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DISTRIBUTION OF HEAVY METALS IN THREE SOIL TYPES AND IN CORN PLANTS AT WESTERN AREA OF NILE ELTA

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ABSTRACT

Eighty soil samples (0-15cm and 15-30cm) and the corresponding 40 samples of leaves and grain of corn plants were collected from three different sites at western Nile Delta of Egypt. The objectives of this study were to investigate the total and bioavailable levels of Cu, Zn, Mn, Fe, Cr, Ni, Cd, and Pb in soils,metals contents in leaves and grains of corn plant grown on these soils and to interelate these levels with each other and with some soil properties.

Both total (aqua regia soluble) and available (DTPA–extractable) amounts of metals in the soils were determined. The mean values of total metal content amounts (mg Kg^{-1} soil) in the surface soil(0-15cm) of Abou Hommos, Abis and North Tahrir were for Cu as 26.8, 25.5, and 13.7, for Zn as 82.0, 84.6 and 60.0 for Mn as 573, 796 and 395, for Fe as 6793, 7766 and 18942 for Cr as 27.3, 28.3 and 57.3 for Ni as 39.8, 46.7 and 27.6 for Cd as 0.12, 0.13 and 0.20 and for Pb as 7.7, 8.0 and 8.2, respectively. The data showed that the amounts of DTPA- extractable metals were in the normal range for agricultural soils except for cadmium which was higher than the normal level. The data showed that Cd was the most mobile metal, implying that it is more bioavailable than Pb, Ni, and Cr. The amounts of DTPA- extractable Cd, Cr, Zn, Mn and Cu were positively and significantly correlated with their total contents in soils. In addition, clay content of soils significantly and positively correlated with DTPA-Cu and with Tot. Cu, Zn, Mn and Ni in soils.

The amounts of Cu, Fe, and Pb in the leaves and grain of corn plants were positively and significantly correlated with their DTPA extractable amount from soils.

The highest values of both the calculated bioconcentration ratio (BCR) and transfer coefficients (TC) were recorded for Cd and Zn. The data also showed that Cd had the highest relative mobility (RM) in the investigated soil relative to the other metals.

Keywords: Heavy metals, Bioconcentration ratio, transfer coefficient, relative mobility

INTRODUCTION

Environmental pollution is increasing due to the increase in industrial and urban activities in the third world countries where, the disposal of ndustrial effluents and municipal wastewater in water streams is becoming a major problem. Industrial effluents are rich sources of both beneficial as well as harmful metals and among these are: Pb, Ni, Cr and Cd which are found in fresh water canals (Narwal *et al*., 1993). In arid regions, where water available for irrigation is scare, industrial and domestic effluent and mixed sewage waters are commonly used for irrigating agricultural lands. Continuous reuse of such waters may lead to metal accumulation in soils to such an extent that may become toxic to soil-plant animal/human health.

It is obvious that the biological significance of metal accumulation in soils depends on the amount available for uptake by plant. Above certain concentration levels, crop quality may be affected. Among heavy metals, Cd has received a great attention because it is highly absorbed and accumulated in plants to toxic levels and causing health problems to animals (Singh and Nayyar, 1989). Appel and Ma (2002) found that Pb was absorbed more strongly than Cd in the soils and posses less threat to underlying ground water due to its lower mobility. As a result, soils are an important sink for Pb due to its high metal retention capacities. Important heavy metals posing threats to soil quality and human health include Cd and Pb (Hrudely *et al*., 1995 and USEPA 1992).

Anthropogenic heavy metals contamination of various environmental media has received unprecedented attention over the last decade. The key concern is bioaccumulation of toxic metals in the food chain, potential adverse health effects, and potential ecosystem perturbation (Sutherland, 2000).

The objectives of this investigation were to: (i) determine the concentrations of total and available of Cu, Mn, Fe, Cr, Ni, Cd and Pb in soils and their contents in leaves and grain of corn plants grown on these soils, (ii) assess the relationship between the concentration of heavy metals in plants versus in soil as related to soil properties and (iii) assess the mobility and transfer of metals from soils to plants.

MATERIALS AND METHODS

Sampling area

Three sampling sites, having different soil types, were selected at the western area of Nile delta (Fig.1). The soil types of three sites are: (i) alluvial (USTFLUVENTS) at Abou Hommos, (ii) lacustrine (USTFLUVENTS) at Abis, and (iii) calcareous "HAPLCACIDS" at North Tahrir. The soils of Abou Hommos and Abis are old cultivated land while those of North Tahrir are recent and cultivated only for about 50 years.

The soils of these sites are usually suffering shortage in the available water for irrigation. As a result, the farmers usually use different water sources, which is a mixture of fresh, domestic and agricultural drainage water, for irrigation especially in summer season.

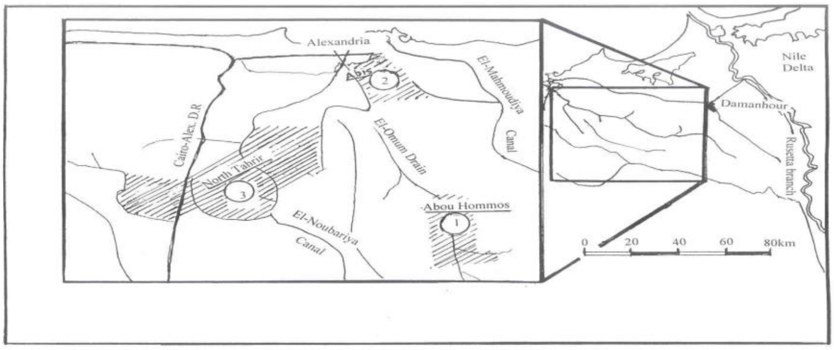

Fig. 1. Locations of the studied sites at the western area of Nile delta.

Sampling:

Soil: Soil samples were collected from the three sites during summer season 1997, where corn was grown, from two depths: 0 – 15 and 15 – 30cm. Forty soil pits were collected consisting of 11 from Abou Hommos, 19 from Abis, and 10 from North Tahrir.

Plant: Samples of leaves were collected from the growing 2 months old corn plant (*zea maize L*.) and those of grains were collected after crop harvest. These samples were collected from the correspond soil where plants were grown.

Analysis:

Soil: The collected soil samples were air-dried, ground in a wooden mortar and passed through 2 mm sieve. Soil pH was measured in a 1:2.5 soil: water suspension, electrical conductivity (EC) was measured in saturated soil water extract, soil organic matter was determined by wet oxidation method of Walkly and Black ,available phosphorus was extracted by 0.5M $NaHCO_3$ pH 8.5 and the concentration was measured by ascorbic acid method and total carbonate was measured by calcimeter (Page ,1982). The hydrometer method (Day,1965) was used for the determination of particle size distribution.

Wet digestion of soil was carried out for the determination of total concentration of metals in soils (Jeng and Bergselh, 1992). The concentrations of Cd, Ni,Cr, and Pb were measured by Perkin Elmer 3030 graphite furnace AAS, and those of Cu, Zn, Fe, and Mn were measured by PiUnicom SP 9 AAS.

The concentrations of available metals were determined by extracting the soil with 0.005M DTPA reagent of pH 7.3 according to the method outlined by Lindsay & Norvell (1978). The concentration of Cd, Ni, Pb, Cr, Cu, Zn, Fe, and Mn were measured by AAS.

Plant: The samples of leaves and grains were rinsed with tap water to remove adhering soil particulates, then washed several times with tap water followed by distilled water, dried at 65ºC for 72 hrs and ground finely in a stainless steel mill.

The oven-dried plant material (3-5gm.) was dry-ashed at 450ºC for 12hrs, then treated with 2:1 solution ratio of concentrated HCl : HNO_3 and placed on the hot plate. After evaporation (at 100 – 120ºC), 5 ml concentrated HC1 was added followed by evaporation and ignition for 30 min at 450ºC.The plant residue was dissolved in 5 ml concentrated HNO_3 and diluted to 50 ml with deionized water. The concentrations of Cu, Zn, Mn, and Fe were measured by atomic absorption spectrophotometer (PiUnicom SP 9 Series), and Cd, Ni, Cr, and Pb were measured by Perkin Elmer 3030 graphite furnace atomic absorption spectrophotometer. Each measurement was carried out in triplicate.

Statistical Analysis: The correlation and regression analysis were performed using Excel programs (Abacus concept, Inc., 1988).

RESULTS AND DISCUSSION

Characteristics of soils of the three sites

Data of table1 show that the soils of the three sites had slightly alkaline reaction with mean pH values of 8.2, 8.2 and 7.9 for the surface soil layer of Abou Hommos, Abis and North Tahrir, respectively. There were no marked variations in pH values between the soils of the upper and lower layers.

It is also cle ar from Table 1 that the mean values of EC of the surface soil layer (0-15cm) was 1.67 dSm^1 for Abou Hommos soils, 1.63 dSm^1 for Abis soils and 2.84 dSm^1 for North Tahrir soils. These indicate that the investigated soils are non-saline. There were no marked variation in salinity of soils of the upper and lower layers of Abou Hommos and Abis sites while it was higher in the upper layer of North Tahrir soils.

Table 1 shows wide variations in the levels of total carbonate in the soils of the three sites. As mean values, Abou Hommos soils contained the lowest levels (mean =6.8%), and North Tahrir soils contained the highest levels (mean = 33.5%) while those of Abis contained relatively high levels up to18.6%. Generally, there are no wide variations in the levels of total carbonate between the surface and subsurface soil layers.

Generally, the amounts of available P (Table 1) in the soils of the three sites markedly varied. There were generally higher levels of available P in the surface soil layer (0-15 cm) than those of the subsurface (15-30 cm). Also, there are marked decreases in the levels of organic matter with soil depth (Table 1) However, the mean levels of soil organic matter of the three sites were nearly close. In addition, the soils of the three sites contained variable proportions of sand and clay fractions (Table 1). Appreciable high amounts of clay fraction were found in soils of Abou Hommos and of Abis and low amounts were found in soils of North Tahrir, which contained the highest proportion of sand fraction.

Total Metal contents in soils

Table 2 shows the concentration of the total amounts of Cu, Zn, Mn, Fe, Cr, Ni, Cd and Pb in soils of the three sites.

Copper: The mean values of Cu in the surface soils of Abou Hommos and Abis are very close (mean = 26.8 and 25.5 mg kg^{-1}, respectively) and were higher than those in the surface soils of North Tahrir (mean = 13.7mg kg^{-1}) The latter soil is originated from Oelietic limestone (El-Demerdashe *et al*., 1991). It is obvious that soils originated from Olietic limestone usually contains low amounts of Cu. Alloway (1995) reported mean value of about 5.5 mg Kg^{-1} soil as total Cu contents in soils originated from limestone. The observed higher total Cu content in soils of North Tahrir (mean 13.7 mg kg^{-1} soil) could be due to agricultural practices carried out during the last fifty years. However, El-Damaty *et* al (1973) reported a mean value of 31.2 mg K^{-1} soil as total amounts of Cu in soil of North Tahrir. On the other hand, Elsokkary and Låg (1980) reported mean values of total Cu in alluvial soils as 50.8 mg kg^{-1} soil and in lacustrine soils as 49.6 mg kg^{-1} soil. These values are much higher than those found in soils of Abou Hommos and Abis reported in the present study.

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In general, the common value of the total Cu contents in agricultural soils were found in the range 20-30mg kg^{-1}soil (Alloway,1995). The data obtained in this study point out that the soils of the three investigated sites are not polluted by Cu. As show in Table2 there were no marked variations in the levels of total Cu in soils of the surface and subsurface layers. This indicates the absence of Cu mobilization in soils of the three sites.

Zinc: As shown in Table 2, the mean values of total Zn in the soils of the surface layer (0-15cm) of Abou Hommos and Abis were very close (82.0 and 84.6 mg kg^{-1}, respectively) and were higher than those of North Tahrir (60.0 mg kg^{-1}) . This low mean level of total Zn in North Tahrir soils could be due to the low Zn content of soil origin which is Oleitic limestone as reported by Alloway (1995) who suggested a mean value of total Zn in soils derive from limestone origin by about 20 mg kg^{-1}. On the other hand, higher values of for total Zn in alluvial soils (mean= 78.5 mg kg^{-1}) and in lacustrine soils (86.4 mg kg^{-1}) were found by Elsokkary and Låg(1980) which agree with the data presented in this study for soils of Abou Hommos and Abis sites. Alloway (1995) reported mean value of about 50 mg kg^{-1} soil as total Zn in common agricultural soil. Elsokkary and Sharaf (1996) reported that the amounts of total Zn in soils of Abou Hommos varied from 112-146 mg kg^{-1} and in soils of Abis from 91-114 mg kg^{-1} soil. Shahin and Abdel Hamid (1993) reported a range value of total Zn from 26-71 with a mean value of 44 mg kg^{-1} in calcareous soils of Maryout. As shown in Table 2, there were no marked variations in the amounts of total Zn in the surface and subsurface soils of Abou Hommos and Abis sites. However, the levels of total Zn were higher in the surface than the subsurface soils of North Tahrir which indicate higher input or deposition of Zn containing materials and also that there were no down word movement of Zn is soil.

Manganese: As shown in Table2, there were marked variations in the levels of total Mn in soils of the three sites. The amount of total Mn in soils of Abou Hommos were lower than those of Abis soils and higher than those of North Tahrir soils, since the mean values were 573, 796 and 395 mg kg^{-1}, respectively. The low levels of total Mn in North Tahrir soils was due to the low Mn in the soil origin which is Oleitic limestone as reported by Alloway (1995). On the other hand, Elsokkary and Låg (1980) reported mean values of total Mn as 617 and 645 mg kg^{-1} in alluvial and lacustrine soils, respectively. However, Alloway (1995) reported higher levels of total Mn (1000mg kg^{-1}) in common agricultural soils. However, El- Demerdashe *et al* (1991) reported values of total Mn in soils of North Tahrir ranging from 90 to 350 mg kg^{-1} in the surface soils. Shahin and Abdel Hamid (1993) found that total Mn contents in calcareous soil of Maryout varied from 186 to 379 mg kg^{-1} soil. As shown in Table 2, there were marked increases in the amounts of total Mn in soils of the subsurface laryer than those of the surface especially for Abou Hommos and Abis soils.

Iron: Table 2 showed higher levels of total Fe in soils of North Tahrir (mean=18942 mg kg^{-1}) than those of Abou Hommos (mean=6739 mg kg^{-1}) and Abis (mean=7766 mg kg^{-1}). However, the amounts of total Fe in soils of Abou Hommos and Abis sites were extremely low as compared with the data obtained by Elsokkary and Låg (1980) who reported mean values of 4.62 and

3.85 % as total Fe in alluvial and Lacustrine soils, respectively. In addition, El-Demerdashe *et al.* (1991) found that total Fe in North Tahrir soils varied from 9375 to 49975 mg kg-^{1} soil which agree so far with data obtained in this study. It is also clear that the total Fe contents in the surface soils of Abou Hommos and Abis were lower than those the subsurface while the opposite was found with soils of North Tahrir.

Chromium: As shown in Table 2, soils of North Tahrir site contained higher levels of total Cr (mean=57.3 mg kg^{-1}) than those of Abou Hommos (mean=27.3mg kg^{-1}) and of Abis (mean=28.3 mg kg^{-1}). The occurrence of high levels of Cr in the calcareous soil is questionable and could point out to soil pollution because the mean level of total Cr in limestone, as reported by Alloway (1995), is 11 mg kg^{-1} soil. However, it has been reported that the mean common range of total Cr in agricultural soil was from 70 to100 mg kg^{-1} (Alloway,1995). Shahin and Abdel Hamid (1993), reported range of total Cr in calcareous soils from 20 to 83 mg k^{-1} soil. These values agree with those found in this study. Table 2 also showed that there were marked higher levels of total Cr in soils of the subsurface layer than those of the surface for the three sites. This indicates the mobility of Cr from surface to subsurface in the soil profile.

Nickel: The mean value of total concentration of Ni in soils of Abou Hommos (39.8 mg kg^{-1}) was lower than in those of Abis (46.7 mg kg^{-1}) and was higher than in those of North Tahrir (27.6 mg kg^{-1}) . The low values of total Ni in soils of North Tahrir could be due to its Oleitic origin which contains low Ni levels (7 mg kg^{-1}) as reported by Alloway (1995). Generally,the concentration of total Ni in soils of the three sites are less than the common value of total Ni in agricultural soils (50 mg kg^{-1}) as reported by Alloway,(1995). Shahin and Abdel Hamid (1993) reported a range of total Cr in calcareous soils from 20 to 83 mg kg^{-1} soil which agree with those found in this study. Metwally and Rabie (1989) reported that the total nickel in alluvial and calcareous Egyptian soils ranged from 25 to 85 and from 29 to72.2ppm, respectively.

Cadmium: Table 2 showed higher levels of total Cd in soils of North Tahrir (mean =0.20 mg kg^{-1}) than those of Abou Hommos (0.12 mg kg^{-1}) and Abis (0.13 mg kg^{-1}). These levels are lower than those reported by Elsokkary and Låg (1980) in alluvial soils (mean= 0.32 mg kg^{-1}) and lacustrine soils (0.47 mg kg^{-1}). Alloway (1995) reported that the common value of total Cd in agricultural soils were within the range 0.2-1.0 mg kg^{-1} soil. These results showed that there was no pollution of the investigated soils by Cd. In addition there were no marked variation in the levels of total Cd in soils of the surface and of the subsurface layers.

Lead: The mean values of total concentrations of Pb in soils of the three investigated sites were nearly close since the mean values were 7.7, 8.0 and 8.2 mg kg^{-1} for soils of Abou Hommos, Abis and North Tahrir, respectively (Table 2). Elsokkary and Låg (1980) reported mean values of total Pb in alluvial and lacustrine soils as 8.6 and 15.3 mg kg $^{-1}$, respectively. In additions, Alloway (1995) reported that a range between 10 and 30 mg kg $^{-1}$ Pb is a common value for agricultural soils. Shahin and Abdel Hamid (1993) reported a range from 7.3 to 10.3 with a mean of 8.7 mg kg^{-1} in calcareous soil from Maryout which are within the levels reported in this study for North Tahrir soils.

DTPA-Extracted Metals

Table 4 showed the concentration of metals extracted from soil of the three sites by DTPA reagent. (Lindsay of Norvell,1978).

Copper: The amounts of DTPA-extracted Cu from soils of the three sites markedly varied (Table 4).Generally, the mean value of DTPA-extracted Cu from soils of Abou hommos (mean = 1.0 mg kg^{-1}), Abis (mean =2.4 mg kg^{-1}) and North Tahrir (mean = 0.7 mg kg^{-1}) were higher than the critical levels of DTPA-extracted Cu from soils (0.2 mg kg^{-1}) reported by Lindsay and Norvell (1978). Elsokkary and Låg(1980) found that the amounts of DTPA extracted Cu from alluvial soils were 1.1 mg kg^{-1} and those from lacustrine soils were 1.0 mg kg^{-1}. Aboulroos *et al* (1996) found that all studied alluvial soils contained between 1.1 and 4.9 $mgKg^{-1}$ DTPA- Cu which were much higher than the deficiency limit (0.2 ppm) reported by Lindsay and Narwel (1978).

Zinc : Table 4 showed that the amounts of DTPA-extracted Zn from soils of Abou Hommos (mean = 0.6 mg kg^{-1}) , Abis (mean = 0.9 mg kg^{-1}) and North Tahrir (mean = 1.1 mg kg^{-1}) were higher than the critical level (0.8 mg kg^{-1}) reported by Lindsay of Narwel (1978). Elsokkary and Låg (1980) reported mean values of DTPA extracted Zn as 0.3 mg kg^{-1} from alluvial soils and 0.45 mg kg^{-1} from lacustrine soils. Aboulroos *et al.* (1996) reported a range from 0.42 to 4.38 ppm DTPA- extracted Zn from alluvial Egyptian soils. They suggested that DTPA-Zn within the range; 1.56-4.38 mg kg^{-1} soil, can be used as the background level in nonpolluted alluvial Egyptian soils. Shahin and Abdel Hamid (1993) reported values of DTPA extracted Zn from calcareous soils within the range 0.4-1.4 with a mean value 0.8mg kg^{-1}. Elsokkary and Sharaf (1996) reported a range value of DTPA extracted Zn from 0.42 to 1.20 and from 0.20 to 2.5 mg kg^{-1} soils of Abou Hommos and Abis soils, respectively.

Manganese : The mean values of DTPA-extracted Mn from soils of Abou Hommos, Abis and North Tahrir were 4.9 , 6.8 and 5.4 mg kg^{-1}, respectively (Table 4). These levels were higher than the critical level (1.0 mg kg^{-1}) reported by Lindsay and Norvell (1978). Elsokkary and Låg (1980) found that the mean amount of DTPA -extracted Mn from either alluvial or lacustrine soil was 3.7 mg kg^{-1} soil. Abdel Hamid *et al* (1991) found that the amounts of DTPA-extracted Mn from surface calcareous soils from North Tahrir varied from 0.4 to 46.0 mg kg^{-1} soil. Shahin and Abdel Hamid (1993) found that the amounts of DTPA-extracted Mn from calcareous soils were from 6 to 17 with a mean value of 12 mg kg^{-1} soil.

Iron : Table 4 showed the mean values of DTPA-extracted Fe from soils of Abou Hommos (11.4 mg kg^{-1}) , Abis (10.3 mg kg^{-1}) and North Tahrir (5.7 mg kg^{-1}). These levels were higher than the critical level (4.5 mg kg^{-1}) reported by Lindsay and Norvell (1978).The data obtained by Elsokkary and Låg (1980) showed that the mean values of DTPA extracted Fe were 8.0 and 7.2 mg kg^{-1} from alluvial and Lacustrine soils, respectively. El-Demerdashe *et al.* (1991) reported a wide range of DTPA extracted Fe from surface calcareous soil from North Tahrir as from 1.0 to 43 mg kg^{-1} soil

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Chromium: The mean amounts of DTPA extracted Cr from soils of Abou Hommos was 0.04 mg kg $^{-1}$, from Abis was 0.09 and from North Tahrir was 0.03 mg kg $^{-1}$ soils (Table 4). Shahin and abdel Hamid (1993) found that the amounts of DTPA extracted Cr from calcareous soils were within the range from 0.1 to 0.2 with a mean value of 0.1 mg kg^{-1} soil

Nickel: Table 4 showed that the mean levels of DTPA extracted Ni was higher in soils of Abou Hommos (mean=0.77 mg kg $^{-1}$) than those of Abis (mean=0.56 mg kg $^{-1}$) and those of North Tahrir (mean=0.59 mg kg $^{-1}$). Shahin and Abdel Hamid (1993) reported a range from 0.1 to 0.5 mg kg^{-1} calcareous soil. Aboulroos *et al.* (1996) found a range from 0.09 to 1.23 DTPA- extracted Ni from alluvial soils . They suggested that a range from 0.54 to 0.74 ppm DTPA extractable Ni can be used as the background level in the alluvial soils of Egypt.

Cadmium : The amounts of DTPA extracted Cd from soils of the three investigated sites were nearly close. The mean values were 0.04 , 0.05 and 0.04 mg kg $^{-1}$ in soils of Abou Hommos , Abis and North Tahrir, respectively (Table 4). Elsokkary and Låg (1980) found that there were no detected amounts of Cd could be extracted with DTPA reagent whether from alluvial or lacustrine soils. Aboulroos et al (1996) reported a range from n.d. to 0.06 mg kg-1 DTPA extracted Cd from alluvial soils. They suggested that background levels of DTPA execrated Cd in the nonpolluted soils of Egypt, in general, was from 0.01 to 0.02 ppm.

Lead : The mean values of DTPA – extracted Pb from soils of Abou Hommos, Abis and North Tahrir, were 0.82, 1.09 and 0.81 mg kg $^{-1}$ soil, respectively (Table 4). The data reported by Elsokkary and Låg (1980) showed that the amounts of DTPA execrated Pb were, on the average, 0.21 and 0.34 mg kg $^{-1}$ soil from alluvial and lacustrine soils, respectively. Shahin and Abdel Hamid (1993) found that DTPA extracted Pb from calcareous soil were within the range n. d. to 0.1 mg kg^{-1}. However, Aboulroos *et al.* (1996) found DTPA-extracted Pb from alluvial soils were within the range 0.51-2.88 mg kg^{-1} soil.They suggested that a range from 1.17 to 1.61 ppm DTPA extracted Pb could be considered as the background level of Pb in the alluvial nonpolluted soils of Egypt.

Interrelationships among total and DTPA-extractable metals.

A correlation matrix for heavy metals in the soils of the different sites was calculated to investigate metals interrelation and the results are presented in Tables5, 6, 7 and 8.

Table 5 showed the correlation matrix for metals in Abou Hommos soils. The data indicated that total Pb significantly correlated with total Mn, Cr, Ni and with Cd and DTPA extractable Cu, Fe and Ni. However correlation was negative for DTPA-Fe. It is also clear that, the amounts of total Cr positively and significantly correlated with DTPA-Cu, Zn and Mn and negatively correlated with DTPA-Ni. In addition, total Ni positively and significantly correlated with Tot. Zn, Mn and Cr. On the other hand DTPA-Cu significantly correlated with DTPA-Zn, Mn, Fe, Ni and Tot. Cr and Pb and correlated negatively with DTPA-Ni.

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Table 6 showed that there is no consistence correlation matrix for heavy metals in Abis soils, in spite of that DTPA-Cu was positively and significantly correlated with DTPA-Zn and Pb and Tot. Cu, Zn, Mn and Ni. The data also showed significant correlation between DTPA-Cu, Zn and Cr and their total content in soils. Total Fe and Ni significantly correlated with Tot. Cu, Zn and Mn.

Table 7 showed correlation matrix for heavy metals in North Tahrir soil. These relations showed that Tot. Cd correlated highly significantly and positively with DTPA-Cu and Cd. While, Tot. Cr was negatively correlated with DTPA-Cr and Cd and with Tot. Zn and Mn. Also Tot. Pb correlated negatively with DTPA-Cr and with Tot. Fe and Ni and positively with Tot. Cr.

The relations presented in Table 8 showed that the concentrations of DTPA extractable Cd, Cr, Mn, Zn, and Cu were positively and significantly correlated with their total amounts except for Pb and Ni while the correlation was negative for Fe. Also, the total amounts of Ni were positively and significantly correlated with (DTPA) extractable Cu, Mn, Fe, and Pb and with total Cu, Zn, Mn, Fe and Cr , but its correlation with total Fe and Cr were negative. Table 8 also showed that Tot. Cd was positively correlated with Tot. Cr and negatively correlated with Tot. Ni, while Tot. Pb was negatively correlated with DTPA-Cr and Cd. The amounts of DTPA extractable Cu and Mn were positively and significantly correlated with DTPA-Zn, Fe, and Pb. On the other hand DTPA-Cd was significantly correlated with DTPA-Mn, Cr, and Pb and DTPA-Ni did not show significant correlation with any form of the metal contents of soil samples.

Relations among heavy metals, clay and total carbonate contents

Clay content:

It was found that clay content (%) of the soil samples was highly significant and positively correlated with DTPA extractable Cu and total of Cu, Zn, Mn, Fe, and Ni. Positive correlation between heavy metals contents in soils and their clay content have been reported by Anderson (1977). On the other hand, Cajuste and Laird (2001) found that clay content in soil had no positive and significant effect on total Cd. They also reported that Cd bound to organic matter was more important as a source of soil Cd than the Cd retained on the mineral exchange complex.

Total carbonate content:

The regression equations between metals content and $CaCO_3$ content in soil are shown in the following:

DTPA-Fe =	-0.181 $CaCo_3$ % + 12.659	R^{2**}=46911	(n=40)
Tot. Fe =	321.73 $CaCo_3$ % + 4421.1	R^{2**}=0.5079	(n=40)
DTPA-Cr =	0.0018 $CaCo_3$ % + 0.0471	R^{2**}=0.414	(n=40)
Tot. Cr =	1.0738 $CaCo_3$ % + 15.409	R^{2**}=0.7007	(n=40)

These relations showed that there were significant regression between calcium carbonate content (%) of soils and total and available iron and chromium. The regression equations showed that total calcium carbonate was responsible for 47, 41, 51 and70%of the variability in DTPA extractable and total content of Fe and Cr, respectively. Flores *et al* (1997) reported that the quantity of $CaCO_3$ was of a great importance for reducing metal availability to plants.

Metal Contents in Leaves and in Grains of Corn

Table 9 showed the levels of total metal contents in the leaves and grain of corn plants grown on soils of the investigated sites.

Copper : As shown in Table 9 the total contents of Cu in leaves of corn plants grown on soils of Abou Hommos (mean = 2.06 mg kg^{-1} DM), Abis (mean= 2.11 mg kg^{-1} DM) and North Tahrir (mean =1.56 mg kg^{-1} DM) were lower than the critical level (5.0 mg kg^{-1} DM) as reported by Jones et al (1990). This points out to the occurrence of Cu deficiency in plants grown on these soils. However, it is clear that the total contents of Cu in corn grain of plants grown on soils of the three sites were within the normal range (1.24-2.21 mg kg^{-1} DM) reported by Kabata Pendias and Pendias (1992).

Zinc : Table 9 showed that the total contents of Zn in leaves of corn plants grown on soils of Abou Hommos, Abis, and North Tahrir sites were Higher than the critical value (15.0mg kg^{-1} DM) as reported by Jones et al (1990). It is also clear that the total amounts of Zn in grain of corn plants grown on the soils of the three sites were within the normal range (17.90-48.75 mg kg^{-1} DM) reported by Kabata Pendias and Pendias (1992).

Manganese : The mean values of total contents of Mn in leaves of corn plants grown on soils of the three sites (Table 9) were higher than the critical value (15.0mg kg^{-1} DM) reported by Jones *et al.* (1990). The data also showed that the total contents of Mn in grain of corn plants grown on the soils of the three sites were within the normal range (19.79-42.19 mg kg^{-1} D.M) reported by Kabata Pendias & Pendias (1992).

Iron : Table 9 showed that the mean values of total contents of Fe in leaves of corn plants grown on soils of the three sites were higher than the critical level (15 mg Kg^{-1} D.M) reported by Jones *et al* (1990). Table 9 also showed that the total contents of Fe in grain of plants grown on these soils were within the normal range (16.36 – 26.70 mg k^{-1} D.M) reported by Kabata Pendias & Pendias (1992).

Nickel : As shown in Table 9, the amounts of total Ni in leaves of corn plants grown in soils of Abis were higher than those grown on soils of Abou Hommos and North Tahrir sites. The same trend was found with total content of Ni in grains of corn.

Cadmium : Table 9 showed that the leaves of corn plants grown on soils of Abis contained the highest amounts of Cd (mean = 2.00 mg K^{-1} D.M) as compared with those of Abou Hommos (mean = 1.49 mg K^{-1} D.M) and North Tahrir (mean = 0.93 mg K^{-1} D.M). However, the total Cd contents in grain of corn plants grown on soils of the these sites were nearly close and were within the normal range (0.9 – 2.6 mg K^{-1} D.M) as reported by Kabata Pendias & Pendias (1992).

Lead : The total amounts of Pb in leaves of corn plants grown on soils of North Tahrir were lower than those grown on soils of Abou Hommos and Abis sites (Table 9). In addition, Pb contents in leaves of corn plants grown on soils of Abis were higher (mean = 2.59 mg K^{-1} D.M) than those of Abou

Hommos (mean = 2.29 mg Kg^{-1} D.M). It is also clear that total Pb contents in corn grain were higher in plants grown in Abou Hommos and Abis soils than those of North Tahrir. Generally, the total contents of Pb in corn plants grown on the three sites were lower than the normal level (4 mg K^{-1} D.M) as reported by Kabata Pendias & Pendias (1992).

Relationships Between Contents of Metals in Plants and in Soils:

Correlation coefficients between the concentrations of heavy metals in corn leaves and grains and in the soils are presented in Tables 10 and 11. Cadmium concentration in corn leaves and grains positively and significantly correlated with soil contents of total Cu, Zn, Mn, Fe and Ni and also with DTPA extractable Cu, Fe and Pb while its correlation with total Fe in soils was negative.

The contents of Pb in leaves and grains positively and significantly correlated with total soil contents of Cu, Mn and Ni, and with total soil Zn only for plant leaves, but its correlation with total soil Fe and Cd were negatively significant. Also, Pb contents in leaves and grains significantly correlated with soil DTPA extractable Cu and Pb while significant correlated with soil DTPA-Fe for corn leaves only.

The content of Ni in leaves and grains significantly correlated with soil total content of Mn, Cu and Pb, also with DTPA extractable Cu, Mn and Pb. The correlation coefficient between plant contents (leaves and grains) of Ni and total soil content of Fe was negative (Tables 10 and 11).

The content of Cu, Zn and Mn in corn leaves and grains positively and significantly correlated with their total soil contents and also soil DTPA extractable Cu (Tables 10 and 11).

Total iron in soils showed negative significant relationships with total soil contents of Fe, Cu, Zn, Mn, Ni, Cd, and Pb of corn plant leaves and grains (Tables 10 and 11).

The total content of Cu,Zn, Mn, Fe, Ni, Pb and Cd in corn leaves and grains significantly correlated with total soil contents of Cu, Zn, Mn, Fe, Ni, and Cd and with DTPA extractable Cu, while these correlations were negative for Fe and Cd metals. The relations in Tables 10 and 11 showed that there were inconsistent significant correlation between metals contents of corn leaves and grains and DTPA extractable Mn, Fe and Pb.

The following are the regression equations:

Cu_{Grain} =	0.370 leaves + 1.340	R^2 =0.212*
Zn_{Grain} =	0.087 leaves + 19.355	R^2 =0.576**
Mn_{Grain} =	0.093 leaves + 18.816	R^2 =0.682**
Fe_{Grain}=	0.197 leaves + 12.299	R^2 =0.698**
Ni_{Grain} =	1.510 leaves + 0.388	R^2 =0.842**
Cd_{Grain} =	0.993 leaves + 0.293	R^2 =0.913**
Pb_{Grain} =	0.920 leaves + 1.237	R^2 =0.787**

These relations reveal that corn leaves contents of Cu, Zn, Mn, Fe, Ni, Cd and Pb were responsible for 21, 58, 68, 70, 84, 91 and79% of the variability in their grains concentrations. Also, the highest regression coefficient was observed when the grain content of Cd was regressed on the amount of Cd in plant leaves.

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Bioconcentration Ratio of Metals:

The results in Tables 9 and 12 show the ability of plant corn for metals uptake from soil. The bioconcentration ratio (BCR) expressed as the ratio of metals (bioavailable) in the soil is an adequate measure to compare the capacity of plant species for metal absorption, translocation from roots to leaves and bio accumulation in plant (Elsokkary and Sharaf 1996). According to the values of BCR in Table 12 the highest capacity of corn plant for absorbing, translocating and bioaccumulating were obtained for Zn and Cd. The mean values of BCR of Zn were 89, 123 and0.52 for Abou Hommos, Abis and North Tahrir soils, respectively. Also, the mean values of BCR of Cd were 33.7, 45.1 and4.9 for Abou Hommos, Abis and North Tahrir soils, respectively (Table 10). On the other hand, the lowest mean values of BCR(0.001) was recorded for Fe in corn plants grown on North Tahrir soils. These results are in agreement with those found by Elsokkary and Sharaf (1996)

The transfer coefficients (TC), expressed as the ratio of the total metals content in the plant (leaves and grains) to the total metals content in the soil (Table12), indicated that Cd and Zn are generally the most available metals. The highest mean values of TC were 12.8, 16.6 and70.6 for cadmium and 0.53, 0.97 and 35.4 for zinc in corn plants grown on Abou Hommos, Abis and North Tahrir soils ,respectively. These data are in agreement with the results obtained by Sauerbeck (1991) and Podlesákóva *et al* (2001). The other metals generally followed the sequence: Pb>Mn>Cu>Ni>Fe. Podlesákóva *et al* (2001) reported that transfer factors (coefficients) determined with field soils are much lower than those determined from soils with simulated pollution. This could be due to differences in metals mobilities and to other many factor which could interfere in the field studies.

Table 13 showed the values of relative mobility (RM) of heavy metals in soils. The results indicated that cadmium had the highest RM, where the mean values of relative mobility were 27.3, 43.3 and21.7 of soil depth 0-15cm and 19.2, 23.7 ans 13.4 of soil depth 15-30cm for Abou Hommos, Abis and North Tahrir soils, respectively. Similar result was found by Podlesákóva *et al.* (2001).It is clear that the lowest mean values of RM were recorded for Fe and Cr. However, Podlesákóva *et al.* (2001) reported that cadmium is the most harmful trace element because it has the highest plant uptake and mobility. They also found that in spite of some elements have high mobility such as Zn, Mn, Cu, there were diminishing uptake rates in the order: Zn>Mn>Cu. They also reported that metal mobility depends upon the specific bonds between the metal and the soils (Podlesákóva *et al.,* 2001).

11

12

CONCLUSIONS

Table 3 shows the mean common concentration values of total heavy metals in agricultural soils reported in the literature. These data showed that the soils of Abou Hommos and Abis contained relatively higher amounts of total Cu and Zn than the normal agricultural soils as reported by Alloway (1995). However, soils of North Tahrir contained lower amounts of total Cu and Mn and higher amounts of total Zn than the normal levels reported by (Alloway 1995). It is also clear from Table 3 that the soils of the three sites contained lower amounts of total Mn, Cr, Ni and Pb than the normal levels (Alloway, 1995). These results points out that these soils are not polluted by heavy metals except Cu and Zn in soils of Abou Hommos.

According to the background DTPA-extracted metals (Aboulroos *et al*., 1996) the studied soils of the three sites were not polluted by Cr, Ni and Pb but slightly polluted with Cd.

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توزيع العناصر الثقيلة فى ثلاثة أنواع أراضى فى ونباتات الذرة بمنطقة غرب دلتا النيل

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جمعت ثمانين عينة أرض من أعماق صفر 15 –،١٥-٣٠ سم ومعها ٤٠ عينة لكل من أوراق وحبوب الذرة وذلك من أماكن مختلفة فى منطقة غرب دلتا النيل بغرض تقدير المحتوى الكلى والتركيز المتاح (المستخلص بمحلول DTPA) فى الأرض للنبات وذلك لعناصر النحاس ، الزنك ، المنجنيز ، الكروم ، النيكل ، الكادميوم والرصاص وكذلك محتوى أوراق وحبوب نباتات الذرة النامية فى تلك الأراضى وعلاقة مستويات تلك العناصر ببعضها وكذا مع بعض خواص الأراضى .

هذا وقد درس كل من المحتوى الكلى للعناصر المستخلص بمحلول Aqua regia وكذا الكمية المستخلصة بواسطة محلول DTPA من تلك العناصر السابقة. وأوضحت النتائج أن متوسط قيم المحتوى الكلى للطبقة السطية لكل من أراضى أبو حمص ، أبيس ، شمال التحرير كانت بالنسبة للنحاس ٦٠ ، ٢٨ ، ٥ ، ٢٥ ، ٧ ، ١٣ وبالنسبة للزنك ٨٢,٠ ، ٨٤,٦ ، ٦٠,٠ وبالنسبة للمنجنيز ٥٧٣ ، ٧٩٦ ، ٣٩٥ وبالنسبة للحديد ٦٧٩٣ ، ٧٧٦٦ ، ١٨٩٤٢ وبالنسبة للكروم ٢٧,٣ ، ٢٨,٣ ، ٥٧,٣ ، وبالنسبة للرصاص ٧,٧ ، ٨,٠ ، ٨,٢ ، ملليجرام /كيلو جرام-١أرض وذلك على التوالى .

وقد وجد أن الكميات المستخلصة من تلك العناصر بواسطة محلول DTPA كانت فى المدى العادى للأراضى الزراعية ما عدا عنصر الكادميوم حيث كان أعلى من المستوى العادى .

وأوضحت النتائج أيضاً أن الكادميوم هو أكثر العناصر حركة فى الأرض وبالتالى أكثر إتاحة للنباتات من الرصاص والنيكل والكروم . وكذا وجد أن الكمية المستخلصة من عناصر الكادميوم ، الكروم والزنك والمنجنيز والنحاس بمحلول DTPA كانت متلازمة معنويا وموجبا مع محتوى الأرض الكلى لتلك العناصر. بالإضافة إلى ذلك فإن مستوى الأرض من الطين قد تلازم معنويا مع الصورة المتاحة وكذا المحتوى الكلى للأرض لكل من النحاس والزنك والمنجنيز والنيكل .

أوضحت النتائج أن تركيزات كل من النحاس والحديد والرصاص فى أوراق وحبوب نباتات الذرة كانت متلازمة معنويا وموجبة مع كميات تلك العناصر المستخلصة من الأرض بواسطة محلول DTPA كذلك أظهرت نتائج الدراسة أن أعلى قيم لكل من نسبة التركيز الحيوى BCR ومعامل الانتقال TC وجدت لكل من عنصرى الكادميوم والزنك ، كذلك أوضحت النتائج أن الكادميوم كانت له أعلى حركية نسبية RM وذلك لعينات الأراضى تحت الدراسة .