistry of the Soil, Chapter 8, Van Nostrand Reinhold Co., New York, 525 pp. assessment. National Academy Press, Washington, DC.
Rashad, I.F., Abdel_Nabi, A.O., El-Hemely, M.E. and Khalaf, M.A. (1995). Background levels of heavy metals in the Nile Delta soils. Egypt. J. Soil Sci., 35: 239-252.
USDA, Soil Survey Laboratory Methods Manual (2004). No.42 version: 40 methods **4H1a**

أجريت هذه الدراسة بغرض تقييم حالة و تركيزات لمستويات عنصر النيكل في أراضي مركز ابشواي محافظة الفيوم .

• تم جمع ١١٧ عينة تربة من ٣٩ موقع باتباع النظام الشبكي "Grid system" على مسافات ٢ كم لتمثل أراضي مركز ابشواي وقد تم جمع عينات التربة لتمثل الثلاث اعماق (صفر – ١٠ سم) و (١٠ – ٣٠ سم) و (٣٠– ٦٠ سم) فى كل موقع، وبعد تجهيز العينات للتحليل قدر بها تركيزات عنصر النيكل الكلي والمستخلص بواسطة محلول ثنائى إلأثيلين ثلاثي الأمين خماسي حمض الخليك DTPA

•وقد وجد أن المتوسط العام لتركيزات عنصر النيكل الكلي فى طبقة التربة السطحية بعمق ٦٠ سم هى ٤٠.٠٢ ملليجرام/كجم، تجاوز تركيز النيكل الكلي الحدود القصوى المسموح بها في بعض الدول مثل الدنمارك وألمانيا و أيرلندا و كندا وهي مشابهه للحدود المسموح بها والمطبقة في بعض الدول المتقدمة مثل دولة فنلندا وأقل من الحدود القصوي المسموح بها والمطبقة في بعض البلدان المتقدمة مثل سويسرا وجمهورية التشيك ودول أوروبا الشرقية (روسيا وأوكرانيا والمالديف وبيلاروسيا)

. **مفتاح الدراسة:** العناصر الثقيلة - النيكل - الأراضي– ابشواي.