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# Mineralogical and geochemical studies on soils and Nile bottom sediments of Luxor–Aswan area, South Egypt

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## Abstract

**Background:** The geochemical studies on the rare earth elements to demonstrate sources of the toxic metals for soils and Nile sediments for Aswan area are seldom.

**Results:** Mineralogically, the studied soil agriculture samples consist mainly of quartz (42%), clay minerals (33%), plagioclase (20%) and magnesin-calcite (5%). Clay minerals are composed of montmorillonite as bentonite. The studied Nile sediments consist mainly of quartz (75%), clay minerals (15%), plagioclase (5%) and calcite (5%). Clay minerals are composed of calcian-montmorillonite (10%) and Kaolinite (5%). Geochemically, the chemical analytical techniques of the environment-sensitive elements, including Pb, Cd, As, Ni, Co, Cu, Cr, Zn, U and Th, have been performed for agricultural soils and sediments of Aswan–Luxor District to assess the geochemical characteristics of these elements and their impact on soil environmental and plant, as well as their provenance.

**Conclusions:** Average content of Cd was about 1.5-fold for the studied Nile sediments and slightly higher soil agriculture than (MPL). Pb and Cr average contents twofold of (MPL) for Nile sediments and Cr average of soil is represented 2.5-fold of (MPL). The average content of As, Cu, Co, Ni and U in both Nile sediments and cultivated soil in the studied area is lower than the maximum permissible limit (MPL). Average content of Pb, Zn and Cr was about 2, 2- and 2.5-fold, respectively, according to USPHS for the Nile sediments and threefold of Cr for the agriculture soils. The agricultural soil of Luxor–Aswan district is characteristic highly enrichment of As, Co, Zn, Cu, Ni, Mn, U and Th than those of the Nile sediments. In addition, the Nile sediments have high concentration average of Cr, Zn, Mn and Pb and low contamination of the other elements. The sources of the toxic metals in the studied area may probably be natural or anthropogenic. The anthropogenic source is resulting from paper, Ferrosilicon factories and Phosphate mines at Edfu, as well as Sand quarry, Shale mine and the Nitrogen Fertilizer factory at Aswan. In addition, natural sources such as waste of the drains floods.

**Keywords:** Soil, Sediments, Toxic metals, Luxor, Aswan

## Background

The sediments of River Nile have different source rocks: igneous, metamorphic and sedimentary along the central and eastern parts of Africa in the south to the Mediterranean Sea in the north.

Historically, most of the agricultural soil in Aswan was deposited throughout the flood periods since Pharaonic period until the creation of two Aswan Dams (Old and High Dams). During the Nile flooding the sediments of fine, silt and clay were deposited on the both sides of the River Nile in Upper Egypt forming narrow strips of fields.

Construction of both Dams led to lack of Nile sediment deposition and natural soil fertility. Thus, all farmers used the chemical and organic fertilizers, fungicides and pesticides to grow and protect their crops. These materials

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affected on the agricultural soil which cause contamination and responsible for the concentration of heavy metals in the soil (Chun et al. 2011; Agca and Ozdel 2014). On the other hand, there are other anthropogenic sources could contribute trace elements in the environment; rural and urban sewage, waste disposal, atmospheric dust, traffic emissions, industry emissions and effluents, and local mining and quarry activities. Consequently, the pollution may be resulting from dust, erosion, chemical weathering or from decay of dead aquatic organisms. In addition, it may be derived from human action such as industrial and agricultural activities or from sewage and ship's wastes.

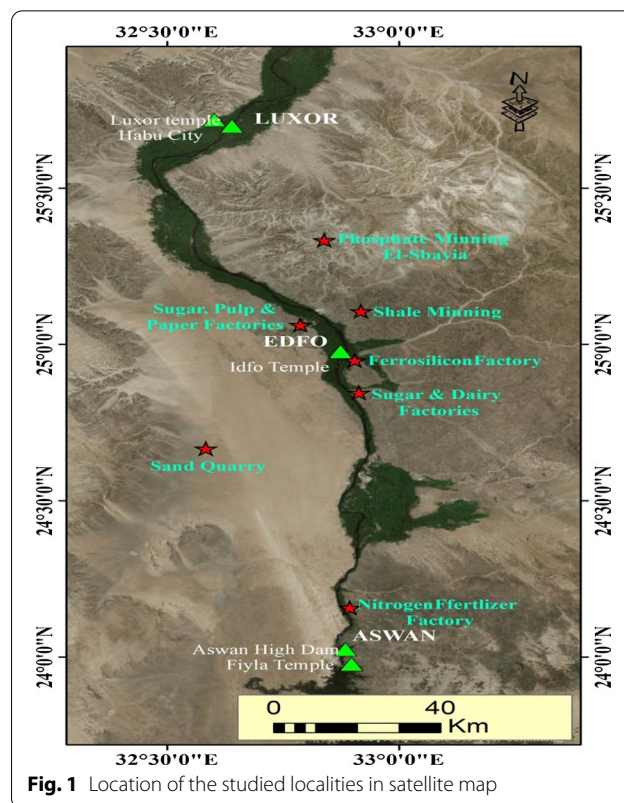
Really, enrichment or lack of some elements within rocks, soils or water may be responsible for various diseases in plants, animals and humans (Chun et al. 2011). Ni, Co, Cd, Pb and U elements are usually considered as potentially. Several types of pollution were found in the alluvial environment as organic materials as well as major and trace metals.

Abou El-Anwar (2019) mentioned that the Nile sediments were considerably ecological risk with Cd and Zn. In contrast, the cultivated soil was very high ecological risk with Cd. In addition, she concluded that Nile sediments and cultivated soils of the Luxor–Aswan district are unpolluted—moderately polluted, except, Zn considered as moderately polluted in cultivated soils.

Thus, the aim of this investigate is defined the geochemical characterization and evaluation of the cultivated soils and Nile sediments of (Luxor–Aswan District), Upper Egypt, located at latitude 23° 58' 40" to 25° 43' 9" N and long. 32° 50' to 33° S (Fig. 1). The study area is characterized by complex activities, including big industries such as cement chemical, fertilizers, detergents, Nitrogen Fertilizer factory at Aswan, the sugar and dairy factory at Kom Ombo and several other factories such as the sugar, pulp, paper, ferrosilicon and phosphate factories at Edfu, urbanization and agriculture. In addition, there is a main sewage station which used for irrigation of many crops. These studied can give information about the distribution and sources of the heavy metals in the studied area.

**Methods**

Bottom sediment samples were collected from the main Nile path between Luxor to Aswan District. Samples were essentially taken from the upper 90 cm of the Nile sediments at water depth ranging from 0.5 m. The cultivated soil samples were collected to represent the eastern and western flank of the Nile from 5 localities (Fig. 1). The samples were air-dried, ground, passed through 2-mm sieve and then oven-dried at 110° C for three hours. Each sample was ground to pass through a 63-micron sieve and homogenized for analysis. For the



**Fig. 1** Location of the studied localities in satellite map

determination of total metal concentration, exactly one gram of powdered soil sample was digested with aqua regia (HNO<sub>3</sub>:HCl = 1:3). The elements were determined in the extract by the atomic absorption.

**Result**

Mineralogically, the studied soil samples are consisting of montmorillonite, Kaolinite as clay minerals as well as quartz, plagioclase (20%) and magnesin-calcite. In contrast, bottom sediments are composed mainly of quartz, clay minerals (calcian-montmorillonite and Kaolinite), plagioclase and calcite. Chemically, the studied samples show some of heavy metals: As, Pb, Cr, Cd, Co, Zn, Cu, Ni, Mn, U and Th.

**Discussions**

**Mineralogical study**

Mineralogical constituents of the clay minerals and their physical properties are very important to the productivity of soil (Salman 2013; Deshmukh and Aher 2014). Clay minerals are so important to evaluate the magnitude of soil fertility (Miller and Donahue 1992). There are few studies carried on the mineralogical of the soil clay mineralogy. Salman (2013) and Asmoay (2017) pointed out that the prevailing of montmorillonite and kaolinite in the soils of Sohag and El Minya, respectively. Abou

El-Anwar et al. (2019a) mentioned that the clay minerals in the Assuit soils are composed of montmorillonite, vermiculite and illite in decreasing order abundance.

Generally, the studied soil of the Nile Valley comprises three main types: sandy silt, sandy clay and sandy. X-ray diffractometry (Fig. 2) revealed that the studied soil agriculture samples consist mainly of quartz (42%), clay minerals (33%), plagioclase (20%) and magnesian-calcite (5%). Clay minerals are composed of montmorillonite as smectite (25%) and Kaolinite (8%). The plagioclase represented by (20%) albite. The percentage of the clay minerals

content is relatively lower than the sand, but they play an important function in the exchangeable cations, which is necessary for plant nutrition.

In addition, X-ray diffraction of the studied Nile sediments showing that the samples consist mainly of quartz (75%), clay minerals (15%), plagioclase (5%) and calcite (5%). Clay minerals are composed of calcian-montmorillonite (10%) and Kaolinite (5%).

The investigated clay minerals show no specific pattern of distribution in the studied area. So, it may be originate from a common parent rock of sedimentary

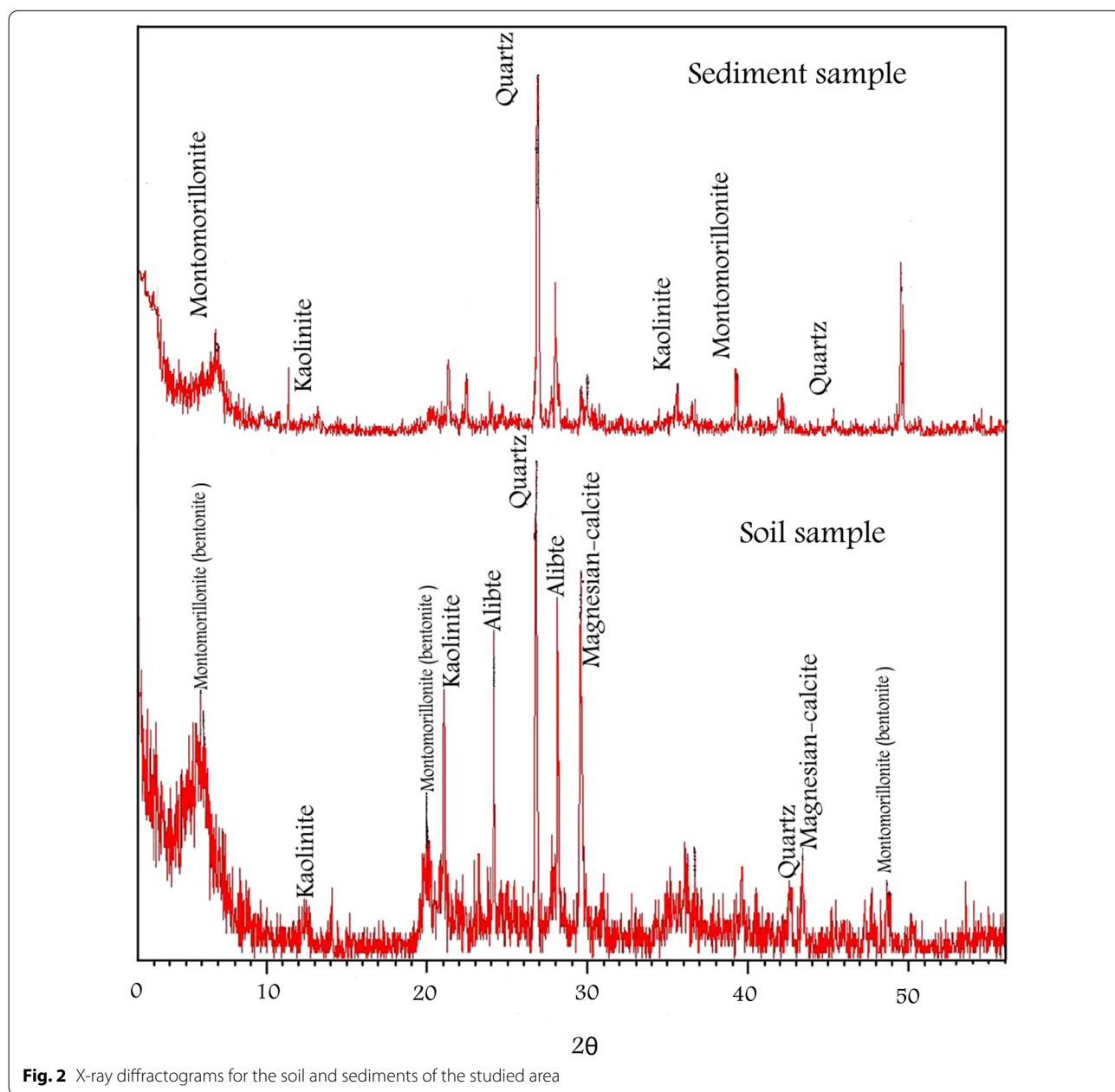


Fig. 2 X-ray diffractograms for the soil and sediments of the studied area

and metamorphic rocks. The presence of clay minerals, montmorillonite and kaolinite, in the studied agriculture soil samples revealed that they came from the river mud. Whereas, in marine mud, must have been the quantity of illite exceeds than of montmorillonite (Weaver 1989). Thus, the clay minerals in the studied soils may be derived from the old alluvial plain (Plio-Pleistocene sediments), which is in agreement with Abou El-Anwar et al. (2019a).

**Geochemical analysis**

The concentrations of the heavy and radioactive metals of the cultivated soil (Habu city, Edfu, High Dam and Philae), and Nile sediments (Luxor–Aswan district), at Upper Egypt are given in Table 1. Table 2 shows correlation matrix between them.

The average of the studied metals compared with those of the average earth’s crust, quoted by Rudnick and Gao (2014) and the freshwater sediments according to USPHS (1997), Table 3 and Fig. 3. This table shows that the average contents of Pb (41.05 ppm) in the studied Nile sediments are about 79 and twofold average of the earth’s

**Table 1** Chemical analysis data of the heavy and radioactive elements (ppm)

S. nos	Location		As	Pb	Cr	Cd	Co	Zn	Cu	Ni	Mn	U	Th
1	Luxor	Nile sediments	0.2	39.8	193.9	0.5	5.5	128.6	6.6	13.7	488.9	0.3	1.2
2			0.21	40.5	201	0.5	7.5	150	7.5	15.2	497	0.4	1.5
3			0.31	45.2	210	0.4	9.2	145	6.9	14.3	510.1	0.4	1.7
4	Aswan		0.01	42.7	15.6	0.8	15.4	72.2	8.7	15.9	2094	0.7	6.7
5			0.02	60.4	13.2	1.1	12.5	80.5	22	14.8	2140	0.8	7.5
6			1.3	17.7	25.7	1.4	15.6	105.3	10.7	19.5	1995	0.5	4.3
		Average	0.34	41.05	109.90	0.78	10.95	113.60	10.40	15.57	1287.50	0.52	3.82
7	Habu City	Agricultural soil	5.3	11.4	150.1	0.7	26.8	135.2	20.8	83.1	1129	0.6	6.1
8			5.6	13.4	160	0.8	30	140	25	90.5	1340	0.5	7.4
9			6.2	15.6	145	0.9	32	145	23	94.8	1546	0.55	6.8
10	Edfu		5.2	9.5	121.4	0.5	34.8	113.1	17.6	71.2	71.2	1.2	9.1
11	High Dam		0.02	9.1	131.1	0.3	28.6	373	16.3	14.9	1044.9	0.7	7.2
12		0.03	10.2	140	0.4	30.5	390	17.8	20.5	11,054	0.8	8.1	
13	Philae		0.04	15.1	150	0.4	35.2	410	12.5	23.3	380.5	0.6	8.5
		Average	3.20	12.04	142.51	0.57	31.13	243.76	19.00	56.90	2366.51	0.71	7.60

As, Pb, Cr, Cd, Co, Zn, Cu and Ni averages after Abou El-Anwar (2019)

**Table 2** The concentration of the elements in studied samples (ppm) compared with others

	As	Pb	Cr	Cd	Co	Zn	Cu	Ni	U	Th
Abou El-Anwar (2019): Nile Sediment	0.34	41.05	109.90	0.78	10.95	113.60	10.40	15.57	0.52	3.82
Abou El-Anwar (2019): Agr. Soil	3.20	12.04	142.51	0.57	31.13	243.76	19.00	56.90	0.71	7.6
UCC (Rudnick and Gao 2014)	4.8	0.52	92	9	17.3	67	28	47	2.7	10.5
Fresh Water sediments (USPHS 1997)		0	20	45	1	0	100	0	45	0
MPL (MPL (Kabata-Pendias 1995)		20	50	0.5	50	300	100	100	2.6	0

**Table 3** The concentration of the elements in soils for the studied localities (ppm)

	As	Pb	Cr	Cd	Co	Zn	Cu	Ni	Mn	U	Th
Habu City	5.7	13.5	151.7	0.8	29.6	140.1	22.9	89.5	1338.3	0.6	6.8
Edfu	5.2	9.5	121.4	0.5	34.8	113.1	17.6	71.2	71.2	1.2	9.1
High Dam	0.02	9.7	135.6	0.4	29.6	381.5	17.1	17.7	6049.5	0.8	7.7
Philae	0.04	15.1	150	0.4	35.2	410	12.5	23.3	380.5	0.6	8.5

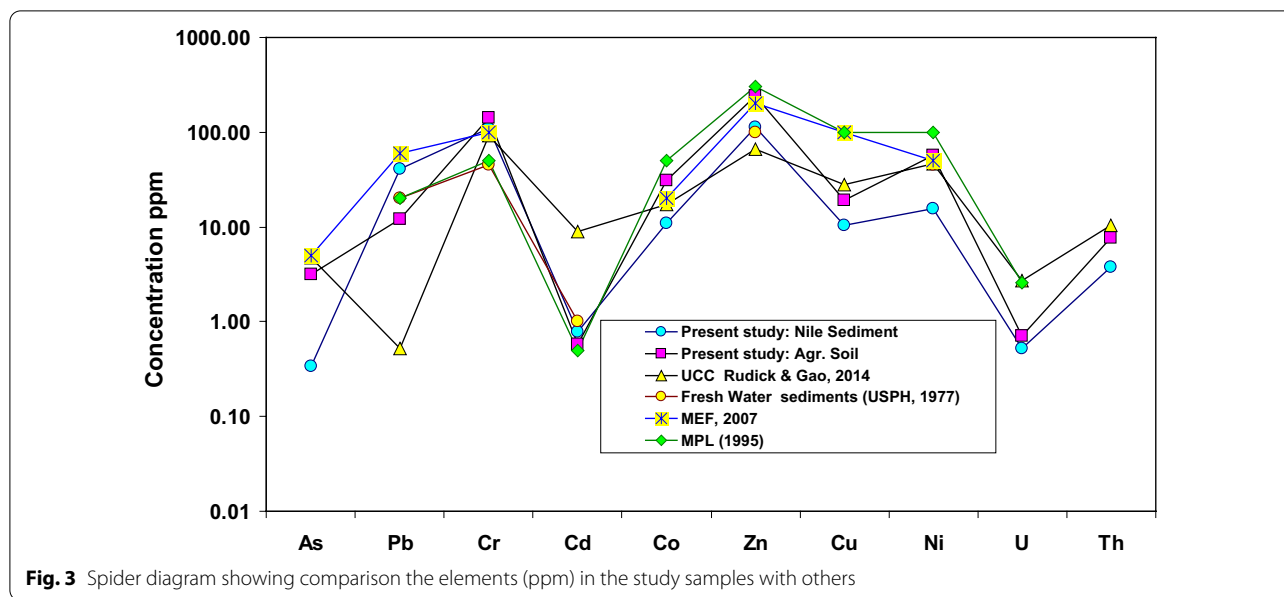


Fig. 3 Spider diagram showing comparison the elements (ppm) in the study samples with others

crust and freshwater sediments, respectively. Average of Zn is (~114 ppm) represented about twofold average of the earth’s crust and slightly higher than the freshwater sediments according to USPHS. Average content of Cr (~110 ppm) was represented about 2.5-fold than freshwater sediments and slightly higher than the UCC. In contrast, Cr content of the studied cultivated soil is about 1.5 and threefold the average of the UCC and USPHS, respectively. Average Zn (244 ppm) is equivalent to 4.5 and threefold the average of the UCC and USPHS, respectively. Average of Co and Ni is slightly higher than both.

**Distribution of potentially toxic metals**

Generally, the toxicity and mobility of metals in soils and sediments depend on their total concentration, specific chemical speciation and binding strength, the metal properties, environmental factors and its properties. In the present study, the Cd content ranges from 0.4 to 1.4 ppm, averaging 0.78 ppm for the Nile Sediment and ranges from 0.3 to 0.9 ppm averaging 0.57 ppm for the cultivate Soil (Table 1). Cd varies from 0.02 to 0.2 ppm in igneous and metamorphic rocks, while sedimentary rocks recorded from 0.1 to 25 ppm (Callahan et al. 1979). Kabata-Pendias (1995) indicated that the maximum permissible limit (MPL) of Cd in cultivated soil is 0.5 ppm (Table 2) and Fig. 3.

Average content of Cd was about 1.5-fold for the studied Nile sediments and slightly higher for soil agriculture than (MPL). Environmental Protection Agency (EPA) was set a limit of 5 ppb of cadmium for drinking water. So, the phosphate fertilizers and mining

phosphate may be possible source where Cd accumulates in the sugarcane crops growing along the riverbanks (Fig. 1). As well as, the fossil fuel ignition and some industrial activities may also contribute far more too human cadmium exposure. Thus, the Nile bottom sediments of Upper Egypt may be considerate as pollutant.

Pb is destructive to the human body. In the present work, the lead content of the Nile Sediment is ranging from 17.6 to 60.4 ppm and averaging 41 ppm, and ranging from 9.1 to 15.1 ppm, averaging 12 ppm for the cultivated soil. The highest values are recorded in the studied Nile Sediments of Aswan (60 ppm) near Aswan dam. This favors believe that the fertilizer factory may be the main possible causes of Pb pollution. MPL of Pb in the worldwide soils is 20 ppm; hence, the polluted areas are localized and restricted near the heavy traffic and arsenal near Aswan.

The studied samples recorded 110 and 143 ppm of Cr as average for sediments and soils, respectively. The highest values of Cr 210 and 160 ppm were recorded in Nile sediments and cultivated soil of Habu city for Luxor. These values are higher than the maximum permissible limit (MPL).

Generally, the average content of As, Cu, Co, Ni and U in both Nile sediments and cultivated soil in the studied area is lower than the maximum permissible limit (MPL) according to Kabata-Pendias (1995) and guideline values for metals in soils measured with Ministry of the Environment, Finland (2007). Pb and Cr average contents twofold of (MPL) for Nile sediments and Cr average of soil are represented 2.5-fold of (MPL).



**Natural radioactivity**

Uranium and thorium in the River Nile are most probably of local sources. They may be represented by the currently active Nile water/granitic rocks interaction at Aswan and the phosphate fertilizers used in the cultivated lands along the river banks.

Uranium ranges from 0.3 to 0.8 ppm, averaging 0.52 ppm for the studied sediments and from 0.5 to 0.8 ppm, averaging 0.71 ppm for the studied cultivated soils in the study area. Thus, these values are obviously lower than both of the averages quoted for Worldwide Marine Sediments (2.3 ppm) and average for the Upper Continental Crust (2.7 ppm) as quoted by Rudick and Gao, (2014). The highest values (0.8 ppm) are recorded for the Nile sediments and agriculture soils in Aswan near the Nitrogen fertilizer factory.

Thorium ranges from 1.2 to 7.5 ppm, averaging 3.8 ppm for the studied sediments and from 6.1 to 9.1 ppm, averaging 7.6 ppm for the studied agriculture soils in the study area, which lower than the averages of Worldwide Marine Sediments (12.9 ppm) and is comparable with the corresponding values of the World Rivers (Viers et al. 2009). The geochemical analysis indicates that the highest pollution of Th occurs near the shale mining North Aswan and Nitrogen fertilizer factory, (average 9 and 8.5 ppm) within Edfu and both Philae and High Dam soils, respectively. While the minimum value (~1.2 ppm) is recorded for the Nile sediments samples for Louxr of the northern part of the study area. Generally, Th content increases in the southern portion of the study area near Aswan.

**Comparison the study samples with others in lower Egypt**

The Nile sediments of Luxor–Aswan district are characteristic by high enrichment of Cr, Zn, Mn and Pb and low contamination of the other elements. Generally, the studied area has high concentration average of As, Co, Zn, Cu,

Ni, Mn, U and Th is recorded for the agriculture soils than those of the Nile sediments (Table 1). The agricultural soil of Aswan area is affected by high enrichment of Zn, Cr and Mn and moderate concentration of Ni, Co and Pd.

Habu City agriculture soil was highly enrichment in As, Cr, Cd, Ni and Cu (average 5.7, 151.7, 0.8, 89.5 and 22.9 ppm, respectively), which resulting mining in the Phosphate mine. The high average recorded of both Zn and Mn (381.5 and 6050 ppm, respectively) for the soils of the High Dam, Table 3 and Fig. 4. The agriculture soil of Philae is highly contaminated with Pb, Co and Zn (15.1, 35.2 and 410 ppm, respectively). So, the contamination of both Philae and High Dam soil may be resulting of the effect of the Nitrogen fertilizer factor in Aswan. However, Edfu soils recorded the highest values of U and Th (1.2 and 9.1 ppm, respectively), which may be attributed to shale mining and the ferrosilicon factory.

The studied Nile Sediments are lower in the average of Fe, Pb, Cr, Cd, Co, Zn, Cu and Ni than those of the Rosetta seedtimes (Abou El-Anwar et al. 2018) which indicated that the contamination of these elements increases from south to north of Egypt sediments Table 4 and Fig. 5. El-Kammar et al. (2009) recorded high percentage in Cd, Co, Cu, Ni, U and Th for Aswan sediments than those detriment of the studied sediments, thus may be indicated decrease these toxic elements during the ten years ago. All the average contents (expected Ni and Mn) of the studied toxic elements are higher than those recorded for the sediments of lack Nasser (Goher et al. 2014).

In contrast, the studied agriculture soils show high average content in As, Cr, Zn and Mn than those studied by Darwish and Pollmann (2015) for the agriculture soils of Aswan area; thus, it revealed that increase in these toxic elements during five years ago. Thus, it can be attributed to the shale and phosphate mines or possibly

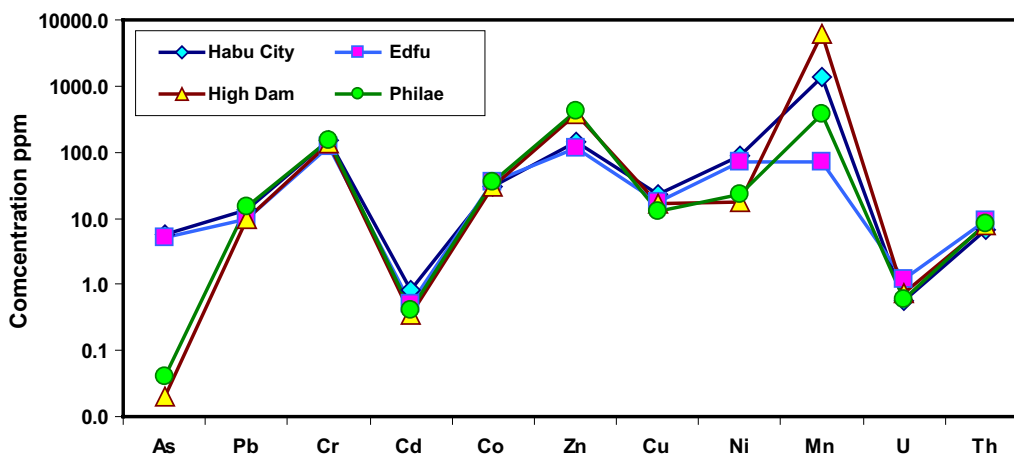
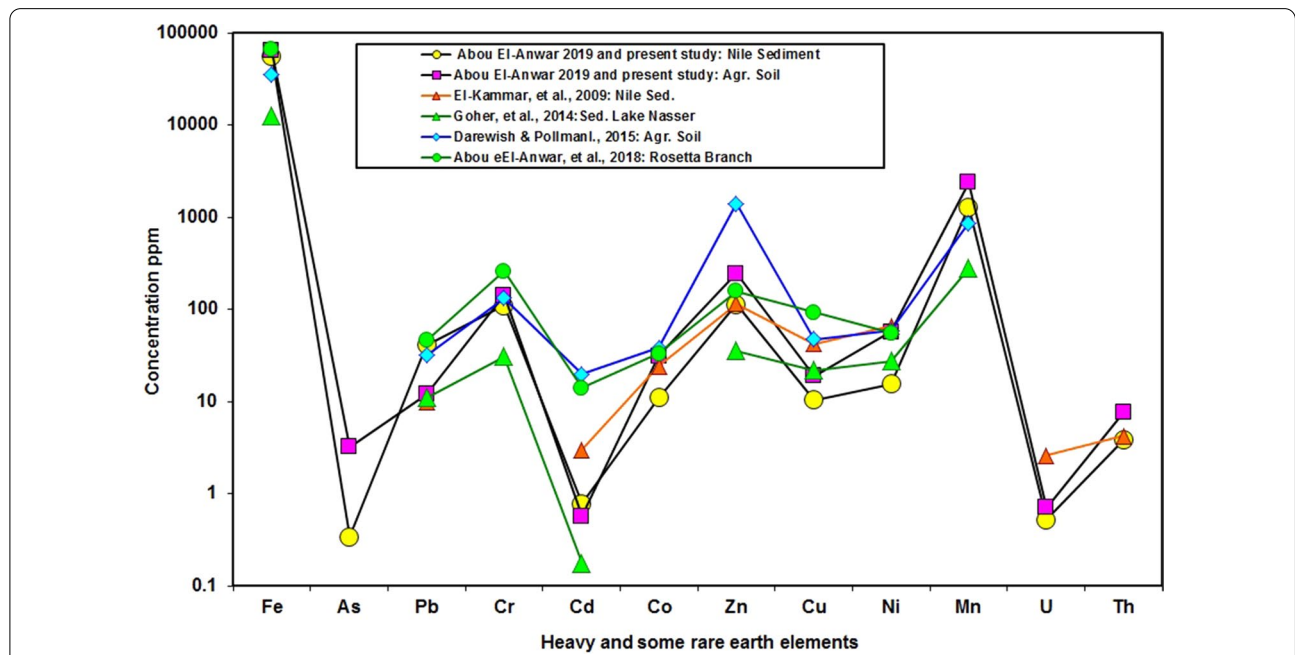


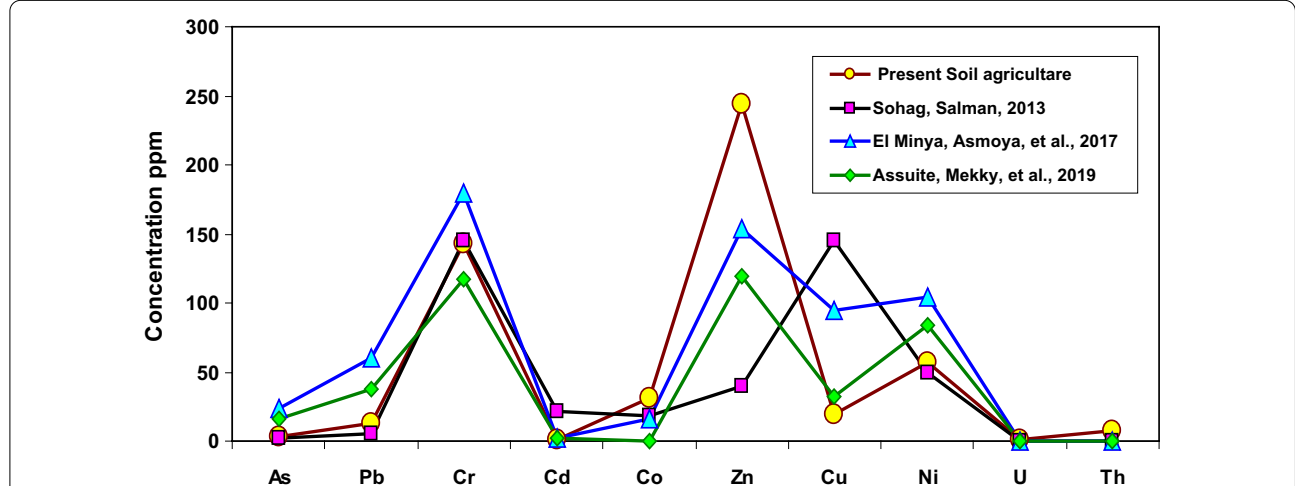
Fig. 4 Comparison the elements (ppm) in soils for the studied localities

**Table 4** The concentration of the elements in study area with others localities (ppm)

	Fe	As	Pb	Cr	Cd	Co	Zn	Cu	Ni	Mn	U	Th
Abou El-Anwar (2019): Nile Sediment	56,059.5	0.34	41.05	109.9	0.78	10.95	113.60	10.40	15.57	1287.5	0.52	3.82
Abou El-Anwar (2019): Agr. Soil	63,876.43	3.20	12.04	142.5	0.57	31.13	243.76	19.0	56.9	2366.5	0.71	7.6
El-Kammar, et al. (2009): Nile Sed	0	0	10	0	3	24	114	42	66	0	2.6	4.2
Goher et al. (2014): Sed. Lake Nasser	12,418	0	10.91	30.79	0.175	0	35.38	21.78	27.56	279.6	0	0
Darwish and Pollmann (2015): Agr. Soil	34,901	0	31.69	133.1	19.69	38.17	1390	47.2	58.19	858.1	0	0
Abou El-Anwar et al. (2018): Rosetta Branch	65,388	0	46	259	14	33	156	93	55	0	0	0



**Fig. 5** Comparison the elements (ppm) in the study area with others localities



**Fig. 6** Comparison the elements (ppm) in the study area with others localities in Upper Egypt

derived from phosphate fertilizers and pesticides, which agreement with Abou El-Anwar et al. (2019b).

While, comparison of the studied cultivated soils with other neighboring localities in Upper Egypt; Sohag, El Minya and Assiut Governorates (Salman 2013; Asmoay 2017; Abou El-Anwar et al. 2019a), indicated that the studied soil is generally decrease in pollution than other adjacent localities (Fig. 6). But, the concentration of Zn and Co is higher than Sohag and Assiut Governorates, respectively, which is agreement with Abou El-Anwar (2019) and Abou El-Anwar et al. (2019a) and Mekky et al. (2019) for the same area.

## Conclusions

Human activities and geogenic processes played important roles to enrichments and pollution of trace element in Nile sediments and agricultural soil for Luxor and Aswan District. Geochemical and mineralogical analyses have been performed to characterize the agriculture and Nile sediments of Egypt. They show small variation in mineralogical composition. The agricultural soil of Luxor and Aswan shows characteristic of high enrichment of As, Co, Zn, Cu, Ni, Mn, U and Th than those of the Nile sediments. In addition, the Nile sediments have high concentration average of Cr, Zn, Mn and Pb and low contamination of the other elements. Generally, the studied agriculture soil is lower in As, Pd, Cd and Cu than those of El Minya and Assiut, which indicated that increase in pollution from south to north direction of Egypt. Consequently, in the study area must be decreasing the sources of pollution from phosphate fertilizers and pesticides and using of them with carefully.

## Abbreviations

MPL: Maximum permissible limit; USPHS: United States Public Health; UCC: Upper continental crust.

## Acknowledgements

The author would like to thank The Geological Sciences Dept., National Research Centre for facilitates during this work.

## Authors' contributions

EA: collect the samples, prepared for chemical analyses, interpret the results and write and revise the manuscript. The author read and approved the final manuscript.

## Funding

Not applicable.

## Availability of data and materials

All data generated or analyzed during this study are included in this published article.

## Declarations

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

## Competing interests

The authors declare that they have no competing interests.

Received: 20 September 2020 Accepted: 7 June 2021

Published online: 13 June 2021

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