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TRACE METALS IN SOILS AND PLANTS FROM FADAMA FARMS IN EKITI STATE, NIGERIA

E.I. Adeyeye

Department of Chemistry, University of Ado Ekiti, P.M.B. 5363, Ado – Ekiti, Nigeria

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ABSTRACT. Levels of zinc, manganese, cobalt, selenium, copper, molybdenum, chromium, iron, aluminium, lead and cadmium were determined in plant organs (buds, flowers, fruits, seeds, leaves, stems, roots, cobs, styles, shaft, grains and efflorescences) and underlying soils of three Fadama farms located in Ifaki-Ekiti, Ado-Ekiti and Ikere-Ekiti of Ekiti State, Nigeria at 0–15 cm topsoil level. The pH levels were alkaline (7.0±0.3 – 8.1±0.7) while the soil texture ranged between loamy sand and sandy loam. There was similarity in Zn trend as was observed in Mn, Fe and Cu but they were of lower levels than Zn. Only Zn and Fe were mostly concentrated in the plant organs with Mn in very few plants. The index of bioaccumulation (ratio in plant/soil) were recorded for only Zn and Fe with the degree of accumulation ranging from medium to intensive (0.87–1.34) in Fe but only intensive (1.41–4.42) in Zn.

KEY WORDS: Trace metals, Soils, Plant organs, Bioaccumulation

INTRODUCTION

Soil is a very specific component of the biosphere because it is not only a geochemical sink for contaminants, but also acts as a natural buffer controlling the transport of chemical elements and substances to the atmosphere, hydrosphere and biota.

Plants can accumulate trace elements, especially heavy metals, in or on their tissues due to their great ability to adapt to variable chemical properties of the environment, thus plants are intermediate reservoirs through which trace elements from soils, and partly from waters and air, move to man and animals. As Tiffin [1] has concluded, plants may be passive receptors of trace elements (fallout interception or root adsorption), but they also exert control over uptake or rejection of some elements by appropriate physiological reactions.

Fadama is a Hausa word meaning the seasonally flooded or floodable flood plains along major savannah rivers and/or depressions on the adjacent low terraces [2]. Fadama utilization has been a major feature of the agricultural, food, economic and demographic experience of the Nigerian dry belt. The rationale for resource utilization here hinges on the availability of valuable agricultural resources in a zone where rain fed agricultural prospects are poor due to the small and erratic nature of rainfall and endemicity of drought. High water demanding crops can be produced during the rainy or flooding season, while less water demand crops can be deferred in time or shifted to upland areas when or where resource status is comparatively low [3].

The reaction of plants to chemical stresses that are caused by both deficiencies and excesses of trace elements cannot be defined exactly because plants have developed during their evolution and course of life (ontogeny and phylogeny) several biochemical mechanisms that have resulted in adaptation to and tolerance of new or chemically imbalanced environments. Therefore, plant responses to trace elements in the soil and ambient air should always be investigated for the particular soil-plant system.

*Corresponding author. E-mail: eiadeyeye@yahoo.com

This work provides correlated information on the levels of eleven elements (Zn, Pb, Mn, Co, Se, Cu, Mo, Cr, Fe, Al and Cd) in the plant organs or parts (buds, flowers, fruits, seeds, leaves, stems, root, cobs, styles, shaft, grains and efflorescences) and the underlying soils in three different Fadama soil sites in Ekiti State, Nigeria.

EXPERIMENTAL

Sampling

Samples were taken from three Fadama farms located in Ifaki-Ekiti (Northern Division), Ado-Ekiti (Central Division) and Ikere-Ekiti (Southern Division) of Ekiti State, Nigeria (Figure 1).

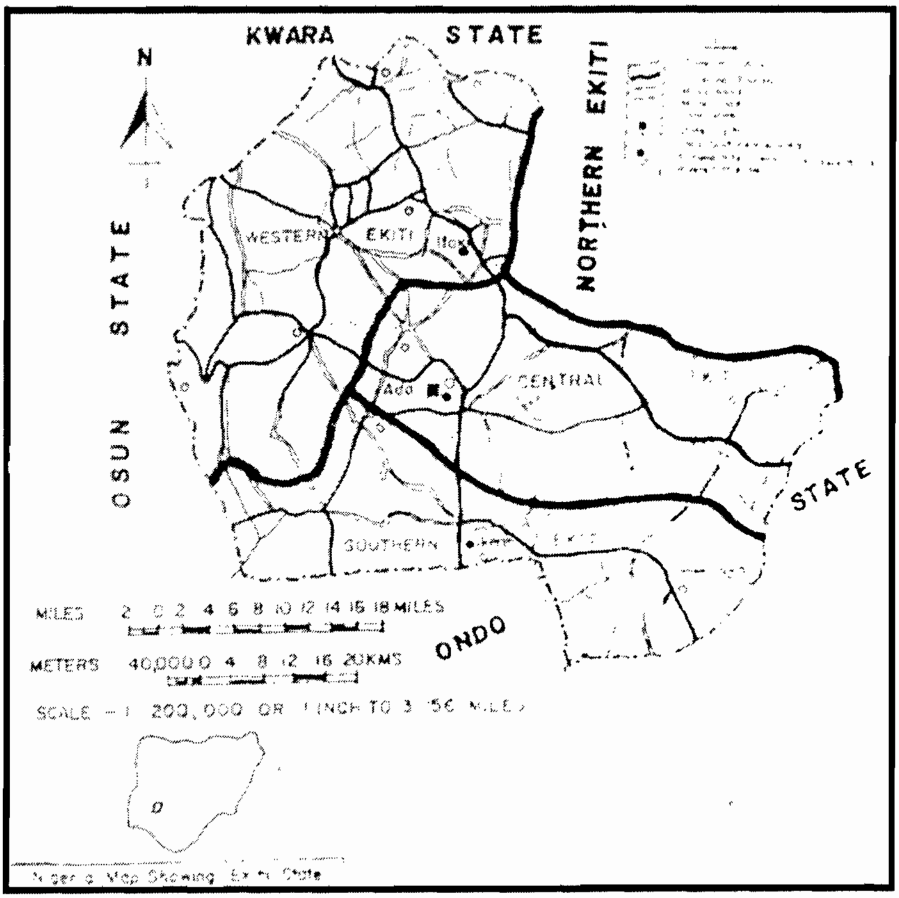

Figure 1. Map of Ekiti State showing the three Divisional regions where the Fadama sites are located.

Soils were taken at the plough zone of 0–15 cm depth at 0–5, 5–10 and 10–15 cm depth. The site of soil collection was determined by the proximity of the planted vegetable. The radius of soil collection was about 8.0 cm. Collected soils were put in acid-leached polythene bags, properly labelled and transferred to the laboratory.

Plant samples were collected at the various sites where soil samples were taken. The plants collected at the sites were *Celosia argentea* (L.), *Hibiscus esculentus* (L.), *Zea mays* (L.), *Corchorus olitorius* (L.) and *Lycopersicon esculentum* (Mill.). The plants were separated into buds, flowers, fruits, seeds, leaves, stems, roots, cobs, styles, shaft, grains and efflorescences as the case may be and put in different acid-leached polythene bags and transferred into the laboratory. Table 1 depicts the characteristics of sampling sites and samples.

Table 1. Characteristics of sampling sites and samples.

	Towns											
	Ifaki Ekiti				Ado Ekiti				Ikere Ekiti			
Site/ zone	IF_1	IF_2	IF_3	IF_4	AD_1	AD_2	AD_3	AD_4	IK_1	IK_2	IK_3	IK_4
Distance* (m)	54	67.5	102	106	48	52.5	55.5	57.5	9	12	9.35	9.35
Sampling date	13th March 2001				15th March 2001				16th March 2001			
Soil texture	LS[a]	SL[b]	SL	-[c]	LS	SL	SL	LS	SL	SL	SL	SL
Soil pH (water)	7.8± 0.2	7.9± 0.5	8.1± 0.7	-	7.8± 0.3	7.6±0.1	7.4±0.2	7.6±0.1	7.3±0.1	7.03± 0.3	7.3±0.4	7.9±0.0
Major site vegetables	*Celosia argentea* (L.)	*Hibiscus esculentus* (L.)	*Zea mays* (L.)	*Corchorus olitorius* (L.)	*H. esculentus*(L.)	*C. argentea* (L.)	*Z. mays* (L.)	*Lycopersicon esculentum*(Mill.)	*Z. mays* (L.)	*H. esculentus* (L.)	*C. argentea* (L.)	*L. esculentum* (Mill.)
(Maturity stage)	Just matured	Fruiting stage	10 weeks old	Flowering stage	Just matured	Not matured	Not matured	Just matured	Matured	Matured	Matured	Matured

*Road centre distance. [a]LS = Loamy sand; [b]SL = Sandy loam; - [C] = Not determined due to loss of sample.

Sample treatment

Both soils and plant parts were transferred to the laboratory where they were spread on polythene sheets until dried. After air-drying and homogenising, the soil and plant samples were sieved using 200 mm mesh. The method of total elemental analysis of cations by hydrofluoric and perchloric acids digestion was employed to prepare the soil solutions for analyses [4]. A known weight (0.5 g) of soil, plus 5-mL each of HF and $HClO_4$ were transferred in a platinum crucible and heated to dryness at 200-225 ^{0}C. The residue was dissolved completely in HCl. At the end of the reactions, the contents were filtered into 100 mL flask and made up to mark with 0.1 M HCl.

After sieving the plant tissues, they were prepared for analyses by the method of wet digestion using a combination of nitric acid and perchloric acid (70% solution). 1.0 g ground tissue plus 5 mL HNO_3 and 2 mL $HClO_4$, digested in fume cupboard, heating to a volume of 3 to 5 mL, 10 mL distilled water added and filtered into 50–mL flask. The filtered solutions were made up to volume with deionized water [5].

Zinc, lead, manganese, cobalt, selenium, copper, molybdenum, chromium, iron, aluminium and cadmium were analysed in the samples using a Perkin Elmer model 306 Atomic Absorption

Spectrophotometer. Analyses were done in duplicate. The detection limits of all the elements were determined before the sample solutions were analysed [6].

Labels used for the towns and zones were IF_1 = Ifaki-Ekiti zone 1, IF_2 = Ifaki-Ekiti zone 2, IF_3 = Ifaki-Ekiti zone 3, IF_4 = Ifaki-Ekiti zone 4; AD_1 = Ado-Ekiti zone 1, AD_2 = Ado-Ekiti zone 2; AD_3 = Ado-Ekiti zone 3, AD_4 = Ado-Ekiti zone 4; IK_1, = Ikere-Ekiti zone 1, IK_2 = Ikere-Ekiti zone 2, IK_3 = Ikere-Ekiti zone 3, IK_4 = Ikere-Ekiti zone 4.

All data generated were analysed statistically [7]. From the average values obtained for metals in the plants and soils, index of bioaccumulation were calculated and the results gave the degree of accumulation [8].

RESULTS AND DISCUSSION

Table 1 shows that the month of sample collection was in March. This is at the center of the dry season in Ekiti State. A close observation of Figure 1 will show that the three towns have small streams where water could be collected to wet the small holdings or the farmers could dig shallow wells to collect water for wetting the crops. The Fadama farms are also relatively close to the roads so that customers could easily reach the farms (Table 1). Most plants planted were vegetables (80%) while cereal was only 20%. These are plants mostly sought for during the dry season.

The organic matter (OM) of the soils ranged from 0.78–2.19% making the soils to fall into the groups of mineral or inorganic soils. Carbon was determined by the Walkley-Black wet oxidation method [9]. This type of soil had been described as the upper and biologically weathered portion of the regolith [10]. The pH of the soils ranged between 7.0±0.3 to 8.1±0.7, that is neutrality to slight alkalinity showing mineral soils behaviour. The soil pH may influence nutrient absorption and plant growth in two ways: (a) through the direct effect of the hydrogen ion; or (b) indirectly, through its influence on nutrient availability and the presence of toxic ions. In most soils the latter effect is of great significance. The availability of several of the essential nutrients is drastically affected by soil pH, as is the solubility of certain elements that are toxic to plant growth. Several essential elements tend to become less available as the pH is raised from 5.0–7.5 or 8.0. Fe, Mn and Zn are good examples. Mo availability, on the other hand, is affected in the opposite way, being higher at the higher pH levels. At pH values below 5.0, Al, Fe and Mn are often soluble in sufficient quantities to be toxic to the growth of some plants. At very high pH values, the bicarbonate ion is sometimes present in sufficient quantities to interfere with the normal uptake of other ions and thus is detrimental to optimum growth. These observations show why much importance must be placed on this characteristic [10].

The textural class names as shown in Table 1 are loamy sand and sandy loam. These soils could contain various levels of sand, silt and clay particles which exhibit light and heavy properties in about equal proportions.

Table 2 depicts the trace metals in Ifaki–Ekiti Fadama farm soil (DW). The following metals were not detected in any of the zones: Pb, Co, Se, Mo, Cr and Cd while Al was not detected in IF_1, (10–15 cm depth) and IF_2 (0–5, 5–10 cm depth). On comparative basis the concentrations of the metals follow this trend: Fe > Zn > Mn >Cu > Al. In Zn, for all the zones the values in the depths follow this trend: 0–5 < 5–10 > 10–15 cm; this trend is similar in IF_1, and IF_2 but 0–5 > 5–10 < 10–15 cm in IF_3 for Mn; in Cu, the trend is 0–5 < 5–10 > 10–15 cm in IF_2 and IF_3 but it is 0–5 < 5–10 <10–15 cm in IF_1; highly inconsistent pattern is observed in Fe; in Al it is 0–5 > 5–10 < 10–15 cm in IF_1 but in IF_3 it is 0–5 = 5–10 = 10–15 cm.

Table 2. Trace heavy metals (ppm) in Ifaki – Ekiti Fadama farm soil (DW).

Zone	Depth (cm)	Zn	Pb	Mn	Co	Se	Cu	Mo	Cr	Fe	Al	Cd
IF_1	0-5	161.0	ND[b]	48.1	ND	ND	18.2	ND	ND	266.8	2.0	ND
	5-10	167.0	ND	48.4	ND	ND	18.8	ND	ND	261.2	0.6	ND
	10-15	163.6	ND	46.4	ND	ND	19.0	ND	ND	247.6	ND	ND
IF_2	0-5	172.6	ND	41.2	ND	ND	20.4	ND	ND	267.8	ND	ND
	5-10	176.0	ND	56.0	ND	ND	22.0	ND	ND	276.4	ND	ND
	10-15	169.2	ND	52.0	ND	ND	18.6	ND	ND	273.6	2.0	ND
IF_3	0-5	162.6	ND	37.2	ND	ND	18.6	ND	ND	257.6	1.6	ND
	5-10	167.0	ND	36.4	ND	ND	20.4	ND	ND	247.6	1.6	ND
	10-15	166.6	ND	39.0	ND	ND	17.0	ND	ND	251.0	1.6	ND

[a]DW = dry weight. [b]ND = not detected.

Table 3 depicts the trace metals in the Ado-Ekiti Fadama farm soil. All the metals not detected in Ifaki-Ekiti Fadama soil are also not detected at Ado-Ekiti. The pattern of concentration in terms of zonal metal levels is also consistently followed in Ado-Ekiti as observed for Ifaki-Ekiti. The Zn levels from the Ado-Ekiti soil are higher than Ifaki-Ekiti but Mn, Cu and Fe levels are lower in Ado-Ekiti than Ifaki-Ekiti while the Al values are almost similar in the two towns.

Table 3. Trace heavy metals (ppm) in Ado – Ekiti Fadama farm soil (DW).

Zone	Depth (cm)	Zn	Pb	Mn	Co	Se	Cu	Mo	Cr	Fe	Al	Cd
AD_1	0-5	9.3	ND[b]	2.02	ND	ND	0.7	ND	ND	7.7	ND	ND
	5-10	180.6	ND	63.4	ND	ND	13.2	ND	ND	153.6	2.6	ND
	10-15	180.6	ND	62.4	ND	ND	13.2	ND	ND	259.2	ND	ND
AD_2	0-5	155.0	ND	34.6	ND	ND	4.4	ND	ND	158.4	2.6	ND
	5-10	185.0	ND	60.8	ND	ND	16.4	ND	ND	280.4	ND	ND
	10-15	176.6	ND	40.4	ND	ND	16.0	ND	ND	186.2	ND	ND
AD_3	0-5	175.0	ND	35.8	ND	ND	13.0	ND	ND	230.3	ND	ND
	5-10	180.6	ND	47.6	ND	ND	10.8	ND	ND	259.2	ND	ND
	10-15	172.6	ND	11.2	ND	ND	9.0	ND	ND	85.4	ND	ND
AD_4	0-5	166.6	ND	41.0	ND	ND	14.4	ND	ND	86.0	1.0	ND
	5-10	176.0	ND	32.0	ND	ND	8.0	ND	ND	121.0	1.6	ND
	10-15	175.6	ND	49.6	ND	ND	12.4	ND	ND	150.6	1.6	ND

Table 4 depicts the trace metal levels present in the Fadama farm soil based in Ikere-Ekiti. In addition to Zn, Mn, Fe and Al, values are also observed for Pb in IK_3 5–10 cm (9.0 ppm DW) and 10–15 cm (8.2 ppm DW) while the other metals are not detected as in Tables 2 and 3. The Zn levels in Table 4 follow the pattern of Zn in Ado-Ekiti with the profile distribution being inconsistent. The Mn in Table 4 is generally higher than the values in Tables 2 and 3 with inconsistent pattern of soil profile distribution. Cu is generally lower than the values in Tables 2 and 3. The pattern of Fe concentration in Table 4 is consistent with the pattern in Table 2 with little evidence of leaching. Al is not detected in only three zones (25%) out of the twelve zones analysed for in Ikere-Ekiti. The Al levels are generally low and fairly consistent (1.0–1.6 ppm DW) or 1.6 ± 0.0 ppm.

Table 4. Trace heavy metals (ppm) in Ikere – Ekiti Fadama farm soil (DW).

Zone	Depth (cm)	Zn	Pb	Mn	Co	Se	Cu	Mo	Cr	Fe	Al	Cd
IK_1	0-5	179.0	ND	86.4	ND	ND	11.0	ND	ND	258.2	1.6	ND
	5-10	170.0	ND	58.6	ND	ND	14.4	ND	ND	252.8	1.6	ND
	10-15	177.0	ND	68.2	ND	ND	16.6	ND	ND	276.4	1.6	ND
IK_2	0-5	177.6	ND	151.0	ND	ND	19.0	ND	ND	271.6	1.6	ND
	5-10	175.6	ND	74.8	ND	ND	17.6	ND	ND	262.0	1.6	ND
	10-15	178.6	ND	72.8	ND	ND	19.2	ND	ND	262.0	1.6	ND
IK_3	0-5	177.6	ND	75.2	ND	ND	17.8	ND	ND	260.0	1.0	ND
	5-10	181.0	9.0	68.4	ND	ND	17.2	ND	ND	257.2	1.2	ND
	10-15	182.0	8.2	44.8	ND	ND	17.6	ND	ND	258.2	ND	ND
IK_4	0-5	182.0	ND	100.2	ND	ND	11.4	ND	ND	261.4	ND	ND
	5-10	180.6	ND	101.6	ND	ND	14.8	ND	ND	262.0	ND	ND
	10-15	177.6	ND	77.8	ND	ND	17.2	ND	ND	280.4	1.5	ND

Total Cu content of soils gives basic information for geochemical studies. The common characteristic of Cu distribution in soil profiles is its accumulation in the top horizons. This phenomenon is an effect of various factors, but above all, Cu concentration in surface soils reflects the bioaccumulation of the metal and also recent anthropogenic sources of the element [8]. Concentrations of Cu in soil solutions obtained by various techniques from different soils vary from 3 to 135 $\mu g\ L^{-1}$. Overall solubility of both cationic and anionic forms of Cu decreases at about pH 7 to 8 [8]. Cu content of soils has already been built up to the extremely high concentration of about 3500 ppm Cu from industrial sources of pollution and of about 1500 ppm Cu from agricultural origins of the metal [11]. The threshold value of 100 ppm Cu has been exceeded in several contaminated surface soils. Table 5 shows that the average levels of Cu ranged between 9.04±7.2 to 20.33±1.7 ppm (DW) with a coefficient of variation percent (CV%) of 2.25 to 79.65. These results show that all the soil Cu levels are far below the threshold level.

Zn is considered to be readily soluble relative to the other heavy metals in soils. The Zn concentrations in soil solutions range from 4 to270 μgL^{-1}. Itoh *et al.* [12] reported the maximum of 17000 μg Zn L^{-1} of solution and this value is, apparently, for highly contaminated soils. However, in natural but very acid soils (pH < 4) Zn concentration in soil solutions is reported to average 7137 μgL^{-1}. Mean total Zn contents in surface soils of different countries and of the U.S.A. range from 17 to 125 ppm. Thus, these values may be considered as background Zn contents. Grand mean Zn for world-wide soils may be calculated for 64 ppm. Obviously, a look at Table 5 shows that the soil Zn grand mean values are all above 64 ppm, only one value, AD_1 with 123.5±98.9 ppm (CV% of 80.08) is lower than 125 ppm while the rest ranged between 163.9±3.0 ppm (CV%, 1.8) to 180.2±2.3 ppm (CV%, 1.3) showing the soils may be Zn contaminated. Zn contamination of soils may create an important environmental problem. Amelioration based on controlling its availability by the addition of lime or organic matter or both [8], one or both is advocated here.

The solutions of neutral soils contain Al in the order of about 400 μgL^{-1}, while in the soil solution at pH 4.4 Al concentration is reported to be 5700 μgL^{-1} [13]. Foy [14] reported that Al toxicity in subsoils is particularly harmful because it causes shallow rooting, drought susceptibility and poor use of subsoil nutrients. In all places where grand mean Al values are reported (Table 5), they all have similar values of 1.6±0.0 ppm showing the soils are far away from Al pollution.

Pb is reported only for IK_3 5–10 cm depth (9.0 ppm) and IK_3 10–15 cm depth (8.2 ppm). Pb values from different countries show that amounts for soil types range from 10 to 67 ppm and average 32 ppm. High Pb levels (above 100 ppm) have been reported only for Denmark, Japan, Great Britain and Ireland and most probably reflect the impact of pollution. Davies [15] stated that an upper limit for the Pb content of a normal soil could be established as 70 ppm. Gough *et al.* [16] found a relatively low Pb content of soils in Alaska. Although Pb ranges in these soils from 4 to 349 ppm (DW), about 90% of the samples contained only up to 20 ppm with a geometric mean of 12. This suggests that baseline values of this metal in most world soils should not be much higher than 20 ppm [8]. Based on these facts, the soils under review are of low Pb value.

Table 5. Mean trace heavy metals (ppm) in the soils and plants of the three towns.

Zone		Soil					Plants	
		Zn	Mn	Cu	Fe	Al	Zn	Fe
IF_1		163.9 (3.0)	47.6 (1.1)	18.7 (0.4)	258.5 (9.9)	-	340.1 (89.8)	225.0 (43.4)
	CV%	1.8	2.2	3.3	3.8		26.4	19.3
IF_2		172.6 (3.4)	49.7 (7.7)	20.3 (1.7)	272.6 (4.4)	-	569.6 (688.9)	366.5 (520.1)
	CV%	2.0	15.4	8.4	1.6		120.9	141.9
IF_3		165.4 (2.4)	37.5 (1.3)	18.7 (1.7)	251.9 (4.9)	1.6 (0.0)	380.8 (18.7)	356.5 (344.4)
	CV%	1.5	3.5	9.1	1.9	-	4.9	96.6
IF_4		-	-	-	-	-	311.6 (110.0)	201.3 (125.2)
	CV%	-	-	-	-	-	35.3	62.2
AD_1		123.5(98.9)	42.6 (35.2)	9.0 (7.2)	140.2(126.3)	-	370.8 (89.3)	177.2 (192.9)
	CV%	80.1	82.5	79.7	90.1		24.1	108.9
AD_2		172.2(15.5)	45.3 (13.8)	12.3 (6.8)	208.3 (63.9)	-	341.8 (22.8)	218.8 (181.4)
	CV%	8.9	30.4	55.6	30.7		6.7	82.9
AD_3		176.1 (4.1)	31.5 (18.6)	10.9 (2.0)	191.6 (93.1)	-	359.1 (24.2)	173.9 (148.2)
	CV%	2.3	58.9	18.3	48.6		6.7	85.2
AD_4		172.7 (5.3)	40.9 (8.8)	11.6 (3.3)	119.2 (32.3)	-	337.3 (7.3)	147.8 (152.6)
	CV%	3.1	21.5	28.2	27.1		2.2	103.3
IK_1		175.3 (4.7)	71.1 (14.1)	14.0 (2.8)	262.5 (12.4)	1.6 (0.0)	247.6 (127.8)	-
	CV%	2.7	19.9	20.1	4.7	-	51.6	-
IK_2		177.3 (1.5)	99.5 (44.6)	18.6 (0.9)	265.2 (5.5)	1.6 (0.0)	784.2 (876.7)	-
	CV%	0.9	44.8	4.7	2.1	-	111.8	
IK_3		180.2 (2.3)	62.8 (16.0)	17.5 (0.3)	258.5 (1.4)	-	307.6 (58.9)	-
	CV%	1.3	25.4	1.8	0.6		19.2	
IK_4		180.1 (2.2)	93.2 (13.4)	14.5 (2.9)	267.9 (10.8)	-	350.1 (24.5)	
	CV%	1.2	14.3	20.1	4.0		7.0	

Figures in parentheses are standard deviation. CV = coefficient of variation. - = see Table 1.

Table 5 shows that the grand mean of Mn in the soils ranges from 31.5±18.6 ppm to 99.5±44.6 ppm (DW). The abundance of soluble species of Mn in the soil solution is reported to range from 25 to 8000 $\mu g L^{-1}$. For solutions of neutral and acid soils, the Mn concentration range is reported to vary from 1 to 100 $\mu g\ L^{-1}$ [17]. Highly alkaline soils (at about pH 8) can produce Mn toxicity. Although one pH value is 8.1±0.7, the values of Mn do not appear high enough to constitute pollution.

The levels of Fe in the soils range from 119.2±32.3 ppm to 272.6±4.4 ppm. The concentration of Fe in soil solutions within common soil pH levels ranges from 30 to 550 $\mu g\ L^{-1}$. The current Fe levels in the soil could not be said to be too high.

The levels of Zn and Fe reported here are higher than the literature values: Asaolu [18] reported a total value of Zn to range between 7.0 $\mu g\ g^{-1}$ and 25.0 $\mu g\ g^{-1}$ and Fe ranged from 28.5

μg g^{-1} to 38.5 μg g^{-1} in the basement complex soils of Western Nigeria. Also Akande *et al.* [19] reported 2.5 mg/kg Zn and 1.2 mg/kg Cu from Sokoto soils. The study of Ndiokwere [20] in soils along the Benin-Onitsha highway showed Cu levels to range from 14.5 to 61.0 μg g^{-1} and Zn to range from 32.8 to 163.0 μg g^{-1} depending on distances from the high way.

Tables 6-8 depict the metal concentrations in the plant samples. In Ifaki-Ekiti Fadama farm (Table 6), only Zn is detected in all the plant parts, Fe is detected in all the plant samples except in the leaves of *Hibiscus esculentus* (L.) and only the leaves of *Celosia argentea* show some level of Mn. In Ado-Ekiti Fadama farm (Table 7) Zn and Fe are detected in all the samples but Cu is detected only in *Zea mays* root while Mn is detected in flower and bud of *Hibiscus esculentus* (AD_1), style of *Z. mays* (AD_3) and stem of *Lycopersicon esculentum (*Mill.*)* (AD_4). In Ikere-Ekiti Fadama farm only Zn is detected in all the plant samples (Table 8).

The meager information on the role of micronutrients suggests that several of the trace elements are effective through certain enzyme systems. For example, Cu, Fe and Mo are capable of acting as electron carriers in enzyme systems which bring about oxidation-reduction reactions in plants. Zn and Mn also function in enzyme systems which are necessary for important reactions in plant metabolism. Mo and Mn are essential for certain nitrogen transformations in microorganisms as well as in plants. Zn is thought to be concerned in the formation of some growth hormones and in the reproduction process of certain plants. Cu is involved in respiration and in the utilization of Fe. Fe is essential for chlorophyll formation and for the synthesis of proteins contained in the chloroplasts [8]. All the above attested to the essentiality of the micro metals in plant metabolism.

Removal of Cu by crops is negligible when compared to its content in soil. In the current report only the root of *Z. mays* contains detectable level of Cu. The strong capability of root tissues to hold Cu against the transport to shoots under conditions of both Cu deficiency and Cu excess has been observed. Loneragan [21] and Tiffin [22] concluded that excretion of Cu from root cells into the xylem and phloem saps where Cu occurs in mobile forms is a key process in the Cu nutrition of plants. This Cu excretion might not have been strong enough in the plants under review.

Table 6. Trace heavy metals (ppm) in Ifaki-Ekiti Fadama farm plants (DW).

Zone	Plant	Plant part	Zn	Pb	Mn	Co	Se	Cu	Mo	Cr	Fe	Al	Cd
IF_1	*Celosia argentea* (L.)	Root	350.0	ND	ND	ND	ND	ND	ND	ND	221.0	ND	ND
		Leaves	427.5	ND	26.0	ND	ND	ND	ND	ND	223.0	ND	ND
		Stem	215.0	ND	ND	ND	ND	ND	ND	ND	175.0	ND	ND
		Fruit	368.0	ND	ND	ND	ND	ND	ND	ND	281.0	ND	ND
IF_2	*Hibiscus esculentus* (L.)	Root	179.0	ND	ND	ND	ND	ND	ND	ND	124.5	ND	ND
		Leaves	375.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Bud	1794.4	ND	ND	ND	ND	ND	ND	ND	1144.4	ND	ND
		Stem	228.0	ND	ND	ND	ND	ND	ND	ND	53.0	ND	ND
		Fruit	211.5	ND	ND	ND	ND	ND	ND	ND	144.0	ND	ND
IF_3	*Zea mays* (L.)	Root	367.5	ND	ND	ND	ND	ND	ND	ND	600.0	ND	ND
		Leaves	394.0	ND	ND	ND	ND	ND	ND	ND	113.0	ND	ND
IF_4	*Corchorus olitorius* (L.)	Root	170.0	ND	ND	ND	ND	ND	ND	ND	103.0	ND	ND
		Leaves	255.0	ND	ND	ND	ND	ND	ND	ND	199.0	ND	ND
		Stem	294.0	ND	ND	ND	ND	ND	ND	ND	122.5	ND	ND
		Flower	392.0	ND	ND	ND	ND	ND	ND	ND	415.0	ND	ND
		Bud	447.0	ND	ND	ND	ND	ND	ND	ND	167.0	ND	ND

Table 7. Trace heavy metals (ppm) in Ado-Ekiti Fadama farm plants (DW).

Zone	Plant	Plant part	Zn	Pb	Mn	Co	Se	Cu	Mo	Cr	Fe	Al	Cd
AD_1	*H. esculentus*	Root	322.0	ND	ND	ND	ND	ND	ND	ND	151.0	ND	ND
		Leaves	340.0	ND	ND	ND	ND	ND	ND	ND	252.0	ND	ND
		Stem	323.0	ND	1.9	ND	ND	ND	ND	ND	27.0	ND	ND
		Fruit	340.0	ND	ND	ND	ND	ND	ND	ND	43.0	ND	ND
		Flower	552.0	ND	1.2	ND	ND	ND	ND	ND	531.0	ND	ND
		Bud	348.0	ND	ND	ND	ND	ND	ND	ND	59.0	ND	ND
AD_2	*C. argentea*	Root	309.0	ND	ND	ND	ND	ND	ND	ND	94.0	ND	ND
		Leaves	362.0	ND	ND	ND	ND	ND	ND	ND	468.0	ND	ND
		Stem	347.0	ND	ND	ND	ND	ND	ND	ND	75.0	ND	ND
		Seed	349.0	ND	ND	ND	ND	ND	ND	ND	238.0	ND	ND
AD_3	*Zea mays*	Root	352.0	ND	ND	ND	ND	237.0	ND	ND	516.0	ND	ND
		Leaves	347.0	ND	ND	ND	ND	ND	ND	ND	108.0	ND	ND
		Stem	372.0	ND	ND	ND	ND	ND	ND	ND	84.0	ND	ND
		Grains	335.0	ND	ND	ND	ND	ND	ND	ND	187.0	ND	ND
		Cob	345.0	ND	ND	ND	ND	ND	ND	ND	63.0	ND	ND
		Style	343.0	ND	2.0	ND	ND	ND	ND	ND	82.0	ND	ND
		Efflorescence	410.0	ND	ND	ND	ND	ND	ND	ND	216.0	ND	ND
		Cob shaft	369.0	ND	ND	ND	ND	ND	ND	ND	135.0	ND	ND
AD_4	*Lycopersicon esculentum* (Mill.)	Root	344.0	ND	ND	ND	ND	ND	ND	ND	175.0	ND	ND
		Leaves	327.0	ND	ND	ND	ND	ND	ND	ND	353.0	ND	ND
		Stem	338.0	ND	2.0	ND	ND	ND	ND	ND	31.0	ND	ND
		Fruit	340.0	ND	ND	ND	ND	ND	ND	ND	32.0	ND	ND

Table 8. Trace heavy metals (ppm) in Ikere-Ekiti Fadama farm plants (DW).

Zone	Plant	Plant part	Zn	Pb	Mn	Co	Se	Cu	Mo	Cr	Fe	Al	Cd
IK_1	*Z. mays*	Root[a]	-	-	-	-	-	-	-	-	-	-	-
		Leaves	315.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Stem	236.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Grains	321.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Cob	211.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Efflorescence	381.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Cob shaft	19.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
IK_2	*H. esculentus*	Root	312.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Leaves	352.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Stem	188.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Fruit	341.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Flower	1050.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Bud	2461.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
IK_3	*C. argentea*	Root	315.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Leaves	326.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Stem	225.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Fruit	364.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
IK_4	*L. esculentum*	Root	377.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Leaves	327.5	ND	10.0	ND	ND	ND	ND	ND	ND	ND	ND
		Stem	364.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Fruit	331.5	ND	69.5	ND	ND	ND	ND	ND	ND	ND	ND

[a]Root = not determined due to loss of sample.

The Zn levels in all the plant parts are much higher than the corresponding levels in the corresponding soils. Where buds are analysed, they appear to serve as luxury accumulators of Zn, for examples in *Hibiscus esculentus* (IF_2) the bud has a value of 1794.4 ppm (DW), *Corchorus olitorius* (IF_4) has 447.0 ppm (DW) in its bud, in *H. esculentus* (AD_1) the bud has a value of 348.0 ppm (DW) and *H. esculentus* (IK_2) the bud has a value of 2461.1 ppm (DW). Flowers also have this type of luxury accumulation of Zn: in *C. olitorius* (IF_4) it is 392.0 ppm (DW) (second only to bud), *H. esculentus* (AD_1) it is 552.0 ppm (DW) (highest), *H. esculentus* (IK_2) it is 1050.0 ppm (DW) and in efflorescences it is 410.0 ppm in *Z. mays* (AD_3) and 381.9 ppm (DW) in *Z. mays* (IK_1) which are the highest in their groups. In most of the samples the Zn levels in leaves are greater than in the roots. The values of Zn in all the plant parts are very important since they will either develop to become available for human consumption or to be consumed by either domestic fowls or goats which might re-circulate the metal for ultimate human consumption. From Tables 2–4 it would appear that the soils contain luxury levels of Zn which enable the plants to translocate Zn from the roots and accumulated by the tops of the plant. It has been calculated by Baumeister and Ernst [23] that up to 75% of the total Zn that is taken up is in the tops of young plants (see Table 1), whereas 20 to 30% occurs in the tops of old plants. Zn content ranged from 1.2 to 73 ppm (DW) in apple and lettuce leaves, respectively. Mean values for Zn in wheat grains ranged from 22 to 33 ppm (DW). In grasses Zn ranged from 12 to 47 ppm (DW) and in clovers ranged from 24 to 45 ppm (DW) [8]. The deficiency content of Zn in plants has been established at 10 to 20 ppm (DW).

Mn is detected in *C. argentea* leaves (IF_1), in flowers and buds in *H. esculentus* (AD_1), in *Z. mays* style (AD_3), in the stem of *Lycopersicon esculentum* (AD_4) and in *L. esculentum* fruit (IK_4). While the highest Mn concentration (69.5 ppm) comes from the fruit, the lowest (1.219 ppm) comes from the flower. Heenan and Campbell [24] reported that at a high Mn supply the leaves accumulated higher concentrations with age. The current report gives 26.0 ppm (DW) in *C. argentea* which is the value in second position.Van Goor [25] concluded that a slight transport of Mn through the phloem vessels is responsible for the low concentration of Mn in fruits, seeds and storage roots. This conclusion might be plant and plant age dependent. Loneragan [26] stated that Mn ranged from an average of 30 ppm (DW) in *Medicago trunculata* to 500 ppm (DW) in *Lupinus albus*. World-wide background contents of Mn range from 17 to 334 ppm in grass and from 25 to 119 ppm in clover. Plant foodstuffs are also reported to contain variable amounts of Mn, being highest in beet roots (36 to 113 ppm DW) and the lowest in tree fruits (1.3 to 1.5 ppm DW). Mn ranged from 15 to 80 ppm throughout the world [8]. The critical Mn deficiency level for most plants ranges from 15 to 25 ppm (DW) whereas the toxic concentration is about 500 ppm (DW) [8].

Fe is not detected in any sample in Ikere-Ekiti Fadama farm (Table 8). The distribution of Fe levels in the plants in Tables 6 and 7 appears to be species, age, organ and ecosystem dependent. Luxury accumulation is found in the bud of *H. esculentus* (1144.4 ppm) (DW). The appropriate content of Fe in plants is essential both for the health of the plant and for the nutrient supply to man and animals. The natural Fe content of fodder plants ranges from 18 to about 1000 ppm (DW). The nutritional requirement of grazing animals is usually met at the Fe concentration range from around 50 to 100 ppm (DW) in forage. Edible parts of vegetables appear to contain fairly similar amounts of Fe, ranging from 29 to 130 ppm (DW) with lettuce being in the upper range and onion in the lower range. The common average Fe content of different cereals ranges from 25 to around 80 ppm (DW). Values about 100 ppm are reported only for a few countries [8]. The grand mean of 48 ppm (DW) for Fe in grains was calculated by excluding the values of 100 ppm and above. The average values in virtually all the plants are higher than 100 ppm (DW) (Table 5).

The bioaccumulation of trace metals by plants from soil is depicted in Table 9. The degree of accumulation is intensive for all the values recorded for Zn while two of the values recorded for Fe are medium while the rest are also intensive. The ability of different plants to absorb trace elements varies greatly. Marked differences in the metal uptake between both plant species and varieties open up new aspects for plant breeding programmes for the bio-depletion in metal transport to the food chain.

Table 9. Bioaccumulation[a] of trace heavy metals by plants from soils.

Zone	Index of bioaccumulation[b]		Degree of accumulation	
	Zn	Fe	Zn	Fe
IF_1	2.1	0.9	Intensive	Medium
IF_2	3.3	1.3	Intensive	Intensive
IF_3	2.3	1.4	Intensive	Intensive
IF_4	-	-	-	-
Mean (SD)	2.6 (0.7)	1.2 (0.3)	-	-
CV%	25.4	24.8		
AD_1	3.0	1.3	Intensive	Intensive
AD_2	2.0	1.1	Intensive	Intensive
AD_3	2.0	0.9	Intensive	Intensive
AD_4	2.0	1.2	Intensive	Intensive
Mean (SD)	2.2 (0.5)	1.1 (0.2)	-	-
CV%	22.8	15.2		
IK_1	1.4	-	Intensive	
IK_2	4.4	-	Intensive	
IK_3	1.7	-	Intensive	
IK_4	1.9	-	Intensive	
Mean (SD)	2.4 (1.4)	-	-	
CV%	58.2			

[a]Ratio in plant/soil. [b]Index of bioaccumulation: $10^{-3} - 10^{-2}$ (lack). $10^{-2} - 10^{-1}$ (slight), $10^{-1} - 1$ (medium), $1 - 10^{1}$ (intensive).

CONCLUSION

The Fadama soils analysed are along the same axis of Ekiti State. While the soils contain detectable levels of Zn, Fe, Mn, Cu, Pb and Al, only Zn and Fe could be regarded as soil and plant contaminants for all the zones. Efforts should therefore be continuously made to reduce to the allowable level the contamination of the environment by Zn and Fe. The following elements (with their detection limits in brackets) are not detected in any sample: Co (0.05 ppm), Se (0.15 ppm), Cr (0.005 ppm), Cd (0.01) and Mo (0.01).

REFERENCES

1. Tiffin, L.O. *The Form and Distribution of Metals in Plants: An overview*, in *Proceeding of Hanford Life Sciences Symposium*, U.S. Department of Energy, Symposium Series: Washington, D.C.; **1977**; p 315.
2. Kolawole, A.; Scoones, I.; Awogbade. M.O.; Voh, J.P. (Eds.), *Strategies for the Sustainable Use of Fadama Lands in Northern Nigeria,* International Institute for Environment and Development (IIED) and Centre for Social and Economic Research (CSER): Ahmadu Bello University, Zaria, Nigeria; **1994**; pp. 29-34.

3. Odihi, J.O. *Fadama Resource Sustainability: Lessons from the Jere Rice Bowl Experience, Borno State* in *Strategies For the Sustainable Use of Fadama Lands in Northern Nigeria,* IIED and CSER; Ahmadu Bellow University, Zaria, Nigeria; **1994**; pp. 43-47.
4. Prat, P.F. *Digestion with Hydrofluoric and Perchloric Acid for Total Potassium and Sodium* in *Methods of Soil Analysis, Agronomy* **9**, American Society of Agronomy, Inc.: Madison, Wisconsin, U.S.A.; **1965**; pp. 1019-1021.
5. Walsh, L.M. (Ed.), *Instrumental Methods for Analysis of Soils and Plant Tissue*, Soil Science. Society of America, Inc.: Madison, Wisconsin, U.S.A.; **1971**; pp. 27-32.
6. Varian Techtron *Basic Atomic Absorption Spectroscopy – A Modern Introduction*, Varian Techtron: Springvale, Australia; **1975**; pp. 104-106.
7. Steel, R.G.D.; Torrie, J.H. *Principles of Procedures of Statistics*, McGraw-Hill: London; **1960**.
8. Kabata-Pendias, A.; Pendias, H. *Trace Elements in Soils and Plants*, 2nd ed., CRC Press: Boca Raton, Florida; **1992**.
9. Walkley, J.T.; Black, C.A. *Soil Sci.* **1934**, 37, 29.
10. Brady, N.C. *The Nature and Properties of Soils*, 8th ed., Macmillan: New York; **1974**.
11. Page, A.L.; Chang, A.C.; Adriano, D.C. *Land Application of Municipal Sewage Sludge, Guidelines – Trace Elements* in *Proceedings of 2nd International Symposium on Land Application of Municipal Sewage Sludge,* Association for Utilization Sewage and Sludge: Tokyo; **1988**; p 154.
12. Itoh, S.; Tokumaga, Y.; Yumura, Y. *Bull. Veg. Ornamental Crops Res. Stn.* **1979(Ja)**, 5a, 145.
13. Gough, L.P.; Shacklette, H.T.; Case, A.A. *U.S. Geol. Surv. Bull.* **1979**, 1466, 80.
14. Foy, C.D. *Iowa State J. Res.* **1983**, 57, 339.
15. Davies, B.E. *Heavy Metal Pollution of British Agricultural Soils with Special Reference to the Role of Lead and Copper Mining* in *Proceedings of International Seminar on Soil Environment and Fertility Management in Intensive Agriculture (*Tokyo); **1977**; p 394.
16. Gough, L.P.; Severson, R.C.; Schacklette, H.T. *U.S. Geol. Survey Prof. Pap.* **1988**, 1458, 53.
17. Hodgson, J.F.; Geering, H.R.; Norvell, W.A. *Soil Sci. Soc. Am. Proc.* **1965**, I, 665; **1966**, II, 723.
18. Asaolu, S.S. *Ghana J. Chem.* **1993**, 1, 385.
19. Akande, M.O.; Oguntoyinbo F.I.; Adediran J.A. *Nigeria J.A.T.* **1999**, 7, 1.
20. Ndiokwere, C.L. *Environ.Pollut.Series B* **1984**, 7, 35.
21. Loneragan, J.F. *Distribution and Movement of Copper in Plants* in *Copper in Soils and Plants*, Academic Press: New York; **1981**, p 165.
22. Tiffin, L.O. *Translocation of Micronutrients in Plants* in *Micronutrients in Agriculture*, Soil Science Society of America: Madison, Wisconsin; **1972**; p 199.
23. Baumeister, W.; Ernst, W. *Mineralstoffe und Pflanzenwachstum*, Fischer: Stuttgart; **1978**; p 416.
24. Heenan, D.P.; Campbell, L.C. *Aust. J. Agric. Res.* **1980**, 31, 943.
25. Van Goor, B.J. *Distribution of Mineral Nutrients in the Plant in Relation to Physiological Disorder* in *Trace Elements in Soils and Plants*, 2nd ed., Kabata-Pendias, A.; Pendias, H. (Eds.); CRC Press: Boca Raton, Florida; **1992**; pp. 258-267.
26. Loneragan, J.F. *The Availability and Absorption of Trace Elements in Soil – Plant Systems and Their Relation to Movement and Concentration of Trace Elements in Plants* in *Trace Elements in Soil – Plant – Animal Systems*, Academic Press: New York; **1975**; p 109.