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Trace element concentrations of soils of Ife-Ijesa area Southwestern Nigeria

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Accumulation of selected trace elements on the surface and sub-soil of the Ife-Ijesa area of southwestern Nigeria was investigated. This was with a view to ascertaining the levels of these elements on some agricultural land that have been receiving chemical fertilizers and pesticides for high crop productivity in the study area. From the nine selected soil types, composite soil samples were taken to the depths 0 to 15 and 15 to 30 cm using simple random technique method. The soil samples were air-dried, crushed, sieved and digested using standard methods. The concentrations of the trace elements were thereafter read on atomic absorption spectrophotometer. Trace elements concentrations were higher in the surface than sub-surface soils. This may be attributed to the application of some fungicides and fertilizers for agricultural purposes in the area. High trace elements concentrations in Itagunmodi area when compared with other areas may be attributed to high clay mineral deposit in the area.

Key words: Trace elements, soil contamination, soil series, enrichment factor, Nigeria.

INTRODUCTION

Metals occur naturally in soil in minute amounts, and life on earth has evolved to cope with only small exposure to these elements. Many industrial processes concentrate metals like copper, cadmium, lead and zinc. These can then end up in the earth (Hendershot, 2005). A large number of trace metals are transported to the oceans from natural sources. However, these natural sources are supplemented by releases from anthropogenic processes which, for some metals, can exceed natural in-puts (Manahan, 1991). Trace metals are found in the soil, water, biota and sediment compartments of the environment, but potentially the most hazardous environmental effects to human health arise when they enter the food chain (Ayodele and Oluyomi, 2011). Trace metals studies have been an area of active investigation over the years (Fatoki et al., 2002). They are important in many fields of human endeavor such as human and animal nutrition, human health and disease, geochemist-try (Davies, 1992) and environmental pollution (Nriagu, 1986). All trace elements are toxic to living organisms at excessive concentrations but some are essential for normal healthy growth and reproduction by either plants and / or animals at low but critical concentrations (Alloway, 1995; Anyakora et al., 2011).

Nigeria is not left behind in this wind of trace element consciousness blowing across the globe, but most trace element studies in Nigeria have been on the water systems (Asubiojo et al., 1997; Mombeshora et al., 1983; Ndiokwere and Cumie, 1983; Nriagu, 1986; Nriagu and Pacyna, 1988). In recent times however, there have been some studies of trace (and major/minor) element concentrations of Nigerian soils (Akanle et al., 1994; Ogunsola et al., 1994; Onianwa, 2001; Oyedele et al., 1995). In all of the soil studies, trace element data of soils from other parts of the world have been used as references. However, for better interpretation of these and other subsequent trace element, data of Nigerian soils that have been receiving various agro-inputs for enhanced crop

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productivity, the levels of trace elements in these soils are important. Hence, this paper presents the trace (and some major/minor) element concentrations of the different soil types of Ife-Ijesa area of Southwestern Nigeria, an area of considerable geological and environmental interest.

Trace element data have found tremendous use in geochemical and environmental pollution studies (Ajayi and SUH$^+$, 1999). In geochemistry, elemental concentration may be used to detect anomalous concentrations of elements that constitute an expression of mineralization. Also, in view of the high degree of variation in the metal contents of rocks (Alloway and Ayres, 1993; Krauskopf, 1967; Rose et al., 1979), there is a possibility that the soils and stream sediments in a locality suspected of being polluted may have developed from rocks with anomalously high concentrations of certain heavy metals and that pollution, in the strict sense of the definition, has not occurred. Nevertheless, the natural enrichment of metals in the soils may still give rise to harmful effects in living organisms. In environmental pollution studies, trace elements have been found adequate in describing the environmental exposure to which the organism has been subjected (Ojo et al., 1994). The natural members of the ecosystem in an area of geochemical enrichment will have evolved tolerance to the elevated concentrations of metals, but newly introduced plant and animal species may be adversely affected. It is therefore important to determine the local background concentrations of heavy metals in order to determine whether the concentrations in the soils and sediments under investigation are significantly higher than those of the area.

MATERIALS AND METHODS

Study sites

The study was carried out within Ife-Ijesa area of Southwestern Nigeria. The major soil types in the region were identified using the semi-detailed soil map of Central Western Nigeria produced by Smyth and Montgomery (1962). A total of nine soil series which differ widely in parent material, texture, drainage, topographic position and chemical composition were sampled, as presented in Table 1.

Sample collection and preparation

The identified soil types (Table 1) were sampled using Dutch soil auger to collect core samples at 0 to 15 and 15 to 30 cm soil depths. For each soil series, ten core samples, randomly taken were homogenized and a composite sample was taken. The homogenized composite samples were air-dried, crushed and sieved using 2 mm sieve. The less-than-2 mm fraction of each sample was kept in a polythene bag and labeled.

Sample analyses

All reagents used were of analytical grade and from which standard solutions were prepared. Glassware were thoroughly washed with detergent and rinsed with distilled water. The digestion method previously described by Francek et al. (1994) was adopted for the extraction of trace metals in this study. One gram each of air-dried soil sample was crushed to fine powder in an agate mortar and digested in 10 ml of 1:1 concentrated HNO_3. The mixture was evaporated to near dryness on a hot plate and then cooled. This procedure was repeated with a 15 ml solution of 1:1 concentrated HCl. The extracts were filtered with No. 40 Whatman filter paper and then made up to 100 ml volume with 2% HNO_3. Solutions of the sample and blanks were run using Atomic Absorption Spectrometer (AAS) (200A Model), at the Centre for Energy Research and Development of Obafemi Awolowo University, Ile-Ife, Nigeria.

Data analyses

The standard deviation of concentrations of replicate measurements was determined for each element. For the subsequent general evaluation of the data, the mean values and calculated enrichment factors of the elements were used. The enrichment factor (EF) was calculated with aluminium as the reference element and using the formula:

$$EF = (CEs / CAs) \times (CAr / CEr)$$

Where CEs = concentration of element in sample; CEr = concentration of element in crustal rock; CAs = concentration of aluminium in sample, and CAr = Concentration of Aluminium in crustal rock.

The new Duncan multiple range test was also carried out to separate mean concentrations of elements that are significantly different. The Pearson correlation was used to test the relationship between the soil parameters.

RESULTS AND DISCUSSION

The results of the total elemental concentrations of the surface and sub-surface soil samples are presented in Tables 2 and 3, respectively. Generally, the results show that for most of the soils, the concentration of Zn, Cu, Ni and Mn is higher at the surface than at the sub- surface. This could be due to applications of copper fungicides and Mn and Zn-containing fertilizers to the soils which lead to higher concentrations of the residues of these elements on the surface. However, there is no particular trend in the changes in concentration of Pb and Cr with increasing depth. This is because, Pb and Cr are not components of the fertilizers and pesticides applied as for those elements which vary substantially with soil depth. The unusually high concentrations of Cu in Ondo and Itagunmodi surface soils are due to the effects of copper fungicides being applied to cocoa plantations in the area, cocoa being a major cash crop of the areas (Akinnifesi et al., 2006). This is also evident from the relatively high soil pH values of the study area in Table 1 (Okoya et al., 2010).

In the study area, the trace element mean concentrations at the top soil (Table 2) are generally lower than (except Itagunmodi soil series) the average given by Alloway (1995) for industrialized countries such as Netherland (Zn 72.5, Cu 18.6, Ni 15.6 Cr 25.4 and Pb 60.2 mg kg^{-1}); Canada (Zn 74.0, Cu 22.0, Ni 20.0 Cr 43.0

Table 1. Characteristics of soil.

Soil series	Sampling site	Major land use in sampling location	Brief description of the soil	*pH (0 to 15 cm) depth	*pH (15 to 30 cm) depth
Iwo	O. A. U. Teaching and Research farm, Ile-Ife	Yam and pepper plot	Well drained, coarse textured soils, overlying weathered rock material, derived from coarse-grained granitic rocks and gneisses	6.53[d]	5.90[e]
Ondo	Near OWENA town	Cocoa and Kolanut plantations	Well drained, medium to fine, textured soil, overlying orange brown, yellow brown and white mottled clay, mainly derived from medium ground granitic rocks and gneisses	6.53[d]	6.17[c]
Egbeda	O.A.U. Teaching and Research Farm, Ile-Ife	Cocoa, kolanut, orange, plantain/ banana plantations	Well drained fine textured soil, overlying red brown, yellow brown and white mottled clay, mainly derived from fine –ground biotite gneiss and schist.	7.36[a]	6.10[d]
Itagun-Modi	Near Itagunmodi village	Cocoa farm	Well drained, very fine textured soils of uniform brownish red or dark chocolate brown colour to depth, derived from amphibolite and related basic rocks.	6.28[c]	5.64[f]
Jago	O.A.U. Teaching and Research farm, Ile-Ife	Sugar cane, bamboo trees banana trees	Soils of various textures in low topographical sites, with drainage affected by seasonally high water table derived from alluvium and local colluvium.	6.18[f]	4.85[h]
Oba	O.A.U. Teaching and Research farm, Ile-Ife	Maize and yam plot	Well drained, coarse textured soils, overlying weathered rock material, derived form coarse-grained granitic rocks and gneisses.	6.83[b]	6.24[a]
Gambari	O.A.U. Teaching and Research farm ,Ile-Ife	Citrus plantation	Sandy and clayey soils either containing very large quantities of ferruginous concretions and fragments of iron stones or overlying massive iron stone pan	5.88[h]	4.81[i]
Apomu	O.A.U. Teaching and Research farm, Ile-Ife	Maize farm	Well drained drift soils, pale brown to reddish brown, sandy to fairly clayey soils, with no gravel concretions and quartz grains.	6.09[g]	5.28[g]
Efon	Ipetu –Ijesa road	Maize, pepper, yam farm	Well drained drift soils, sandy or fairly clayey, gravel soils merging to rotten rock.	6.61[c]	6.22[h]

*: Means with the same letter are not significantly different by new Duncan's multiple range test at $p < 0.05$.

and Pb 20.0 mg kg^{-1}) and England and Wales (Zn 78.2, Cu 15.6, Ni 22.1 Cr 44.0 and Pb 48.7 mg kg^{-1}). Table 3 showed values lower than those in Table 2 which agreed with Alloway (1995) that observed higher values of minerals in the topsoil than the subsoil as a result of cycling through vegetation,

Table 2. Total elemental concentration (mg/kg) of the soil's surface (0 to15 cm) (n = 9).

Soil series	Zn	Cu	Ni	Pb	Fe	Cr	Na	Mn	Mg	Al
Apomu	9.60^{h}± 0.0	2.30^{g}±0.01	10.00^{g}±0.08	9.00^{i}±0.06	7990^{i}±0.1	2.00^{h}±0.00	248^{i}±0.03	272^{i}±0.01	441^{b}±0.00	4670^{g}±3.0
Efon	31.60^{c}±0.01	8.9^{f}±0.01	16.00^{c}±0.02	10.00^{f}±0.06	30200^{b}±4.1	34.00^{b}±0.01	352^{e}±0.12	687^{d}±0.06	213^{e}±0.00	6370^{f}±1.2
Egbeda	36.30^{b}±0.00	9.4^{c}±0.00	19.00±0.00	30.00^{f}±0.09	16000^{c}±2.3	22.00^{c}±0.00	350^{f}±0.10	795^{b}±0.05	365^{c}±0.06	9940^{d}±1.8
Gambari	15.90^{f}±0.01	9.20^{d}±0.00	11.00^{e}±0.00	36.00^{a}±0.07	14040^{e}±1.03	12.00^{g}±0.00	298^{h}±0.02	367^{g}±0.01	180^{i}±0.02	11310^{b}±3.1
Itagunmodi	59.80^{a}±0.01	50.7^{a}±0.00	36.00^{a}±0.01	29.00^{c}±0.00	111400^{a}±19.4	75.00^{a}±0.02	426^{c}±0.04	860^{a}±0.15	167^{a}±0.01	21240^{a}±2.7
Iwo	3.60^{i}±0.00	2.10^{h}±0.01	3.00^{i}±0.08	10.00^{g}±0.15	8940^{h}±2.1	9.0^{i}±0.01	408^{d}±0.03	207^{f}±0.02	87^{h}±0.00	3850^{i}±3.1
Jago	16.70^{e}±0.00	1.5^{i}±0.01	14.00^{d}±0.01	9.00^{h}±0.00	15630^{d}±0.1	17.00^{f}±0.00	321^{g}±0.06	398^{e}±0.06	200^{f}±0.01	11260^{c}±1.4
Oba	12.40^{g}±0.00	9.1^{e}±0.00	10.00^{f}±0.01	15.00^{d}±0.04	12250^{f}±1.3	18.00^{d}±0.02	454^{a}±0.17	791^{c}±0.06	199^{g}±0.01	8500^{d}±6.0
Ondo	27.10^{d}±0.00	30.00^{b}±0.00	7.00^{h}±0.00	10.00^{e}±0.05	9450^{g}±1.4	18.00^{e}±0.02	430^{b}±0.11	298^{h}±0.03	221^{d}±0.00	4080^{h}±4.1

Means with the same letter are not significantly different by new Duncan's multiple range test at $p < 0.05$.

Table 3. Total elemental concentration (mg/kg) of the soil's sub- surface at 15 to 30 cm depth (n = 9).

Soil series	Zn	Cu	Ni	Pb	Fe	Cr	Na	Mn	Mg	Al
Apomu	9.1^{g}±0.00	2.0^{g}±0.00	5.00^{g}±0.05	9^{i}±0.04	7270^{g}±1.2	11.00^{h}±0.01	342^{g}±0.06	131^{g}±0.00	404^{a}±0.00	4670^{g}±3.7
Efon	32.8^{b}±0.00	8.6^{d}±0.00	10^{e}±0.03	10^{f}±0.04	37700^{b} ±3.0	30.00^{b}±0.01	311^{h}±0.09	501^{d}±0.08	198^{e}±0.01	8130^{b}±0.04
Egbeda	27.80^{d}±0.01	12.0^{b}±0.01	18.00^{b}±0.00	34^{a}±0.12	2780^{h}±0.2	28^{c}±0.00	613^{a}±0.27	665^{c}±0.09	307^{c}±0.00	7970^{c}±11.5
Gambari	3.9^{i}±0.00	7.80^{e}±0.01	6.0^{f}±0.03	21^{d}±0.07	20110^{c}±0.5	16^{f}±0.00	230^{i}±0.10	232^{f}±0.03	63^{i}±0.01	9510^{a}±7.6
Itagunm-odi	45.30^{a}±0.00	36.00^{a}±0.00	36^{a}±0.01	24^{c}±0.02	112620^{a}±4.2	72^{a}±0.01	555^{c}±0.13	1075^{a}±0.18	351^{b}±0.07	1379^{i}±15.60
Iwo	7.00^{h}±0.02	1.7^{a}±0.00	5.00^{i}±0.04	10.0^{h}±0.27	13650^{e}±2.6	18^{e}±0.00	388^{d}±0.03	305^{e}±0.08	165^{f}±0.00	6790^{e}±4.4
Jago	28.30^{c}±0.01	3.6^{f}±0.01	1^{i}±0.03	15^{e}±0.09	1580^{i}±0.4	1.0^{i}±0.00	358^{f}±0.03	120^{i}±0.02	216^{d}±0.01	2590^{g}±4.4
Oba	12.5^{e}±0.00	9.4^{c}±0.00	11^{d}±0.04	30^{b}±0.03	17310^{d}±0.01	16^{g}±0.01	380^{e}±0.16	791^{b}±0.01	87^{g}±0.01	7700^{d}±9.2
Ondo	9.60^{f}±0.00	1.50^{i}±0.00	12^{c}±0.03	10^{g}±0.01	8520^{f}±0.4	22^{d}±0.00	582^{b}±0.16	129^{h}±0.01	65^{h}±0.00	1730^{h}±0.08

Means with the same letter are not significantly different by new Duncan's multiple range test at $p < 0.05$.

atmospheric deposition and adsorption by the soil organic matter. The trace element levels in Itagunmodi soil series compare well with the European/American soils; however this is an area where mining activity takes place. The distribution of trace metals among soil textural classes (e.g. sandy, silty, loamy soils) are differentiated more strongly than among taxonomic units.

Hence, a comparison of the trace elements in the loamy soils of the study area determined with the loamy soils of Poland fall within the same range. However, it is higher than the sandy soils in Poland (Kabata-Pendias et al., 1992) as expected since trace metal contents in sands are significantly lower than in loams and clays.

The results of the new Duncan multiple range test (DMRT) is indicated on the values in Tables 2 and 3 showed that the mean elemental concentrations were statistically different from one soil series to another. This variability of in concentrations of trace elements in these soils may be

Table 4. Enrichment factors for the elements at 0 to 15 cm soil depth (n = 9).

Soil series	Zn	Cu	Ni	Fe	Pb	Cr	Na	Mn	Mg
Apomu	2.93	1.76	3.82	3.21	13.74	0.15	0.60	4.89	1.08
Efon	7.07	4.98	4.48	8.90	11.19	1.90	0.63	9.05	0.38
Egbeda	5.21	3.37	3.41	3.02	21.52	0.79	0.40	6.71	0.42
Gambari	2.00	2.90	1.73	2.33	22.69	0.38	0.30	2.72	0.18
Itagunmodi	4.01	8.5	3.02	9.84	9.73	1.26	0.22	3.40	0.36
Iwo	1.33	1.94	1.39	4.63	18.52	0.08	1.20	5.86	0.55
Jago	2.11	0.47	2.22	2.60	5.70	0.54	0.32	2.96	0.20
Oba	2.08	3.82	2.10	2.70	12.58	0.75	0.60	7.81	0.26
Ondo	9.47	26.21	3.06	4.35	17.48	1.57	1.19	6.13	0.61

Table 5. Enrichment factors for the elements at 15 to 30 cm soil depth (n = 9).

Soil series	Zn	Cu	Ni	Fe	Pb	Cr	Na	Mn	Mg
Apomu	2.78	1.53	2.92	13.74	13.74	0.84	0.83	2.35	0.98
Efon	5.75	5.98	8.70	13.90	13.90	2.08	0.43	5.17	0.28
Egbeda	4.97	5.37	0.65	30.42	30.42	1.12	0.87	7.0	0.44
Gambari	0.58	2.92	3.97	15.74	15.74	0.60	0.27	2.05	0.07
Itagunmodi	46.84	93.07	153.23	124.09	124.09	18.61	4.55	65.39	2.88
Iwo	1.47	0.89	1.31	10.50	10.50	0.95	0.65	3.77	0.28
Jago	15.58	4.96	0.69	41.29	41.29	0.14	1.56	3.89	0.94
Oba	22.94	4.35	2.55	27.78	27.78	0.74	5.53	85.39	1.27
Ondo	7.91	3.09	12.36	9.24	41.21	4.53	3.81	6.25	0.43

caused by the variety of underlying rocks of different ages and lithology (Davies, 1985; McGrath, 1987; Bini et al., 1990). It may also be due to local phenomena of contamination (Angelone, 1991). The enrichment factors (EF) for the elements in the soil samples were calculated with aluminium as the reference element and the results are presented in Tables 4 and 5. The fact that there is no enrichment for most of the elements in the various locations imply that there is not much pollution in these areas. The enrichment factors of Zn in Efon, Egbeda, Itagunmodi and Ondo soil series are greater than 3. This implies that these soils are enriched with Zn from anthropogenic source(s). High Zn concentrations in these soils could be due to the use of agrochemicals such as fertilizers and pesticides (Fatoki et al., 2002). The enrichment factor of Cu in Itagunmodi and Ondo soil series are also high (EF >3). This may be due to the effects of copper fungicides being applied to the soils. Incidentally, cocoa is the major crop grown on these soils and is usually sprayed with copper fungicides, whose residues directly increase the pH and the organic matter contents of the soils (Akinnifesi et al., 2006). The resultant effects bring about variation in the concentration and distribution of some major and trace elements in the soils.

The high enrichment of Pb in all the soils is attributed to a substantial contribution from motor vehicle exhaust; Nigerian gasoline being leaded (Mombeshora et al., 1983). It may also be due to the use of agrochemicals such as Pb- containing pesticides (Fatoki et al., 2002). Zn enrichment could be due to tyre wear.

Another element with high enrichment factor in these soils is manganese. Soils derive virtually all their Mn content from the parent materials, and the concentrations found in mineral soils reflect the composition of these parent materials. Apart from these natural mineralogical sources, the only other significant source of Mn in soils, that explains its very high enrichment factors in all the soils considered, is its application to soils in the form of fertilizers. This is normally in the form of $MnSO_4$, MnO, or as an addition to macronutrient fertilizer (Fatoki et al., 2002). Nigeria has become home to various forms of fertilizers for some time now, hence some Mn containing fertilizers could be responsible for the high enrichment (EF>3) observed for Mn in almost all the Ife-Ijesa soils. Itagunmodi series is highly enriched with virtually all the elements in the sub-surface. This may be associated with the fact that Itagunmodi soil is very rich in clay. Clayey soils usually have strong affinity for binding metal ions.

A possible relationship between total metal concentrations and selected soil properties for both top soil and sub-soil was also made as presented in Tables 6 and 7.

Table 6. Correlation between total metal and the selected soil properties at depth 0 to 15 cm.

Soil properties	Zn	Cu	Ni	Fe	Pb	Cr	Na	Mn	Mg	Al
pH	0.2047 (ns)	-0.03844 (ns)	0.04146 (ns)	-0.12033 (ns)	0.00804 (ns)	0.04920 (ns)	0.44724 (ns)	0.58532(ns)	-0.03717 (ns)	-0.15826 (ns)
OM	0.55696(ns)	0.33584 (ns)	0.52845 (ns)	0.33774 (ns)	0.34145 (ns)	0.48418 (ns)	-0.31236 (ns)	0.14180 (ns)	0.19390 (ns)	0.48714 (ns)
Sand	-0.76948*	*-0.73296 (ns)	**-0.85402 (ns)	***-0.96574	-0.37844 (ns)	0.90276***	-0.26557 (ns)	-0.50358 (ns)	-0.65948 (ns)	-0.83970*
Silt	0.25201(ns)	0.42037 (ns)	0.38993 (ns)	0.63891(ns)	-0.27372 (ns)	0.47825 (ns)	0.22621 (ns)	0.00579 (ns)	0.41676 (ns)	0.42990 (ns)
Clay	0.86346**	*0.74279	***0.90962	***0.94111	0.58717 (ns)	***0.93233	0.23647 (ns)	0.63543 (ns)	0.65129 (ns)	*0.87381

Table 7. Correlation between total metal and the selected soil properties at depth 15 to 30 cm.

Soil properties	Zn	Cu	Ni	Fe	Pb	Cr	Na	Mn	Mg	Al
pH	0.12868 (ns)	0.06458 (ns)	0.32261 (ns)	0.06190 (ns)	0.15122 (ns)	0.29604 (ns)	0.51044 (ns)	0.43370 (ns)	-0.12972 (ns)	0.11056 (ns)
OM	0.53333 (ns)	0.59114 (ns)	0.37478 (ns)	0.63727 (ns)	0.07585 (ns)	0.48458 (ns)	-026643 (ns)	0.27608 (ns)	0.09543 (ns)	-0.01046 (ns)
Sand	-0.80741**	**-0.87399	*0.69821	**-0.88540	-0.21427 (ns)	-0.77503*	-0.10058 (ns)	-0.60922 (ns)	-0.37190 (ns)	0.28969 (ns)
Silt	0.40740 (ns)	0.32154 (ns)	0.10352 (ns)	0.49553 (ns)	-0.30712 (ns)	0.19590 (ns)	-0.22958 (ns)	0.13527 (ns)	0.22782 (ns)	0.54585 (ns)
Clay	*0.79028	***0.89816	*0.76053	**0.85150	0.33847 (ns)	**0.81910	0.18531 (ns)	0.64967 (ns)	0.35156 (ns)	0.15963 (ns)

The selected soil properties are pH, organic matter (OM), sand, silt and clay.

Significant negative correlations were observed between the total metals and the sand content of the soil at both depths, while the correlations between clay and total metal concentrations (Zn, Cu, Ni, Fe, Cr, Al) at both depths are positive and significant at the different probability levels indicated in the tables. This follows the trend observed in the correlation between the extractable metals and physico-chemical properties of some southwestern Nigerian soils (Okoya et al., 2010) in which at both depths, none of the metals correlated significantly with silt while Ni, Cr, Al, Fe, and Mg are correlated significantly with clay.

This is in line with the general principle that trace metal contents in sands are significantly lower than in loams and clays (Davies, 1985). Clayey soils usually have strong affinity for binding metal ions. The heavy metals bound in clayey soils are therefore protected from leaching by water and made available in soil as plant nutrient (Nriagu and Pacyna, 1988). As the sand content is increasing, silicon content is expected to increase. Increase in silicon content (being a major element in the earth crust) implies a decrease in trace and minor elements content. However there is no significant correlation between the total metal and OM for both surface soils (0 to 15 cm) and sub- surface soils (15 to 30 cm).

Conclusions

The study showed that trace element concentrations of most of the soils of the area varied from one soil type to another. Higher trace element levels in the surface than sub-surface soils may be attributed to applications of some fungicides and fertilizers for agricultural purposes in the area. On the other hand, the anomalously high trace element concentrations found between the trace element concentrations and physico-chemical characteristics of the soils of the area may be attributed to the effects of the anthropogenic activities on the soils.

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