



Research Journal of
**Environmental
Sciences**

ISSN 1819-3412



Academic
Journals Inc.

www.academicjournals.com

Trace Elements Status of Staple Food Crops, Soils, Surface and Underground Water Sources in Ebonyi State, Nigeria

¹C.O. Edeogu, ²F.C. Ezeonu, ²A.N.C. Okaka, ¹S.O. Elom and ³C.E. Ekuma

¹Department of Medical Biochemistry, College of Medicine and Health Sciences,
Ebonyi State University, Abakaliki, Nigeria

²Department of Applied Biochemistry, Nnamdi Azikiwe University,
Awaka, Anambra State, Nigeria

³Department of Industrial Physics, Ebonyi State University, Abakaliki, Nigeria

Abstract: The trace elements (Fe, Zn, Cu, Mn, Cd, Pb and Co) level in staple food crops (yam, cassava, maize, cowpea and African yambean); soils; surface and underground water sources in Ebonyi State, Nigeria has been quantitatively determined using the Atomic Absorption Spectrophotometer (AAS). The results show that the Fe level in staple food crops is in the range of 15.26 to 78.28 mg kg⁻¹ with a mean value of 48.98±24.96 mg kg⁻¹ which is significant (p<0.05) when compared to the Recommended Daily Allowance (RDA) of 18.0 mg Fe day⁻¹. Also, it was inferred that the levels of Fe, Zn and Mn in the staple food crops, soils, surface and underground water sources exceeded the RDA, while Co and Ni were absent or not detected in the samples analyzed. The correlation analysis were significant: Cu (95.30%), Fe (54%) and Zn (61%) in the soil and rice; Cu (59%), Fe (84%) and Mn (78%) in the soil and maize; Zn (82%), Cd (70%) and Mn (50%) in the soil and cassava while for soil and yam is significant for Fe (83%) and fairly significant for Cd (49%). Significant correlations also existed between surface H₂O and rice for Fe (74%) and Cu (88%); maize Mn (67%), cassava Fe (75%) and Mn (91%); yam Fe (53%) and Cu (86%); cowpea Zn (82%); African yambean Cu (58%). Perfect correlations abound between the trace element levels in cereals and tubers; cereals and legumes; tubers and legumes while that between trace elements in surface and underground water were significant only for Zn (87%).

Key words: Trace elements, staple foods, correlations, AAS

INTRODUCTION

The increased economic and industrial growth of any nation is often accompanied by environmental pollution and contamination. Egboka *et al.* (1989) defined pollution as the introduction of certain substances in such high dosages or concentrations that render the environment hazardous or highly deleterious to biota. Contamination occurs to a lesser magnitude when compared to pollution, but it may render the contaminated medium unsuitable or make it slightly hazardous to life. Gindings (1973) and Harrison (1982) defined pollutants as substances present in greater than natural concentration as a result of human activity and which have net detrimental effect on the environment. Volumes of these pollutants/contaminants are produced yearly through natural and anthropogenic sources. Important natural sources include volcanic activity, continental weathering and forest fire (Zoller, 1984). Anthropogenic sources are industrial activities and agricultural practices (FAO, 1994).

The danger associated with naturally occurring toxic metals and compounds depends on their distribution in the environment which remains relatively constant largely due to natural biological

Corresponding Author: C.O. Edeogu, Department of Medical Biochemistry, College of Medicine and Health Sciences, Ebonyi State University, Abakaliki Nigeria Tel: +2348035411845 +2348034382467

processes that affect both their degradation and synthesis hence they do not pose serious health problems when used in industrial processes. However, they may re-enter the environment and disrupt the natural action of organism in such a way that the balance between their production and degradation can no longer be maintained (Wood, 1974). Many of the pollutants constitute severe environmental damage especially in industrialized nations, inspite of many painstaking control programmes (Fano *et al.*, 1985). Lack of funds and technical expertise has grossly affected pollution/contaminants management in many developing countries including Nigeria.

Crop plants are the ultimate source of food in nature. These plants derive essential nutrients from the environment. Some of these nutrients such as nitrogen, phosphorus, potassium, sulphur, calcium and magnesium are required in large quantities (macronutrients) while other nutrients required in small amounts are called micronutrients. The abundance of the micronutrients in food is related to their abundance in the environment (Warren, 1972). Among the essential micronutrients in the food crops, include iron (Fe), zinc (Zn), copper (Cu), lead (Pb), molybdenum (Mo), nickel (Ni), manganese Mn) etc. Some of these trace elements (Fe, Zn, Cu, Se) are components of many enzymes: cytochrome-oxidase, amine oxidase, carbonic anhydrase, alcohol dehydrogenase (Underwood, 1997; Berg, 1990; Guthrie and Picciano, 1995) while some are essential components of proteins: haemoglobin, haemosiderin, selenoprotein, ceruloplasmin (Beilby *et al.*, 1992; Punnonen *et al.*, 1994; Danks, 1995).

Cobb *et al.* (2000), Khan and Frankland (1983) and Gracia *et al.* (1981) reported that some common vegetables and root crops are capable of accumulating high levels of these metals from the soil. Certain brassica species (cabbage) are hyper-accumulators of trace elements into edible tissues of the plant (Xiong, 1998).

The aim of the present research is to investigate the status of basic trace elements in staple food crops, soils, surface and underground water sources in Ebonyi state, Nigeria. The result is envisaged to be of great importance in helping the government in proper evaluation survey on the health status of both the occupationally and non-occupationally exposed inhabitants of the study areas.

MATERIALS AND METHODS

Location of the Study Area

The study areas are located in Ebonyi State, in the central part of the eastern region of Nigeria. Specifically, the project sites are Abakaliki, Afikpo North, Ohaukwu, Ohaozara and Ikwo Local Government Areas, respectively.

The entire study area lies within the Cross River Basin and are in the humid zone with a climate typical of the tropical zone. That is, wet-hot and rainy. Cross River-system, Ebonyi-River system and Azu-River system are the major inland water bodies. The hydrochemical and hydrobiological properties of the river systems are of technical interest, considering the abundant sodium chloride content of Azu-River system and the guinea worm (*Dracunculus medinensis*) infestation in all the study areas except in Afikpo North.

Materials

The materials used are staple food crops: cereals (maize and rice); legumes (African yambean and cowpea); root tubers (yam and cassava); composite soil samples were collected with a metal auger from the sample sites at the depth of 0-15 cm using random sampling technique as reported by Onyeike *et al.* (2002) while the water samples were collected from the available sources nearest to the study areas. Two streams, three underground for Ikwo, Ohaukwu, Ohaozara, Abakaliki and Afikpo Local Government Areas of Ebonyi State were collected at regular intervals of one week for 2 months from 25 different sources in stopper plastic bottles and stored in a freezer until the analysis was done colorimetrically.

Table 1: Salts used in the preparation of the standard solution (Stewart *et al.*, 1974)

Trace element	Salt
Zinc (Zn)	ZnSO ₄ .7H ₂ O
Copper (Cu)	CuSO ₄ .5H ₂ O
Lead (Pb)	Pb(NO ₃) ₂
Iron (Fe)	FeSO ₄ .6H ₂ O
Nickel (Ni)	NiSO ₄ .6H ₂ O
Cobalt (Co)	CoSO ₄ .H ₂ O
Manganese (Mn)	MnSO ₄ .H ₂ O
Cadmium (Cd)	Cd (CH ₃ COO) ₂ .2H ₂ O

Equipment

The equipments used were the Atomic Absorption/Emission spectrophotometer (AAS): Buck Scientific Atomic Absorption/Emission Spectrophotometer 205 Model which is highly sensitive, accurate and precision equipment; the pH meter: Pye Unicam Model; water bath made by Gram Instruments Cambridge Limited; weighing balance: Metal Hdw Balance, centrifuge: Mse Minor 35, oven by B and T A Searle Company; Muffle furnace: IMF 4 Carbolite Sheffield England etc.

Preparation of Standard Solutions

The primary solution was prepared using the appropriate salt. The salts used in the preparation of the standard or primary solution are shown in Table 1 and the concentration of the trace elements in the samples being analyzed was read off from the calibration curve of the standard.

Ashing of the Food Crop Samples

After the food crop samples were peeled to remove the peels and the rice dehusked, 50 g each were made into slurry and 2.0 g each of the sample weighed into a silica dish placed in muffle furnace at 400-500°C for an hour. The ashing process was not aided because the staple food crop (yam, cassava, rice, maize, cowpea and African yambean) have relatively bulky ash strength. The muffle furnace was switched off and allowed open for 30 min before the samples were brought out. The samples were cooled in a dessicator before digestion. Digestion was done by dissolving ashed sample with 10 mL of aqua-regia (conc. HCl/HNO₃) in the ratio of 3:1. The mixture was heated at the temp of 150°C on a hot plate for 2 h. The heating was to convert the metal into soluble salt. About 30 mL of de-ionized water was added to the conical flask containing the digestate. It was then stirred and filtered. The filtrate was then used for the determination of the trace elements in the sample using AAS based on the absorbance of each of the trace element normally compared with the standard of the element using the wavelength, band path as is known that the degree of absorption is proportional to the concentration of the element in the sample and this was measured spectrophotometrically.

RESULTS AND DISCUSSION

The analysis of the accumulated data of the trace elements in staple food crops, soils, surface and underground water revealed that iron (Fe) had the highest concentration (mg kg⁻¹) for all the staple food crops and soils, except for African yambean in which manganese had the highest concentration (Table 2-10). The following trace elements were found in food crops, soils surface and underground water, iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), lead (Pb) and cobalt (Co). Cadmium (Cd) and Nickel were virtually absent or not detected in samples.

The levels of Fe in staple food crops range between 15.26 and 78.28 mg kg⁻¹ with a mean value of 48.98±24.96 mg kg⁻¹. The Fe content of these food crops exceeds the recommended daily allowance (RDA) of 18.0 mg of Fe per day (Wayne and Dale, 1989). The values of Fe detected in soil of the study areas range between 242 and 55,761 mg kg⁻¹, this range of values is lower than the natural

Table 2: Concentration of trace elements (mg kg⁻¹) of rice

Area	Trace element				
	Fe	Zn	Cu	Mn	Cd
Afikpo	125.06	7.42	1.15	41.59	0.49
Ikwo	26.08	5.63	0.73	31.44	0.49
Ohaozara	100.48	9.48	1.39	66.38	0.34
Ohaukwu	28.04	13.62	1.53	95.94	0.54
Abakaliki	38.18	12.63	1.57	80.28	0.40
Mean value	63.57±45.98	9.76±3.38	1.27±0.35	63.13±27.69	0.45±0.08

Table 3: Concentration of trace elements (mg kg⁻¹) of maize

Area	Trace element					
	Fe	Zn	Cu	Mn	Cd	Ni
Afikpo	34.45	12.58	0.90	13.18	0.46	4.31
Ikwo	38.18	12.67	0.87	16.66	0.57	-
Ohaozara	42.95	13.91	2.69	6.67	1.17	-
Ohaukwu	30.65	8.37	3.91	8.84	0.63	-
Abakaliki	67.95	25.29	0.97	18.84	0.48	-
Mean value	42.83±14.77	14.56±6.35	1.87±1.38	12.84±5.12	0.66±0.29	4.31±0.00

Table 4: Concentration of trace elements (mg kg⁻¹) of cassava

Area	Trace element				
	Fe	Zn	Cu	Mn	Cd
Afikpo	26.73	9.35	0.94	11.30	0.78
Ikwo	6.52	2.52	ND	0.28	-
Ohaozara	17.60	4.38	1.60	29.71	0.97
Ohaukwu	6.52	9.14	1.01	12.31	1.26
Abakaliki	18.91	2.97	0.76	6.96	0.57
Mean value	15.26±8.71	5.67±3.33	1.08±0.36	12.11±10.92	0.09±0.29

level of 10,000-100,000 mg kg⁻¹ reported for mineral soils of the humid-region (Brady and Weil, 1996). The levels of Fe in the surface water (mean 1.84±0.15 mg L⁻¹) and underground water (mean 0.44±0.15 mg L⁻¹) also exceed the WHO permissible limit of 0.300 mg L⁻¹ for potable water (WHO, 1984).

The Zn contents of the samples vary from one area of study to another. For rice, the distribution profile is in the order Ohaukwu > Abakaliki > Ikwo > Ohaozara > Afikpo; while maize, is in the order Abakaliki > Ohaozara > Ikwo > Afikpo > Ohaukwu. In the soil samples, the values of Zn is in the order Ikwo > Abakaliki > Ohaozara > Afikpo > Ohaukwu. The levels of Zn in the soil samples of the study areas with a mean value of 64.77±2.24 mg kg⁻¹ did not exceed the natural level of 10-300 mg kg⁻¹ (Bohn *et al.*, 1979). However, its mean levels in all the staple food crops (Table 2-7) exceed the recommended daily allowance of 10-15 mg day⁻¹ for Zn (Tietz *et al.*, 1994). Also, the mean levels of Zn in surface water (mean 0.01±0.00 mg L⁻¹) and underground water (0.04±0.07 mg L⁻¹) are lower than the permissible limit (5.0 mg L⁻¹) of Zn in drinking water (WHO, 1984). The implication of this is that the water sources in the study areas are good for human consumption and industrial uses.

The levels of Cu in the staple food crops varied. For rice, the highest value (1.57 mg kg⁻¹) was recorded in Abakaliki while Ikwo had the least value (Table 2). In Ohaukwu, maize had the highest value of copper followed by Ohaozara while the least was Ikwo (Table 3). Copper was not detected in cassava from Ikwo L.G.A; while Ohaozara recorded the highest concentration of copper (Table 4). Ikwo L.G.A that recorded the least value of Cu in rice and maize had the highest value of copper in yam and soil samples (Table 5 and 8). The copper levels in the soil samples of the study areas ranged from 1.67 to 18.74 mg kg⁻¹. These ranges of values are normal when compared with copper contents of the soil that ranged from 2-100 mg kg⁻¹ (Bohn *et al.*, 1979). Copper was not detected in the surface

Table 5: Concentration of trace elements (mg kg⁻¹) of yam

Area	Trace element				
	Fe	Zn	Cu	Mn	Cd
Afikpo	15.00	11.93	2.57	41.57	0.49
Ikwo	22.17	12.51	3.53	3.76	1.15
Ohaozara	26.08	4.87	2.30	1.59	1.01
Ohaukwu	20.86	5.66	2.62	1.44	0.88
Abakaliki	45.00	5.61	1.81	3.33	0.63
Mean value	25.82±11.3	8.12±3.77	2.57±0.63	10.34±17.50	0.83±0.27

Table 6: Concentration of trace elements (mg kg⁻¹) of cowpea

Area	Trace element					
	Fe	Zn	Cu	Mn	Cd	Ni
Afikpo	52.45	45.30	4.50	54.0	0.70	-
Ikwo	67.22	41.44	3.28	55.36	0.73	4.31
Ohaozara	104.81	36.12	4.02	60.72	0.91	4.99
Ohaukwu	95.42	56.52	4.86	62.17	0.94	-
Abakaliki	45.68	32.06	3.04	25.94	0.33	-
Mean value	78.28±26.97	41.54±10.70	3.80±0.82	51.05±16.99	0.73±0.28	4.31±0.00

Table 7: Concentration of trace elements (mg kg⁻¹) of African yambean

Area	Trace element					
	Fe	Zn	Cu	Mn	Cd	Ni
Afikpo	51.13	15.79	5.03	187.36	0.82	12.24
Ikwo	50.45	16.15	2.09	127.82	0.75	4.65
Ohaozara	51.13	14.40	5.66	83.18	0.81	-
Ohaukwu	124.33	14.35	2.09	57.24	0.64	4.65
Abakaliki	73.01	35.84	4.26	56.08	-	-
Mean value	70.01±31.84	19.31±9.27	3.83±1.67	102.34±55.72	0.76±0.08	7.18±4.38

water sources from Afikpo, Ohaozara, Ohaukwu and Abakaliki. The level of copper in Ikwo surface water is 0.002 mg L⁻¹ and in Abakaliki underground water, the concentration is 0.003 mg L⁻¹. These values are below the permissible limit of 0.05 mg L⁻¹ of copper in drinking water. Therefore both surface and underground water sources of the study areas are safe for human consumption. Also the concentration of copper in the staple food crops did not exceed the RDA of 1.5 to 3.0 mg of Cu/day (Guthrie and Picciano, 1995).

The level of Mn in the cereals ranged from 31.44 to 95.94 mg kg⁻¹ for rice and 2.87-3.91 mg kg⁻¹ for maize (Table 2 and 3) while in tubers the values were in the range of 0.28-29.71 mg kg⁻¹ for cassava and 1.44-41.57 mg kg⁻¹ for yam; in legumes, the levels are 16.99 to 60.72 mg kg⁻¹ and 55.72 to 187.36 mg kg⁻¹, respectively for cowpea and African yam bean (Table 6 and 7). The results indicate that rice from Ohaukwu had the highest levels of Mn while the rice from Ikwo had the least value. In tubers, Ohaozara cassava recorded the highest value of Mn while no Mn was detected in cassava from Ikwo Local Government Area (Table 4). The concentration of Mn in the soil samples ranged from 65.45 to 3,993.0 mg kg⁻¹ with a mean value of 1,268.34±22.68 mg kg⁻¹. This range of values is appreciable when compared with the natural level of 200-2000 mg kg⁻¹ in mineral soil (Bohn *et al.*, 1979).

The range of values of lead recorded in soils from the study areas ranged from 2.08-588.91 mg kg⁻¹ (Table 8) while lead was not detected in any of the food crops analyzed. The value obtained is low compared to the 218-10,900 and 51-21,546 mg kg⁻¹ recorded in urban vicinity of the U.S. and in old mining areas (Chaneny, 1980, Troyer *et al.*, 1980). The level of Pb in the soils of the study areas was high compared to the natural level of Pb (2-200 mg kg⁻¹ Bohn *et al.*, 1979).

Table 8: Concentration of trace elements (mg kg⁻¹) of soils

Area	Trace element							
	Fe	Zn	Cu	Mn	Pb	Co	Cd	Ni
Afikpo	242.00	17.81	1.81	65.45	2.08	-	1.56	29.90
Ikwo	34,698.00	166.61	18.74	1,424.00	25.04	22.45	8.47	47.93
Ohaozara	5,967.00	62.89	4.75	90.16	8.34	-	2.23	-
Ohaukwu	52.00	10.78	1.67	769.09	2.08	2.68	1.80	-
Abakaliki	55,761.00	65.75	13.14	3,993.00	588.91	-	5.24	29.99
Mean value	19,344.00±889.53	64.77±2.24	8.02±0.59	1268.34±622.68	125.29±59.34	12.57±3.98	3.86±0.97	38.96±2.69

Table 9: Concentration of trace elements (mg L⁻¹) of surface water

Area	Trace element				
	Fe	Zn	Cu	Mn	Pb
Afikpo	7.47	0.004	-	0.80	-
Ikwo	0.41	0.015	0.002	0.18	-
Ohaozara	0.34	0.004	-	15.72	-
Ohaukwu	0.54	0.019	-	0.11	-
Abakaliki	0.45	0.008	-	0.39	0.01
Mean value	1.84±0.15	0.01±0.00	0.002±0.00	3.44±0.87	0.01±0.00

Table 10: Concentration of trace elements (mg L⁻¹) of underground water

Area	Trace element				
	Fe	Zn	Cu	Mn	Pb
Afikpo	0.41	0.004	-	-	-
Ikwo	0.69	0.040	-	0.01	-
Ohaozara	0.30	0.006	-	1.02	0.01
Ohaukwu	0.47	0.160	-	3.28	-
Abakaliki	0.34	0.010	0.003	-	0.10
Mean value	0.44±0.15	0.04±0.07	0.003±0.00	1.44±0.67	0.06±0.06

Cobalt was not detected in the staple food crops, surface and underground water analyzed (Table 2-7). However, its levels in the soils are in the range of 2.68-22.45 mg kg⁻¹ (Table 8). The level of cobalt is low in the soil of the study areas compared to its natural level of 1-70 mg kg⁻¹ (Bohn *et al.*, 1979).

Cadmium was detected in all the staple food crops and soils. The values ranged from 0.34-0.54, 0.29-1.17, 0.09-1.26, 0.27-1.15, 0.28-0.94 and 0.08-0.82 mg kg⁻¹ for rice, maize, cassava, yam, cowpea and African yambean respectively (Table 2-7). The values of Cd in soils ranged from 1.80-8.47 mg kg⁻¹ (Table 10). Ikwo soil had the highest levels of Cd followed by Abakaliki while Ohaukwu had the least value. Cd was not detected in surface and underground water (Table 9 and 10).

Nickel was not detected in cereals and tubers except for maize from Afikpo which had a value of 4.31 mg kg⁻¹. However, cowpea from Ikwo and Ohaozara had nickel range of values 4.31-4.99 mg kg⁻¹ and African yam beans recorded a range of 4.65-12.24 mg kg⁻¹. Nickel was not detected in soils from Afikpo, Ohaozara and Ohaukwu but the values obtained for Ikwo and Abakaliki soils were 47.93 and 29.99 mg kg⁻¹, respectively. The levels of nickel in Ikwo, Afikpo and Abakaliki soils were low when compared with natural levels of 10-1000 mg kg⁻¹ (Bohn *et al.*, 1979). However, Akpan and Akpanidiok (2006) reported that low levels of nickel may be toxic if associated with high exchangeable Mg:Ca ratios in soil.

The existence of significant correlations between the trace elements level in the staple food crops and soils, surface water and underground water implies that the staple food crops examined are likely to be the major exogenous contamination source of these trace elements in Ebonyi State (Table 11-13). This is because the levels of these trace elements in staple food crops reflect their status in the soils of the areas studied. This observation agrees with the findings of Ezeonu *et al.* (2005).

Table 11: T-test comparison between trace elements (mg kg⁻¹) of rice and soil

Pairs		N	Correlation	Sig.
1	Cd food and Cd soil	5	0.018	0.977
2	Cu food and Cu soil	5	-0.529	0.360
3	Fe food and Fe soil	5	-0.542	0.345
4	Mn food and Mn soil	5	0.274	0.655
5	Zn food and Zn soil	5	-0.613	0.272

Table 12: T-test comparison between trace elements (mg kg⁻¹) of maize and soil

Pairs		N	Correlation	Sig.
1	Cd food and Cd soil	5	-0.280	0.648
2	Cu food and Cu soil	5	-0.596	0.289
3	Fe food and Fe soil	5	0.842	0.073
4	Mn food and Mn soil	5	0.777	0.122
5	Zn food and Zn soil	5	0.156	0.802

Table 13: T-test comparison between trace elements (mg kg⁻¹) of cassava and soil

Pairs		N	Correlation	Sig.
1	Cd food and Cd soil	4	-0.703	0.297
2	Cu food and Cu soil	4	-0.349	0.651
3	Fe food and Fe soil	5	-0.096	0.878
4	Mn food and Mn soil	5	-0.504	0.386
5	Zn food and Zn soil	5	-0.821	0.089

Significant correlations exist between Fe/Cu, Zn/Cu, Fe/Zn, Fe/Mn, Cu/Ni, Zn/Ni, Zn/Mn, Cu/Mn, Fe/Pb, Ni/Co across the localities studied ($p < 0.05$). Fundamentally, these correlations may occur due to the trace elements sharing the same absorptive pathways or deficiency of one trace element which affects absorption and metabolism of another.

Hill and Matrone (1970) postulated that elements that have a similar configuration in water solution can compete for absorptive pathways. The concentrations of iron in the samples analyzed in the study areas affected the status of copper. Therefore, the correlation between copper and iron is in agreement with Lönnnerdal and Hernell (1994) findings that infants fed on a formula containing 7.0 mg Fe L⁻¹ had a lower serum copper concentration than infants fed with the same formula containing 4.0 mg Fe L⁻¹. This is also supported by the study of De-Freitas *et al.* (2003) that copper and iron metabolism in mammals are intricately interwoven.

The correlations existing between zinc and copper can be attributed to high levels of zinc comparatively to copper in the study areas. Zinc induces deficiency of copper because it is believed that zinc and copper compete for absorption, therefore the presence of one in excess may result in a deficiency of the other. Copper is an essential trace element required for adequate growth, cardiovascular integrity, central nervous structure and function, iron metabolism (O'Dell, 2002). It is a cofactor for several enzyme systems and copper containing metalloenzymes are important in the free radical scavenging (Taylor, 1996). Low levels of copper as a result of high concentrations of zinc in the study areas may be a risk factor for cardiovascular diseases through reduced antioxidant activity (Bourre, 2004; Klevay, 2000, 1975). There may be altered lipoprotein and catecholamine metabolism and vesicular changes (Rayssiguier *et al.*, 1993) among the inhabitants of the areas studied.

The observed correlations between iron and lead, zinc and lead are occasioned by the high concentrations of iron and zinc in the soils of the study areas. Studies with animal model indicate that zinc appears to be antagonistic to lead. Robert *et al.* (1995) reported that lead increases zinc excretion and that zinc deficiency enhances lead absorption and status in animals.

The correlation existing between nickel and cobalt in the soils was not unexpected. Cobalt is a naturally occurring element that has properties similar to those of iron and nickel (ATSDR, 2004). What is surprising is the non-existence of correlation between cobalt and iron despite the fact that they share the same oxidation states (+2, +3) and similar configurations, which are the attributes of trace

Table 14: The pH values of soil samples from the study areas in Ebonyi State

Area	pH
Afikpo	4.81
Ikwo	5.21
Ohaozara	5.46
Ohaukwu	6.17
Abakaliki	5.16

elements that compete for absorptive pathways (Hill and Matrone, 1970). The non correlation existing between cobalt and iron could be attributed to the environmental differences in the soils and water of the areas studied. Both in soil and water, the amount of cobalt that is mobile will increase under more acidic condition (ATSDR, 2004). The soil pH of the various localities studied were in the range of 4.81 to 6.17 (Table 14), these values are acidic. Furthermore, soils low in organic matter such as clay soil, peaty and mucky soils show micronutrient deficiencies especially in Cu and Mn (AFRR, 2000). The soil survey of the study areas shows that the areas are predominantly clay loam and silty loam (Corie Farms Industrial Limited, 2003).

The levels of iron, zinc, copper and manganese in both surface and underground water from the study areas were significantly lower than that of the soil samples from the same locations. The mean difference between the concentrations of these trace elements in soil and surface water reached significant with regards to Cu. There are also significant differences in soils and underground water in respect of Cu. The observable differences in the levels of these trace elements in soils, surface and underground water could be as a result of hydrogeologic processes such as rainfalls run-off, leaches, seepages, infiltration, percolation, exfiltration, which are essential in trace elements distribution kinetics (Egboka *et al.*, 1989).

The levels of Zn, Fe and Mn (Table 2-7) exceed the maximum recommended daily allowance (RDA) of 10-15 mg day⁻¹ for Zn (Tietz *et al.*, 1994); 18.0 mg Fe day⁻¹ (Wayne and Dale, 1989); 0.100 mg Mn day⁻¹ (WHO, 2000). The observed high levels of these metals in the staple food crops examined implies that these food substances might be contributory sources of exogenous heavy metal intake not only among the inhabitants of the study areas but other parts of the country (or the globe) where these staple food crops are exported to.

CONCLUSION

From the foregoing discussions, it can be concluded that trace elements (Fe, Zn, Cu, Mn, Pb and Cd) were present in the staple food crops, soils, surface and underground water sources in Ebonyi State while Co and Ni were virtually absent or not detected. Also, the observed high level of trace elements (Fe, Zn and Mn) in the staple food crops, soils, surface and underground H₂O sources in Ebonyi state, evident from the correlation analyses is obviously cause for concern as they may make them unsafe for human, livestock and industrial uses and if not checked may render the soils unsuitable for agricultural purposes.

The concentrations of the trace elements (Fe, Mn and Zn) in the staple food crops, soils, surface and underground water in Ebonyi State is higher than the maximum recommended daily allowance.

The level of the trace elements in soils, surface and underground water were found to vary from one study zone to the other. These observable differences may be due to hydrogeologic processes and physiography of the study areas.

ACKNOWLEDGMENT

The authors are most grateful to God and their families for their patience during the course of this research. Also to Staff of Ideyi Consults Limited (Chemical Analysts and Training Consultants) whose laboratories were used for most of the research.

REFERENCES

- Agency for Toxic Substances and Disease Registry (ATSDR), 2004. Toxicological profile for cobalt, Atlanta G.A, U.S. Department of Health and Human Services, Public Health Service, pp: 150.
- Agriculture, Food and Rural Revitalization (AFRR), 2000. Micronutrients in crop production Saskatchewan, Canada Update 2000, pp: 1-30
- Akpan, L.O. and A.U. Akpanidiok, 2006. Heavy metal status of municipal wastes in Calabar metropolis, Nigeria, using atomic absorption spectrometric technique. *J. Nigerian Environ. Soc.*, 3: 119-125.
- Beilby, J., J. Olynk, S. Ching, A. Prins, A. Swanson, W. Reed, H. Harley and P. Garcia-Webb, 1992. Transferrin index: An alternative method for calculating the iron saturation of transferrin. *Clin. Chem.*, 38: 2078-2081.
- Berg, T.M., 1990. Zinc Fingers Domains: Hypothesis and Current Knowledge. *Ann. Rev. Biophys. Chem.*, 19: 45.
- Bohn, H.L., B.L. McNeal and G.A. O' Conor, 1979. Soil Chemistry. John Wiley and Sons. New Yorks, pp: 272-275.
- Bourre, J.M., 2004. The role of nutritional factors on the structure and function of the brain: An update on dietary requirements. *J. Rev. Neurol.*, 160: 767-792.
- Brady, N.C. and R.B. Wiel, 1996. The Nature and Properties of Soils. 11th Edn., Prentice Hall, Upper Saddle River, New York, pp: 150-158.
- Chaneny, R.C., 1980. Spring seminar on sludge management, Washington DC., 19: 28-30.
- Cobb, G.P., S.K. Sand, M. Waters, B.G. Wixson and K.E. Dorwars, 2000. Accumulation of heavy metals by vegetables grown in mine wastes. *Environ. Toxicol. Chem.*, 19: 600-607.
- Corie Farms Industrial Limited, 2003. Meteorology and Agronomic Status of Ebonyi State, pp: 1-10.
- Danks, D.M., 1995. Disorders of Copper Transport. In: The Metabolic Basis of Inherited Diseases. Scriver, C.R., A.L. Beaudet, W.S. Sly and D. Valhe (Eds.), 7th Edn., New York, Mcgraw Hill, pp: 2211-2235.
- De Freitas, J., H. Wintz, J.H. Kim, H. Poynton, T. Fox and C. Volpe, 2003. Yeast, A Model Organism for Iron and Copper Metabolism Studies. *Biometals*, 16: 185-197.
- Egboka, B.C.E., G.I. Nwankwor, I.P. Orajaka and A.O. Ejiofor, 1989. Principles and problems of environmental pollution of groundwater resources with case examples from developing countries. *Environ. Health Perspect.*, 83: 39-68.
- Ezeonu, F.C., C.O. Edeogu and S.C. Udedi, 2005. Phytoremediation of Nitrate Over-fertilized Rice Farm-A Case Study of Ikwo Area of Nigeria, Nigerian Society for Experimental Biology (NISEB), 5th-9th July, 2005, Book of Abstract, pp: 39.
- Fano, E., M. Brewster and T. Thompson, 1985. Water Quality Management in Developing Countries Part 1. In: Proceeding of the 5th World Congress on Water Resources, Brussels, Belgium, pp: 641-654.
- Food and Agriculture Organization of the United Nations, 1994. Review of pollution in the African aquatic environment, CIFA Technical Paper 25 by David Calamani and Heiner Naeve. CIFA Technical Paper No. 25, Rome, FAO, 1994.
- Gindings, J.C., 1973. Chemistry, Man and Environment Change. Archfield Press, San Francisco, Vol. 25.
- Gracia, W.J., C.I.N. Blessin, G.E. Inglett and W.F. Kwolek, 1981. Metal accumulation and crop yield for a variety of edible crops grown in diverse soil media amended with sewage sludge. *Environ. Sci. Technol.*, 15: 793-804.
- Guthrie, H.A. and M.F. Picciano, 1995. Nutrition in Pregnancy. In: Human Nutrition, Mossby Year Book, pp: 303-542.

- Harrison, R.M., 1982. Pollution: Causes, Effect and Control. The Royal Society of Chemistry, Burlington House, London, pp: 27-39.
- Hill, C. and G. Matrone, 1970. Chemical Parameters in the Study of *in vivo* and *in vitro* Interactions of Trace Elements. Food Processing, 29: 1478-1481.
- Khan, D.H. and B. Frankland, 1983. Effects of cadmium and lead on radish plants with particular reference to movements of metals through soil profile and plant. Plant Soil, 70: 335-345.
- Klevay, L.M., 1975. Coronary heart disease: The zinc/copper hypothesis. Am. J. Clin. Nutr., 28: 764-774.
- Klevay, L.M., 2000. Cardiovascular disease from copper deficiency-A history. J. Nutr., 130: 4898-4928.
- Lönnnerdal, B. and O. Hernel, 1994. Iron, zinc, copper and selenium status of breast-fed infants and infants fed trace element fortified milk-based infants formula. USAID/OMINI Research Project.
- O'Dell, B.L., 2002. Biochemistry of Copper. Science, 296: 619-621.
- Onyeike, E.N., S.I. Ogbuia and N.M. Nwinuka, 2002. Inorganic Ion Levels of Soils and Streams in Some Areas of Ogoni Land, Nigeria Affected by Crude Oil Spillage. Environmental Monitoring and Assessment, 77: 151-205.
- Punnonen, K., K. Irajala and A. Rajamaki, 1994. Iron-deficiency Anaemias associated with high concentrations of transferrin receptor in serum. Clin. Chem., 40: 774-776.
- Rayssiguier, Y., E. Gueux, L. Bussiere and A. Mazur, 1993. Copper deficiency increases the susceptibility of lipoproteins and tissues to peroxidation in rats. J. Nutr., 123: 1342-1348.
- Robert, A.G., 1995. Nutrition and metal toxicity. Am. J. Clin. Nutr., (Suppl) 6: 454-505.
- Stewart, E.A., H. MaxGrimshaw, J. Parkinson and C. Quarmby, 1974. Chemical Analysis of Ecological Materials. 2nd Edn., Blackwell Scientific Publications, Oxford London, Edinburgh Melbourne, John Wiley and Sons Incorporated, New-York, pp: 161, 167, 178, 180, 299, 317, 313, 328, 392, 399.
- Taylor, A., 1996. Detection and monitoring for disorders of essential trace elements. Ann. Clin. Biochem., 33: 486-510.
- Tietz, N.W., A.B. Carl and R.A. Edward, 1994. Tietz Text Book of Clinical Chemistry. 2nd Edn., London, Sander Company, pp: 1211-1235, 1353.
- Troye, L., B.H. Olson, B.C. Hill, L. Thornton and H. Matthews, 1980. Trace Substances. Hemphill, D.D. (Ed.), University of Missouri, Columbia. Environ. Health, 14: 129-131.
- Underwood, E.J., 1997. Trace Elements in Human and Animal Nutrition. 4th Edn., New York Academy Press Inc., pp: 125-132.
- Warren, H.V., 1972. Variation in the trace elements content of some vegetables. J. Royal College of General Practitioners, 22: 56-60.
- Wayne, A.P. and B.H. Dale, 1989. Understanding Your Health. 2nd Edn., Times Mirror/Mosby College Publishing St. Louis, pp: 107.
- Wood, J.M., 1974. Biological cycle for toxic elements in the environment. Science, 21: 524-527.
- World Health Organization, 1984. Guidelines for Drinking Water. Quality Vol. 1 Recommendations. Geneva: WHO.
- Xiong, Z.T., 1998. Lead Uptake and Effects on Seed Germination and Plant Growth in a Pb Hyper-accumulating *Brassica pekinensis*. Bull. Environ. Contam. Toxicol., 60: 286-291.
- Zoller, W.H., 1984. Anthropogenic Perturbation of Metal Fluxes into the Atmosphere. In: Changing Metal Cycles and Human Health. Dahlem Konferenzen. Berlin, Nriagu, J.O. (Ed.), Springer, pp: 27-34.