

**DISTRIBUTION OF SOME HEAVY METALS AMONG THE DIFFERENT FRACTIONS OF SOME POLLUTED SOILS IN EGYPT.**  
**BY**

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**ABSTRACT**

A sequential extraction study was conducted according to Tessier *et al.* (1979) on Cd, Co, Pb, Cu and Zn to assess their distribution among different fractions of soils polluted due to different anthropogenic activities. It was thought that such a study will be helpful for determining the metal ion pools in the more labile forms which are of potentially toxic hazards. Results showed that the distribution of the metal ions among the different soil components varied from an element to another and also from a soil to another. However, the summations of soluble and exchangeable fractions of these metal ions which are considered the most biologically active fractions were rather low. In this concern, Cd and Co showed the highest percentages of soluble plus exchangeable fractions in spite of their low total contents in soils. Percentages of carbonate bound fractions of the metal ions were relatively higher than the corresponding exchangeable ones. Generally, the Fe-Mn oxides bound fractions exceeded the corresponding carbonate bound ones (except in Arab Abou-Saad calcareous soil, where the opposite was sometimes true). However, percentages of metal ions bound to Fe-Mn oxides differed from one metal ion to another and from one soil to another. The organically-bound metal fractions seemed generally of obviously higher percentages than the other corresponding fractions except for the residual ones. According to values of the mobility index, the metal ions followed the descending order: Co > Cd > Pb > Zn > Cu. This sequence indicates that Co and Cd may have greater environmental risk than the other studied metal ions in spite of their low total contents.

**INTRODUCTION**

Metalliferous mining and smelting, electroplating, industrial wastes, chemical and other manufacturing industries, chemical fertilizers, pesticides, vehicle exhausts and irrigation with industrial waste waters are the most important anthropogenic sources of soil pollution (Atia, 2005 and Abbas, 2007). Land application represents an economically desirable outlet for the producers of a waste and a potential cheap source of organic matter and fertilizer elements for landowners (Iwegbue *et al.*, 2006). In addition to the potential beneficial components, some waste materials may also contain non-essential elements, persistent organic compounds and microorganisms that may be harmful to plants (Mullin and Mitchell, 1994 and Lwegbue *et al.*, 2005).

The chemical forms of the heavy metals affect their mobility and bioavailability and accordingly their absorption by plant, therefore remediation of the soils polluted with heavy metals is dependent, to a large extent, on recognition of distribution of the heavy metals among the different soil fractions (Sánchez-Martin *et al.*, 2007).

Sequential extraction technique was adopted by many investigators to assess reactivity of the different species of various heavy metals in soils. El-Gendi (2003) in a fractionation study on Cd, Co, Cu, Pb and Zn in Al-Gabal Al-Asfar soil, Qalyoubia Governorate, Egypt found that these metals were distributed among the different soil fractions

following different sequences. Pb followed the descending order: organically- bound (ORG) > Fe-Mn oxides- bound > Residual- bound (RES) > carbonate- bound (CA) > exchangeable (EXC) whereas Cd followed the sequence: ORG > RES > Fe-Mn oxides-bound > CA > EXC. Also, Co was predominately organically bound or in the residual fraction, and the residual fraction was the dominant form of both Zn and Cu. Potential difficulties associated with fractionation procedures have been grouped in four categories i.e., absence of validation, sensitivity to procedural variables, post extraction re-adsorption and selectivity and sample preservation. Despite such difficulties, sequential extraction

is considered the most reliable method for assessing the origin, manner of occurrence, bioavailability, mobilization and transport of heavy metals (Ma and Rao, 1997).

The current study was conducted to (i) determine the total metal contents of the essential heavy metals (Zn and Cu) and the non essential ones (Cd, Co and Pb) in some soils of Egypt polluted with metal ions due to different anthropogenic activities (ii) assess the metal ion distribution among the different soil fractions and (iii) assess the mobility index which represents the potentially available forms of these metal ions.

## MATERIALS AND METHODS

### The soil samples:

Six surface soil samples (0-30 cm) were collected from six locations polluted with heavy metals due to different anthropogenic activities. These locations are:

- 1- Al-Gabal Al-Asfar farm where the soil is polluted with heavy metals due to irrigation with the sewage water.
- 2- Arab Abou-Saed arable fields whose source of irrigation and pollution is the treated sewage and industrial wastewaters of Arab Abou-Saed waste water treating plant.
- 3- Bahr Al-Baqar arable soil where the soil is irrigated with Bahr Al-Baqar drain.
- 4- Toukh agricultural fields along the Cairo-Alexandria highway, where the source of pollution is the car exhausts due to the heavy traffic density on the highway.
- 5- Namoul village where the source of irrigation and pollution is Namoul drain.
- 6- Shobra Al-Khema industrial area where the source of soil pollution is the smelters and factories in this area.

### Methods of soil analyses:

The soil samples were air dried, crushed, sieved through a 2 mm sieve and kept for the following analyses:

- Particle size distribution by pipette method according to Kilmer and Alexander (1949)

using Na-hexameta-phosphate as a dispersing agent.

- Organic matter content according to Walkley and Black method, as described by Page *et al.* (1982)
- Total carbonates by means of the calcimeter, (Piper, 1950)
- pH electrometrically in 1:2.5 soil – water suspension using a pH meter as outlined by Page *et al.* (1982)
- Electrical conductivity of the soil paste extract using electrical conductivity bridge as described by Richards (1954)
- Cationic and anionic composition in the soil paste extract using the standard methods outlined by Page *et al.* (1982)
- Total Cd, Co, Pb, Cu and Zn in soil digests of a mixture of conc. HNO<sub>3</sub> and conc. H<sub>2</sub>SO<sub>4</sub> and 62% perchloric acid as recommended by Hesse (1971)

### Heavy metals fractionation:

The method for heavy elements fractionation proposed by Tessier *et al.* (1979) was followed for the determination of Cd, Co, Pb, Cu and Zn fractions in the studied soils.

The method consists of sequential extraction of the soil with different solutions, and it is designed to separate heavy metals into six operationally defined fractions. A summary of the procedure is as follows:

**Table (1): Some physical and chemical properties of the investigated soils.**

The property	Soil location					
	Al-Gabal Al-Asfar (S1)	Arab Abou-Saed (S2)	Bahr Al-Baqar (S3)	Toukh (S4)	Namoul (S5)	Shobra Al-Khema (S6)
<b>Particle size distribution %</b>						
Sand	87.53	49.01	17.60	24.02	14.75	21.00
Silt	5.42	36.09	24.37	24.99	30.25	29.49
Clay	7.05	14.90	58.03	50.99	55.00	49.51
Textural class	Sand	Loam	Clay	Clay	Clay	Clay loam
Organic matter %	3.87	0.98	1.49	2.29	2.52	1.21
Calcium carbonate %	3.07	18.62	4.54	2.42	1.88	2.40
pH (1:2.5) soil-water suspension	6.85	7.45	7.4	7.15	7.4	7.60
EC (dSm <sup>-1</sup> )	1.69	13.10	5.92	8.10	9.3	6.10
<b>Soluble ions (mmol<sub>e</sub> L<sup>-1</sup>)</b>						
Ca <sup>2+</sup>	7.37	37.98	12.30	47.98	31.03	31.03
Mg <sup>2+</sup>	0.83	7.78	6.42	21.04	17.55	11.61
Na <sup>+</sup>	7.08	106.00	35.53	23.52	51.77	32.96
K <sup>+</sup>	0.72	0.85	0.85	1.28	0.83	0.24
CO <sub>3</sub> <sup>2-</sup>	0.00	0.00	0.00	0.00	0.00	0.00
HCO <sub>3</sub> <sup>-</sup>	2.28	3.74	4.80	4.28	4.28	3.74
Cl <sup>-</sup>	5.88	66.64	27.44	17.64	39.28	29.40
SO <sub>4</sub> <sup>2-</sup>	7.84	82.23	22.86	71.90	57.62	42.70

One gram of each dry soil was weighted and put into a 40 mL polycarbonate centrifuge tube to obtain the different fractions as follows:

- **Water-soluble:** The soil samples were extracted with 15 mL portions of deionized water after shaking for 2 hours.
- **Exchangeable:** The residues from water-soluble fraction were extracted with 8 mL portions of 1 M MgCl<sub>2</sub> (pH 7) after shaking for 1 hour with continuous agitation.
- **Carbonate-bound:** The residues from exchangeable fraction were extracted with 8 mL portions of 1 M sodium acetate (NaOAc), adjusted to pH 5 with HOAc, for 5 hours with continuous agitation.
- **Fe-Mn oxides bound:** The residues from carbonate fraction were extracted with 20 mL portions of 0.04 M hydroxylamine hydrochloric (NH<sub>2</sub>OH.HCl) in 25% (v/v) acetic acid (HOAc) at 96°C with occasional agitation for 6 hours.
- **Organically- bound:** The residues from Fe-Mn oxides fraction were extracted with 3 mL portions of 0.02 M HNO<sub>3</sub> and 5 mL of 30% H<sub>2</sub>O<sub>2</sub> (adjusted at pH 2 with HNO<sub>3</sub>). The mixtures were heated to 85°C for two hours with occasional agitation
- **Residual:** The residues from organically-bound fraction were placed in platinum crucibles and digested with hydrofluoric and perchloric acid according to Jackson (1973).

Following each extraction, mixtures were centrifuged at 5000 rpm for 10 minutes. Prior to the start of the next extraction step, the residues were shaken with 8 mL water for 30 minutes, centrifuged, and the wash solutions were discarded. All total and chemically extractable heavy metals were determined using ICP-MS. (Inductively Coupled Plasma Mass Spectrometer) TSA (POE.MS.111).

## RESULTS AND DISCUSSION

### Total contents of the studied metal ions:

Data presented in Tables 2 to 6 reveal that total contents of the investigated metal ions varied depending on types of both soil and metal ion. In Al-Gabal Al-Asfar and Bahr Al-Baqar soils, these metal ions could be arranged according to their total content in the following descending order: Zn > Cu > Pb > Co > Cd. A rather different sequence characterized Arab Abou-Saed, Toukh and Namoul soils where the following descending order was attained Zn > Cu > Co > Pb > Cd. A third sequence characterized Shobra Al-Khema soil in which the studied metal ions followed the descending order: Cu > Zn > Co > Pb > Cd. The variations in the sequence of the metal ions in the studied soils might be attributed to the parent material from which the soil was originated as well as the source of contamination of soil. However, total contents of heavy metals provide little information on the bioavailability of heavy metals and potential hazard that may occur due to these metal ions (Li and Shuman, 1996). Therefore, the current study dealt with the distribution of the metal ions among the different fractions. Such a fractionation study would be helpful in determining the readily mobile fractions as well as the other metal fractions, especially the residual fraction which are considered immobile and tightly bound and may not be expected to be released under natural conditions (Zorpas *et al.*, 2007 and Iwegbue *et al.*, 2007).

### Distribution of the metal ions among the different soils:

Data presented in Tables 2 to 6 reveal that the sum of extractable fractions of Cd, Co, Pb, Cu and Zn relative to the total content varied from a metal ion to another and also from one soil to another. This sum varied from 81 to 88% for Cd, 78 to 84% for Co, 76 to 88% for Pb, 77 to 83% for Cu and from 80 to 83% for Zn.

On the other hand, the sum of extractable fractions of different metal ions varied from 79 to 88% of the total contents in Al-Gabal Al-Asfar soil, from 76 to 80% in Arab Abou-Saed soil, from 80 to 88% in Bahr Al-Baqar soil, from 78 to 83% in Toukh soil,

from 79 to 84% in Namoul soil and from 81 to 84% in Shobra Al-Khema soil.

Tessier *et al.* (1979) reported that the extractable fractions of Cd, Co, Ni and Pb in sediment samples were within 88 to 97% of their sums. In the same consideration, El-Gendi (1994) reported that Pb extractable fractions in normal, moderately, and highly polluted soils amounted 73, 76 and 94% of their total Pb, respectively. The association between heavy metals and the different soil components determine their mobility and availability (Kabala and Singh, 2001).

### Soluble fraction:

In all the soils, the percentages of the soluble fractions of any of the studied metal ions seemed the lowest. Percentage of soluble fraction relative to the total content of Cd ranged from 0.59% in Al-Gabal Al-Asfar soil to 3.66% in Namoul soil. The corresponding percentages of Co, Pb, Cu and Zn ranged from 0.01, 0.46, 0.62 and 0.13% in Arab Abou-Saed, Arab Abou-Saed, Al-Gabal Al-Asfar and Al-Gabal Al-Asfar soils to 0.29, 0.96, 0.96, 0.69% in Toukh, Al-Gabal Al-Asfar, Bahr Al-Baqar and Bahr Al-Baqar soils, respectively.

The low percentages of soluble metal ions are ascribed to the reactions between metal ions and soils, which mainly include complexation, surface adsorption, exchange reactions, chelation and precipitation of metal ions on the soil particle surface; or to diffusion into the mesopores and macropores of soil leading to conversion of highly soluble forms into less soluble ones (Ma and Rao, 1997).

### Exchangeable fraction:

The lowest percentages of exchangeable fractions of Cd, Co, Pb, Cu and Zn were 5.94, 3.18, 1.10, 0.44 and 1.19% in Al-Gabal Al-Asfar, Arab Abou-Saed, Arab Abou-Saed, Shobra Al-Khema and Al-Gabal Al-Asfar soils, respectively. The corresponding highest percentages of the aforementioned metal ions were 9.13, 8.22; 4.69, 2.36 and 2.92% in Namoul, Namoul, Namoul, Arab Abou-Saed and Toukh Soils, respectively.

The aforementioned results reveal that the summations of soluble and exchangeable fractions of the investigated soils are rather low. These fractions (soluble + exchangeable) are considered the most biologically active fractions (Leita and De-Nobili, 1991; He *et al.*, 1992). Accordingly, these fractions have somewhat low potential of contamination of food chain, surface water and ground water.

In spite of the low total contents of both Cd and Co, the percentages of their soluble + exchangeable fractions seemed higher than the other studied metal ions. This finding holds true in all the investigated soils regardless of their physical and chemical properties as well as the source of pollution. Naidu *et al.* (1994) reported that the exchangeable Cd was probably hydrated  $Cd^{2+}$  and adsorbed via outsphere surface complexation.

#### **Carbonate-bound fraction:**

Percentages of carbonate-bound fractions of the studied metal ions although are generally, relatively higher than the corresponding exchangeable fractions, yet they varied from one metal ion to another and from one soil to another.

Percentages of Co- bound to the carbonate fraction in the different studied soils seemed higher than the corresponding ones of Cd, Pb, Cu or Zn and also, the calcareous soil of Arab Abou Saed showed the highest percentage of Co- bound to the carbonate fraction (27.25%). The relatively higher content of  $CaCO_3$  in this soil might account for such a high fraction. These results agree with those of Renella *et al.* (2004) who found that in a calcareous soil under various managements, most of Cd of the soil was slightly available, being mostly bound to carbonate and residual fractions.

#### **Fe-Mn oxides bound fraction:**

Percentages of metal ions bound to Fe-Mn oxides, (which differed from one metal ion to another and from one soil to another) were generally higher than the corresponding carbonate-bound ones except in Arab Abou-Saed soil where percentage of the carbonate-

bound fractions sometimes exceeded the Fe-Mn oxides- bound ones. The Zn- bound to Fe-Mn oxides was at the highest percentages compared with the other heavy metals in Al-Gabal Al-Asfar, whereas Cu bound to Fe-Mn oxides represented the highest percentage as compared with the other metal ions bound to these oxides in Arab Abou-Saed soil. Higher percentages of Pb bound to Fe- Mn oxides characterized Bahr Al-Baqar and Shobra Al-Khema soils. The Cd bound to Fe-Mn oxides was the dominant form as compared with the other metal ions bound to the Fe- Mn oxides in both Toukh and Namoul soils. Abd- El-Fattah and Wada (1981) stated that Fe oxides showed the highest affinity for the selective adsorption of Cd and Zn and a greater affinity for selective adsorption of Co. Cobalt is also adsorbed by crystalline Mn- oxides. In soils of relatively high pH such as the case herein, the formation of hydroxy species,  $Co(OH)_2$ , is expected to be precipitated at the oxide surface. Kabata Pendias and Pendias (2001) found that the highest proportion of adsorbed Cu were bound with Fe and Mn oxides, amorphous Fe and Al- hydroxides and clays. Riffaldi *et al.* (1976) reported that Pb was found associated mainly with Mn oxides, Fe and Al hydroxides.

#### **Organic-bound fraction:**

Data presented in Tables 2 to 6 reveal that generally higher percentages of the studied metal ions are bound to the organic fraction. Generally, Cd was the highest metal ion that was bound by organic fraction as compared with the other studied metal ions in Al-Gabal Al-Asfar and Arab Abou- Saed soils. The high portion of Cd associated with organic matter indicates a high affinity of these metals.

Percentages of Cu- organically bound fractions exceeded the other metal ions organically bound fractions in the other contaminated soils. Sánchez- Martin *et al.* (2007) found that Cu distribution was mainly found in the organic fraction. The increased affinity of Cu for the organic matter was reported also by Merrington *et al.* (2003) and Sánchez- Martin *et al.* (2007). Presence of Cu in organic matter fraction agrees with many

studies (Mabila *et al.*, 2001 and El- Gendi, 2003) that have shown that Cu has high affinity for organic matter and forms strong specific bond with electron- rich functional groups in organic matter. It is obvious that organic ligands complex Cu ions preferentially over the other metal ions.

Percentage of Zn bound to the organic matter seemed, generally, lower than the percentages of the other metal ions organically bound fractions in Al-Gabal Al-Asfar, Toukh and Namoul soils. This result stands in good agreement with that of El-Gendi (2004) who stated that low portion of Zn was associated with organic matter. Soil organic matter is capable of bonding Zn in stable form. However, stability constants of Zn- organic matter in soils are relatively low (Stevenson, 1967).

Pronounced percentages of Pb are organically bound. The relatively high percentage of Pb- organically bound fraction is expected since Pb has high affinity with organic matter (Zimdahl and Skogerboe, 1977).

#### **Residual fraction:**

The residual fraction of the studied metal ions was either the highest dominant fraction or the second dominant one. For example; it was the dominant fraction for Co, Pb and Zn in Al Gabal Al- Asfar, Bahr Al-Baqar, Toukh and Namoul soils. On the other hand, it was the second dominant fraction for Cd at the same soils. Kabala and Singh (2001) indicated that metal ions incorporated into the crystalline lattices of clays appear relatively inactive. These results agree with those of El-Gendi (2003 and 2004) and indicate that the greatest percentages of the metal ions are present in forms tightly bound and consequently are not readily available.

#### **Bioavailability and mobility Index (MI):**

Water soluble and exchangeable fractions are considered readily mobile and bioavailable, whereas other metal fractions,

especially the residual fraction within the primary mineral lattice phase (Li and Shuman, 1996) are considered immobile and tightly bound and may not be expected to be released under natural conditions.

Accordingly, the studied metal ions can be arranged according to their bioavailability in the following descending order: Cd > Co > Pb > Zn > Cu in all the investigated soils except Arab Abou-Saed soil which is of a calcareous nature where the following descending order was obtained: Co > Pb > Zn > Cd > Cu.

The aforementioned results show that with the exception of Cd, the very small percentages of heavy metal ions found in the soluble and exchangeable fractions would indicate that these ions originate from different anthropogenic sources as well as those primary found in soil undergo immobilization process. Accordingly, the risk of heavy metals pollution might be reduced.

Kabala and Singh (2001) calculated what is known as the mobility index (MI) on the basis of metal percentages in the soluble and exchangeable fractions beside the carbonate bound fraction, which normally represent the metal pool in more labile forms (potentially available forms according to Shrivastava and Banerjee, 2004 and Fuentes *et al.*, 2004).

Calculation of the overall mobility index of the studied metal ions reveal that these metal ions followed the descending order: Co > Cd > Pb > Zn > Cu. This result indicates that Co is suggested to be as one of the most mobile elements and accordingly this element plus Cd may have the greatest environmental significance. By contrast, the potential mobilities of Zn and Cu are relatively lower, probably due to complexation of these metals by organic matter and the other soil components.

Table (2): Distribution of Cd among the different fractions of the investigated soils.

Soil Location	Total content mg kg <sup>-1</sup>	Fractions												Sum. of Fractions	
		Soluble		Exchangeable		Carbonate bound		Fe-Mn oxides bound		Organically bound		Residual			
		mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%
Al-Gabal Al-Asfar	2.70	0.014	0.59	0.141	5.94	0.033	1.37	0.245	10.29	1.060	44.71	0.883	37.10	2.38	88
Arab- Abou saed	2.29	0.013	0.69	0.115	6.29	0.168	9.15	0.197	10.87	0.557	30.43	0.780	42.57	1.83	80
Bahr Al- Baqar	0.195	0.002	1.10	0.012	7.20	0.013	8.05	0.029	18.46	0.057	35.13	0.049	30.06	0.162	83
Toukh	0.191	0.002	1.18	0.012	7.82	0.013	8.38	0.033	20.94	0.056	35.23	0.042	26.45	0.159	83
Namoul	0.30	0.009	3.66	0.022	9.13	0.013	5.35	0.048	19.57	0.093	38.10	0.059	24.19	0.243	81
Shobra Al- Khema	0.31	0.008	3.21	0.020	7.84	0.009	3.28	0.044	17.03	0.086	33.26	0.092	35.38	0.260	84

Table (3): Distribution of Co among the different fractions of the investigated soils.

Soil Location	Total content mg kg <sup>-1</sup>	Fractions												Sum. of Fractions	
		Soluble		Exchangeable		Carbonate bound		Fe-Mn oxides bound		Organically bound		Residual			
		mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%
Al-Gabal Al-Asfar	25.15	0.040	0.19	0.880	4.16	2.790	13.20	1.880	8.92	7.290	34.50	8.250	39.03	21.13	84
Arab- Abou saed	12.17	0.001	0.01	0.317	3.18	2.720	27.25	0.770	7.72	1.723	17.26	4.450	44.58	9.98	82
Bahr Al- Baqar	27.14	0.061	0.28	1.160	5.32	3.470	16.00	2.910	13.39	5.040	23.21	9.080	41.80	217.12	80
Toukh	26.54	0.060	0.29	1.550	7.48	2.570	12.42	2.990	14.42	5.540	26.75	7.990	38.64	20.70	78
Namoul	26.10	0.039	0.18	1.800	8.22	2.770	12.62	3.070	13.99	5.630	25.76	8.620	39.32	21.92	84
Shobra Al- Khema	24.08	0.016	0.08	1.23	6.29	2.68	13.73	2.600	13.33	3.87	19.87	9.11	46.70	19.50	81

Table (4): Distribution of Pb among the different fractions of the investigated soils.

Soil Location	Total content mg kg <sup>-1</sup>	Fractions												Sum. of Fractions	
		Soluble		Exchangeable		Carbonate bound		Fe-Mn oxides bound		Organically bound		Residual		mg kg <sup>-1</sup>	% of total
		mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%		
Al-Gabal Al-Asfar	83.47	0.650	0.96	1.140	1.68	2.520	3.72	5.040	7.45	20.990	31.04	37.290	55.15	67.61	81
Arab- Abou saed	10.91	0.038	0.46	0.091	1.10	1.607	19.38	0.817	9.85	2.461	29.68	3.278	39.53	8.29	76
Bahr Al- Baqar	40.33	0.330	0.94	1.280	3.61	3.360	9.48	8.680	24.47	9.480	26.71	12.350	34.79	35.490	88
Toukh	15.84	0.079	0.63	0.568	4.54	0.578	4.62	2.510	20.08	3.990	31.89	4.780	38.24	12.51	79
Namoul	12.24	0.049	0.50	0.459	4.69	0.323	3.30	1.840	18.80	3.670	37.47	3.450	35.24	9.79	80
Shobra Al- Khema	19.57	0.117	0.72	0.51	3.12	1.27	7.80	3.040	18.69	6.37	39.24	4.94	30.43	16.24	83

Table (5): Distribution of Cu among the different fractions of the investigated soils.

Soil Location	Total content mg kg <sup>-1</sup>	Fractions												Sum. of Fractions	
		Soluble		Exchangeable		Carbonate bound		Fe-Mn oxides bound		Organically bound		Residual		mg kg <sup>-1</sup>	% of total
		mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%		
Al-Gabal Al-Asfar	137.50	0.674	0.62	0.880	0.81	1.260	1.16	17.565	16.17	31.894	29.36	56.357	51.88	108.63	79
Arab- Abou saed	48.96	0.336	0.89	0.890	2.36	1.606	4.26	7.932	21.04	6.861	18.20	20.077	53.26	37.70	77
Bahr Al- Baqar	47.80	0.372	0.96	0.317	0.82	0.759	1.96	5.033	13.00	14.690	37.94	17.550	45.33	38.718	81
Toukh	59.22	0.359	0.730	0.378	0.77	0.492	1.00	3.391	6.90	19.660	40.00	24.871	50.60	49.15	83
Namoul	57.66	0.387	0.85	0.451	0.99	0.208	0.46	3.502	7.69	18.256	40.08	22.752	49.95	45.55	79
Shobra Al- Khema	109.71	0.585	0.65	0.396	0.44	0.434	0.48	5.775	6.42	50.782	56.45	31.99	35.56	89.96	82



**Table (6): Distribution of Zn among the different fractions of the investigated soils.**

Soil Location	Total content mg kg <sup>-1</sup>	Fractions												Sum. of Fractions	
		Soluble		Exchangeable		Carbonate bound		Fe-Mn oxides bound		Organically bound		Residual			
		mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	%	mg kg <sup>-1</sup>	% of total
Al-Gabal Al-Asfar	417.89	0.450	0.13	4.120	1.19	9.550	2.76	69.100	19.96	27.560	7.96	235.40	68.00	346.18	83
Arab- Abou saad	282.65	0.565	0.25	3.007	1.33	36.700	16.23	42.890	18.97	56.259	24.88	86.690	38.34	226.12	80
Bahr Al-Baqar	324.88	1.856	0.69	7.990	2.82	17.323	6.44	40.590	15.09	66.230	24.62	135.41	50.34	268.99	83
Tukh	69.85	0.340	0.60	1.650	2.92	1.320	2.33	8.290	14.65	8.280	14.64	36.700	64.86	56.58	81
Namoul	227.48	1.000	0.57	5.070	2.72	2.650	1.42	24.830	13.31	34.990	18.76	117.92	63.22	186.53	82
Shebra Al- Khama	62.65	0.300	0.61	1.02	2.01	1.17	2.30	7.530	14.84	13.77	27.13	26.95	53.11	80.75	81

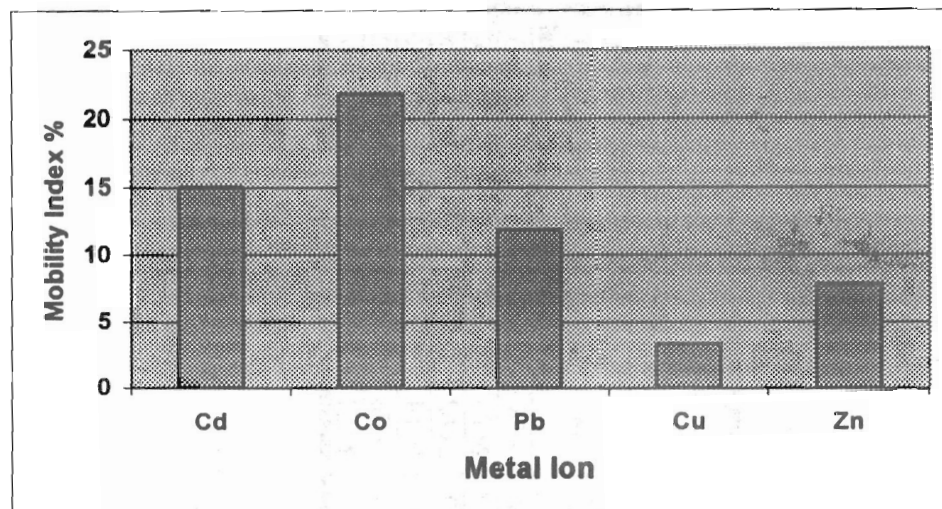


Fig. (1): Mobility index of Cd, Co, Pb, Cu and Zn of the studied soils.

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توزيع بعض الفلزات الثقيلة بين الصور الكيميائية المختلفة في بعض الأراضي الملوثة في مصر.

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يهدف هذا البحث إلى دراسة الصور الكيميائية المختلفة (المفصولات الكيماوية) لأيونات معادن الكاديوم والكوبلت والرصاص والنحاس والزنك، وكذلك تقدير حركية تلك المعادن وتأثيراتها السمية في الأراضي الملوثة نتيجة الأنشطة البشرية، وذلك من خلال الاستخلاص المتتابع لها بطريقة Tessier *et al.* (1979).

أوضحت النتائج أن توزيع أيونات المعادن بين صورها الكيميائية المختلفة تختلف من عنصر لآخر ومن أرض لآخرى، ورغم ذلك فإن مجموع الصور الكيميائية الذاتية والمتبادلة لأيونات هذه المعادن والتي تمثل أكثر الصور الكيميائية تأثيراً على الأنشطة الحيوية كان منخفضاً. أوضحت النتائج أن التواجد النسبي لصور أيونات المعادن المرتبطة مع الكربونات كان أعلى من مثيله الموجود في الحالة المتبادلة وبصفة عامة فإن أيونات المعادن المرتبطة بأكاسيد الحديد والمنجنيز كانت أعلى من مثيلتها المرتبطة مع الكربونات وذلك في جميع الأراضي فيما عدا أرض عرب أبو ساعد (أرض جيرية) وقد اختلفت نسبة تواجد أيونات المعادن المرتبطة مع أكاسيد الحديد والمنجنيز من عنصر لآخر ومن أرض لآخرى. كذلك أوضحت النتائج بصفة عامة أن النسبة المئوية لأيونات المعادن المرتبطة مع الصورة العضوية تكون أعلى من باقي الصور الكيميائية الأخرى فيما عدا الصورة المتبقية. أوضحت نتائج دراسة حركية المعادن أنه يمكن ترتيبها تنازلياً تبعاً لـ Mobility index كما يلي:

$Co > Cd > Pb > Zn > Cu$  ويتضح من ذلك الترتيب أن للكوبلت والكاديوم (على الرغم من إنخفاض نسبة تواجدهم في البيئة) تأثير بيئي خطير يفوق تأثير باقي المعادن الأخرى موضع الدراسة.