Sequential Extraction of Some Heavy Metals in Southwest Giza Soil, Egypt

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THE POLLUTION of agriculture soil in southwest Giza, Egypt with As, Cd, Pb and Cr were assessed by the application of Index of Geoaccumulation (I_{geo}) and five steps sequential extractions technique. The results indicated that the soils are muddy sand, alkaline (pH ≈ 8.3), calcareous ($CaCO_3$>5%) and have low organic matter (3.1%). Soil contains about 142.8, 1.7, 123.5 and 209.1 ppm of As, Cd, Pb and Cr, respectively. The I_{geo} indicated that the soils of the study area ranged from uncontaminated-moderately to extremely contaminated. The sequential extraction showed the incorporation of Pb and Cr in the residual fraction and the incorporation of As and Cd in the carbonate fraction. The exchangeable fraction contains 9, 7.9, 5.1 and 2.6% of As, Cd, Pb and Cr extracts, respectively. The environmental risk in the study area comes from the presence of 10.4 ppm As in the exchangeable fraction. The risk assessment code illustrated that Pb ranged from low to medium risk, Cr medium to high risk, As high to very high risk and Cd shows very high risk. These results reflect the mixed sources (geogenic and anthropogenic) of metals in the soil of the study area.

Keywords: Bioavailable, Giza, Egypt, Heavy metals, Anthropogenic, Sequential extraction, Soil pollution.

Introduction

The industrial, agriculture and transportation activities have an adverse effect on the water and soil quality. These activities release a high amount of chemical pollutants (especially heavy metals) into the environment. The accumulation of heavy metals in soil and water above their normal ranges adversely affect the health of biota. The toxicity, persistent and non-biodegradable characteristics of heavy metals make them one of the most serious and widespread environmental pollutants [1].

The total concentration of metals can't be used to predict the bioavailability, toxicity and distribution of them in the environment [2,3]. The heterogeneous composition of soil (minerals, salts, hydroxides, humus, liquids and gasses, etc.) not only determines its physical and chemical properties but also the binding mechanism of heavy metals and their occurrence forms in soil [4]. Therefore, the mobility and toxicity of metal are strongly dependent on its chemical form in soil

[5]. Metal availability to plants can be assessed by using selective extraction and chemical speciation. One of the first sequential extraction schemes is that proposed by Tessier et al. [6]. This scheme and its modifications [7-11], have been widely applied to distinguish between exchangeable, metal bound to carbonates, iron–manganese oxides or organic matter and residual metals in soils. In all of the sequential extraction schemes, the exchangeable fraction represents bioavailable part of metal to plants [12]. Water-soluble and exchangeable fractions are considered to be bioavailable; oxide-, carbonate-, and organic-matter-bound fractions may be potentially bioavailable, but the residual fraction is mainly not available to plants and microorganisms.

The study area represents a part of Giza Governorate and lies between longitudes 31° 13` 08`` and 31° 19` 53`` and latitudes 29° 46` 40`` and 29° 54` 00`` (Figure 1). This area is characterized by sedimentary rocks ranging in age from Eocene to Recent and arid climate. It is characterized

by complex human activities including big industries (Sugar industries, bricks factories, chemical industries and agricultural chemicals), several petrol stations, crowded traffic, touristic places, agriculture and urbanization. Such human activities had led to the pollution of water resources and soil with heavy metals at El-Minia, Egypt [13]. The sugar and chemical industries at Giza are one of the heaviest metals pollution sources of the Nile [14]. At the study area, Abu El Ella et al. [15] pointed out the role of human activity in the pollution of water resources with heavy metals. Unfortunately, the studied area has not received attention and lacks studies of soil pollution with heavy metals. Therefore, the current research aims to assess the soil pollution with As, Cd, Pb and Cr and to determine the degree of pollution with these metals through the application of sequential extraction protocol.

Material and Methods

Surface agricultural soil (15 cm depth) samples from 11 sampling sites were collected (Figure 1). After being air-dried, they were sieved through a 2mm sieve. Soil pH was measured in 1:1 soils to water ratio by using HANNA (HI93300) combined electrode. Calcium carbonate percentage ($CaCO_3$%) was estimated by the titrimetric method. Soil organic matter percentage (SOM %) was determined according to the modified Walkley and Black method [16]. The soil samples were dried at 110 °C for 3 hrs, then ground to pass through a 63-mesh sieve, and homogenized for analysis. For the determination of total metal concentration, exactly 1 g of powdered soil sample was digested with aqua regia ($1HNO_3$:3 HCl). The concentrations of As, Cd, Pb, and Cr were determined using atomic absorption spectroscopy (model AA 650).

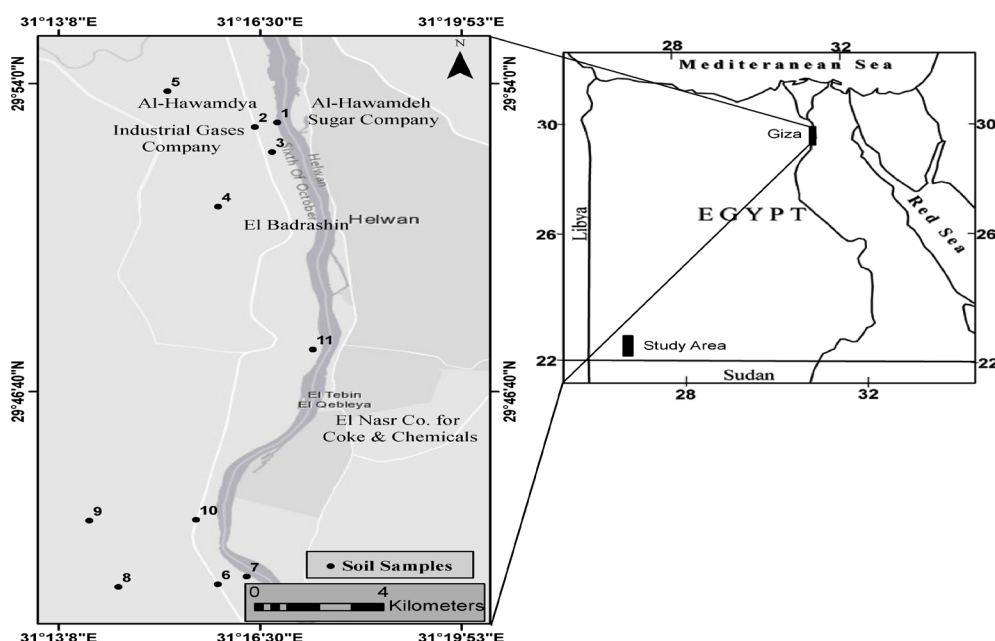**Fig.1. Location map of the study area and sampling sites.**

Index of geoaccumulation (I_{geo}) [17], was applied to assess the degree of soil pollution with heavy metals in this study. This method is used because it is a useful tool for the prediction of soil pollution and had been used by many authors as Sarkar et al. [1], Zheng et al. [18] and Milicevic et al. [19].

$$I_{geo} = Log_2 (C_m/1.5*B_m)$$

Where C_m is the measured concentration of the examined metal (m) in the soil samples and B_m

is the geochemical background value of the same metal (m). The constant 1.5 is used for the possible variations of the background data due to the lithogenic effects. The background reference in this study is based on the world soil average abundance of metals (Pb=25, Cd=0.5 and Cr= 54 ppm) [4] and As=5 [20]. The following seven grades of the I_{geo} are distinguished [17]:-

Grade	Value	Soil quality
1	$I_{geo} \leq 0$	uncontaminated
2	$0 < I_{geo} < 1$	uncontaminated to moderately contaminated
3	$1 < I_{geo} < 2$	moderately contaminated
4	$2 < I_{geo} < 3$	moderately to strongly contaminated
5	$3 < I_{geo} < 4$	strongly contaminated
6	$4 < I_{geo} < 5$	strongly to extremely contaminated
7	$I_{geo} > 5$	extremely contaminated

In this study, we used the modified scheme of Tessier et al. [6] adapted from Gleyzes et al. [21] and Phuong [11], as the following:-

1. Exchangeable fraction (**F1**): 1 g of soil was attacked by 25 mL of 1 M CH_3COONH_4 at pH of 7 in 50 mL centrifugation tubes for 1 h at room temperature with continuous shaking. **Sample collecting:** then the mixture was centrifuged for 20 min at 4500 rpm. The supernatant was decanted and filtered through 0.45 μm membrane filters. The solid residue was rinsed with 10 mL deionized water, centrifuged and then discards the rinse before the next extraction reagent is added.

2. Carbonate fraction (**F2**): The residue from (1) was extracted with 25 mL of 1 M CH_3COONa adjusted to pH 5 with CH_3COOH. The experiment was allowed to continue for 4 h at room temperature. **Sample collecting:** same as the fraction (1).

3. Fraction bound to amorphous and poorly crystalline Fe and Mn hydroxides (**F3**): The residue from (3) was extracted with 25 mL of 0.04 M hydroxylamine hydrochloride ($NH_2OH.HCl$) in 25 % v/v acetic acid at pH 3. The experiment was allowed to shake for 6 h at 80 °C. **Sample collecting:** same as the fraction (1).

4. Organic matter and sulfide fraction (**F4**): For the residue from (2), 25 mL of 30% H_2O_2 adjusted to pH 2 with HNO_3 was added. The mixture was extracted at 35°C for 3 h. **Sample collecting:** same as the fraction (1).

5. Residual fraction (**F5**): The residue from (4) was decomposed with a mixture of strong acid 3 ml of HCl, 5 mL of concentrated HNO_3 and 25 mL of concentrated HF. The solution was heated about 150 – 180°C on a hot plate for 2 days. Then evaporate the solution at about 250°C until nearly dry. Finally, the residue was dissolved in 5 mL of 6 M HCl and made up to 50 mL with distilled water.

All the filtrates collected were acidified with HCl prior to elements determination using atomic absorption spectroscopy (model AA 650).

Results and Discussion

General characteristics

The measured parameters of the collected soil samples were listed in Table (1). The pH values varied from 8.1 to 8.5, indicating the alkalinity of the studied soil. The soil content of $CaCO_3$ is ranged from 7.5 to 12.4 %, indicating the calcareous nature of soils. These high pH values and $CaCO_3$% of the studied samples are primarily due to the aridity and the adjacent carbonate rocks. The alkaline pH will lead to the adsorption of metals on the organic matter particles through the formation of negative charges on the humic substances part of organic matter [22]. This process will assist in the transportation of heavy metals in the environment as indicated by the positive correlation between the studied metals and SOM (Table 2). Calcium carbonate particles often form strong sorption sites for phosphorus and micronutrients rendering them unavailable to plants [23]. Lime acts as a buffer, maintaining soil pH in the high alkaline range [24]. This appears from the positive correlation (r=0.66) between pH and $CaCO_3$ (Table 2). The pH and $CaCO_3$ are recorded [25] about 7.5 and 7.4%, respectively in the soil of El-Tebbin area on opposite bank of the River Nile. Also, the alkalinity and calcareous nature of soil at El-Saff, southeast Giza, Egypt, were studied [26].

In the studied soils, organic matter (SOM%) flocculated between 1.34 and 5.21% (Table 1). Generally, the Egyptian soils contain a low amount of organic matter due to the negligible addition of crop residues and manure, aridity of the area [27] and seasonal tillage operation [28]. These contents are higher than those (1.95%) reported by Wahba [26] in the El-Saff soil, Giza, Egypt. The SOM plays important role in adsorption and absorption of metals in soil [29]. SOM represents a promoter of inorganic pollutants interaction with soil. This can be supported by the positive relation between SOM and the studied heavy metals (Table 2).

TABLE 1. Physical and chemical characteristics of studied agricultural soil samples.

S. No	pH	SOM%	CaCO₃%	Sand%	Silt%	Clay%	As ppm	Cd ppm	Cr ppm	Pb ppm
1	8.4	4.37	11.6	5.1	58.5	36.5	335.4	2.1	297.6	196.1
2	8.3	3.36	10	29.1	40.5	30.4	211.4	1.95	265.6	148.8
3	8.2	1.34	7.5	82.9	5.1	12	60.8	1.45	173.7	42.1
4	8.4	5.21	12	45.6	26.6	27.8	187.7	1.55	208.1	134.2
5	8.5	3.87	12.4	43.0	34.2	22.8	211.8	1.8	245.6	146.5
6	8.2	1.85	10.9	55.7	19.0	25.3	75.0	1.45	229.7	110.6
7	8.2	2.79	9.9	15.2	41.8	43.0	212.6	2	169.4	134.1
8	8.4	2.35	11.1	72.2	12.7	15.2	76.4	1.35	186.7	76.2
9	8.3	2.29	9.3	74.7	11.4	13.9	77.3	1.25	141.7	81.7
10	8.1	4.61	10.4	29.1	40.5	30.4	9.2	1.6	219.5	128.0
11	8.3	2.59	9.3	59.5	22.8	17.7	113.0	1.7	162.6	160.2
Mean	8.3	3.1	10.4	46.6	28.5	25.0	142.8	1.7	209.1	123.5

S.No.: Sample Number   **SOM:** Soil organic matter

**TABLE 2. Correlation coefficient between soil parameters.**

	pH	SOM	CaCO₃	Sand	Silt	Clay	As	Cd	Cr	Pb
pH	1.00									
SOM	0.40	1.00								
CaCO₃	0.66	0.68	1.00							
Sand	-0.16	-0.65	-0.46	1.00						
Silt	0.25	0.69	0.50	-0.98	1.00					
Clay	0.00	0.52	0.36	-0.94	0.86	1.00				
As	0.67	0.45	0.47	-0.70	0.72	0.60	1.00			
Cd	0.30	0.43	0.27	-0.88	0.88	0.80	0.81	1.00		
Cr	0.40	0.53	0.59	-0.65	0.71	0.50	0.61	0.61	1.00	
Pb	0.38	0.66	0.55	-0.82	0.87	0.65	0.73	0.81	0.63	1.00

The particle size distribution (PSD) is an important issue in environmental research [30]. The obtained results show that the sand fraction is prevailing over the other fractions followed by silt then clay. The studied soils comprise three main groups [31] (Figure 2); mud (No.1), sandy mud (Nos. 2, 3, 5, 8 and 9) and muddy sand (Nos. 4, 6, 7, 10 and 11). The muddy nature of the studied soil was assessed by the incorporation of metals in soil because the fine particles are more reactive and have a higher surface area than coarser fractions [32]. This is supported by the positive correlation between silt and clay against studied heavy metals (Table 2). The new inputs of metals into soil adsorbed firstly on the silt particles [32] as appeared from the positive correlation between these metals and silt.

Heavy Metals content

Soil total contents of As, Cd, Cr, and Pb are listed in Table (1). Arsenic content ranged from 9.2 to 335.4 ppm. This high concentration of As may be due to the industrial activities, traffic emissions and agricultural practices because the highest concentrations were recorded near the sugar and chemical factories, roadside and residential area. It was reported that industrial activities could increases As in the soil into 20000 ppm [33]. Also, fertilizers are one of the main contributors to As in soil [34]. Soils from other parts of Egypt contain lower concentration of As; soils near Sadat city contain about 10.6 ppm [35], Nile Delta soils contain concentrations from 2.2 to 16 ppm [36] and Kafr El-Sheikh soil contains

concentrations ranging from 25 to 67.5 ppm [37]. In addition, high range (152 – 2130 ppm) of As was recorded in the dust near the lead smelter in Egypt [38]. Also, a high concentration of As was recorded in soils near industries worldwide; the industrial Bitterfeld-Wolfen district (in Germany) is contaminated with up to 265 ppm As [39]. Also, As was recorded 29.05 - 144.3 ppm in the paddy soils southwest China [40], while was 11–1217 ppm in the southern China agricultural soil [41]. The estimated range of Cd in the studied soils was from 1.25 to 2.1 ppm (Table 1), which is higher than the global average content of Cd 0.53 ppm [4]. On the other hand, other parts of Egypt contain higher concentrations of Cd such as soils of El-Mehala El-kobra contain 28.9 ppm [42] and soils of Fayoum contain 40.8 ppm Cd [43]. The most important sources of Cd and Pb in Egypt are P-fertilizers [44] and atmospheric deposition of traffic exhausts [45].
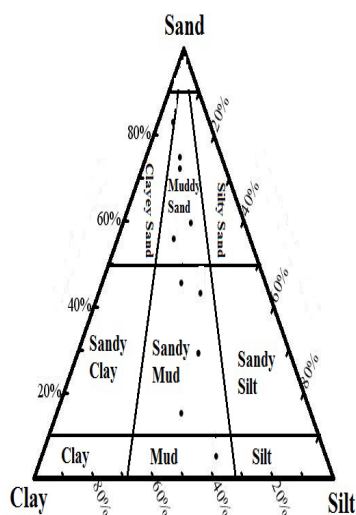
Fig. 2. Folk's [34] diagram of soil classification including the studied soil samples.

The concentration of Cr in the studied soils varies widely from 141.7 to 297.6 ppm (Table 1). This total Cr content is significantly higher than the reported worldwide soils Cr (54 ppm) [4]. Such relative higher content of Cr in the floodplain is attributed to its elevated level in the parent source rocks particularly the ultramafic-mafic rocks of the Ethiopian plateau, where chromium is mainly present substituting iron in the structure of ferromagnesian silicate minerals [46]. This is supported by the positive relation between Cr and silt in the studied samples (Table 2). Also, the role of the industrial activities appears strongly in the Cr distribution where the highest concentrations were recorded close to the sugar and chemical factories. The soils of Bahr El-Baker, Egypt contain about 95.01-134.06 ppm of Cr [47]. Also, surface soil of Sohag area contains about 143 ppm of Cr [48] and soils near Sadat city contains about 129 ppm [36]. The positive correlations (Table 2) between the studied metals indicate that these metals have the same sources and behavior in the study area. The samples closed to the sugar and chemical factories, roadside, bricks factories and residential areas contain the highest levels of the studied metals. The concentrations of Pb ranged from 42.1 to 196.1 ppm (Table 1), and its mean content (123.5 ppm) is four times greater than the average of worldwide soils (25 ppm) [4]. The Pb was recorded (314 ppm) in the surface soil of El-Saff, southeast Giza, Egypt [26]. The sources of Pb in the study area may be the traffic emissions, sugar and chemical industries because the highest concentrations were recorded near the roads and the factories.

Index of geoaccumulation (I_{geo})

The calculated I_{geo} (Table 3; Figure 3) indicated that the soils of the study area ranged from grade 1 (uncontaminated to moderately contaminated) to grade 7 (extremely contaminated). Arsenic recorded the highest I_{geo} values; where five samples were strongly contaminated (grade 5), four samples of grade 6 (strongly to extremely contaminated). Only, one sample was of grade 7 (extremely contaminated) and one sample of grade 2 (uncontaminated to moderately contaminated). Cadmium and Cr were mostly fallen in grade 3 (moderately contaminated). The low variation in the Igeo of these two metals indicated the restriction of their sources in the study area. Six samples were moderately contaminated (grade 3) with Pb, three samples were fallen in grade 4 (moderately to strongly contaminated) and one sample was fallen in grade 2 (uncontaminated to moderately contaminated).

Sequential extraction

The measured concentrations of As, Cd,

TABLE 3. Index of geoaccumulation values for the studied elements.

S. No	As	Cd	Cr	Pb
1	5.5	1.5	1.9	2.4
2	4.8	1.4	1.7	2.0
3	3.0	1.0	1.1	0.2
4	4.6	1.0	1.4	1.8
5	4.8	1.3	1.6	2.0
6	3.3	1.0	1.5	1.6
7	4.8	1.4	1.1	1.8
8	3.3	0.8	1.2	1.0
9	3.4	0.7	0.8	1.1
10	0.3	1.1	1.4	1.8
11	3.9	1.2	1.0	2.1
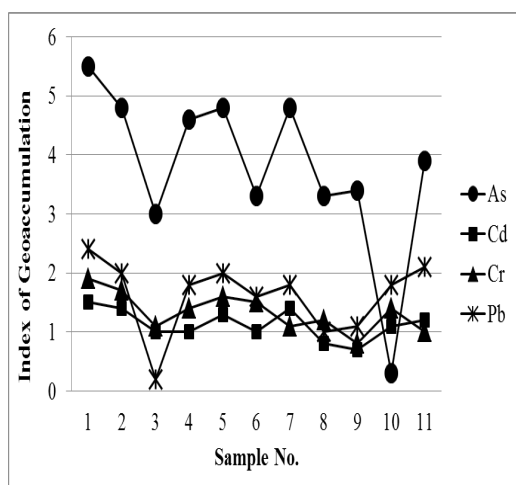
Fig. 3. comparative distribution of Igeo results.

Pb and Cr in the conducted five-step sequential extraction were listed in (Table 4) and the percent (%) of each extract is illustrated in (Figure 4). The Exchangeable As, Cd, Pb and Cr fraction (F1) concentrations are flocculated around 10.4, 0.1, 4.9 and 4.9 ppm, respectively (Table 4). This fraction represents about 9, 7.9, 5.1 and 2.6% of the total extract, respectively (Fig. 4). These concentrations of the studied metals in the exchangeable fraction are considered the most potentially labile and bioavailable fraction and consequentially the highest toxic to the environment [49, 50]. This fraction includes the water soluble and exchangeable ions on both of fine particles and organic matter surfaces of soil and accordingly is influenced by clays and organic matter contents of soils [51, 52].

The carbonate fraction contains loosely bound metals (F2). It is important fraction because the studied soils are alkaline, calcareous ($CaCO_3 > 5\%$) and have low organic matter (Table 1) that lead to the precipitation of metals as carbonates. The carbonate fraction retained about 35.3, 48.5, 6.9 and 26.7% of the total extract for As, Cd, Pb and Cr, respectively (Fig. 4). Generally, this fraction is sensitive to pH changes and the metal can be released from this fraction at pH close to 5 [20]. The high percentage of As and Cd in the exchangeable and carbonate fractions indicate the recent anthropogenic input of this element into the soil because these fractions contain the weakly bonded metals [50].

Regarding the third extraction step (F3), hydrous oxides of iron and manganese are extracted together. They are referred to as sink for heavy metals [21, 53].Scavenging by these secondary oxides, present as coatings on mineral surfaces or as fine discrete particles, can occur by any or a combination of the following mechanisms: co-precipitation; adsorption; surface complex formation; ion exchange; and penetration of the lattice [54, 55]. The recorded average As, Cd, Pb and Cr concentrations in this fraction were about 21.4, 0.1, 4.4 and 9.8 ppm, respectively (Table 4). In addition, the concentrations of As and Cd extracted in this fraction are positively correlated with the total metal concentrations in soil (Figure 5). This positive correlation suggests overloading of the geochemical system by contamination with these metals from anthropogenic sources [52, 56].

The organic fraction (F4) content of As, Cd, Pb and Cr was flocculated around 19.4, 0.1, 8.6 and 7.3 ppm, respectively (Table 4). This fraction represents about 14.9, 3.3, 4.5 and 5.3% of the total As, Cd, Pb and Cr extract, respectively (Figure 4). Generally, metals bind to SOM through complication and exchangeable processes [57]. The obtained low contents of metals in this fraction may be due to the low SOM% in the studied soil (Table 1). The organic fraction, non-exchangeable, is not considered very mobile or available since strong metal adsorption by soil organic matter by the formation of metal chelates reduces metal solubility in soil [55, 58].

Finally, in the residual fraction (F5) Cr and Pb average concentrations were 117.2 and 89.6 ppm that represent about 61.6 and 74.9% of total extract, respectively (Figure 4). The high level of these metals in the residual fraction indicates their low mobility [59] and their mixed geogenic and anthropogenic sources. Omer [46] and Abu Khatita [60] pointed out the geogenic source of Cr and Pb, respectively in the Egyptian soil. The sediments of Lake Nasser, Egypt, which consider the source of the Egyptian soil contain Pb from 2 to 36.14 ppm [61]. On the other hand, the percent of As and Cd in the residual fraction were about 22.6 and 36.7%, respectively indicating the environmental hazard of these metals in the study area. Generally, this fraction indicates the long-term potential risk of heavy metal or toxic metals entering the biosphere [57].

TABLE 4. Sequential extraction results of the studied soil samples (ppm).

S.No.	As					Cd				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
1	25.95	96.74	75.04	38.43	66.50	0.11	0.98	0.08	0.08	0.71
2	10.48	54.88	33.64	18.97	72.24	0.14	0.91	0.05	0.06	0.67
3	3.28	25.06	16.24	3.35	6.44	0.11	0.66	0.04	0.05	0.5
4	6.04	63.25	40.88	16.38	44.31	0.13	0.68	0.06	0.05	0.55
5	13.24	71.16	33.95	4.83	70.07	0.14	0.8	0.07	0.06	0.64
6	3.76	24.21	9.66	14.77	14.56	0.12	0.65	0.08	0.04	0.54
7	25.65	102.13	1.89	52.50	11.27	0.15	0.9	0.09	0.04	0.71
8	9.41	15.70	1.33	24.28	18.83	0.09	0.65	0.01	0.06	0.44
9	6.27	17.49	10.57	21.61	14.70	0.1	0.53	0.07	0.05	0.45
10	1.52	2.73	0.47	2.46	1.07	0.14	0.76	0.01	0.05	0.54
11	8.94	39.13	11.97	15.73	27.55	0.11	0.85	0.01	0.08	0.58
Mean	**10.4**	**46.6**	**21.4**	**19.4**	**31.6**	**0.1**	**0.8**	**0.1**	**0.1**	**0.6**
S.No.	Pb					Cr				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
1	6.14	5.62	6.17	18.94	112.13	4.89	36.22	8.33	5.54	93.82
2	8.64	5.74	3.43	5.35	113.47	6.01	56.11	10.73	7.2	153.92
3	5.52	5.54	3.36	6.96	16.32	3.61	38.65	8.54	7.76	103.64
4	5.5	6.48	5.52	6.41	98.21	5.21	53.33	7.67	6.34	119.78
5	4.56	6.72	3.36	7.92	115.2	4.8	61.11	13.1	7.4	142.88
6	3.48	6.22	3.58	6.74	82.27	3.6	63.38	9.69	9.24	122.72
7	4.08	5.62	3.79	7.9	104.45	4.07	34.53	10.78	6.65	98.71
8	3.46	6.26	4.66	10.25	45.41	5.19	46.65	12.26	8.19	103.8
9	4.87	7.39	4.85	7.44	50.02	3.68	35.15	6.81	5.01	81.48
10	4.08	9.26	5.16	8.16	93.41	5.57	55.05	13.65	7.35	116.6
11	3.77	9.74	4.8	8.28	154.27	7.25	87.45	5.99	9.13	152.18
Mean	**4.9**	**6.8**	**4.4**	**8.6**	**89.6**	**4.9**	**51.6**	**9.8**	**7.3**	**117.2**

F1: Exchangeable fraction, **F2:** Carbonate fraction, **F3:** Fe-Mn fraction, **F4:** Organic matter fraction and **F5:** Residual fraction
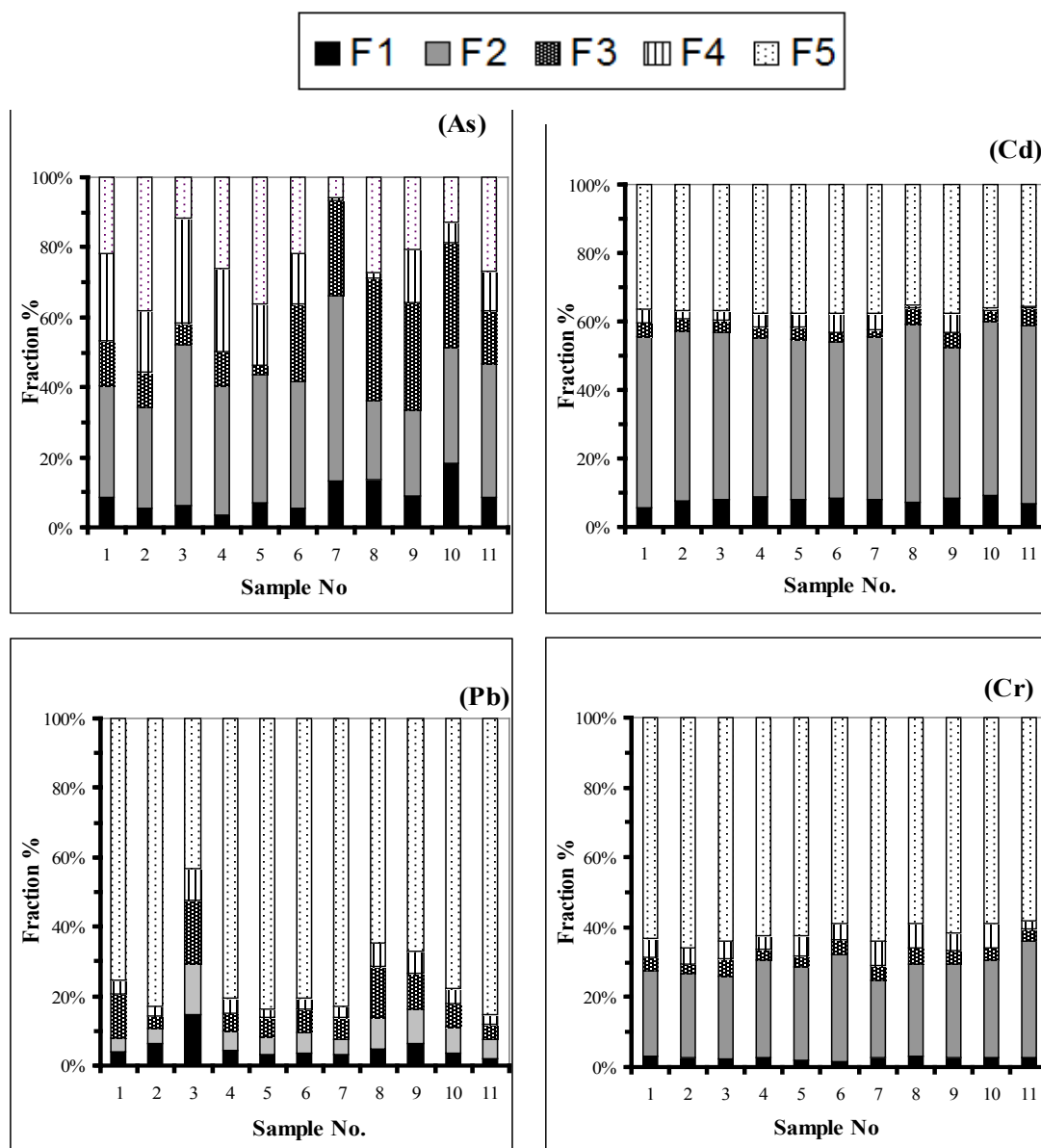
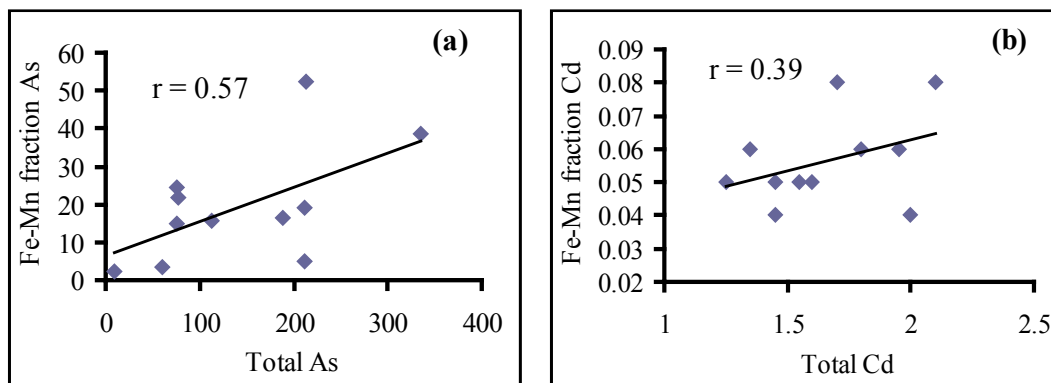**Fig. 4. Sequential extraction percent of metals in the different fractions.**

Fig. 5. Relationship between Fe-Mn fraction and (a) As and (b) Cd total content (µg/g).

Risk Assessment Code (RAC)

The exchangeable and carbonate fractions contain the rapid bioavailable part of metals due to their weak bonds [50]. The Risk Assessment Code (RAC) was first used by Perin et al. [62] and is applied by many authors [1, 50, 59], for the assessment of the environmental risk of soil pollution by heavy metals. RAC represents the percentage of the exchangeable and carbonate fractions which is calculated by the following equation:

RAC = 100 × (F1+F2) / (F1+F2+F3+F4+F5)

The five classes of RAC are listed in Table (5). The calculated RAC of the studied sample ranges were 7.5 – 29.3%, 24.9 – 36.1%, 33.6 – 66.1% and 52.5 – 60% for Pb, Cr, As and Cd, respectively (Fig. 6). These results indicate that there is a low to medium risk for Pb, medium to high risk for Cr, high to very high risk for As and very high risk for Cd (Table 5; Fig. 6). The order of pollution degrees of heavy metals is (Pb<Cr<As<Cd).

TABLE 5. RAC classes and the studied samples status for the studied metals.

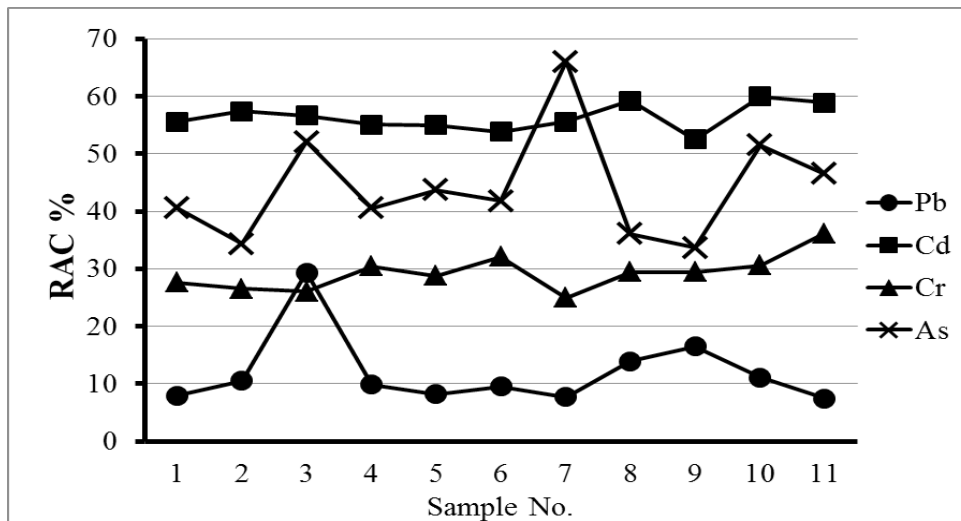| RAC classification		Studied samples status for the studied metals			
RAC value	Class	As	Cd	Cr	Pb
<1%	No risk	-	-	-	-
1–10%	Low risk	-	-	-	1, 4, 5, 6, 7, 11
11–30%	Medium risk	-	-	1, 2, 3, 5, 7, 8, 9	2, 3, 8, 9, 10
31–50%	High risk	1, 2, 4, 5, 6, 8, 9, 11	-	4, 6, 10, 11	-
>50%	Very high risk	3, 7, 10	All samples	-	-

Fig. 6. RAC% of the studied metals for the studied samples.

Conclusion

In the present study, the total concentration of As, Cd, Pb and Cr in the studied soil samples were higher than the average content of these metals in the world soil. The I_{geo} pointed out the pollution of soil with heavy metals especially arsenic. The pollution of soil with these metals may be attributed to the Sugar and chemical industries, bricks factories, traffic emissions, agricultural chemicals and urban runoff in the study area. Sequential extraction results indicate the incorporation of most Pb in the residual fraction while As, Cd and Cr are mostly associated with the carbonate and residual fractions. The association of about 77.4% of As and 63.3% of Cd with the non-residual fractions (F1 – F4) support the anthropogenic source of these metals in the studied soil samples. On the other hand, the incorporation of Pb and Cr in the residual fraction indicates the geogenic origin of them in addition to anthropogenic inputs. The alkalinity of soil and its $CaCO_3$ content play an important role in

the distribution of the studied metals between the different fractions. The Risk Assessment Code (RAC) showed that the studied heavy metals are varied from low to very high risk. Finally, more detailed studies are recommended to investigate the organic and inorganic pollutants as well as monitor the sources of pollution.

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الاستخراج المتسلسل لبعض العناصر الثقيلة من التربة في جنوب غرب الجيزة ، مصر

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تعتبر منطقة جنوب الجيزة من المناطق الحيوية التى تحتوى على العديد من الأنشطة (سكنية وزراعية وسياحية وصناعية) وبالرغم من وجود العديد من مصادر التلوث الا انه لا يوجد تقييم لتلوث التربة بالعناصر الثقيلة السامة. أجرت الدراسة الحالية تقييماً لتلوث التربة الزراعية بالزرنيخ والرصاص والكادميوم والكروم بتلك المنطقة. ولتحديد مقدار الخطر الناتج من تلوث التربة بتلك العناصر تم تطبيق تقنية الاستخلاص الكيميائى المتسلسل لتقدير مدى حركية تلك العناصر وامكانية وصولها للنبات والإنسان. أشارت النتائج إلى أن التربة تحتوى على تركيزات مرتفعة من العناصر محل الدراسة وأشار عامل التراكم الجيولوجى (Igeo) الى أن التربة تراوحت بين غير ملوثه إلى شديدة التلوث بالعناصر الثقيلة. أوضح الاستخلاص المتسلسل تمركز الرصاص والكروم فى البناء البلورى لمعادن التربة بينما الزرنيخ والكادميوم تمركز فى الكربونات. ويمثل الزرنيخ اعلى العناصر خطورة فى منطقة الدراسة حيث وجد حوالى ١٠,٤ جزء من المليون منه على شكل ايونات حرة قابلة للتبادل الأيونى والحركة. كما دل كود تقييم المخاطر البيئية للعناصر الثقيلة على درجة عالية من الخطورة بسبب تلوث التربة بالكادميوم والزرنيخ. هذه النتائج تعكس تعدد مصادر التلوث بتلك العناصر في منطقة الدراسة.