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Assessment and Spatial Distribution of Cadmium, Nickel and Lead within Soils of Sinnours, Fayoum, Egypt

Hamdi A. Abdurrahman[1*], Abdel-Naser A.A. Hafeez[1], Gamal A. Kamel[2] and Howaida S. Ahmed[3]

[1]*Dept. of Soils and Water, Fac. of Agric, Fayoum Univ.*
[2]*Drainage Research Inst. National Water Research Center, El-Qnater El-Kiaria,*
[3]*General Authority for Agrarian Reform, Fayoum Branch, Egypt*

THIS RESEARCH study addresses a problem of soil pollution caused by heavy metals. One hundred twelve soil samples were taken from fifty six locations to represent Sinnours lands using the grid system at two kms distance to assess and distribute of cadmium (Cd), nickel (Ni) and lead (Pb) in soils of Sinnours district, Fayoum Governorate, Egypt The geographic information system techniques were applied to map the spatial distribution of three heavy metals. The results obtained showed that the overall mean of each of Cd and Pb concentrations were higher within the surface (0 – 30 cm) of soils than the subsurface (30 – 60 cm) layer, indicating that Cd and Pb pollution of soil surface. In general, the concentrations of nickel (Ni) have been higher in the lower than the top soil layer indicating Ni normal soil contamination. The maps generated through Geographical Information systems (GIS) are beneficial for decision makers for land use planning, conservation and evaluating the level of environmental pollution with hazardous metals. The authors emphasize the actual absence of Egypt to develop detailed standards for the assessment of soil pollution with heavy metals primarily based on the nature and properties of the Egyptian soils.

Keywords: Cd, Pb, Ni, Total, Extractable, Sinnours, Fayoum, Egypt.

Introduction

Pollution of soils by heavy metals, which includes cadmium, nickel, zinc, lead, copper, has elevated dramatically during the last years all over the world. That is due to mobilization via human actions, such as mining, smelting, industry, use of agricultural fertilizers, insecticides, municipal wastes, traffic exhausts and industrial effluents and chemicals (Chibuike and Obiora 2014 and Al Naggar et al. 2013; Nordberg et al. 2011). Land degradation due to heavy metals has remarkable negative effects at the environment and atmosphere worldwide (Li et al., 2013).

Gomah (2016) found that the using of some organic (Charcoal) and inorganic (Silica gel, Cement Bypass and Rock phosphate) materials reduced the DTPA extractable Cd, Ni and Pb from 0.895, 12.097 and 26.02 $mgkg^{-1}$ in the control treatment to 0.376, 3.13 and 9.06 mg kg^{-1}, respectively. Cadmium is evidently found in soils at concentrations 0.1 – 1 mg/kg (Alloway, 2013). Alternatively, Aydenalp and Gresser (2003) determined that the total Cd level in soils on calcareous material (marl materials) ranged from 0.23 to 0.51 mg/kg in Turkey and DTPA extractable Cd varied from 0.04 to 0.08 mg/kg.

Nickel concentrations in soils varies widely and were determined to range from 3.00 to 1000 mg/kg for the world soils, the range is among 0.2 and 450 mg/kg, while the mean is calculated as 22 mg/kg (Kabata Pendias and Pendias, 1992; Cempel and Nikel 2005; Bencko 1983 and Scott-Fordsmand, 1997). Duke (1980) stated a mean attention of 86 mg/kg for the natural nickel content material in the earth crust. Values representing the pollution of nickel in rural soils of the world for various countries have been mentioned through Chen et al. (1996) as: Australia (60 mg/kg), Canada (150 mg/kg), China (20 mg/kg), France (50 mg/kg), Germany (200 mg/kg), Japan (100 mg/kg) Netherlands (210 mg/kg), South Africa (15 mg/kg), United Kingdom (60 mg/kg), and USA (420 mg/kg).

*Corressponding author:E-mail:haa01@fayoum.edu.eg
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Lead is naturally found in earth crust, though in most regions at fairly low ranges. The US Geological survey has determined naturally lead in soil to have a national suggest of 16 mg/kg (Shacklette and Boerngen 1984). Lead present as air pollutants from motor exhausts (vehicle and aircraft) in addition to mining and commercial resources (Bogdanov 2005; Markus and McBratney 2001), and it is set at No. 2 on the complete environmental response, compensation, and legal responsibility act priorities list of risky substances (US EPA, CERCLA 2011).

Osama and Atef (2020) used products of sugarcane such as perssmud, bagasse and molasse to remediate of heavy metals contaminated soils near some industrial sites at Qena Governorate, Egypt. They found that the addition of bagasse was more effective in remediation of heavy metals contaminated soils than other treatments.

Sweed (2019) found that in loamy sand soil filter cake had more ability to adsorption of both Copper and Nickel compared with vinasse as shaking intervals increased and the highest adsorbed amount was 4.72 mgg^{-1} for Ni with soil treatment of filter cake.

The present work was performed to determine the Cd, Ni and Pb concentration and make geographical distribution maps for three metals within soils of Sinnours district, Fayoum Governorate, Egypt.

Materials and Methods

Sinnours district located in the northern east of Fayoum Depression. one hundred twelve soil samples were taken from fifty-six locations to represent Sinnours lands using the grid system at tow km distance. Locations of investigated areas are shown in Fig. 1. Two samples were collected from each location: the first from the surface soil layer (0 – 30 cm) and the second taken from the subsurface soil layer (30– 60 cm). Collected samples were to air dried, gently ground to pass a 2 mm sieve and stored in plastic bottles. Soil samples were analyzed for total and available cadmium, lead and nickel. Available forms of Cd, Ni and Pb in soil were extracted using DTPA solution at pH 7.3 according to Soltanpour (1985) and measured using Atomic Absorption Spectrophotometer (AAS). Soil total content of three elements were determined in HNO_3 – HCl digests using Inductively Coupled Plasma (ICP) according to USDA, Soil Survey Lab Manual (2004).

Mapping

Samples locations were defined using global positioning systems (GPS) model GERMAN. Maps representing results obtained were created using integrated land and water information system (ILWIS) software following several steps. Firstly, topographic map was digitized to create raster map, then geo-reference and coordinate system were created. The next step was created table contain all of coordinates and results obtained, then each of result in table converted to point map. Point map was converted to raster map through interpolation and moving average. The produced raster map was converted to polygon map to define the map parts representing every element level. Finally, layout for each polygon map was created.

Results and Discussion

Distribution of heavy metals in Sinnours district soils

Total cadmium

The concentrations and distribution of Cd in the surface layer (0-30 cm) and subsurface layer (30-60cm) of Sinnours soils are showed in Table 1 and Fig. 2 (a, b respectively). Total Cd levels within the surface layer of Sinnours soils ranged between 0.20 and 0.128 mg/kg with an average of 0.189 mg/kg. Equivalent levels for the subsurface layers were ranged between 0.020 and 0.056 mg/kg with a mean value of 0.135 mg/kg soil. The general mean level of the upper 60 cm layer changed into 0.162 mg/kg.

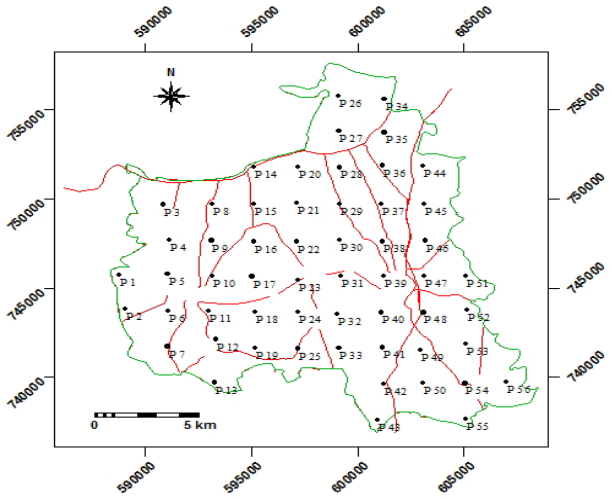

Fig. 1. Location of investigation sites samples collected from Sinnours District area

TABLE 1. Distribution of Soil total and DTPA-extractable Cd concentrations within Sinnours District area, Fayoum Governorate

Heavy metal	Distribution level (mg kg^{-1})	Area (ha)	% of district area
Total Cd	0.16 – 0.29	21256.07	91.09
	0.30 – 0.39	1003.80	4.30
	0.40 – 0.79	679.14	2.91
	0.80 – 1.28	400.54	1.70
DTPA Extractable Cd	0.002 – 0.02	22805.16	98.00
	0.021 – 0.025	410.33	1.70
	0.025 – 0.05	59.6	0.10
	0.076 – 0.092	41.86	0.10
	0.05 – 0.075	22.40	0.10

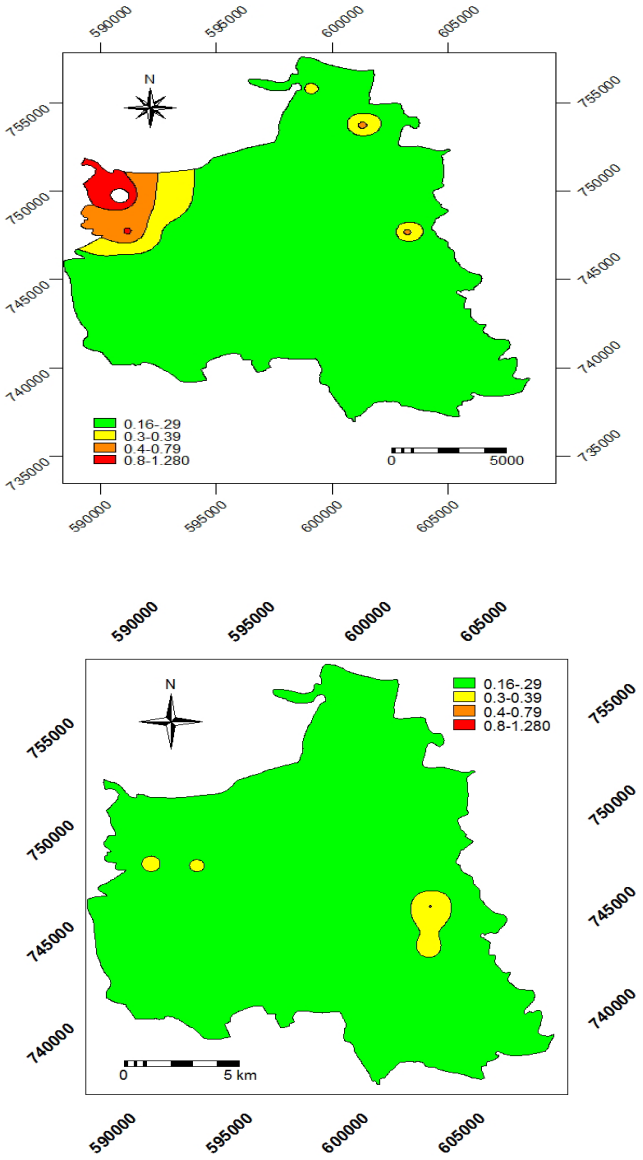

Fig. 2. spatial Distribution of total Cd levels in mg/kg within the 0-30 (a) and 30-60 (b) cm layers of Sinnours District soils

Based on the results of numerous investigators, Lindsay (1979) reported that the suggest Cd content is 0.2 mg/kg in the earth crust and varied between 0.01-0.7 with overall mean of 0.06 mg/kg in soils of the allover the world. Data of the present work indicated that the mean of total Cd in the surface 30 cm was 0.189 mg/kg which was higher than that of the world soils. The total Cd concentration in more than 98% of the studied area lies within the world soils range. The distribution and levels of total Cd for complete area of Sinnours soils as diagnosed using the geographic information system (GIS) and mapped with the ILWIS application is showed in Table 1 and Fig. 2 (a and b respectively).

According to the Dutch rules as stated through Chen (2000), 2 parameters are used for the assessment of soil pollution with Cd: the first is the target degree (0.8 mg/kg) or "A-value" which represents the normal level of the metal above which the soil is taken into consideration polluted and the second one is the cleanup level or "C-value" (12.0 mg/kg) at which the soil is taken into consideration polluted and have to be remediated.

Additionally, Chen (2000) stated that the advanced Taiwan system relies upon on 3 parameters for assessing the status of soil contamination with heavy metals: A-level (the permissible limit), B-level (the marginal stage) and C-level at which the soil have to be remediated, those values for total Cd contents of soil are 2, 4 and 5 mg/kg soil respectively. In line with the Fenland and Denmark requirements about 9% of Sinnours district soils might be taken into consideration Cd-polluted. Based on the Netherlands limits and the standards of some different advanced nations approximately 2% of Sinnours district soils are taken into consideration polluted with cadmium. According to the Taiwan requirements approximately 100% of soils can be evaluated as uncontaminated with cadmium. It's worthy to say on this appreciate that Egypt until now doesn't have authorized standards for heavy metals limits of soil pollution. The exceeded levels of cadmium in some soils of Sinnours district in the surface in comparison with the subsoil layer may be originated from atmospheric deposition, their richness in lime and/or shale, carried out industrial chemical fertilizers, pesticides, manures and/or the use of Nile water combined with drainage water in a few areas.

Available form of cadmium

Distribution of DTPA-extractable Cd concentrations in both the upper and lower layers for Sinnours district is showed in a map (Fig. 3 a and b) and Table 1. The mean values of DTPA-extractable Cd had been 0.018 mg/kg within the surface layer and 0.017 mg/kg in soil subsurface layer. Research of Abdurrahman (2012) on some Fayoum soils showed that DTPA – extractable Cd status at which 10% reduction of barley dry material yield occurred is nearly 0.11 mg/kg and the average DTPA – extractable Cd level at which 50% reduction in barley dry material yield took place is ready 0.32 mg/kg. In evaluating the received consequences of the prevailing work with Abdurrahman (2012) findings for DTPA-extractable Cd concentrations it may be visible that the majority of Sinnours soils are under the Cd-critical restrict related to 10% reduction in barley dry weight.

The general mean of total and DTPA-extractable Cd had been calculated. Data showed in Fig. 4 and 5 indicated that Cd mean concentration within the upper 30 cm soil is more than that of the lower one (30 – 60 cm). This indicated feasible Cd pollution of top soil probably because of the heavy application of chemical fertilizers especially superphosphate and/or polluted irrigation water with drainage and municipal wastes in the studied place. Abdel-Kader et al. (2013) found that cement was the more effective in reducing DTPA-Cd by 60% as comparing with the un-treated soils after one year of soil treatment.

Total content of Pb

The levels and distribution of total Pb in the upper 30 cm and the lower 30-60 cm layers of Sinnours soils are showed in maps (Fig. 6 a, b) and Table 2. Total Pb concentrations in the top layer of soils ranged from 8.64 to 52.48 with a mean value of 16.45 mg/kg. Analogous values for the lower layer ranged between 5.72 and 55.48 mg/kg with an average of 16.169 mg/kg. The general mean of the upper 60 cm changed into 17.13 mg/kg. The total contents of Pb in 71 samples collected from 14 saline sodic sites in alluvial soils ranged between 25 and a 100 mg/kg **(**El-Rashidi et al. 1997). Abdel-Shakour (1982) found a lesser level of lead (between 8 and 21 mg/kg) within the alluvial soils in Nile valley. For evaluation and assessment of lead concentrations in Sinnours soils, with side to the degree of pollution, acquired outcomes of the entire detail levels had been in comparison with global criteria and acceptable limits set by related establishments everywhere in the world.

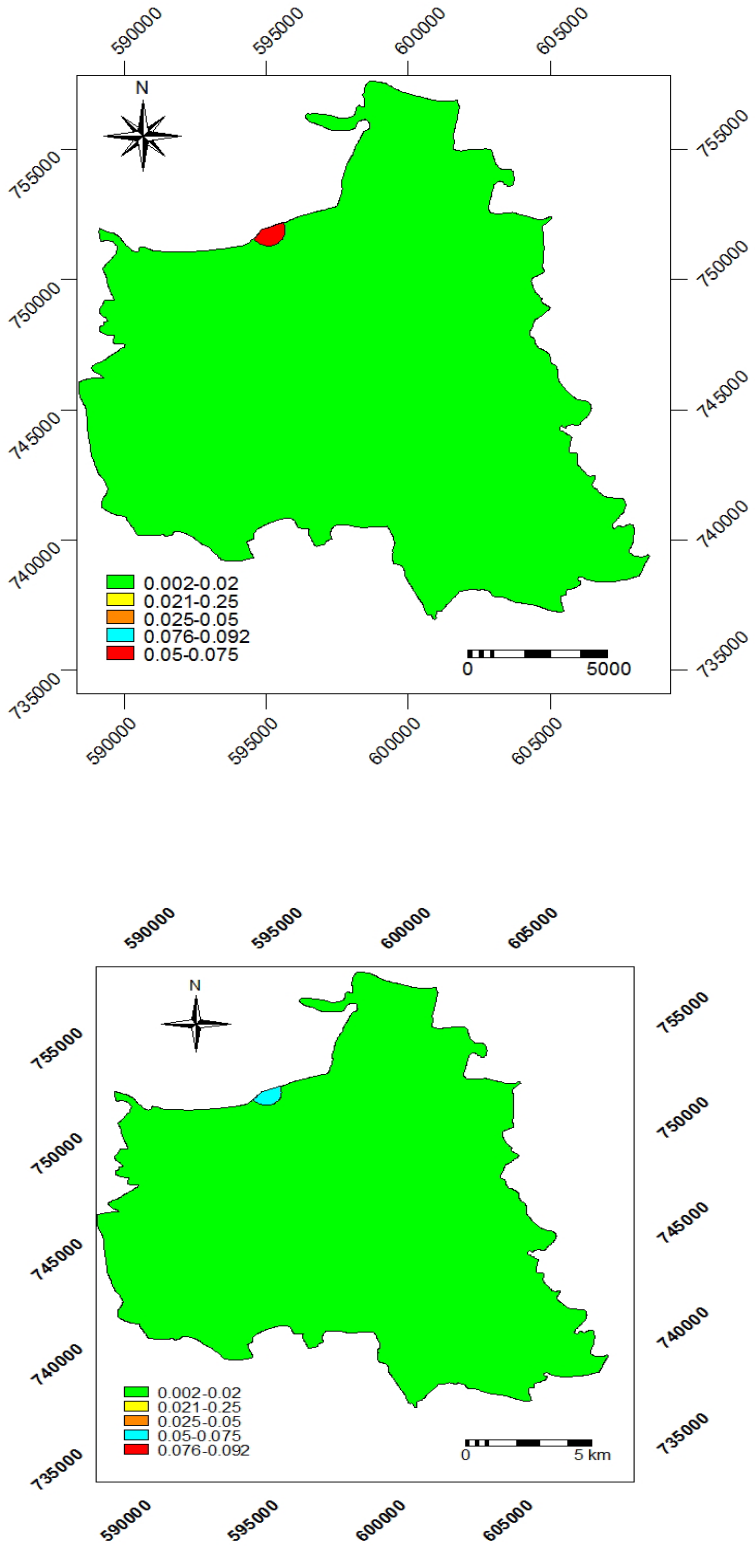

Fig. 3. Spatial Distribution of DTPA-extractable Cd levels in mg/kg within the 0 – 30 cm (a) and 30-60 cm (b) layers of Sinnours District soils

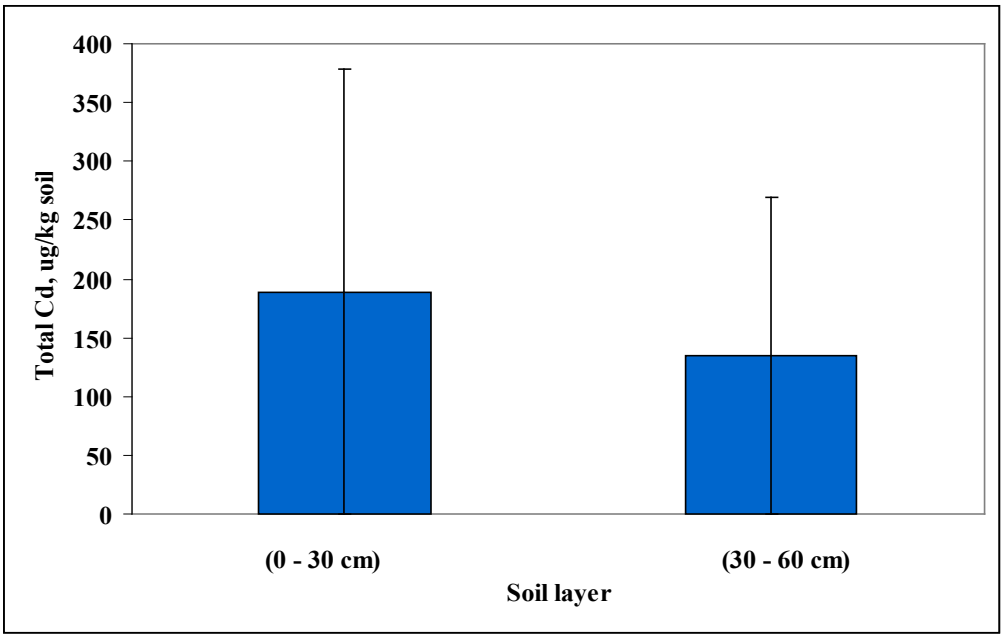

Fig. 4. General means of Total Cd in the studied soil layers

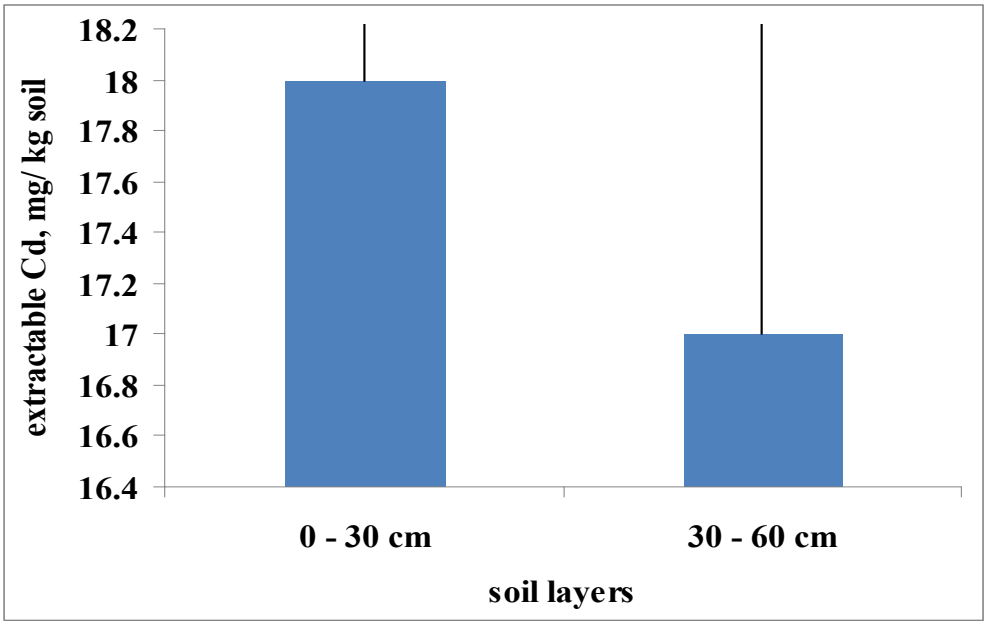

Fig. 5. General means of DTPA- extractable Cd in the studied soil Layers

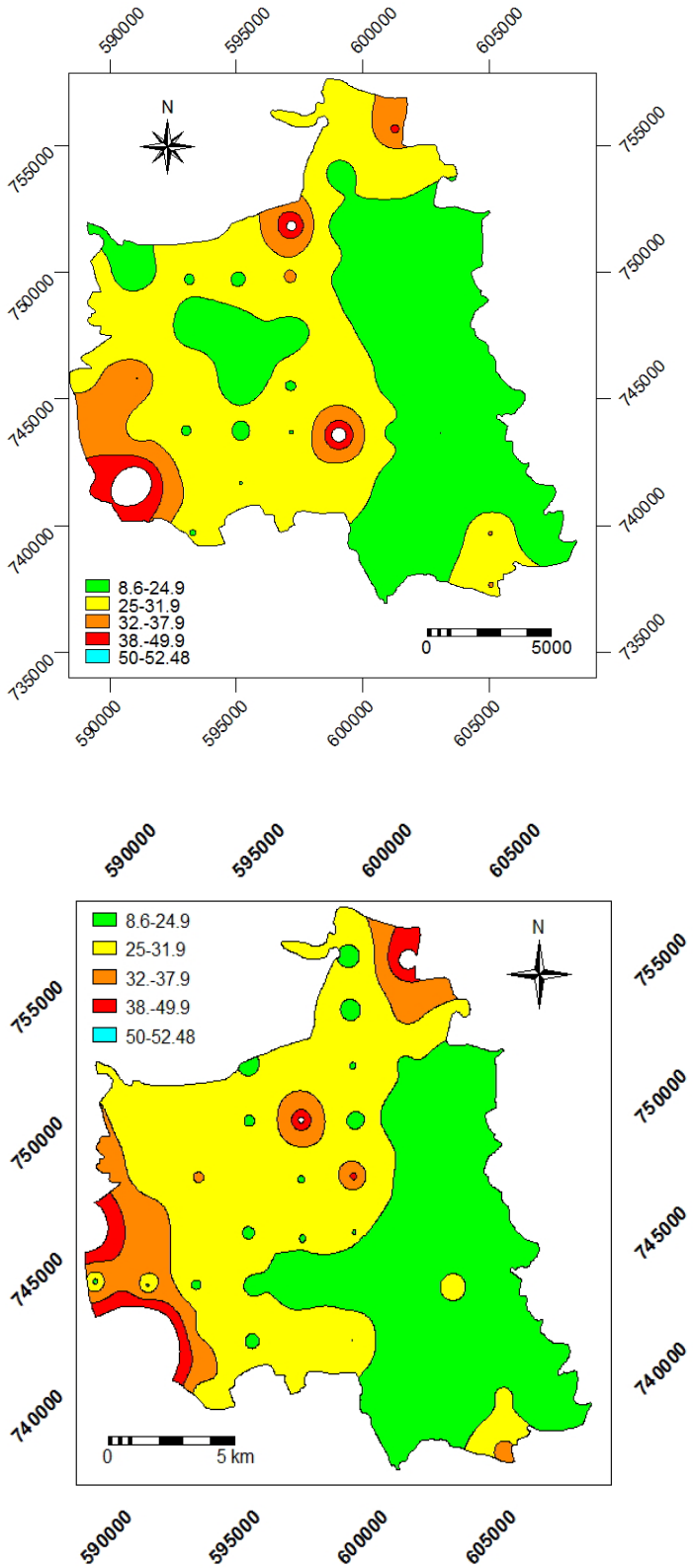

Fig. 6. Spatial distribution of total Pb levels in mg/kg within the 0 – 30 cm (a) and 30-60 cm (b) layers of Sinnours District soils

TABLE 2. Distribution of soil total and DTPA-extractable Pb concentrations within Sinnours District area, Fayoum Governorate

Heavy metal	Distribution level (mg kg^{-1})	Area (ha)	% of District area
Total Pb	8.6 – 24.9	10105.84	43.3
	25 – 31.9	10594.68	45.4
	32 – 37.9	1892.00	8.1
	38 – 49.9	747.03	3.2
DTPA Extractable Pb	0.1 – 0.5	1033.95	4.50
	0.51 – 1.0	6735.19	28.86
	1.1 – 1.5	8209.68	35.21
	1.51 – 2.36	7335.99	31.43

De-Vries and Bakker (1998) mentioned that the total contents of Pb consistent with ecological rules of developed international locations are 25, 32, 38, 40, 40, 100, 50, 70 and 85 mg/kg in Canada; Eastern Europe; Finland; Denmark; for clay soils and sandy soils in Germany; Switzerland; Ireland; Czech republic and Netherlands, respectively. In line with Canada standards approximately 2% of Sinnours district (approximately 562.38 hectare) carries more total Pb than the permissible limits and about 1% of the district soils (approximately 281,4 hectare) contain greater total Pb than the limit of a few other international together with Eastern Europe, Fenland and Denmark. In step with the Dutch standards as pronounced by way of Chen (2000), parameters are used for the assessment of soil contamination with Pb: the first is the target degree (85 mg/kg) or "A-level" which represents the natural value of the metal and the second is the cleanup level or "C-level" (530 mg/kg) at which the soil is considered contaminated and have to be remediated. Chen (2000) additionally said that the developed Taiwan standards depend on three parameters for assessing the level of soil contamination with Pb: A-level (the permissible limit 50 mg/kg soil), B-level (the marginal level 300 mg/kg) and C-value (500 mg/kg) at which the soil ought to be remediated. The levels of Pb all over the district soils are rather beneath each the permissible limits of the Netherlands (85 mg/kg) and the permissible-value limit of Taiwan (50 mg/kg). However approximately 10.6% of the studied district soils can be considered polluted with Pb according to the standards of some Eastern Europe countries (Russia, Ukraine, Moldavia and Belarus) and Canada because the Pb permissible limit is 32 and 25 mg/kg respectively. The suggest values of Pb total contents of soils had been typically more in the surface than the ones in the subsurface layer.

Available form of lead

Geographical distribution of extractable levels of lead (Pb) in soils of the studied area is provided in Figure 7 (a and b) and Table 2. DTPA extractable Pb concentrations had been usually greater in the higher than the ones of the subsurface layer. The suggest values of DTPA-extractable Pb had been 1.298 in the surface and 1.216 mg/kg within the subsurface layer. Hegazy (1993) stated that the amounts of Pb extracted by DTPA solution ranged from 2.0 to 4.6 mg/kg soil with a mean of 3.6 mg/kg in Helwan top soils (0- 15 cm) irrigated with industrial wastewater and from 0.8-1.8 mg/kg soil with a mean of 0.9 mg/kg soil (15-30 cm). The general average of total and DTPA- extractable Pb had been calculated and supplied in figures (12 and 13). Records indicated that both general and DTPA extractable Pb mean attention within the top 30 cm soil is greater than that of the subsurface (30 – 60 cm). This could suggest Pb pollution of the top soil probable because of the mobilization via visitors' emissions, the usage of high levels of chemical fertilizers in particular superphosphate, municipal wastes and/or irrigation using Nile water blended with drainage water.

Total nickel

The levels and spatial spreading of Ni concentrations within the upper (30 cm) and the lower (30-60cm) layers of the investigated area were presented in maps (Fig. 10 a, b) and table 3. General Ni concentrations within the upper layer ranged between 20.32 and 53.28 with an average of 40.44 mg/kg. Corresponding values for the subsurface layer have been from 21.88 to 59.12 mg/kg with an average of 43.55 mg/kg.

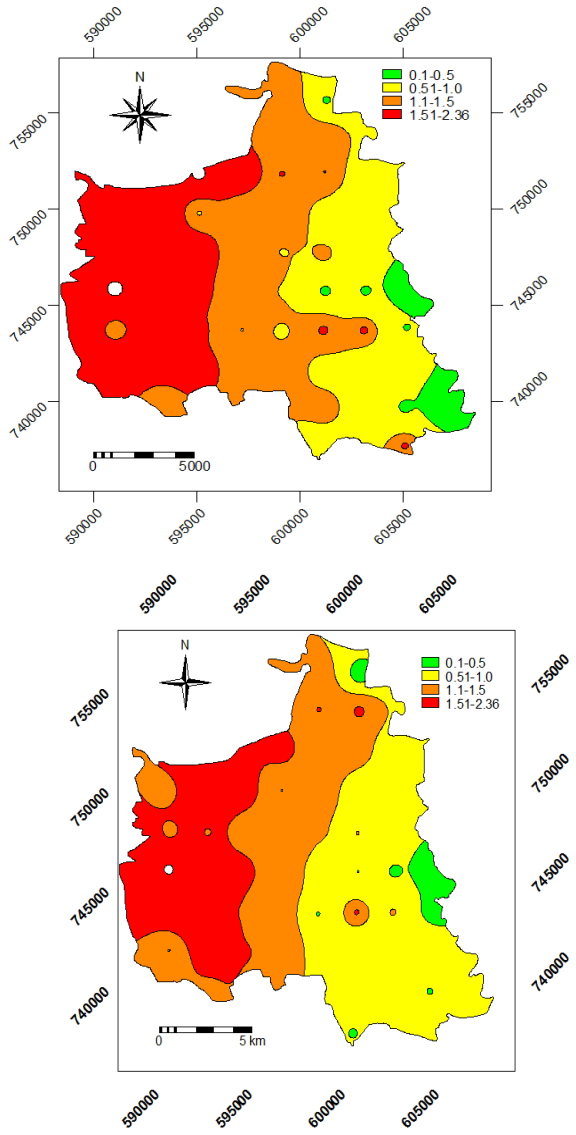

Fig. 7. Spatial Distribution of DTPA-extractable Pb levels in mg/kg within the 0 – 30 cm (a) and 30-60 cm (b) layers of Sinnours District soils

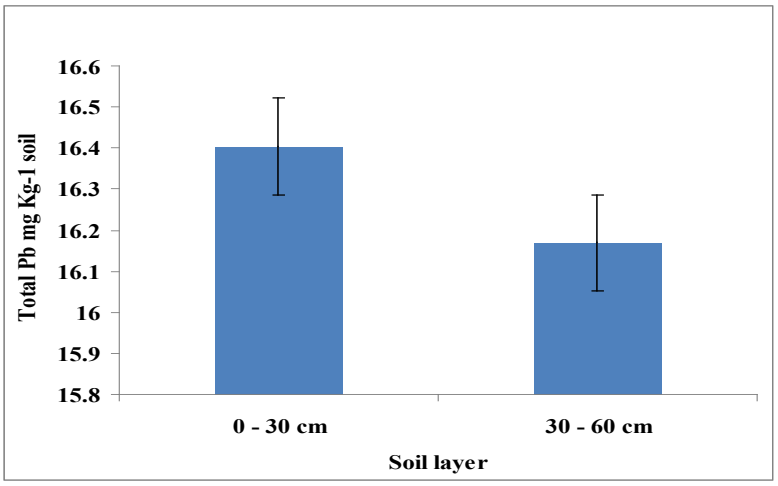

Fig. 8. General means of total Pb in the studied soil layers

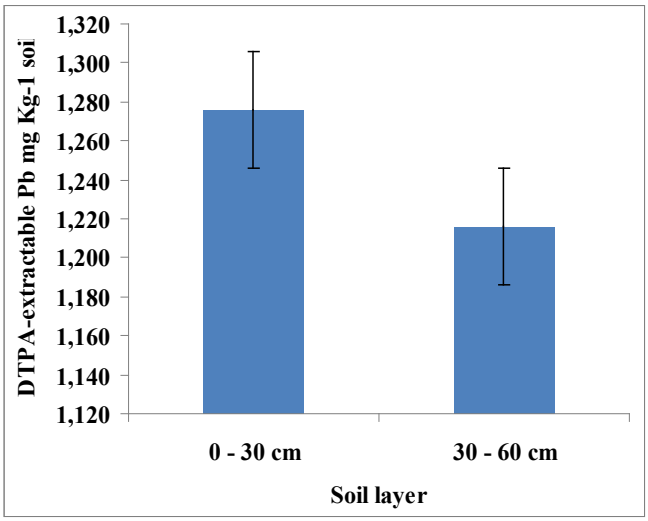

Fig. 9. General means of DTPA-extractable Pb in the studied soil layers.

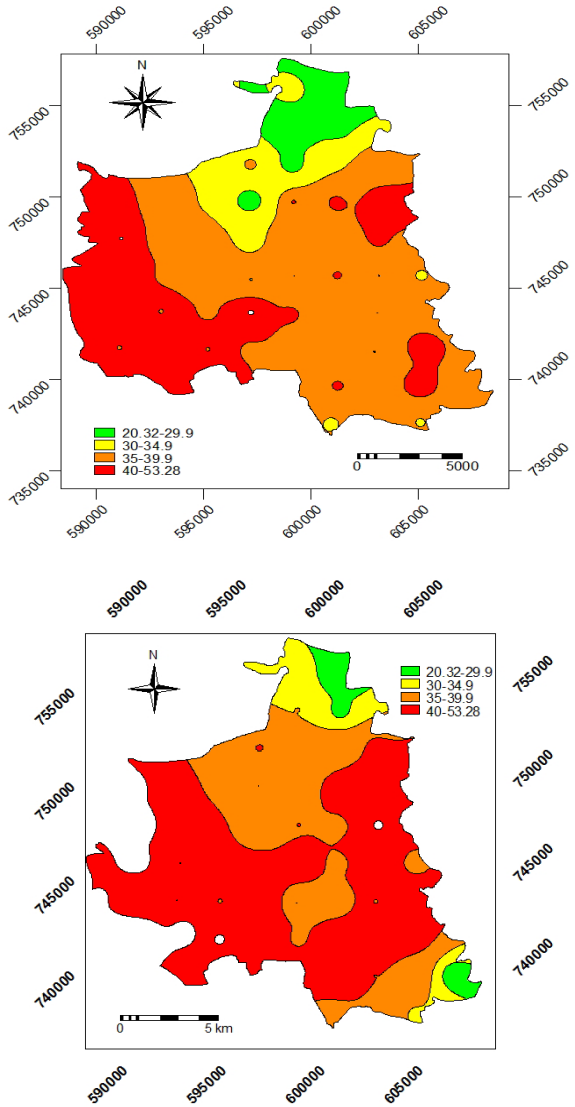

Fig. 10. Spatial distribution of total Ni levels in mg/kg within the 0 – 30 cm (a) and 30-60 (b) cm layers of Sinnours District soils

TABLE 3. Distribution of total and available forms of Ni in Sinnours soils, Fayoum Governorate

Heavy metal	Distribution level (mg kg^{-1})	Area (ha)	% of district area
Total Ni	20.32 – 29.90	1763.66	7.6
	30 – 34.9	2646.83	11.3
	35 – 39.90	11899.75	50.99
	40 – 53.28	7029.31	30.11
DTPA Extractable Ni	0.4 – 0.8	2238.45	9.6
	0.8 – 1.0	6668.97	28.5
	1.1 – 1.49	13369.86	57.3
	1.50 – 2.50	1062.16	4.6

The general mean of the 60 cm layer turned into 42.00 mg/kg soil. According to Lindsay (1979) the concentration of Ni is 100.00 mg/kg in the earth crust and varied among 5 to 500 with a general mean of 40 mg/kg in world soils. Facts of the present examine indicated that the mean of total Ni concentrations in Sinnours soils is somewhat similar to that of worldwide soils. The suggested total concentrations of nickel in rural soils of a few nations had been were 15, 20, 30, 30, 80 , 50, 60, 75, 100, 120, 150, 200, 300, 210 and 420 mg/kg for South Africa; China; Sweden and Denmark; Norway before and after the usage of sewage sludge; France; Australia; Italy; Belgium; Taiwan; Canada; Germany; UK; and United States of America before and after using sewage sludge respectively (Chen et al., 1996). According to the Dutch standards as suggested through Chen (2000)**,** two parameters are used for the assessment of soil pollution with Ni: the first is the target or "A-level" (35 mg/kg) which represents the ordinary level above which the soil is considered polluted with Ni and the second one is the cleanup level or "C-level" (210 mg/kg) at which soil is taken into consideration polluted and ought to be remediated. In this biases more than 80% of Sinnours district soils have greater Ni than the normal level but nonetheless past the cleanup limit. The Taiwan standards relies upon on three parameters for assessing the degree of soil pollution with Ni: A-level (the permissible limit, 30 mg/kg) B-level (the marginal degree, 60 mg/kg) and C-level (200 mg/kg) at which the soil need to be remediated Chen (2000). In evaluation with such Taiwan standards about 90% of Sinnours soils are taken into consideration Ni contaminated on the grounds that they'd > 30 mg/kg total Ni. According to Denmark and Canada standards (10 and 20 mg/kg respectively) all of the studied soils of Sinnours district could be considered Ni – contaminated. To addition of montmorillonite, $CaCO_3$ and humic acid minimize nickel content in some soils s. This reduction dependent on soil pH (Farid et al., 2013).

DTPA-extractable nickel

Geographical distribution of extractable Nickel concentrations in Sinnours soils are showed in figure 11 (a and b). DTPA extractable level of Ni ranged from 0.406 to 2.494 mg/kg within surface 30 cm layer with an average of 1.114 mg/kg. The concentrations in lower layer (30-60 cm) ranged from 0.30 to 2.43 mg/kg with an average of 1.13 mg/kg. The general mean of the upper 60 cm layer was 1.122 mg/kg. Studies of Rashad et al. (1995) confirmed that extractable Ni concentrations ranged between 0. 38 and 1.04 mg/kg with a mean of 0.66 mg/kg in alluvial soils of Nile valley, though in coastal sandy soils Ni concentrations ranged between 0.2 and 0.4 with a mean of 0.31 mg/kg. The general manner of total and DTPA- extractable Ni had been calculated and supplied in Fig. 12 and 13. Data showed that Ni average within the subsurface (30 – 60 cm) is extra than that of the upper 30 cm of soil. The extra total and extractable forms of Ni in Sinnours soils than acceptable limits for most of the world countries can be because of the richness of soil parent material in Ni aside from the environmental pollution by way of human activities. The overall ratios of DTPA-extractable metals to their overall contents were determined to be 12.6, 7. 5 and 2.6% for Cd, Pb and Ni, respectively.

Conclusion

From data of the present work it is able to be detected that total and DTPA- extractable Cd and Pb have been high in the top soil layer comparison with the subsurface soil layer. Alternatively, total and DTPA extractable Ni concentrations had been higher in subsurface than surface layer. Those outcomes may additionally lead to the assumption that soil surface of the investigated soils has been exposed to pollutants of Cd and

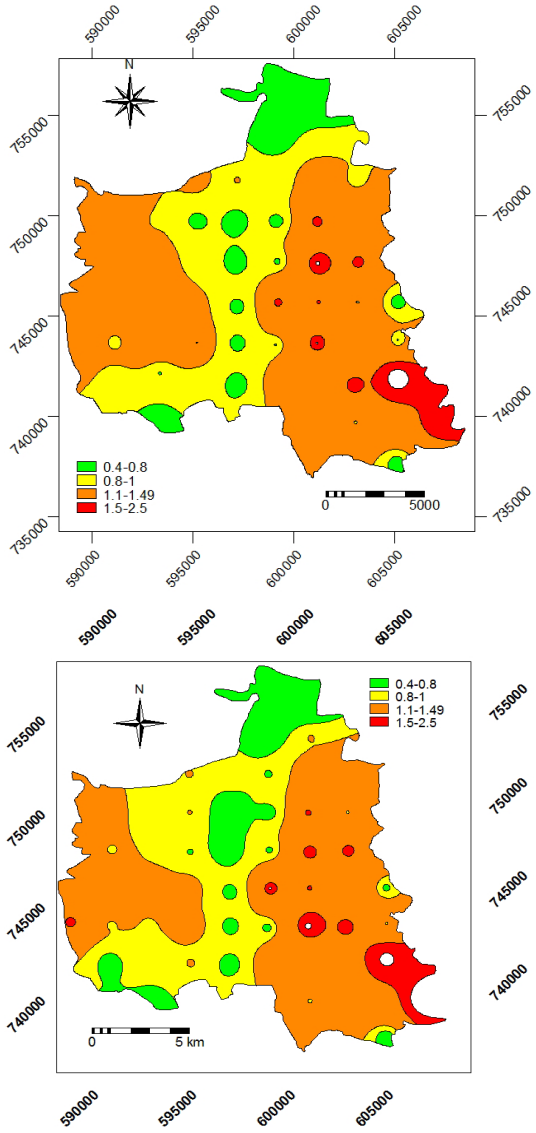

Fig. 11. Spatial Distribution of DTPA-extractable Ni levels in mg/kg within the 0 – 30 cm (a) and 30-60 cm (b) layers of Sinnours District soils

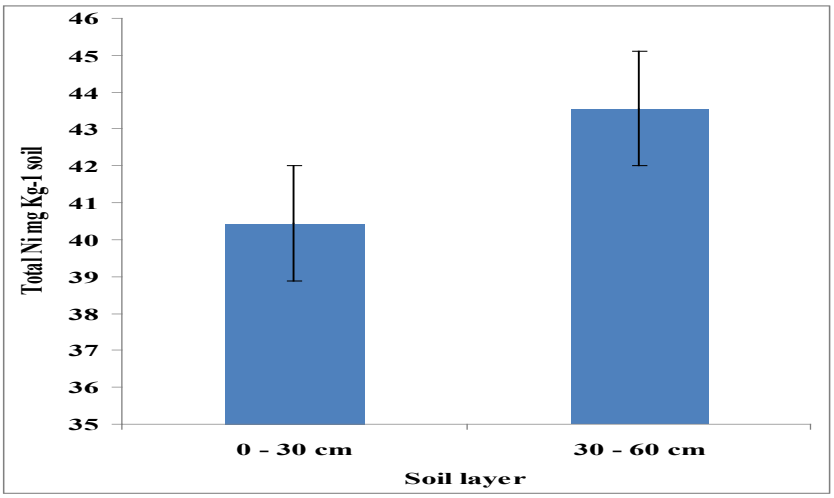

Fig. 12. General means of total Ni in the studied soil layers

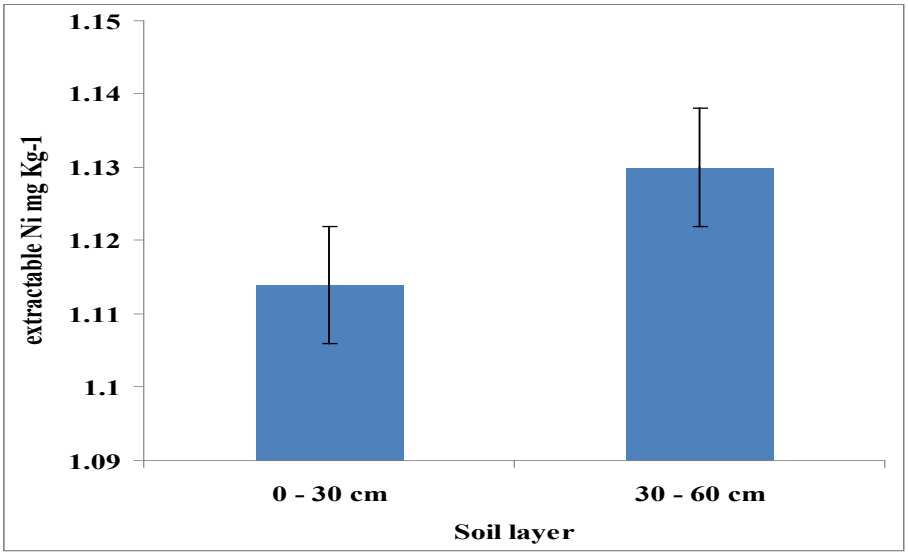

Fig. 13. General means of extractable Ni in the studied soil layers

Pb that can be originated from atmospheric deposition, excessive application of commercial chemical fertilizers (superphosphate mainly) and/or irrigation the usage of blended Nile with drainage water. It can be also concluded that soils of Sinnours district, Fayoum Governorate in Egypt are normally Ni polluted when we consider that subsoil had Ni content exceeded the higher layer and both contained more total Ni than limits of world countries standards. Similarly, studies paintings ought to be finished to identify the dominant Ni minerals in Sinnours district soils. The authors emphasize the actual need of Egypt to set particular standards for the assessment of soil contamination or pollution with heavy metals on basis of the nature and characteristics of Egyptian soils.

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التوزيع الجغرافي وتقدير الكادميوم والنيكل والرصاص في أراضي مركز سنورس محافظة الفيوم- مصر

تمت دراسة التوزيع المكاني للكادميوم والنيكل والرصاص في أراضي مركز سنورس – محافظة الفيوم – مصر، باتباع نظام شبكي على مسافة 2 كم. وقد بينت النتائج أن المتوسط العام لكل من الكادميوم والرصاص في الطبقة العليا (30 سم) كانت أعلى من نظيرتها في طبقة تحت التربة (30 -60 سم). بما يبين أن التلوث بالكادميوم والرصاص ربما يكون ناشئا عن الإفراط في إضافة الأسمدة الكيماوية خاصة السوبرفوسفات، والري بمياه ري نيلية عذبة مخلوطة بمياه الصرف في منطقة الدراسة. كما بينت النتائج أن تركيزات النيكل كانت أعلى في الطبقة تحت السطحية، بما يشير إلى أن التربة ملوثة طبيعيا بالنيكل، الذي يبدو أنه موجود في مادة أصل التربة. وتعتبر الخرائط المصممة باستخدام نظم المعلومات الجغرافية مفيدة لمتخذي القرار بشأن التخطيط لاستعمال الأرض وتقييم مستويات تلوث البيئة بالمعادن الخطرة والحفاظ عليها. ويؤكد الباحثون على غياب معايير مصرية مفصلة لتقييم حالة تلوث التربة بالعناصر الثقيلة تعتمد في الأساس على خواص وطبيعة الأراضي المصرية.