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Elemental Contents of Spinach and Lettuce from Irrigated Gardens in Kano, Nigeria

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Abstract

One way analysis (ANOVA) was used to analyze a large dataset of elemental levels of two vegetables – spinach (*Amaranthus cruentus*) and lettuce (*Lactuca sativa*) grown around River Jakara in Kano, Nigeria using data generated during 12 months of monitoring Ca, K, Mg, Na, (essential bulk elements) Cu, Zn, Cd, Ni, Cr, Co, Pb and Fe (trace/heavy elements) concentrations collected at three designated sites. The concentrations of the elements showed insignificant differences between sites but significant differences between some months. The soil was implicated as the major source of the elements. The concentrations of the trace/heavy metals exceeded those of the international permissible limits which pointed to the contamination of the vegetables. The mean concentrations of the elements occurred in the magnitude of Ca > Mg > K > Na > Fe > Zn > Pb > Co > Cr > Cu > Ni > Cd and Ca > Na > K >Mg > Fe > Zn > Pb > Cr > Co > Cu > Ni > Cd in the spinach and lettuce respectively. The continued consumption of these vegetables by the inhabitants of Kano and its environs present a public health risk with regards to their concentrations with heavy metals. It is therefore recommended that the relevant organ of government should find an alternative farmland for the farmers within the catchment area of River Jakara where unpolluted soil can be utilized for the production of the vegetables.

Keywords: contamination, metals, irrigation, vegetables, wastewater

1. Introduction

Vegetables constitute an important component of the diet of most people in the world. They contain essential elements and are rich in vitamins, dietary fibers and minerals. They are essential for growth and maintenance of good health. Some are suitable for medicinal and other applications. The production of vegetables is important as a means of livelihood, employment and income generation to the traders/vendors who market the produce, input suppliers such as farm machines, fertilizers, pesticides, herbicides and other service providers. Yet vegetables are being constantly contaminated with pollutants such as heavy metals through various types of anthropogenic activities. Activities such as mining and smelting operation and agriculture have contaminated extensive areas of the world such as Japan, Indonesia, and China mostly such as Cd, Cu and Zn (Herawati, Susuki, Hayashi, Rivai, & Koyama, 2000).

Application of untreated and polluted wastewater to irrigate vegetable gardens has been a global practice. Recent surveys across 50 cities in Asia, Africa and Latin America show that waste water irrigation is a common reality in three – fourths of the cities and global estimates of the total area under raw and diluted waste water irrigation range from 3 to 3.5 million hectares; however the proportion of harvested area that is irrigated is largest in Asia and smallest in Sub - Saharan Africa (International Management Institute, 2006 & 2013). Irrigation of plants particularly with sewage and solid wastewater disposal ends to soil contamination and heavy metal accumulation both in soil and crops (Doyle, 1995) and the crops contain metals in higher concentrations than those irrigated using uncontaminated water (Chang, Granato, & Page, 1992; Nrghole, 2007). Heavy metals may be present either as a deposit on the surface of vegetables or taken up by the roots and incorporated into the edible part of the vegetable tissues; leafy vegetables tend to absorb higher concentrations of heavy metals than non-leafy vegetables (Al Chaarani, El-Nakat, Obeid, & Aouad, 2006). Literature on the heavy metal contamination of vegetables through anthropogenic activities abound nationally (Ojeka & Achi, 2004), (Chiroma, Ebewale, & Hymore (2012) and internationally (Kisku, Barman, & Bhargara, 2000; Behbahaninia & Mirbagheri, 2008;

Bigdeli & Seilsepour, 2008). Several heavy metals have toxic, mutagenic and carcinogenic effects on man even at a very low concentration (Das, 1990). Concentration of vegetables with toxic elements is therefore a serious threat because of its toxicity, bioaccumulation, and bio-magnification in the food chain. The seriousness of this problem cannot be underestimated in the light of the findings of Dike, Ezealor, and Oniye (2004) and Dike, Ezealor, Oniye, and Ajibola (2013) which revealed that River Jakara in Kano, Nigeria, used extensively for the irrigation of vegetables consumed by its inhabitants and environs is contaminated with heavy metals. In addition, large quantities of fertilizers are regularly added to the top soils during intensive farming to supplement the macro elements such as Ca, Mg and K. The current investigation is carried out to determine the concentrations of some elements - calcium (Ca), potassium (K), magnesium (Mg), sodium (Na), with particular emphasis on copper (Cu), zinc (Zn), cadmium Cd), nickel Ni), chromium Cr), cobalt (Co), lead (Pb) and iron (Fe) in spinach (*Spinacea oleracea*) and lettuce (*Lactuca sativa*) leaves from gardens irrigated with wastewater from River Jakara to ensure that their levels meet the agreed international standards. Determination of the chemical composition of plants is one of the most frequently used methods of monitoring environmental pollution.

2. Sampling Sites

Collection of vegetable samples were made at 3 designated points (sites 2, 3 and 4) along the River Jakara based on the irrigation activities carried out on the areas (Figure1). Site 1 is at the “T” junction of Ibrahim Babangida and Taiwo roads and near the origin of the river but was devoid of irrigation activities and hence samples were not collected there. Site 2 is at the Abattoire and Katsina road junction where the water used for the irrigation of the vegetables receives sewage from the abattoire and domestic wastes from the residential areas in Fagge. Site 3 is at the junction of Burma and Zungeru roads and receives effluents and wastes mainly from a hospital and also effluents from car washing activities and mechanic workshops. Site 4 is at the Airport road bridge which receives domestic wastes and runoffs from dump sites particularly during the rainy season.

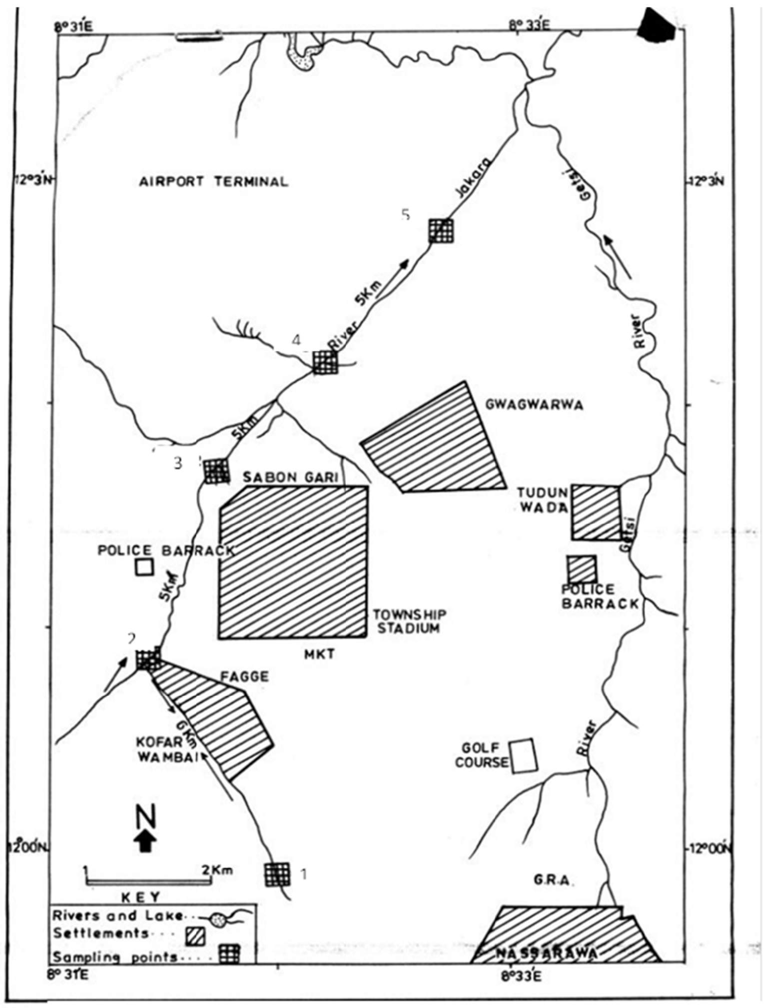

Fig. 1: Map of the study area showing the sampling points.

Figure 1. Map of the study area showing the sampling points

2.1 Sample Collection and Treatment

10-15 matured vegetables were collected monthly from the sites (see plate 1) at random and packed lightly in loosely woven bags to the laboratory. Samples were washed with running tap water to clean adhered impurities, then rinsed with distilled water and air-dried thereafter. Dried samples were pulverized using mortar and pestle and passed through a 2mm sieve. Pulverized vegetable samples were further kept in oven at 65^0C ± 1^0C for 24 hours to obtain a constant weight (Kisku *et al*., 2000). Digestion of samples was carried out using HNO_3 (sp. gr. 1.42) and HCl (sp. gr. 1.18) according to the standard method described by Kisku *et al*. (2000). Metal analysis was carried using Atomic Absorption Spectrophotometer (UNICAM 969) at the National Research Institute for Chemical Technology, Zaria, Nigeria.

Plate 1. Some vegetables irrigated with waste water at site 3 on River Jakara

2.2 Data Analysis

Variations in the concentrations of metals in the vegetables between sites and months of study were compared using a one-way ANOVA. All the means were compared using multiple range tests (MRT) and the Pearson's correlation coefficient was employed to compare the relationships between the metal concentrations of the vegetable and soil samples

3. Results

Table 1. Mean concentration of metals in spinach *(Amaranthus cruentus)* at different sites along River Jakara, in Kano State, Nigeria (January 2003 – December 2003)

Metals (mg/g)	Sites		
	2	3	4
Ca	224.65^a (±43.92)	189^a ((±29.79)	209.20^a (±30.42)
Mg	42.24^a ((±6.26)	41.49^a (±8.73)	49.84^a (±11.82)
Na	21.34^a (±9.02)	24.05^a ((±10.36)	41.17^a (±12.16)
K	43.88^a (±12.26)	29.28^a (±10.15)	39.42^a (±11.47)
Pb	2.347^a (±0.56)	1.804^a (±0.57)	1.632^a (±0.47)
Cd	0.011^a (±0.004)	0.009^a (±0.003)	0.013^a (±0.005)
Cr	0.680^a (±0.15)	0.768^a (±0.18)	0.973^a (0.25)
Ni	0.485^a (±0.17)	0.325^a (±0.07)	0.524^a (±0.08)
Cu	0.445^a (±0.07)	0.485^a (±0.08)	0.453^a (±0.07)
Zn	1.955^a (±0.41)	1.659^a (±0.33)	2.196^a (±0.41)
Co	0.941^a (±0.23)	0.504^a (±0.11)	1.026^a (±0.46)
Fe	2.773^a (±0.42)	2.434^a (±0.36)	2.658^a (±0.51)

Mean values with the same letter within the same row are not significantly different (p>0.05). Values in parenthesis are standard errors of means.

Table 1 reveals that the metal mean concentration in spinach (*Amaranthus cruentus*) varied insignificantly (p>0.05) between sites. Mean concentrations of metals in spinach for different months

Table 2. Mean concentrations of metals in spinach *(Amarantus cruentus)* for different months along River Jakara, in Kano State, Nigeria (January 2003 – December 2003)

Metals (mg/g)	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ca	187.19^{c}	241.35^{bc}	158.94^{c}	133.85^{c}	213.47^{c}	350.52^{ab}	122.85^{c}	176.26^{c}	149.11^{c}	153.74^{c}	146.66^{c}	461.40^{a}
	(±26.51)	(±5.99)	(±26.26)	(±62.94)	(±4.22)	(±85.20)	(±4.27)	(±115.20)	(±13.99)	(±13.00)	(±49.96)	(±43.18)
Mg	34.58^{bcd}	25.80^{cd}	26.18^{cd}	29.72^{cd}	10.77^{d}	37.79^{bcd}	59.99^{bc}	$99..32^{a}$	61.82^{abc}	26.60^{cd}	50.66^{bcd}	71.06^{ab}
	(±3.02)	(±0.16)	(±5.46)	(±2.21)	(±0.05)	(±27.55)	(±0.39)	(±32.04)	(±1.15)	(±3.58)	(±20.72)	(±21.71)
Na	18.18^{b}	11.08^{b}	17.86^{b}	35.55^{b}	124.87^{a}	22.50^{b}	10.19^{b}	16.62^{b}	11.21^{b}	18.04^{b}	44.31^{b}	15.83^{b}
	(±10.68)	(±2.39)	(±7.57)	(±29.03)	(±6.40)	(±10.22)	(±1.96)	(±16.14)	(±2.18)	(±6.27)	(±32.94)	(±3.78)
K	35.96^{bc}	47.02^{b}	92.49^{a}	93.48^{a}	13.79^{cd}	6.69^{d}	5.29^{d}	4.64^{d}	6.29^{d}	9.30^{d}	48.10^{b}	87.26^{a}
	(±10.68)	(±25.65)	(±5.59)	(±5.56)	(±1.69)	(±6.032)	(±0.13)	(±0.20)	(±1.32)	(±4.56)	(±11.51)	(±17.57)
Pb	2.460^{ab}	2.117^{ab}	1.728^{ab}	0.997^{b}	1.577^{ab}	1.647^{ab}	4.320^{a}	1.687^{ab}	4.253^{a}	1.273^{b}	0.580^{b}	0.490^{b}
	(±0.27)	(±1.29)	(±0.89)	(±0.12)	(±1.55)	(±1.91)	(±1.43)	(±0.32)	(±1.76)	(±0.54)	(±0.06)	(±0.07)
Cd	0.006^{b}	0.009^{b}	0.048^{a}	0.017^{b}	0.002^{s}	0.012^{b}	0.005^{b}	0.006^{b}	0.005^{b}	0.006^{b}	0.011^{b}	0.004^{b}
	(±0.008)	(±0.007)	(± 0.012)	(±0.013)	(±0.001)	(±0.000)	(±0.00)	(±0.001)	(±0.001)	(±0.004)	(±0.003)	(±0.050)
Cr	0.450^{cd}	0.170^{d}	0.733^{cd}	0.540^{cd}	0.107^{d}	1.140^{bc}	0.620^{cd}	2.043^{a}	0.690^{cd} (±0.05)	0.283^{d}	1.420^{ab}	1.487^{ab}
	(±0.26)	(±0.08)	(±0.32)	(±0.07)	(±0.10)	(±0.19)	(±0.09)	(±0.38)		(±0.02)	(±0.70)	(±0.16)
Ni	1.270^{a} (±0.55)	0.460^{b}	0.306^{b}	0.773^{ab}	0.210^{b}	0.413^{b}	0.247^{b}	0.280^{b}	0.367^{b}	0.393^{b}	0.337^{b}	0.280^{b}
		(±0.22)	(±0.20)	(±0.24)	(±0.11)	(±0.19)	(±0.15)	(±0.06)	(±0.33)	(±0.36)	(±0.17)	(±0.01)
Cu	0.390^{bcd}	0.337^{bcd}	0.089^{d}	0.777^{a}	0.703^{a}	0.290^{cd}	0.490^{abc}	0.560^{abc}	0.613^{ab} (±0.05)	0.340^{bcd}	0.583^{abc}	0.357^{bcd}
	(±0.18)	(±0.19)	(±0.05)	(±0.10)	(±0.08)	(±0.23)	(±0.04)	(±0.04)		(±0.07)	(±0.05)	(±0.01)
Zn	1.360^{bc}	0.700^{bc}	0.437^{c}	1.84^{abc}	0.800^{bc}	3.19^{a}	1.50^{bc}	3.337^{a}	2.223^{ab} (±1.01)	1.410^{bc}	3.147^{a}	3.303^{a}
	(±0.17)	(±0.21)	(±0.05)	(±0.67)_	(±0.12)	(±0.09)	(±0.48)	(±0.92)		(±0.25)	(±1.21)	(±0.16)
Co	0.297^{c} (±0.09)	0.397^{c}	0.787^{c}	1.087^{bc}	0.380^{c}	0.333^{c}	2.337^{ab}	0.780^{c}	2.603^{a}	0.370^{c}	0.200^{c}	0.313^{c}
		(±0.18)	(±0.50)	(±0.35)	(±0.14)	(±0.15)	(±0.08)	(±0.56)	(±1.22)	(±0.09)	(±0.04)	(±0.39)
Fe	4.557^{ab}	2.197^{cdef}	1.457^{ef}	1.193^{f}	3.507^{bc}	2.550^{cde}	2.043^{def}	3.137^{cd}	1.760^{ef}	1.083^{f}	5.347^{a}	2.630^{cde}
	(±0.37)	(±0.46)	(±0.55)	(±0.28)	(±0.95)	(±0.16)	(±0.90)	(±0.07)	(±0.18)	(±0.10)	(±0.67)	(±0.34)

Mean values with the same letter within the same row are not significantly different (p>0.05). Values in parenthesis are standard errors of means.

Table 2 shows that Ca was highest (461.40mg/g) in December and it varied significantly ($p<0.05$) with lower concentrations in February and June but insignificantly ($p>0.05$) with lower concentrations in the other months with the lowest (122.85 mg/g) in July. Both the highest mean value of Mg (99.32 mg/kg) and the lowest (10.77 mg/g) in August and May respectively were significantly different ($p<0.05$) from the other months. The highest mean value of Na (124.87 mg/g) was in May and showed significant difference ($p<0.05$) also from the other months and the lowest value (10.19 mg/g) occurred in July. High values of K in March, April and December (92.49 mg/g, 93.48 mg/g and 87.26 mg/g respectively) had no significant difference ($p>0.05$). The highest occurred in April while the lowest value of (4.64 mg/g) was in August.

Mean value of Pb was highest (4.32 mg/g) in July and revealed insignificant difference ($p>0.05$) with that of September and the lowest value (0.490 mg/g) was obtained in December. Cadmium mean values in all the months did not vary significantly ($p>0.05$) except that of March with the highest value of 0.048 mg/g while the lowest (0.002 mg/g) occurred in May. The highest mean value of Cr (2.043 mg/g) was in August and revealed significant variation ($p<0.05$) with that of June and the lowest (0.107 mg/g) was in May. The highest mean value of Ni (1.270 mg/g) obtained in January varied significantly ($p<0.05$) with that of May (0.773 mg/g) but the lower values in the other months with the lowest (0.210 mg/g) in May, varied insignificantly ($p>0.05$).

There was no significant difference (p>0.05) in the highest mean concentration of Cu (0.77 mg/g) in April and May but the lowest (0.089 mg/g) which was obtained in March had significant difference (p<0.05) with the other months. The highest mean value of Zn (3.337 mg/g) was in August and showed insignificant difference (p>0.05) with those of June, November and December while the lowest value (0.437 mg/g) in March showed significant difference (p<0.05). The highest mean value of Co (2.337 mg/g) observed in September varied significantly (p<0.05) with lower values in April (1.087 mg/g) and July (2.337 mg/g). The values in all the other months revealed insignificant variation (p>0.05) and the lowest (0.200 mg/g) occurred in November. The mean value of Fe was highest (5.347 mg/g) in November and showed significant difference (p<0.05) from the other months and so did the values in January, February, May and August. The lowest value (1.083 mg/g) was in October and it varied insignificantly (p>0.05) with that of April.

Table 3. Mean concentrations of metals in lettuce (*Lactuca sativa*) at different sites along River Jakara in Kano State, Nigeria (January 2003 – December 2003)

Metals (mg/g)	Sites		
	2	3	4
Ca	108.39[a] (±19.45)	110.04[a] (±11.12)	136.82[a] (±22.06)
Mg	30.29[a] (±5.89)	29.28[a] (±4.14)	36.74[a] (±6.68)
Na	41.02[a] (±3.21)	48.26[a] (±10.02)	63.10[a] (±18.04)
K	44.14[a] (±12.19)	37.08[a] (±12.63)	43.80[a] (±13.17)
Pb	1.896[a] (±0.32)	1.561[a] (±0.39)	2.112[a] (±0.51)
Cd	0.009[a] (±0.003)	0.009[a] (±0.004)	0.113[a] (±0.004)
Cr	0.643[a] (±0.16)	1.004[a] (±0.22)	1.095[a] (±0.24)
Ni	0.248[a] (±0.06)	0.388[a] (±0.09)	0.430[a] (±0.08)
Cu	0.503[a] (±0.10)	0.568[a] (±0.17)	0.493[a] (±0.08)
Zn	1.693[a] (±0.37)	2.207[a] (±0.47)	2.265[a] (±0.35)
Co	0.597[a] (±0.17)	0.533[a] (±0.17)	1.104[a] (±0.40)
Fe	2.843[a] (±0.60)	2.348[a] (±0.44)	2.936[a] (±0.46)

Mean values with the same letter within the same row are not significantly different (p>0.05). Values in parenthesis are standard errors of means

The mean values of metals in lettuce (*Lactuca sativa*) presented in Table 3, revealed that there was also an insignificant difference (p>0.05) between sites.

Table 4. Mean concentration of metals in lettuce *(Lactuca sativa)* for different months along River Jakara, in Kano State, Nigeria (January 2003 – December 2003)

Metals (mg/g)	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ca	73.63^{c}	108.53^{bc}	64.24^{c}	101.87^{bc}	129.49^{bc}	218.27^{a}	69.99^{c}	131.41^{bc}	63.52^{c}	101.87^{bc}	155.44^{ab}	203.07^{a}
	(±7.76)	(±6.87)	(±9.11)	(±10.74)	(±25.95)	(±48.74)	(±5.40)	(±69.55)	(±6.37)	(±11.35)	(±6.62)	(±26.15)
Mg	19.27^{cde}	20.973^{bcde}	12.473^{de}	24.987^{bcd}e	10.50^{e}	32.463^{bcd}e	34.463^{bcd}	42.49^{b}	41.567^{bc}	41.897^{bc}	69.417^{a}	34.747^{bcd}
	(±1.49)	(±1.25)	(±0.75)	(±4.44)	(±0.83)	(±9.19)	(±9.84)	(±19.10)	(±2.96)	(±2.87)	(±11.43)	(±11.29)
Na	35.54^{c}	31.57^{c}	32.59^{c}	60.25^{bc}	103.63^{ab}	24.07^{c}	45.21^{c}	25.02^{c}	50.70^{bc}	39.36^{c}	122.18^{a}	39.38^{c}
	(±3.30)	(±1.51)	(±4.13)	(±33.99)	(±24.91)	(±14.42)	(±11.17)	(±12.69)	(±3.58)	(±4.07)	(±60.66)	((±1.75)
K	39.30^{cd}	56.10^{c}	86.61^{ab}	106.53^{a}	14.49^{de}	5.67^{e}	6.71^{e}	6.70^{e}	6.88^{e}	5.76^{e}	64.56^{bc}	100.17^{a}
	(±9.21)	(±32.54)	(±6.20)	(±10.99)	(±0.23)	(±1.12)	(±0.03)	(±1.43)	(±0.59)	(±1.57)	(±16.60)	(±6.99)
Pb	2.220^{bcd}	1.723^{cd}	1.957^{bcd}	1.370^{cd}	2.730^{abc}	0.770^{d}	3.493^{ab}	1.527^{cd}	4.150^{a}	1.400^{cd}	0.480^{d}	0.453^{d}
	(±0.16)	(±1.45)	(±0.34)	(±0.35)	(±0.27)	(±0.26)	(±1.08)	(±0.33)	(±1.02)	(±0.45)	(±0.17)	(±0.18)
Cd	0.007^{bc}	0.012^{b}	0.047^{a}	0.007^{bc}	0.002^{c}	0.009^{bc}	0.003^{bc}	0.006^{bc}	0.005^{bc}	0.007^{bc}	0.009^{bc}	0.003^{bc}
	(±0.001)	(±0.009)	(±0.005)	(±0.000)	(±0.000	(±0.002)	(±0.001)	(±0.001)	(±0.001)	(±0.000)	(±0.003)	(±0.001)
Cr	1.297^{abcd}	0.393^{de}	0.923^{abcde}	0.547^{cde}	0.150^{e}	1.270^{abcd}	0.667^{bcde}	1.80^{a}	0.589^{bcde}	0.260^{de}	1.453^{abc}	1.620^{ab}
	(±0.71)	(±0.39)	(±0.36)	(±0.08)	(±0.03)	(±0.07)	(±0.16)	(±0.64)	(±0.08)	(±0.10)	(±0.70)	(±0.10)
Ni	0.673^{ab}	0.440^{abc}	0.067^{c}	0.757^{a}	0.280^{bc}	0.140^{c}	0.277^{bc}	0.280^{bc}	0.403^{abc}	0.367^{abc}	0.330^{bc}	0.253^{c}
	(±0.41)	(±0.02)	(±0.008)	(±0.18)	(±0.10)	(±0.07)	(±0.12)	(±0.16)	(±0.06)	(±0.06)	(±0.11)	(±0.03)
Cu	0.197^{c}	0.233^{c}	0.267^{c}	0.797^{b}	0.710^{b}	0.177^{c}	0.457^{bc}	0.503^{bc}	0.550^{bc}	1.457^{a}	0.533^{bc}	0.377^{bc}
	(±0.18)	(±0.13)	(±0.04)	(±0.06)	(±0.21)	(±0.10)	(±0.03)	(±0.10)	(±0.02)	(±0.42)	(±0.10)	(±0.11)
Zn	1.673^{bc}	1.020^{c}	0.607^{c}	1.303^{c}	1.140^{c}	3.993^{a}	1.577^{bc}	2.950^{ab}	1.340^{c}	1.877^{bc}	3.667^{a}	3.510^{a}
	(±0.02)	(±0.18)	(±0.19)	(±0.32)	(±0.15)	(±0.46)	(±0.43)	(±0.53)	(±0.57)	(±0.02)	(±0.58)	(±0.15)
Co	0.313^{c}	0.557^{c}	0.770^{c}	1.050^{bc}	0.293^{e}	0.220^{c}	2.020^{ab}	0.400^{c}	2.577^{a}	0.223^{c}	0.240^{c}	0.273^{c}
	(±0.23)	(±0.20)	(±0.02)	(±0.20)	(±0.10)	(±0.06)	(±0.37)	(±0.13)	(±0.15)	(±0.10)	(±0.14)	(±0.16)
Fe	6.117^{a}	2.827^{bc}	1.647^{bc}	1.210^{c}	1.951^{bc}	3.840^{bc}	1.673^{bc}	2.337^{bc}	2.363^{bc}	1.233^{c}	5.343^{c}	2.967^{b}
	(±0.37)	(±0.40)	(±0.48)	(±0.25)	(±0.32)	(±0.52)	(±0.44)	(±0.15)	(±0.30)	(±0.33)	(±0.30)	(±0.54)

Mean values with the same letter within the same row are not significantly different (p>0.05). Values in parenthesis are standard errors of means.

Table 4 showed that the highest value of Ca (218.27mg/g) in lettuce was in June and showed insignificant difference (p>0.05) with that of December. The Ca values in January, March, July and September and in February, April, May, August and October also had insignificant variation (p>0.05) and the lowest (63.52 mg/g) was in September. The mean values of Mg in January, March, May, August and November had significant difference (p<0.05). The highest concentration of 69.417 mg/g and lowest (10.50 mg/g) were in November and May respectively. The highest mean value of Na (122.18 mg/g) was obtained in November while the lowest (25.02 mg/g) was in June.

Potassium mean concentrations from June to October had insignificant difference (p>0.05) while the remaining months had significant difference (p<0.05). The highest (100.17 mg/g) occurred in December and the lowest (5.67 mg/g) in June. The highest mean concentration of Pb (2.220 mg/g) was in January and varied insignificantly (p>0.05) with the concentration in March (1.957 mg/g). The lowest (0.453 mg/g) obtained in December varied insignificantly (p>0.05) with the concentrations in June and November. Cadmium mean concentrations exhibited insignificant difference (p>0.05) in all the months except in February and March. The highest value of 0.047 mg/g) was in also in March and the lowest (0.002 mg/g) in May. The highest mean concentration of Cr (1.80 mg/g) was in August and the lowest (0.150 mg/g) in November and December.

Nickel was highest (0.757 mg/g) in April and showed significant difference (p<0.05) from the other months and the lowest (0.140 mg/g) was in June. While the highest mean concentration of Cu (1.457 mg/g) obtained in October had significant difference (p<0.05), the lowest (0.177 mg/g) which occurred in June showed insignificant variation with the values in January, February and March. Zinc was highest (3.993 mg/g) in June and showed insignificant difference (p>0.05) with those of November and December. The lowest (0.607 mg/g) was in March and also had insignificant difference (p>0.05) but with values in February, April, May and September. Cobalt mean concentrations showed insignificant variations (p>0.05) in all the months except in April, July and September (which had the highest value of 2.577 mg/g). The lowest (0.220 mg/g) occurred in June. The highest mean concentration of Fe (6.117 mg/g) was in January and the lowest (1.210 mg/g) in April. The mean concentrations in December varied significantly (p<0.05) from all the other months.

Table 5. Mean square values for metals found in the two vegetables

Vegetable		Elements											
	Source	Ca	Mg	Na	K	Pb	Cd	Cr	Ni	Cu	Zn	Co	Fe
Spinach	Site	5966.54	151.54	2278.33	220.17	—	0.13	0.05	0.16	1.62	2.03	1.63	2.53
	Season	3228.58	477.92	572.58	10523.89*	—	0.49	0.007	0.06	6.74	0.1	1.64	1.22
	Interaction	346.53	68.13	532.32	70.57	—	1.66*	—	0.08	0.53	0.17	3.17	2.08
Lettuce	Site	6842.08	243.02	27.63	158.14	0.82	0.77	1.981	0.89	0.72	1.29	0.61	3.83
	Season	8752.59	1348.87*	90.85	16639.17*	0.04	0.07	0.92	2.39	0.08	0.23	0.51	2.86
	Interaction	10388.3*	729.3*	1020.02	6.41	—	2.06*	—	1.96	0.75	1.22	0.24	0.63

The metal content in spinach grown in all the sites in the dry season varied insignificantly (p>0.05) with those of the rainy reason (except K) (Table 5 and Figure.2). The concentrations of K were significantly higher during the dry season than in the rainy season (p<0.05). The concentration of metals by season in lettuce presented in Table 5 and Figure 3 also showed that the metal content grown in all the sites in the dry season did not vary significantly (p>0.05) with those of the rainy season (except Mg and K). In all the sites, the concentrations of Mg were significantly higher during the rainy season than the dry season (p<0.05). In the three sites also, the concentrations of K were significantly higher during the dry season than in the rainy season (p<0.05).

Table 6. Comparison of annual mean concentrations of metals in vegetables (mg/g) along River Jakara in Kano

Vegetables	Metals											
	Ca	Mg	Na	K	Pb	Cd	Cr	Ni	Cu	Zn	Co	Fe
Spinach	207.95	44.52	28.85	37.53	1.93	0.011	0.81	0.44	0.46	1.92	0.82	2.62
	(± 19.11)	(± 4.99)	(± 5.88)	(± 6.17)	(± 0.29)	(± 0.002)	(± 0.11)	(± 0.06)	(± 0.04)	(± 0.21)	(± 0.17)	(± 0.24)
Lettuce	118.42	32.10	50.79	41.67	1.86	0.010	0.91	0.36	0.52	2.05	0.74	2.71
	(±9.99)	(± 3.09)	(± 6.65)	(± 6.82)	(± 0.22)	(± 0.002)	(± 0.12)	(± 0.04)	(± 0.07)	(± 0.22)	(± 0.15)	(± 0.28)
Permissible	-	-	-	-	0.00005	0.0024	0.00005	0.001	0.0025	0.015	0.0001	0.04
limits					-0.003		-0.0005	-0.01	-0.025	0.10	-0.006	-0.50

Values in parenthesis are standard errors of mean Source of permissible limits: Allen, S.E., Grimshew, H. Parkinson, J.A. and Quamby, C. (1974)

Table 7. Coefficient correlation of elements in soils and spinach (*Amaranthus cruentus)* within the catchment of River Jakara in Kano Nigeria

	CaSp	MgSp	NaSp	KSp	PbSp	CdSp	CrSp	NiSp	CuSp	ZnSp	CoSp	FeSp
CaSoil	0.06	-0.47**	0.27	0.20	-0.07	0.21	-0.46**	0.29	-0.05	-0.41*	-0.18	-0.06
MgSoil	-0.001	-0.003	-0.31	-0.14	0.20	0.19	-0.41*	-0.17	-0.20	0.006	0.11	-0.12
NaSoil	0.13	-0.50**	0.38*	-0.03	-0.22	-0.10	-0.45*	0.03	0.09	-0.27	-0.33*	0.13
KSoil	-0.04	-0.23	-0.15	0.36*	-0.05	0.37*	-0.23	0.17	0.007	-0.12	-0.05	-0.18
PbSoil	-0.15	0.33*	-0.19	-0.63**	0.39*	-0.29	0.20	-0.12	0.10	0.27	0.44**	-0.08
CdSoil	-0.13	-0.12	0.002	0.62**	-0.28	0.39*	-0.01	0.19	0.28	0.03	0.02	-0.35*
CrSoil	-0.01	0.13	-0.29	0.30	-0.10	0.15	0.09	-0.09	-0.07	0.07	0.12	-0.21
NiSoil	-0.11	-0.03	-0.19	0.39*	-0.25	0.30	0.32	-0.05	-0.28	0.005	-0.07	-0.15
CuSoil	0.37*	0.22	0.05	0.32	-0.39*	-0.14	0.39*	-0.26	0.33*	0.35*	-0.23	0.18
ZnSoil	0.01	-0.20	-0.04	0.68**	-0.52**	0.38*	0.003	0.10	-0.26	0.38*	-0.39	-0.05
CoSoil	-0.21	0.33*	-0.24	-0.25	0.10	-0.12	0.28	-0.14	-0.09	0.14	0.48*	-0.28
FeSoil	-0.02	-0.46**	0.45**	0.20	-0.14	-0.06	-0.47**	0.27	0.27	-0.43**	-0.28	0.36*

Sp – spinach

- Correlation is significant at 0.05 level (2 tailed)
- Correlation is significant at 0.01 level (2 tailed)

Table 8. Coefficient correlation of elements in soils and lettuce (*Lactuca sativa)* within the catchment of River Jakara in Kano Nigeria

	CaLe	MgLe	NaLe	KLe	PbLe	CdLe	CrLe	NiLe	CuLe	ZnLe	CoLe	FeLe
CaSoil	-0.07	-0.59**	-0.03	0.13	0.10	0.10	-0.04	0.31	-0.40*	-0.28	-0.20	0.49**
MgSoil	-0.06	0.36*	-0.35	-0.25	0.04	0.16	-0.10	-0.35*	-0.14	-0.16	0.02	-0.17
NaSoil	0.20	-0.35*	0.14	-0.04	-0.08	-0.20	-0.27	-0.06	-0.004	-0.03	-0.34*	0.07
KSoil	-0.22	-0.26	-0.22	0.32*	0.06	0.06	-0.17	0.15	-0.07	-0.29	-0.003	-0.06
PbSoil	-0.08	0.20	-0.19	-0.62**	0.39*	-0.36*	0.02	-0.18	-0.12	0.18	0.46**	-0.14
CdSoil	-0.03	-0.07	0.07	0.63**	-0.25	0.10	0.08	0.34*	0.25	-0.10	0.03	-0.31
CrSoil	-0.07	0.05	-0.21	0.29	0.08	0.12	-0.10	0.20	-0.03	-0.04	0.16	-0.16
NiSoil	-0.08	0.27	-0.04	0.41*	-0.23	0.44**	-0.18	-0.13	0.42*	0.04	-0.07	-0.06
CuSoil	0.44*	0.37*	0.30	0.39*	-0.42*	-0.14	0.30	-0.19	0.44*	0.45**	-0.22	0.11
ZnSoil	0.08	0.04	0.07	0.69**	-0.43**	0.49**	-0.12	0.14	0.13	-0.03	-0.28	0.06
CoSoil	-0.12	0.20	-0.19	-0.29	0.47**	-0.11	-0.008	-0.15	-0.08	0.009	0.48**	-0.23
FeSoil	-0.09	-0.591*	0.19	0.24	-0.009	-0.07	-0.23	0.40*	-0.05	-0.35*	-0.25	0.24

Le - lettuce

- Correlation is significant at 0.05 level (2 tailed)
- Correlation is significant at 0.01 level (2 tailed)

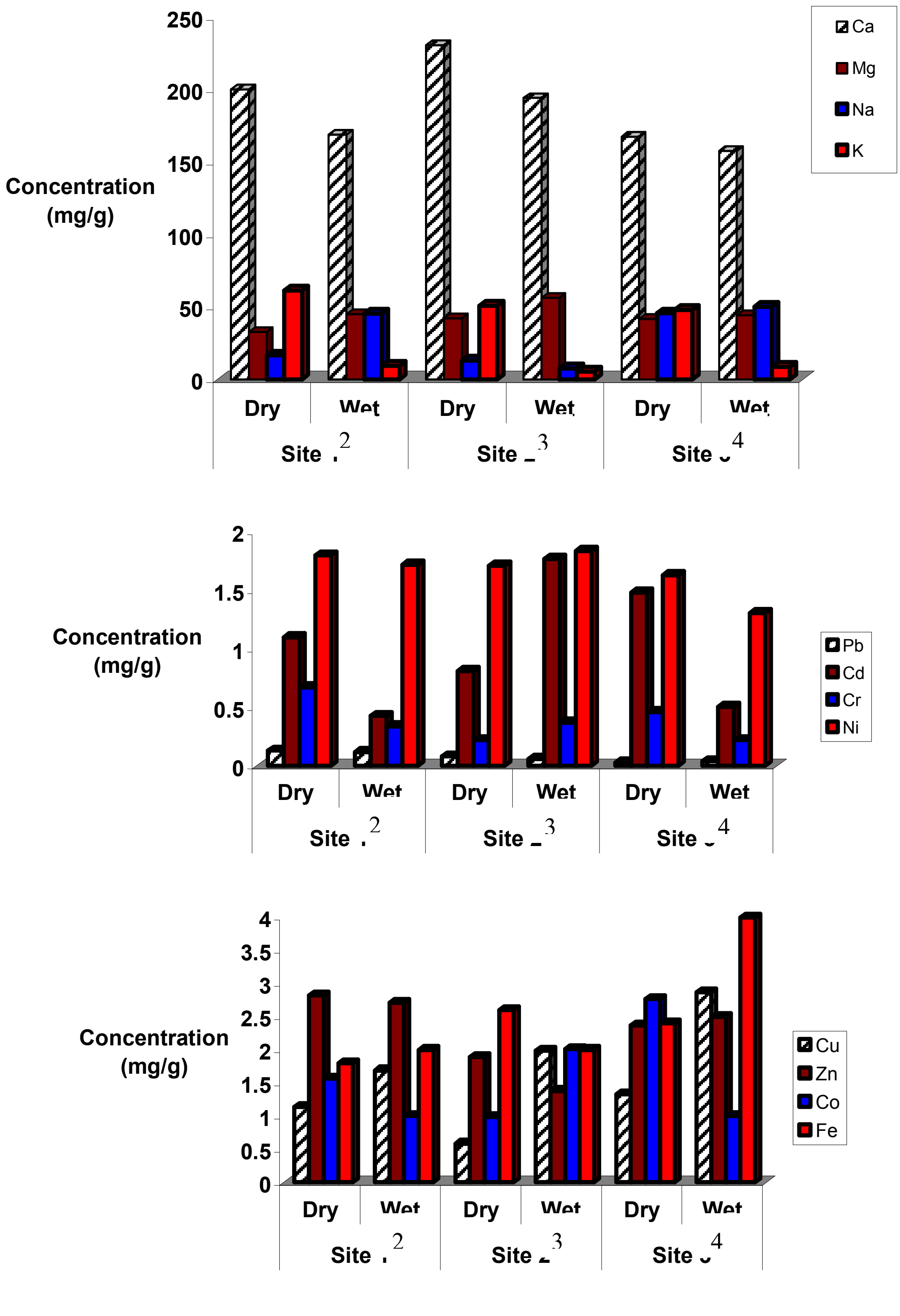

Figure 2. Concentration of metals by season in spinach (Amaranthus cruntus) growing within the catchment of River Jakara

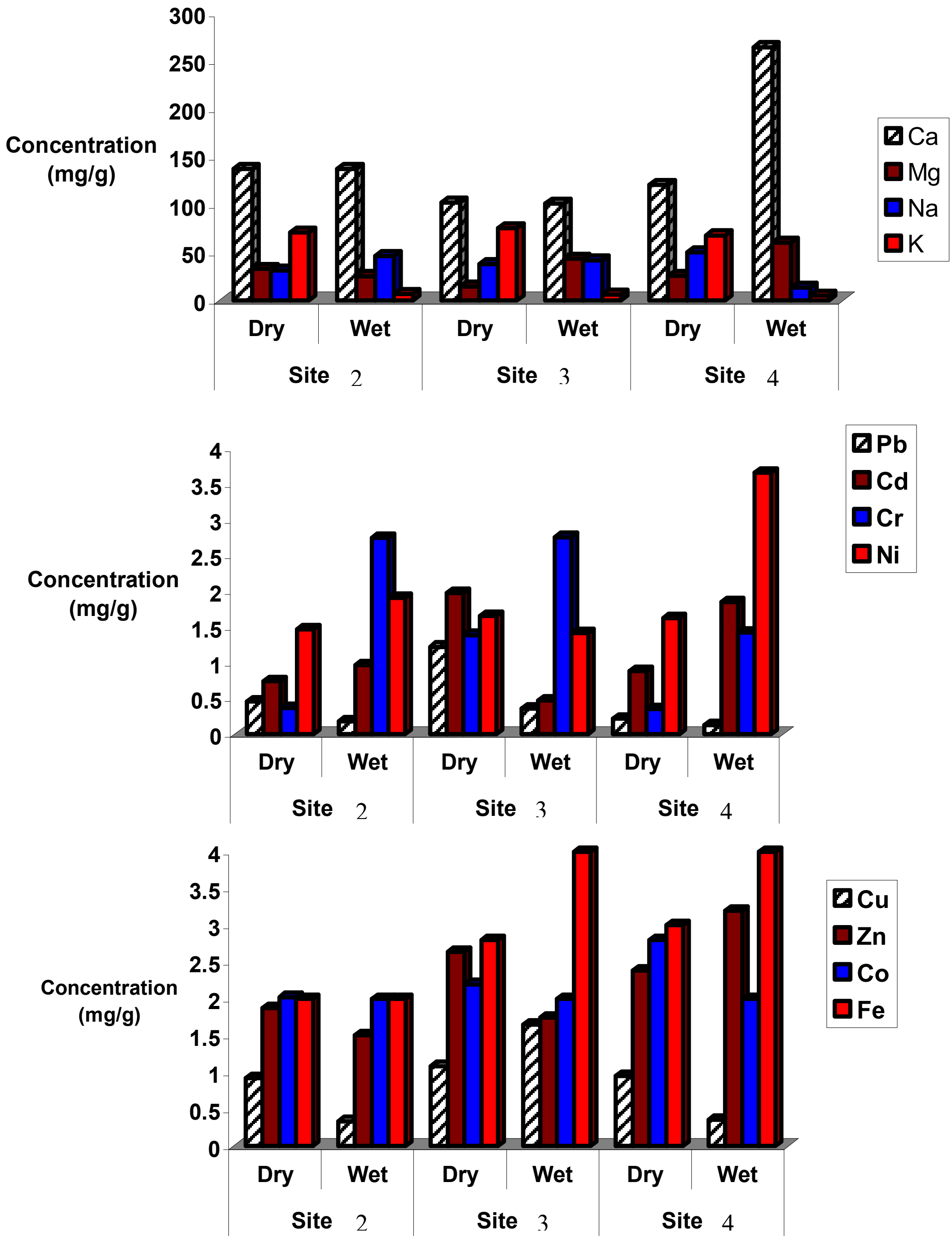

Figure 3. Concentrations of metals by season in lettuce (*Lactuca sativa*) growing within the catchment of River Jakara

4. Discussion

The elements investigated in spinach and lettuce grown within the catchment area of River Jakara in Kano, Nigeria, showed no significant difference in their concentrations between sites but however showed significant difference between some months. Metal variations in the vegetables between some months may be related to stage of growth, availability of metals to vegetables and the form in which they occur (Kisku *et al.,* 2000). The pattern of accumulation of the elements suggested that there was no seasonal influence on the tendencies of spinach to accumulate the elements (except Cd). There was also no seasonal influence on the tendencies of lettuce to accumulate the elements (except Ca, Mg and Cd). This observation contradicts the findings of Bako, Funtua, and Ijachi (2004), who reported an apparent seasonal influence on the tendencies of all four plant species studied to accumulate heavy metals.

The annual mean concentrations of the elements in the vegetables occurred in the order of Ca> Mg> K> Na> Fe> Zn> Pb> Co> Cr> Cu> Ni> Cd and Ca> Na> K> Mg> Fe> Zn> Pb> Cr> Co> Cu> Ni> Cd in spinach and lettuce respectively. The higher concentrations of Ca, Mg and K are related to the point that they are macronutrients which are essential for plant growth and Na is a beneficial element. The lower concentrations of Fe, Zn, Cr, Co, Cu and Ni are attributed to the fact that they are micronutrients which are needed by plants in minute quantity. Their various concentrations though, in addition to Pb and Cd in the two vegetables exceeded the international recommended desirable limits (Table 6). The high abundance of these elements can be associated with their availability in the soil. Some of the elements in the soil correlated with those in the vegetables (Tables 7 and 8). For instance, Pb in soil showed a positive correlation (r=0.39) with Pb in spinach. Cadmium in soil and in spinach showed a positive correlation (r= 0.39) and also showed a positive correlation (r= 0.62) with Fe in spinach. Lead in soil and Pb in lettuce were positively correlated (r= 0.39) and so was Pb in soil and Co in lettuce (r= 0.46). High positive correlations (r=0.68 and 0.63) were established also between Zn in soil and K in spinach and Cd in soil and K in lettuce respectively revealing that as these elements in the soil increased, those in the respective vegetables also increased. These indicated also that the soil is the major source of the elements to the vegetables. Gerritse, Daniel, Smilde, and Vann (1983) asserted that high availability of a particular element in the soil can affect the relative uptake and consequently high accumulation of such element.

The higher accumulation of the elements by the vegetables can also be attributed to the fact that they are leafy vegetables which according to Flynn (1999) are the most vulnerable to metal contamination and accumulation. Copper, Ni, Zn and Pb among other elements are known to be toxic to plants (Bako *et al*., 2004). Contamination of leafy vegetables with Cu, Pb, Zn, Ni, Co and Cd along the banks of River Kaduna have been reported (Ojeka & Achi, 2004); Cd, Cr, Pb, Ni and Zn from e-waste dumping site in Alaba International Market, Lagos (Olafisoye, Adefioye,& Osibote, 2012); and Pb, Cd, and Cr from abandoned mechanic workshops in Umuahia (Abii, 2012). Researches by Flynn (1999), Alam, Snow and Tanaka, (2003) City of Helsinki Environmental Centre, (2003), Behbahaninia and Mirbagheri (2008), Bigdeli and Seilsepour (2008), and Mahakalkar, Gupta, and Nandeshwar (2013) also showed high concentrations of some of these elements in various vegetables studied in various parts of the globe.

Humans consuming vegetables grown in contaminated soils and animals raised in such areas stand a risk as they pose a direct threat to their health (Sedki, Pineau, & Pihan, 1995, Damek-Poprawa & Sawicka-Kapusta, 2003). Miranda *et al*. (2009) asserted that the tissue accumulation of metals in animals was related to contaminated soils and forage. Prolonged human consumption of unsafe concentrations of heavy metals in foodstuffs may lead to the disruption of numerous biological and biochemical processes in the body (Marshall *et al*., 2003). These elements have carcinogenic, mutagenic and teratogenic effects in humans with long-term cumulative exposure (Das, 1990). Some elements such as Cd and Cr for instance act as carcinogens and others such as Pb are associated with developmental abnormalities in children (Marshall *et al*., 2003). Exposure to high Pb levels can also damage the organs responsible for sperm production in men, cause miscarriage in pregnant women and damage the brain and kidneys and ultimately cause death (Martin & Griswold, 2009). According to Parveen *et al.* (2003), a slight increase in the concentration of Zn may interfere with physiological processes and toxic level of Cu results in anaemia, intestinal disorders, circulatory disturbances and liver and kidney failure when its concentration crosses the safe limits. Higher cardiotoxocity than general toxicity has been indicated (Donald *et al*., 1986) as a result of high levels of Co in the kidney, liver and testes. It is therefore imperative that consumers of these vegetables obtained within the catchment of River Jakara may be liable to the effects of these elements particularly to the carcinogenic effect of Cd after cumulative consumption.

5. Conclusions and Recommendations

There was accumulation of the micro elements/heavy metals investigated in the spinach and lettuce grown within the catchment area of River Jakara. The concentrations of the elements showed insignificant difference between sites but significant difference between the months of study. The soil was asserted as the major source of the elements and their concentrations exceeded those of the international permissible limits pointing to the contamination of the vegetables. The continued consumption of these vegetables by the inhabitants of Kano and its environs present a public health risk particularly with regards to their concentrations with the heavy metals. In this regard, the relevant organ of government should find an alternative farmland for the farmers within the catchment area of River Jakara where unpolluted waste sources can be utilized for production of vegetables. Where this is not feasible, soil management may be feasible for the urban farmers. For example, addition of lime to soil raises the pH level of soils which hinders heavy metal uptake. Organic matter such as manure can also be added to the soil which restricts metal transport to the plants. Metal-tolerant species (hyper-accumulator plants/weeds) could also be selected and grown with the vegetables to eliminate or to reduce the concentration of heavy metals in the soil, thereby reducing its availability to the vegetables. Furthermore, research should also be carried out to determine the effect of contaminated vegetables and its bioaccumulation in man.

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