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Levels of Some Essential and Toxic Elements in Soils, Foods and Diets on the Jos Plateau, Nigeria

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ABSTRACT

The tin-mining region of Jos Plateau in Nigeria is also one of the major food baskets for the whole country, especially of some fruits and vegetables which require the peculiar temperate climate of the plateau to thrive. However, the prevalence of large-scale reclamation of abandoned mines land for agricultural use in this region could introduce toxic heavy metals into the food chain. In this work, using both Flame-Atomic Absorption Spectrometry and X-ray Fluorescence techniques, the levels of the toxic elements Cd, Cr and Pb together with the essential elements Zn and Cu were determined in 43 food and diet samples from the Jos Plateau. Levels of some heavy metals in soil samples from the region were also determined and compared with samples from gold mines around Ile-Ife and Ilesa in South West Nigeria. While considerable pollution of some soils was recorded, the transfer of the pollutants into most foods and diets have been minimal. The only exception is Maize which seems capable of accumulating Cd beyond levels tolerable for humans, especially following prolonged drying.

Keywords: toxic elements, essential elements, soil, food, diet, mining pollution

Introduction

Tin mining which has been associated with the famous Nok culture around the Jos Plateau of Nigeria (dated between about 500 BC and 200 AD) became accentuated with the coming of the British colonialists about 1900. The resulting extensive large scale tin/lead mining continued for several decades and culminated in Nigeria at a time being ranked as the world's sixth largest tin producer. However, the Jos tin mines were nationalized in 1972, and largely abandoned in subsequent years leading to the current situation where most tin mining is now carried out by artisanal and small scale miners. Apart from the rapid fall in the value of tin in the world market coupled with exponential increase in earnings from crude oil, a major reason for the large abandonment of tin mining on the Jos Plateau was the dwindling tin deposits. This resulted not only in more and more agricultural land being acquired in the search for ore, but also necessitated that deeper holes be dug following the depletion of surface deposits. It has been estimated that 80% of Nigeria's tin ore deposits are now around 36m below the surface, twice as deep as they were some 25 years ago (Drillbits & Tailings, 1999).

It was therefore inevitable that when government agencies finally began land reclamation efforts in recent years, such reclaimed land should be ploughed back largely into agricultural use. Large private companies as well as government-sponsored programmes are establishing large farm settlements on reclaimed mining sites producing agricultural products which are consumed by several million Nigerians. While the radiation hazard of this practice has been studied somewhat extensively, {e.g. Nwosu and Sanni (1974), Oluwole *et al.*, (1994)}, there has been paucity of data on the level of contamination of the food chain by heavy metals and other toxic elements. Such contamination has been reported in a number of other regions of the world including the abandoned tin and silver mines from the Cordillera Real of the Andes (Reed, 2002), the Iron Quadrangle in Brazil, (Menezes, 2003) and the Idrija mines of Slovenia (Falnoga, 2003).

In the past four years, under a Coordinated Research Project sponsored by the International Atomic Energy Agency (IAEA), our efforts have been focused on assessing the levels of contamination of foods and diets emanating from reclaimed mining sites on the Jos plateau by toxic elements. In this paper, we report on the levels of the toxic elements Cr, Cd, Pb in soils, foods and diets from the Jos plateau. Since the toxic impacts of heavy metals could be somewhat mitigated by the presence of essential elements, the essential elements Zn and Cu were also measured in the food and diet samples.

Materials and Methods

Sample Collection

Most of the food samples were collected *in situ* from farms on previously active mining sites now reclaimed for agricultural purposes from the villages of Wereh in Barkin Ladi Local Government Area and Tenti in Bokkos Local Government Area on the Jos Plateau. Both are settlements that grew around reclaimed mines land, and practice extensively the dry season *Lambu* method of farming which involves the use of rainwater harvested into disused mine pits for irrigation. A few other food samples were obtained from the market at Kavitex Junction in Barkin Ladi, where several fresh agricultural products pooled from several villages in the region are displayed for sale. With the assistance of local qualified Nutritionists, a food basket survey of the major foods consumed on the Plateau was compiled (Table 1) and this formed the basis for our choice of foods and diets for sampling. Diets were either obtained from local restaurants or prepared in the usual traditional ways at the Nutrition and Dietetics department of the Jos University Teaching Hospital, Jos, from raw food materials collected by us from the field. The diet samples were transported to the laboratory at Ile-Ife, some 1,000 km away, together with ice packing in thermos food flasks. Samples of raw food stuffs and soil did not require refrigeration during the 12 hour trip to the laboratory.

Soil samples were collected from the top soil (about top 7 cm) from the various farms, and also around a tin-lead smelter factory in Jos. Soil samples from artisanal gold mines around Ile-Ife, and the now closed medium-scale gold mines at Igun village, near Ilesa both from South West Nigeria, were also analysed and compared with soils from the Jos plateau.

Elemental Analyses

Elemental analyses by Flame Atomic Absorption Spectrometry (FAAS) were carried out both at the Central Science Laboratory (CSL) of the Obafemi Awolowo University, Ile-Ife (ALPHA4 Atomic Absorption Spectrophotometer with automatic background correction) and at the International Institute for Tropical Agriculture (IITA), Ibadan. Analyses by Total Reflection X-ray Fluorescence (TXRF) were carried out at both the Physics Department of the Obafemi Awolowo University (OAU), Ile-Ife, and the Physics Department of the University of Mining and Metallurgy (UMM), Krakow, Poland. The TXRF facilities at both institutions were identical, both using Molybdenum anodes, and analyses were based on identical standard operating protocols. Furthermore at the UMM, Krakow, a conventional XRF bulk sample analyzer system was used to analyse the soil samples, some of which had been analysed by Atomic Absorption Spectrometry. The multifunctional system for energy dispersive X-ray fluorescence at Krakow, incorporating both the total reflection module and the conventional bulk sample analyzer module together with an X-ray microfluorescence system has been fully described by Holynska and co-workers (Holynska *et al.,* 1995).

Samples for analyses by AAS and TXRF required acid digestion. The main digestion procedures used in the course of this work, all involving suprapure quality nitric acid (Aldrich, redistilled, 99.999+%), were: ashing, followed by digestion in HNO_3 (for soil and food samples analyzed at IITA, Ibadan); closed acid digestion (HNO_3) involving 6 hrs in Oven at 60'C (for some food samples at CSL, OAU, Ile-Ife); and microwave digestion (0.1g + 2.5 ml HNO_3) for 30s at nominal power of 900 Watts (mainly for a few non-fatty food samples).

For TXRF analyses, a few µL of Ga, amounting to about 5 ppm end-concentration, used as internal standard, was added to 5 mL aliquot of digested sample. After thorough homogenization by shaking, 10 µL of the mixture was pippetted on a spectroscopically clean carrier and dried under infra red lamp. The carrier was then bombarded with 40 keV X-rays (current of 30 mA) and the resulting fluorescence detected by a Si(Li) detector. Canberra's Inspector 2K Spec Assistant (Model 1300) was used for signal processing at Ile-Ife while a conventional Canberra amplifier was used at Krakow. At both institutions, Canberra S100 multichannel analyzer together with IAEA-supplied AXIL software was used for data reduction including peak area and concentration determination.

Analyses of soil samples by Energy-Dispersive X-ray Fluorescence were carried out at the UMM, Krakow using the bulk XRF facility. Dried samples were thoroughly ground and about 35% cellulose added as binder. The mixture was then further homogenized for not less than 15 minutes using an agate mortar. Three pellets of each sample were then made and these were bombarded with 40 kV X-rays and the resulting X-ray fluorescence picked at the conventional angle 45º by a Si(Li) detector. For the "intermediate-thickness" geometry used, the AXIL software, based on the Emission-Transmission method, required the sample to be counted alone (for 3000 s in this case), then with a secondary target on top of the sample. Finally, the secondary target and also the cellulose binder pellet were also counted separately. This procedure, suggested by (Van Dyck *et al.*, 1980), thus provides an estimation of the absorption factor for the matrix including the so-called 'dark elements' which do not produce any significant fluorescent radiation on account of their low atomic numbers.

For TXRF measurements which were directly under our control, reference materials were analysed together with the samples as quality control measures. Table 2, comparing our results for some geological and biological reference materials with certified/consensus values, indicate fair agreement. Measurements by FAAS were contracted out and were beyond our direct control. For these, pure elemental standards at different concentrations were introduced into the samples submitted for analysis. By comparing the reported concentrations with the actual known concentrations, it was possible to adjust the results submitted by the laboratories. Typical calibration curves for Pb and Cr from one of the laboratories are shown in Figures 1 and 2.

Results

With the multi-elemental TXRF system, we were able to simultaneously detect in most samples, up to 13 elements, viz - K, Ca, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Rb Sr, Pb. However for FAAS, each element had to be analysed separately. Cost considerations compelled us to limit our investigations to the important five elements Pb, Cd, Cr, Cu and Zn. Lead and Cadmium are among the most toxic elements, causing primary damages to the renal system. Other health effects associated with both Cd and Pb are stomach pains and severe vomiting, reproductive failure and psychological disorders (Lenntech, 1998a ; 1998b). These two elements are closely associated with tin mining. Zn and Cu on the other hand, are essential elements, and their presence has been known to reduce the potential toxic impacts of Pb and Cd (e.g. Parizek *et al.*, 1969). Cr is both toxic, causing spinal/joint degeneration, depressed immune system, etc; and at the same time essential in its anti-inflammatory properties as well as in its regulation of glucose uptake in some forms of diabetes (Lenntech, 1998c).

Table 3 shows the levels of the toxic elements, lead, chromium and cadmium in 6 soil samples from the Jos Plateau (obtained by FAAS) while Table 4 shows the levels of lead, chromium, tin and titanium in 13 soil and ash samples from both the Sn mining/smelting areas on the Jos plateau and Au mining areas of South West Nigeria.

Values in Table 4 were obtained by both EDXRF and TXRF. Table 5 shows the levels of the toxic elements Pb, Cr and Cd, as well as those of the essential elements Zn and Cu, in 43 food and diet samples from the Jos Plateau. These values are based on dry weights.

Discussion

The concentrations of the elements in soil varied widely, with samples near the lead smelter being much higher than those from other locations [Tables 3 and 4]. In the United States, the screening values for the soil levels of Pb, Cr, and Cd are 400 ppm (USEPA), 210 ppm (USEPA) and 10 ppm (ATSDR) respectively. All the Cr and Cd levels measured in this work are far below the recommended screening levels. However, Pb levels in the soil samples from two farms around the Pb Smelter (both outside the main premises, near the highway, 1936 ppm; and within the Staff Quarters, 941 ppm) exceed the screening level recommended by the US Environmental Protection Agency (USEPA). This result suggests that there is, in general, minimal contamination of the soil with heavy metals as a result of tin mining – except perhaps for cases where farming occurs directly on mine tailings or in the vicinity of the smelter. The use of EDXRF, as previously described, provides the values for Sn and Ti [Table 4]. Titanium levels in soils from the South West region of Nigeria (at least for the few locations sampled in this work) are distinctly higher than those from the Jos Plateau, and might even be worth considering for exploitation.

Some food and diet samples have relatively low levels of the toxic elements while others have quite elevated levels [Table 5]. Pb values were low in foodstuffs such as onion (0.67 ppm), Berom Yam (0.39 ppm), Applan fruit (1.28 ppm) and fish (0.09 ppm). Foods with high Pb include cooked Riziga (4.67 ppm), cooked maize (5.92 ppm), and raw snail (4.70 ppm). These concentrations are similar to values reported from other countries. For example Pb in rice from Thailand was reported in the range of 0.1 – 3.41 ppm (Cortes Toro *et al.*, 1994). For carrots, our measured Pb level of 1.34 ppm can be compared with 0.081 ppm reported Pb levels for carrots from an industrial area in Spain (cited in Oyedele *et al.*, 1995), and 9.4 ppm reported for carrots from an Industrial area in Poland (Bosque, 1990). Our values for Pb in cassava tuber and corn (3.14 ppm and 1.77 ppm respectively) are much lower compared with the values of Pb in the same foods from roadside with heavy Pb pollution somewhere else in Nigeria (28.4 ppm and 17.0 ppm respectively) (Ndiokwere, 1984). However, these data at least suggest that of these two major Nigerian staples, cassava is the greater accumulator of Pb. Highest level of lead (5.92 ppm) measured in any sample was in cooked maize, but in general, tubers have high Pb values relatively.

Cr values ranged from 0.5 ppm (dry corn), 1.22 ppm (cooked corn), and 1.83 ppm (Riziga) to very high levels of 19 ppm in carrot and 32 ppm in cooked beans. The possibilities of Cr having been incorporated from the soil in the case of carrot, and from the cooking utensils in the case of cooked corn and beans are highly suggested by these values. However, the absorption of Cr from food is known to be very low indeed, and it is generally considered unlikely that chromium toxicity could arise from the ingestion of natural food (Food and Nutrition Board, 2001). In general, Cr is consistently higher in vegetables than any other food types.

Likewise, Cd ranged from 0.1 ppm in Onion to 1.38 ppm in Tuwon Asha. This can be compared with the range 0.12-1.8 ppm found for the element in 40 food and mineral supplements by Anderson *et al.*, (1990). They considered this range as non-toxic. However, maize in this study, has consistent high values of Cd. Of the three different maize samples analysed, dried maize (stored from the previous harvest season) has the highest Cd level of 2.08 ppm. This is not surprising as the drying process obviously serves to concentrate the elements. Fresh maize from one farm contained 1.85 ppm Cd while the cooked one (obviously considerably diluted) contained 0.86 ppm of cadmium.

Snails have been recently implicated as an important source for incorporating toxic elements from polluted soils into the food chain (Scheifler, 2002). In this study, it was observed that while the high toxicity potential of snails is confirmed, cooking seems to drastically reduce the levels of toxic elements. Most likely, it is the non-edible portion (which has been discarded from our cooked samples), that accumulates these toxic elements. The entire snail was homogenized and aliquoted for analyses of the raw snail. The same reasoning will suggest that the edible portion of snail is highly enriched in zinc (1186 ppm in cooked snail versus 306 ppm in raw snail). The differences in these elements between cooked and raw snail may however be due to the cooking process, especially as the cooked snail was fried in palm oil, which is the traditional way of preparing it.

There is significant correlation between the levels of the two essential elements Zn and Cu in food and diet samples ($r = 0.5306$, $n=42$; $p < 0.005$). This is not surprising and it reflects the fact that the levels of these elements are not due to mere contamination. Zinc levels ranged from 1.63 ppm (Eba, TXRF) to 1186.5 ppm (Fried Snail), while Cu levels ranged from 0.24 ppm (Fish) to 6.6 ppm (Fried Snail). It will be interesting and useful to confirm the level of Se and some other essential elements later on, possibly using an analytical technique with multi-elemental capabilities to save costs. The scatterplot for Zn and Cu in food and diet samples is shown in Figure 3.

In summary, while considerable pollution of some soils on the Jos Plateau has been confirmed, this work suggests that the transfer of the pollutants into most foods and diets has been minimal and poses no serious threat to the general public. A notable but unusual exception could be the case of foods (such as Maize) planted directly on heavily polluted soil, and further preserved for long-term storage by drying. The dehydration process could serve to increase the concentration of the toxic heavy metals in such food items and could pose grave dangers to individual families involved depending on their dietary habit. Public health officers should be on the lookout for such cases and appropriate advice be given to farmers that might be under such risk.

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Table 1: Main Foods and Diets consumed on the Jos Plateau

TUBERS	CEREALS	DRINKS	VEGETABLES	LEGUMES
Yam (Pounded Yam) Cassava (Fufu) Irish potatoes (Porridge) Cocoyam (Boiled + palm oil) Riziga (Boiled + Groundnut + Pepper) Sweet Potatoes (or Porridge with vegetables) Berom Yam	Rice (Tuwo Shinkafa) Acha (T/Acha) Massara (T/Massara) Dry Corn Millet (T/Millet) Surghum (T/Dawa) Tamba	Kunu Zaki Kunu Acha Kunu Tamba Nunu Madara (milk) Zobo	Spinach (soups) Carrots* Cabbage* Tomatoes* Lettuce* Cucumber* Green Beans* Pumpkin Yakwua (Soup) Karkashi (Soup) Okro (Okro) Onions (Soup) Kuka (Baobab dry leaves)	Beans (Jollof beans) Soya Beans (Milk, cheese) Groundnuts (Kulikuli) Ridi (Sesemi seed, Binai seed)

* Taken with Rice, Beans, Gwette

Table 2a. Results of analyses of Reference Materials by TXRF (Geological)

	IAEA SOIL 3		BCR 320 (Dried river sediment)	
ELEMENT	OBSERVED CONC.(μg/g)	CERTIFIED VALUES ((μg/g)	OBSERVED CONC.(μg/g)	CERTIFIED VALUES (μg/g)
Cr	20.5 ± 3.8	27.0	-	-
Pb	7.90 ± 3.60	13.0	53.5 ± 13.7	42.3 ± 1.6
Cu	14.5 ± 0.42	17.0	47.3 ± 0.2	44.1 ± 1.0
Zn	-	-	142 ± 1.3	142 ± 3.0

Table 2b. Results of analyses of Reference Materials by TXRF (Biological)

ELEMENT	BCR/CRM 060 – AQUATIC PLANT		BCR/CRM 061 – AQUATIC PLANT	
	OBSERVED VALUES (μg/g)	CERTIFIED/ INFORMATION VALUES (μg/g)	OBSERVED VALUES (μg/g)	CERTIFIED/ INFORMATION VALUES (μg/g)
Zn	337±2	313±8	621±3	566±13
Cu	58.2±1.0	51.2±1.9	623±7	720±31
Pb	62.7±4.1	63.8±3.2	55.6±4.5	64.4±3.5

Table 3: Some Toxic elements in some agricultural Soils from Jos (FAAS)

Sample Code	Location	Pb (µg/g)	Cr (µg/g)	Cd (µg/g)
JSS01A	Farm at Barkin Ladi	17.7	0.7	0.01
JSS01B	Soil scraped off potato samples collected at Farm at Barkin Ladi, as above	21.3	6.2	0.04
JSS01C	Another location on Farm at Barkin Ladi	22.7	5.5	0.02
JSS03	Farm at the front entrance of Pb Smelter, Jos	1936.3	148.3	0.10
JSS05	Farm in Staff Quarters of Pb Smelter, Jos	940.7	74.0	0.07
JSC	Residential Area, Wereh	0.2	0.2	0.02

Table 4. Some metals in soil and other environmental samples from Jos and Ile-Ife using Conventional XRF* and Total Reflection XRF**

Sample Description	Pb (µg/g)	Cr (µg/g)	Sn (µg/g)	Ti (µg/g)
Soil from Tenti*	82±11	276± 49	-	4,470 ±320
Soil from Lead-Tin Smelter (farm), Jos*	940± 110	74± 18	-	5,780 ± 400
Soil, Site 1, Ile-Ife*	67±6	73 ± 6	-	14,200± 600
Soil from Gold Mining Site 1, Ile-Ife**	67±14	73 ±24	-	14,200 ±3000
Soil from Gold Mining Site 2, Ile-Ife**	88.3 ±18.5	106 ±35	-	17,243 ±4000
Soil from Gold Mining Site 3, Ile-Ife**	165.6 ±34.6	141±46	-	27,386 ±6000
Soil from Non-mining site, Ile-Ife**	57.6 ±12.0	4104 ±133	-	16,229 ±4000
Soil, Igun (Ilesa)*	168±40	151± 33	-	22,590± 550
Sediment, Igun (Ilesa)*	47±6	295± 60	-	12,430± 180
Concentrate, Igun (Ilesa)*	74 ± 10	123± 27	-	192,100± 7900
Gold Ore, Site 1, Ile-Ife*	34±3	96± 13	-	14,820± 560
Ash (Tin Smelter, Jos)*	2810± 180	381± 58	153,700 ± 9,500	-
Ash (Lead Smelter, Jos)*	162200± 7100	-	77,000 ± 5,800	-

Table 5: Concentrations of Pb, Cr, Cd, Zn and Cu in foods from the Jos Plateau (Standard deviations in brackets)

NAME	Pb (µg/g)	Cr (µg/g)	Cd (µg/g)	Zn (µg/g)	Cu (µg/g)
READY-TO-EAT, DIET					
Cooked Beans	2.04 (0.5)	32.1 (9.0)	0.037 (0.001)	382.8 (99.7)	2.12 (0.32)
Cooked Riziga	4.67 (1.2)	1.8 (0.5)	0.114 (0.001)	134.1 (27.4)	2.02 (0.30)
Cooked Cassava	2.99 (0.9)	8.3 (2.3)	0.002 (0.001)	86.6 (19.9)	0.52 (0.08)
Cooked Cocoyam	2.35 (0.8)	7.7 (2.1)	0.002 (0.001)	307.5 (70.7)	1.22 (0.18)
Cooked Maize	5.92 (1.5)	1.2 (0.3)	0.856 (0.092)	138.0 (31.7)	2.01 (0.30)
Tuwon Acha	3.45 (1.1)	1.4 (0.4)	2.967 (1.200)	311.0 (71.53)	2.98 (0.45)
Fried Snail	2.47 (0.7)	0.9 (0.1)	0.002 (0.001)	1186.5(275.5)	6.6 (1.0)
Eba *(TXRF)*	0.68 (0.22)	0.61 (0.11)	-	1.63 (0.32)	0.47 (0.25)
DRINKS					
Sugar Cane Juice	4.58 (1.3)	2.7 (0.7)	0.023 (0.003)	74.2 (17.1)	3.35 (0.50)
Well Water	0.28 (0.20)	0.5 (0.1)	0.001 (0.001)	7.2 (1.7)	0.24 (0.04)
Well Water *(TXRF)*	-	0.03 (0.01)	-	1.2 (0.3)	0.03 (0.01)
Nunu (P. Milk)	0.04 (0.02)	0.63 (0.17)	0.030 (0.005)	36.5 (8.4)	4.7 (0.7)
Burukutu (Liqueur)- TXRF	0.26 (0.10)	0.44 (0.11)	-	3.91 (0.04)	1.35 (0.41)
LEGUMES					
Green Beans	1.46 (0.6)	1.7 (0.6)	0.002 (0.001)	147.8 (34.1)	0.85 (0.13)
Soya Beans	0.31 (0.1)	1.27 (0.4)	0.173 (0.035)	42.2 (9.7)	1.42 (0.21)
Green Peas	1.40 (0.6)	3.9 (1.0)	0.002 (0.001)	623.6 (144.3)	2.31 (0.35)
MEAT					
Snail	4.70 (1.3)	5.9 (1.4)	0.114 (0.032)	306.2 (70.4)	5.02 (0.75)
Fish	0.09 (0.05)	2.1 (0.6)	0.004 (0.001)	11.8 (2.7)	0.24 (0.04)
Goat meat	2.01 (0.7)	1.9 (0.6)	0.035 (0.009)	839.5 (193.1)	2.08 (0.31)
TUBERS					
Riziga	0.32 (0.1)	1.02 (0.4)	-	21.3 (4.9)	1.51 (0.23)
Berom Yam	0.39 (0.1)	2.25 (0.7)	0.007 (0.001)	22.8 (5.2)	0.7 (0.1)
Berom Yam (dried)	1.04 (0.4)	2.7 (0.8)	0.003 (0.001)	59.6 (13.7)	2.8 (0.42)
Cocoyam	4.00 (1.3)	2.4 (0.7)	0.002 (0.001)	203.7 (46.9)	1.37 (0.21)
Cassava	3.14 (0.8)	3.6 (1.1)	0.002 (0.001)	210.5 (48.4)	1.30 (0.2)
Sweet Potato	1.46 (0.5)	5.1 (1.5)	0.002 (0.001)	42.9 (9.9)	0.63 (0.09)
Dankali (dried)	1.14 (0.6)	0.94 (0.21)	`-	45.0 (10.4)	1.45 (0.22)
FRUITS AND VEGETABLES					
Cucumber	3.69 (1.2)	4.5 (1.2)	0.003 (0.001)	181.9 (41.8)	3.18 (0.48)
Tomatoes	1.19 (0.4)	4.3 (1.1)	0.042 (0.007)	186.1 (42.8)	2.3 (0.3)
Carrot	1.34 (0.4)	18.8 (6.1)	0.003 (0.001)	112.3 (25.8)	1.82 (0.27)
Mango	3.76 (0.9)	9.5 (2.3)	0.154 (0.032)	22.2 (5.1)	1.03 (0.15)
Applan	1.28 (0.4)	2.6 (0.4)	0.014 (0.002)	149.3 (34.3)	1.75 (0.26)
Amaranthus	2.20 (0.8)	2.3 (0.4)	0.090 (0.021)	627.5 (144.3)	1.21 (0.18)
Onion	0.67 (0.1)	2.5 (0.4)	0.002 (0.001)	357.6 (82.2)	1.78 (0.27)
Cabbage *(TXRF)*	0.30 (0.02)	0.67 (0.46)	-	1.97 (0.05)	0.56 (0.16)
Chinese Cabbage *(TXRF)*	0.31 (0.08)	1.0 (0.1)	-	5.4 (0.26)	0.61 (0.02)
Ginger	2.75 (0.6)	5.5 (1.4)	0.002 (0.001)	231.3 (53.2)	3.33 (0.50)
Groundnut	0.14 (0.06)	1.44 (0.4)	-	32.9 (7.567)	2.15 (0.32)
Egusi Soup (TXRF)	13.0 (0.35)	1.61 (0.65)	-	-	4.1 (0.1)
CEREALS					
Acha (Ground)	0.18 (0.05)	0.77 (0.22)	0.096 (0.018)	20.6 (4.7)	1.81 (0.27)

Maize (Dried Corn)	1.77 (0.5)	0.5 (0.1)	2.080 (0.039)	201.3 (46.3)	3.19 (0.48)
Maize (Fresh)	0.30 (0.1)	0.94 (0.21	1.848 (0.032)	45.4 (10.5)	1.06 (0.16)
Maize *(TXRF)*	1.26 (0.24)	1.19 (0.19)	-	31.8 (1.36)	2.3 (0.6)
Millet	0.18 (0.06)	20.89 (6.7)	0.095 (0.027)	51.4 (11.8)	1.83 (0.27)

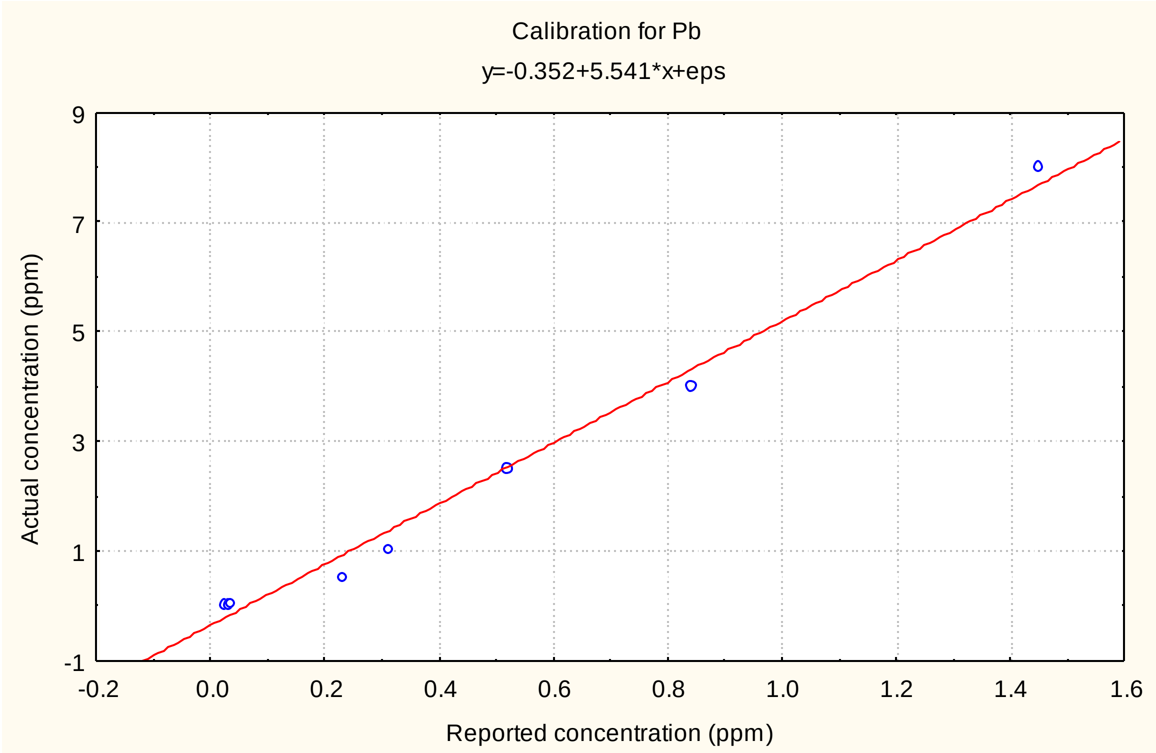

Figure 1: A typical Calibration curve for Pb for analyses by FAAS by one laboratory

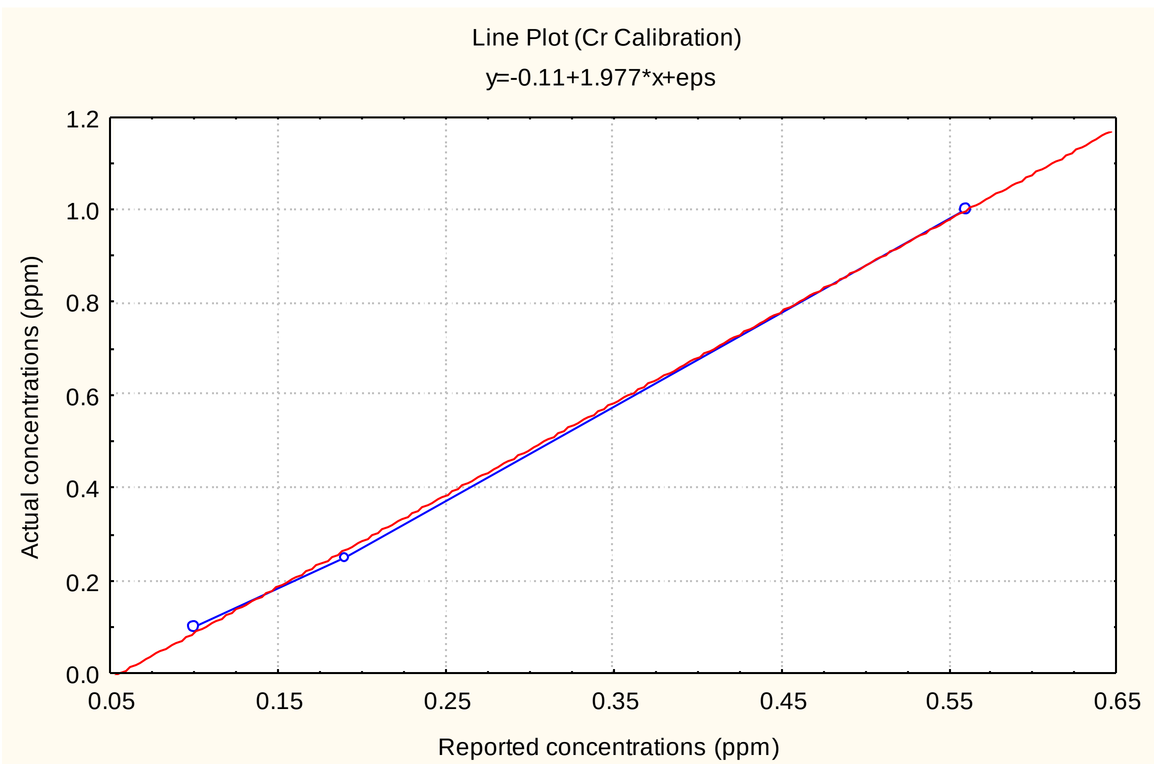

Figure 2: A typical Calibration curve for Cr for analyses by FAAS by one laboratory

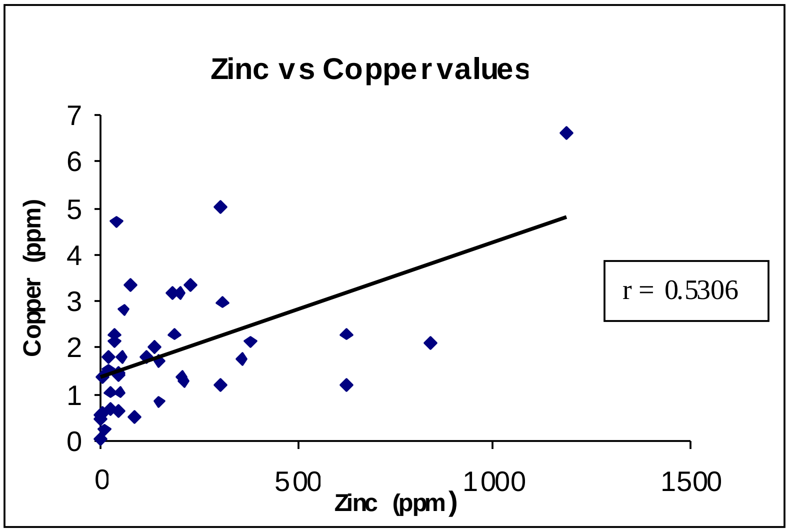

Figure 3: Scatter plot showing correlation between Zinc and Copper levels in food and diet samples