Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2019, 6(3):237-247

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Study of Heavy Metal Pollutants in Soils and Vegetables of Irrigated Farm Sites in Niger State of Nigeria

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Abstract Heavy metals are known to cause health problems when ingested above tolerable level. The study was conducted to determine the concentration of cadmium, chromium and manganese in soil and vegetable (spinach leaves) grown in nine irrigation farms across three Local Government Areas in Niger State, Nigeria. The results showed varying concentrations of these metals in the samples studied. The concentration of cadmium (Cd) in soil was higher in Kontagora (0.08078) with 0.07022 and 0.04144 obtained for Minna and Bida respectively. Chromium (Cr) and manganese (Mn) were higher (1.38189 mg/Kg and 1.20889 mg/Kg) in Kontagora than the 0.29467 mg/Kg and 1.20992 mg/Kg in Minna and 1.211589 mg/Kg and 0.86900 mg/Kg obtained from soils in Bida. The concentrations of Cd, Cr and Mn in spinach leaves were in the order of Mn > Cr > Cd for Kontagora, Minna and Bida. Concentrations obtained were lower than the critical values of FEMA and WHO. Hence the spinach leaves obtained from the studied areas are safe for consumption and the soil suitable for growing them.

Keywords Heavy Metal Pollutants, Soils and Vegetables, Irrigated Farm Sites

1. Introduction

Metals and their compounds are indispensable to the industrial, agricultural and technological development of any nation. With rapid increase in industrial activities like mining operations, tanneries, electronics, electroplating and petrochemicals industries, pollution derived from heavy metals and organic pollutants have increased in surface and underground water ways [1]. Some of these pollutants especially heavy metals can remain for decades in the environment increasing the likelihood of human exposure since they cannot be degraded or destroyed. When ingested above tolerable levels, heavy metals can have harmful effects on human biological system. Concentrations below these levels have potentials for long term contamination, because heavy metals are known to be accumulative within biological systems [2]. It has been estimated that the annual toxicity resulting from heavy metal discharge into the environment exceeds the combined total toxicity of all radioactive and organic wastes [3].

Many toxic heavy metals have been discharged into the environment as industrial wastes, through natural geological processes, small and large scale mining activities and poorly designed landfills causing soil, surface and ground water pollution. These pollutants have found their way into human body through the food chain as untreated wastewater has been used in several irrigation sites to water vegetables and in dry season farming. Ingestion of these metals has caused grave health problems which many times are not usually identified early.

Many farmers who use wastewater from rivers where mining activities takes place or effluent is discharged may not fully be aware of the enormous danger they are exposing themselves and other consumers of their farm produce to. Some even ask for excreta from toilets, industrial and agricultural wastes to be dumped upon their irrigation farm sites. This research will reveal the level of heavy metals contamination or otherwise of soils and vegetables growing on those sites

The study seeks to determine the concentrations of heavy metal pollutants of great concern in vegetables and soils of irrigation farms in selected local government areas in Niger State, Nigeria.

Methodology

Sampling Sites

Niger State lies between latitudes $8^{o}20^{I}$ N and $11^{o}30^{I}$ N. longitudes 30^{o} 30^{I} E and $7^{o}20^{I}$E. Study areas selected are nine irrigation farm sites in three Local Governments Areas (three farm sites in each area), one from each senatorial zone of the State. The Local Governments are Bida (zone A), Chanchaga (zone B) and Kontagora (zone C).

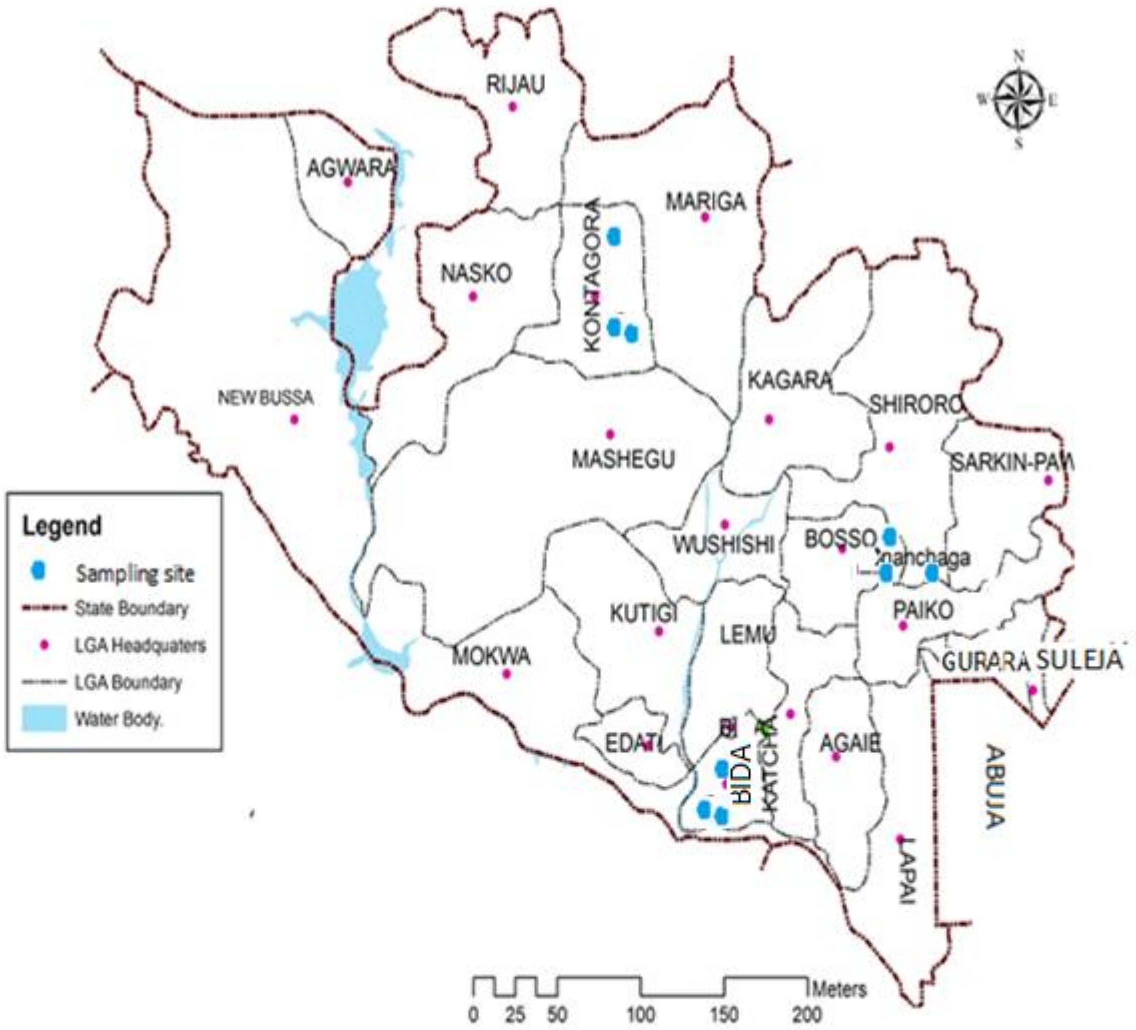

Figure 1: Map Niger State showing sampling sites

Sample Collection and Treatment

Sampling of soils and spinach leaves from Bida, Minna and Kontagora were done between February and March, 2017.

Soil Sample

The soil samples were collected from 0 to 20 cm depth beneath the roots of the cultivated spinach plant. In each of the irrigation farms, three (3) points were identified and three sub soil samples around the roots of the uprooted spinach plant were collected using hand trowel which had been pre-cleaned with nitric acid and distilled water. The three sub-samples at each point were homogenized to form composite of each point. The samples were stored in labeled polyethylene bags.

The soil samples collected were dried for one week at room temperature after which debris were manually removed then grounded using porcelain mortar and pestle then sieved through a 2.0 mm stainless sieve to remove aggregates, stones and pebbles. Portions of each sample was further pulverized to fine powder to pass through a 0.5 mm stainless sieve and stored for heavy metals analyses [4].

Spinach Sample

The edible part of spinach from each portion plot (irrigation farm site) were soil was collected were selected. The selected samples were collected and stored in labeled polythene bags then taken to the laboratory for treatment. The samples were washed with distilled water to remove particles after which the stalks were removed from the samples then sliced and dried to remove moisture. The dried samples were ground in a mortar to fine powder that passes through a 0.5 mm stainless steel sieve then stored for heavy metals analyses [5].

Sample Digestion and Heavy Metals Determination

A tri-acid mixture of 5 cm^3 concentrated HNO_3, 15 cm^3 H_2SO_4 and 0.3 cm^3 $HClO_4$ was added to 1 g of each sample using a dropping pipette. The mixtures were then digested in fume cupboard until clear solutions were obtained. After cooling, the digested samples were filtered into 50 cm^3 volumetric flask using Whatman No. 42 filter paper then diluted to mark using distilled water [6]. Cadmium, chromium and manganese were determined from the digested samples using AA320N Atomic Absorption Spectrophotometer.

Results and Discussion

Results

Table 1: Heavy metals concentration in soils and vegetable leaves of selected farm sites in Bida

Location	Farm site	Sample No.	Concentration of metals (mg/kg)		
			Cd	**Cr**	**Mn**
BIDA (Soil)	A	1	0.034	1.053	0.626
		2	0.037	1.085	0.461
		3	0.044	1.269	0.736
	B	4	0.044	1.087	1.002
		5	0.035	1.026	0.262
		6	0.041	1.028	1.628
	C	7	0.041	1.301	2.539
		8	0.048	1.408	0.306
		9	0.049	1.686	0.261
BIDA (Corresponding Leaves)	A	1	0.01	0.172	0.207
		2	0.009	0.144	0.231
		3	0.006	0.124	0.146
	B	4	0.015	0.129	0.912
		5	0.012	0.053	0.238
		6	0.013	0.09	0.343
	C	7	0.015	0.244	0.47
		8	0.014	0.26	0.187
		9	0.018	0.178	0.247

Table 2: Heavy metals concentration in soils and vegetable leaves of selected farm sites in Minna

Location	Farm site	Sample No	Concentration of metals (mg/Kg)		
			Cd (mg/kg)	**Cr (mg/kg)**	**Mn (mg/kg)**
MINNA (Soil)	A	1	0.053	0.358	0.625
		2	0.069	0.175	1.037
		3	0.068	0.251	0.397
	B	4	0.071	0.186	0.318
		5	0.075	0.167	1.026
		6	0.067	0.354	1.682
	C	7	0.082	0.402	1.205
		8	0.074	0.431	2.972
		9	0.073	0.328	1.621
MINNA (Corresponding Leaves)	A	1	0.049	0.185	0.177
		2	0.049	0.127	0.21
		3	0.051	0.191	0.19
	B	4	0.052	0.109	0.173
		5	0.052	0.108	0.364
		6	0.055	0.289	0.237
	C	7	0.055	0.151	0.463
		8	0.049	0.261	2.044
		9	0.047	0.181	0.129

Table 3: Heavy metals concentration in soils and vegetable leaves of selected farm sites in Kontagora

Location	Farm site	Sample No	Concentration of metals (mg/Kg)		
			Cd (mg/kg)	**Cr (mg/kg)**	**Mn (mg/kg)**
KONTAGORA (Soil)	A	1	0.082	1.459	1.074
		2	0.086	1.399	1.021
		3	0.084	1.714	1.298
	B	4	0.081	1.849	1.41
		5	0.084	1.921	1.119
		6	0.084	1.026	1.364
	C	7	0.071	1.024	0.859
		8	0.077	0.937	1.673
		9	0.078	1.108	1.062
KONTAGORA (Corresponding Leaves)	A	1	0.038	0.213	0.367
		2	0.033	0.265	0.781
		3	0.041	0.409	0.306
	B	4	0.043	0.239	0.451
		5	0.039	0.283	0.239
		6	0.029	0.217	0.325
	C	7	0.041	0.301	0.329
		8	0.037	0.293	0.378
		9	0.031	0.307	0.062

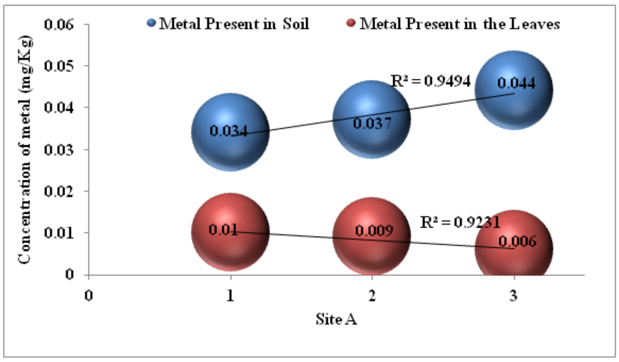

Figure 1: Cadmium concentration in soil and leaves of farm site A in Bida Area

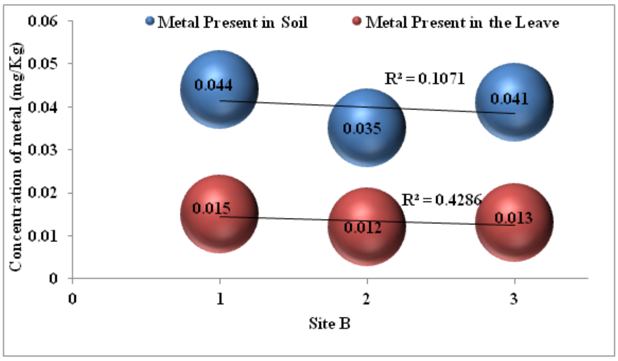

Figure 2: Cadmium concentration in soil and leaves of farm site B in Bida Area

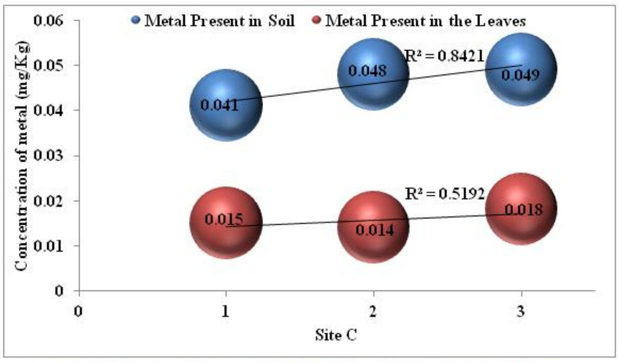

Figure 3: Cadmium concentration in soil and leaves of farm site C in Bida Area

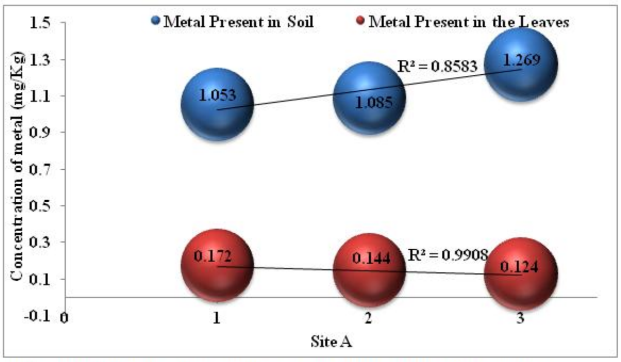

Figure 4: Chromium concentration in soil and leaves of farm site A in Bida Area

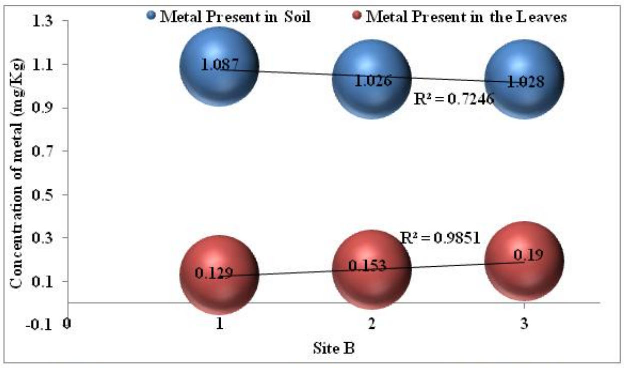

Figure 5: Chromium concentration in soil and leaves of farm site B in Bida Area

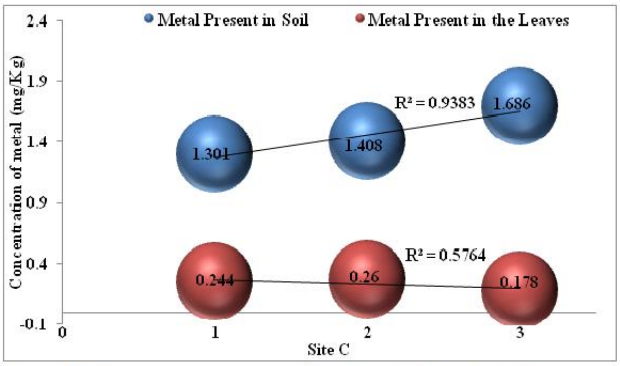

Figure 6: Chromium concentration in soil and leaves of farm site C in Bida Area

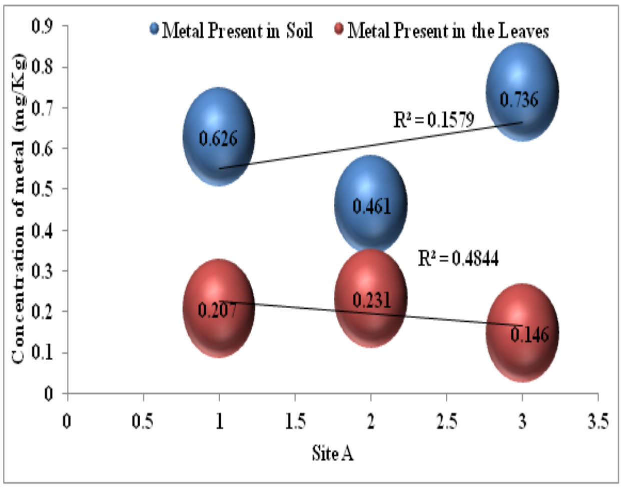

Figure 7: Manganese concentration in soil and leaves of farm site A in Bida Area

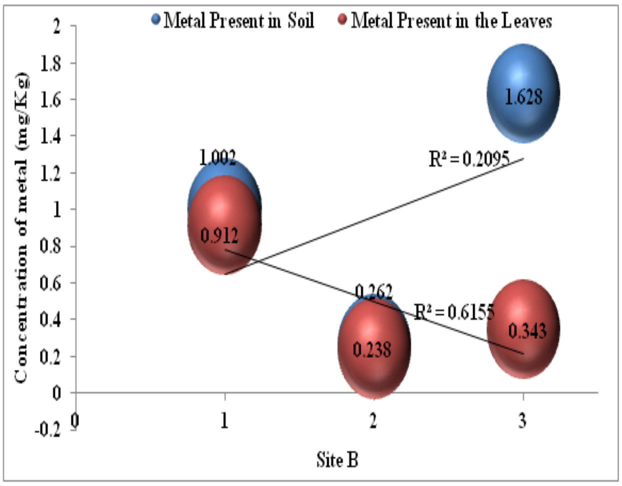

Figure 8: Manganese concentration in soil and leaves of farm site B in Bida Area

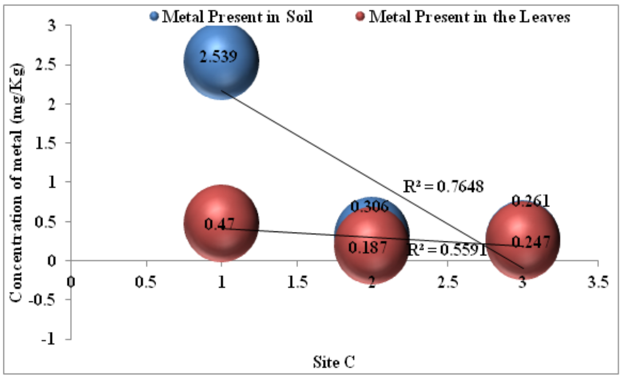

Figure 9: Manganese concentration in soil and leaves of farm site C in Bida Area

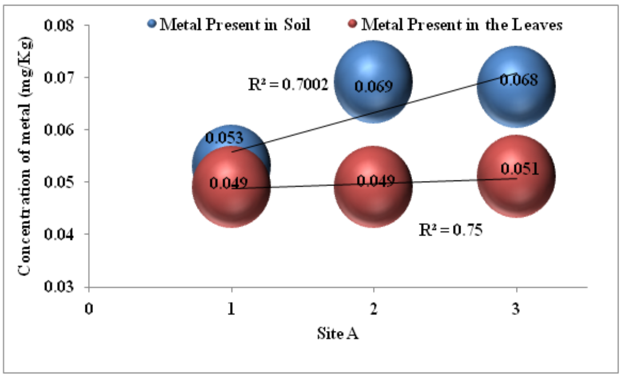

Figure 10: Cadmium concentration in soil and leaves of farm site A in Minna Area

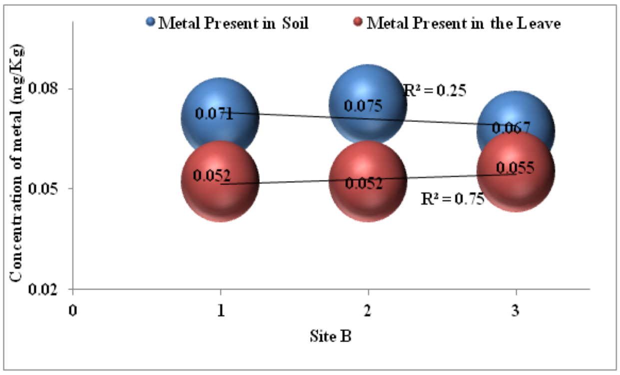

Figure 11: Cadmium concentration in soil and leaves of farm site B in Minna Area

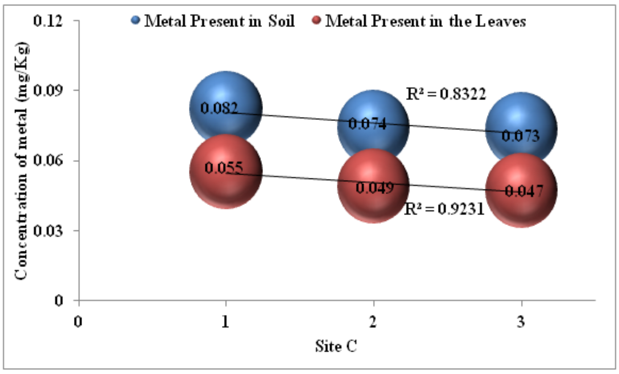

Figure 12: Cadmium concentration in soil and leaves of farm site C in Minna Area

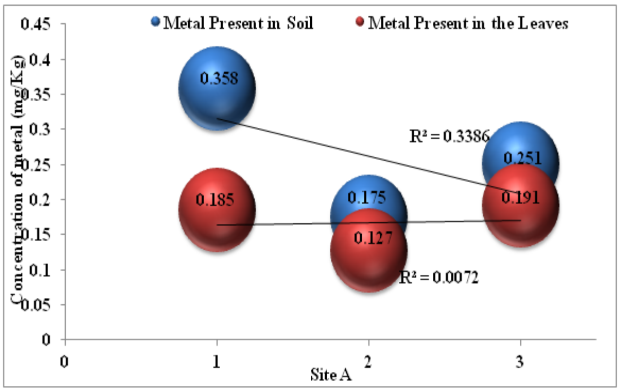

Figure 13: Chromium concentration in soil and leaves of farm site A in Minna Area

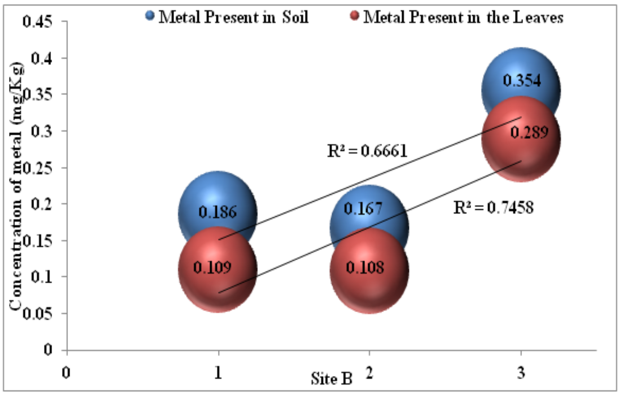

Figure 14: Chromium concentration in soil and leaves of farm site B in Minna Area

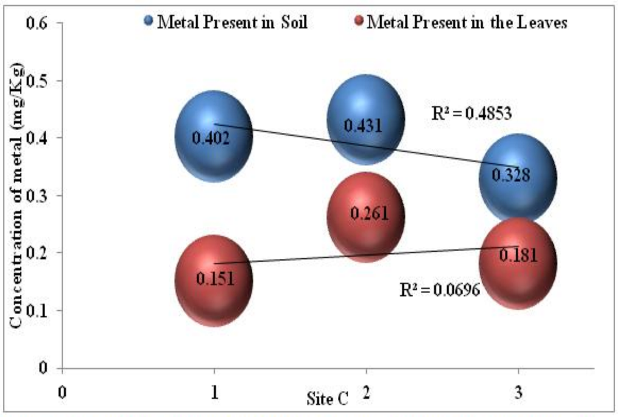

Figure 15: Chromium concentration in soil and leaves of farm site C in Minna Area

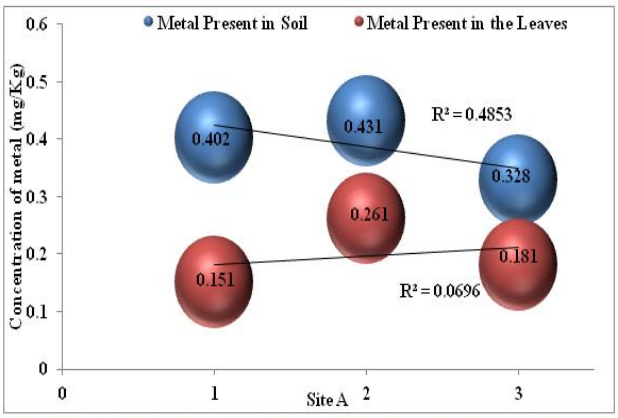

Figure 16: Manganese concentration in soil and leaves of farm site A in Minna Area

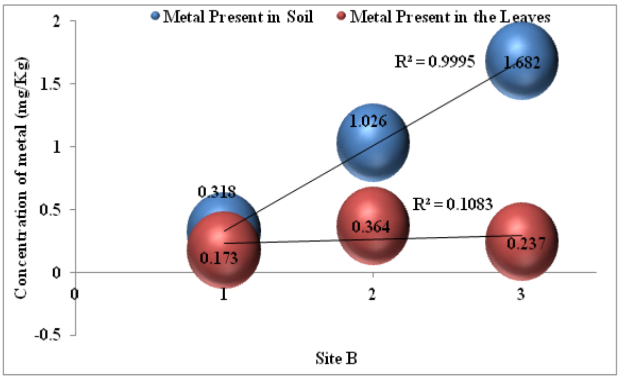

Figure 17: Manganese concentration in soil and leaves of farm site B in Minna Area

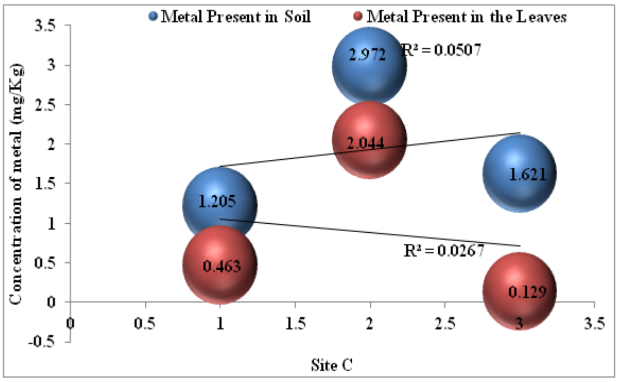

Figure 18: Manganese concentration in soil and leaves of farm site C in Minna Area

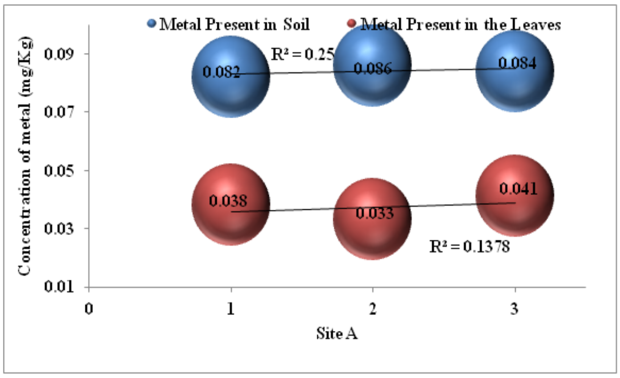

Figure 19: Cadmium concentration in soil and leaves of farm site A in Kontagora Area

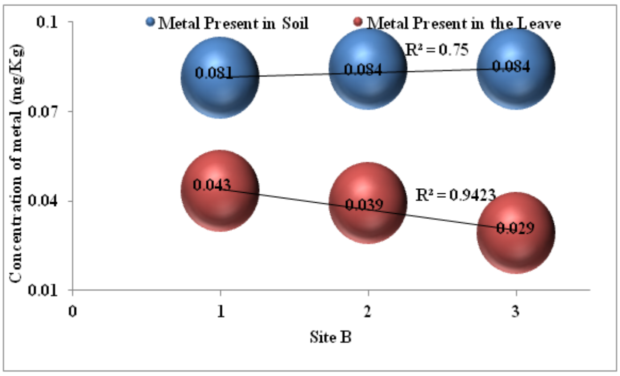

Figure 20: Cadmium concentration in soil and leaves of farm site B in Kontagora Area

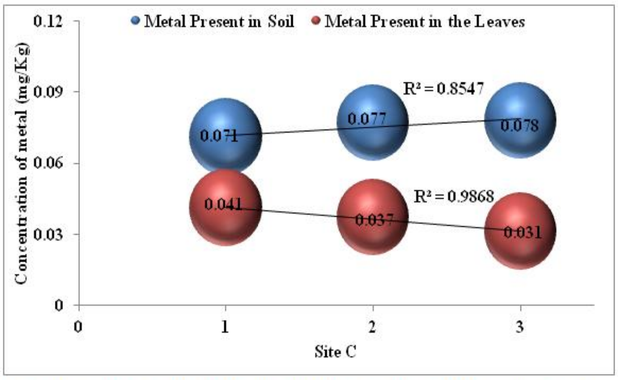

Figure 21: Cadmium concentration in soil and leaves of farm site C in Kontagora Area

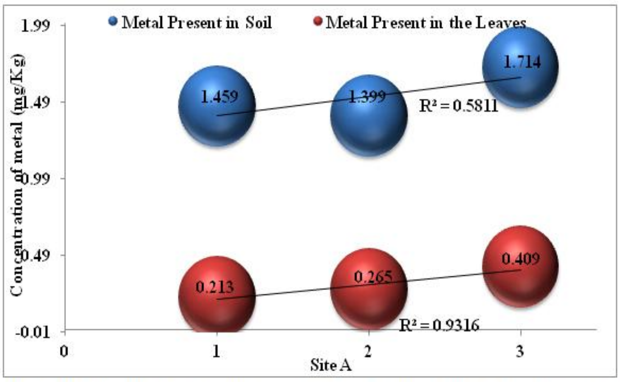

Figure 22: Chromium concentration in soil and leaves of farm site A in Kontagora Area

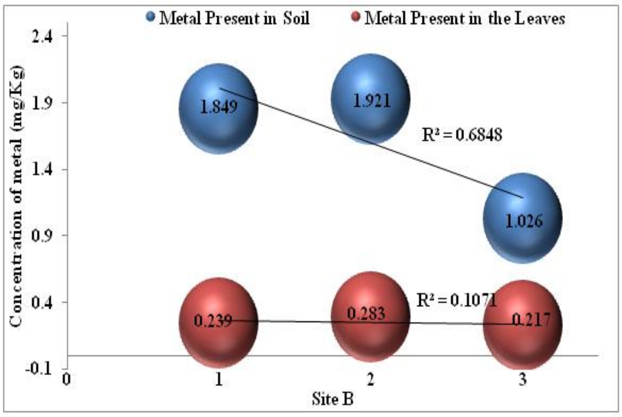

Figure 23: Chromium concentration in soil and leaves of farm site B in Kontagora Area

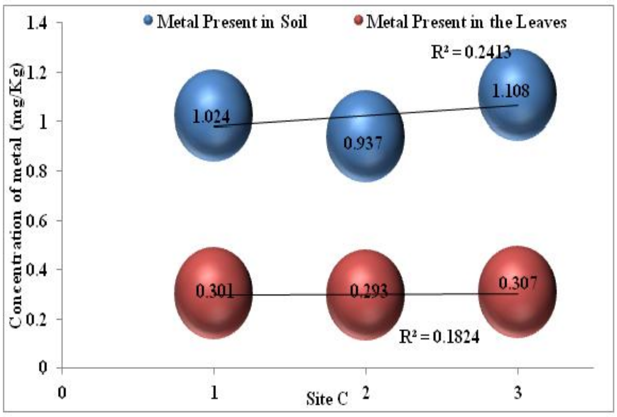

Figure 24: Chromium concentration in soil and leaves of farm site C in Kontagora Area

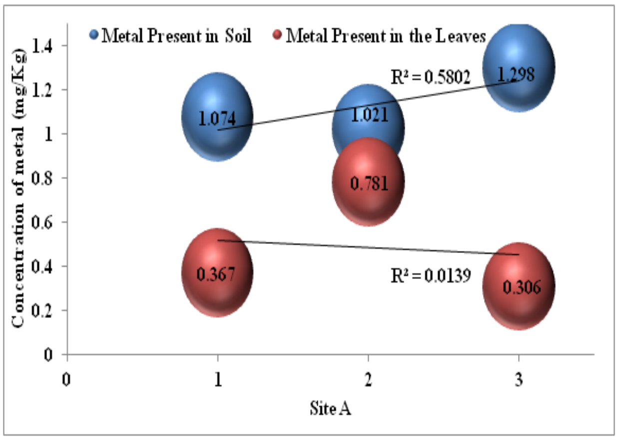

Figure 25: Manganese concentration in soil and leaves of farm site A in Kontagora Area

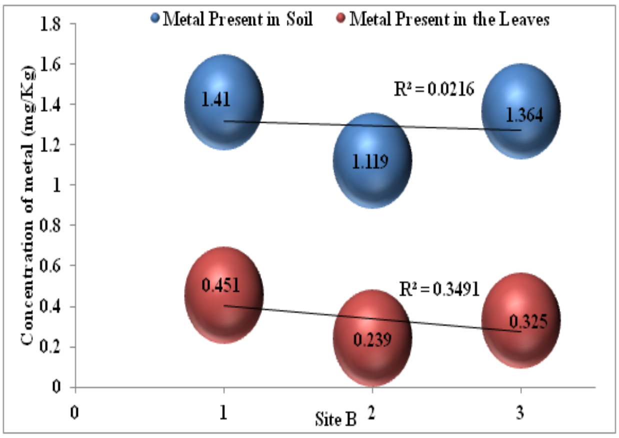

Figure 26: Manganese concentration in soil and leaves of farm site B in Kontagora Area

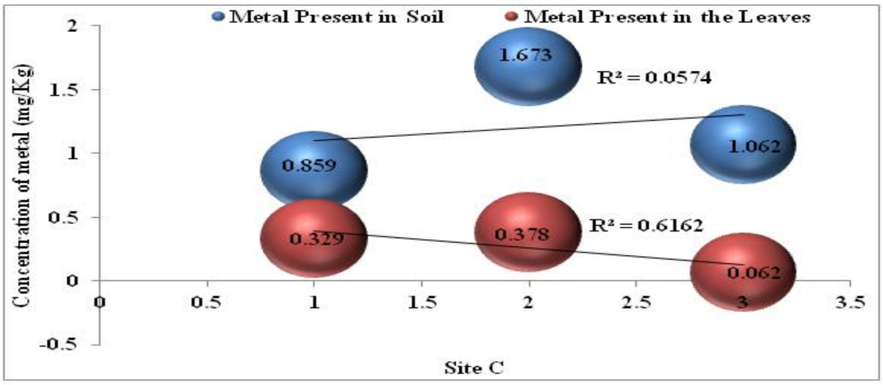

Figure 27: Manganese concentration in soil and leaves of farm site C in Kontagora Area

Table 4: Heavy metal concentrations in soil for different farm sites

Location	Farm site	Cadmium (mg/kg)	Chromium (mg/kg)	Manganese (mg/kg)
Kontagora	A	0.08300a	1.02300a	1.13100a
	B	0.07533b	1.52400a	1.19800a
	C	0.08400a	1.59867a	1.29767a
Minna	A	0.06333a	0.23567a	0.68633a
	B	0.07100a	0.26133a	1.00867a
	C	0.07633a	0.38700a	1.93267a
Bida	A	0.03833a	1.04700b	0.60767a
	B	0.04000a	1.13567b	0.96400a
	C	0.04600a	1.46500a	1.03533a

Table 5: Heavy metal concentration in spinach leaves for different farm sites

Location	Farm site	Cadmium (mg/kg)	Chromium (mg/kg)	Manganese (mg/kg)
Kontagora	A	0.03633a	0.24633a	0.25633a
	B	0.03700a	0.29567a	0.33833a
	C	0.03733a	0.30033a	0.48467a
Minna	A	0.04967a	0.16767a	0.19233a
	B	0.05033a	0.16867a	0.25800a
	C	0.05300a	0.19767a	0.87867a
Bida	A	0.01330a	0.14667b	0.19467a
	B	0.00830b	0.09067b	0.30133a
	C	0.01570a	0.22733a	0.49767a

Table 6: Heavy metal concentration in soil for different towns

Sample	Location	Cadmium (mg/kg)	Chromium (mg/kg)	Manganese (mg/kg)
Soil	Kontagora	0.08078a	1.38189a	1.20889a
	Minna	0.07022b	0.29467b	1.20922a
	Bida	0.04144c	1.21589a	0.86900a

Table 7: Heavy metal concentration in Spinach Leave for different towns

Sample	Location (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Manganese (mg/kg)
Leave	Kontagora	0.05100a	0.28078a	0.35978a
	Minna	0.03690b	0.15489b	0.44300a
	Bida	0.01240c	0.17800b	0.33122a

Discussion

The 54 composite soils and corresponding leaves from 27 irrigation farm sites (plots) in the three senatorial zones of Niger State revealed varying concentrations of cadmium, chromium and manganese based on the location farm site in the study area.

Figures 1 – 3, 10 – 12 and 19 – 21 present the graphical results of cadmium concentration in soil and spinach leaves of each sampling point of irrigation farm site in Bida, Minna and Kontagora areas of Niger State. It was observed in all cases that cadmium concentration in soil was higher than in the corresponding leaves sample. Point (sample number) 1 in irrigation farm site (plot) A of Bida area had the lowest cadmium concentration in both soil (0.034 mg/kg) and leaves (0.006 mg/kg) as seen in Figure 1 while point 2 in plot A in Kontagora area had the highest soil concentration of cadmium (0.086 mg/kg) as seen in Figure 19. The highest cadmium concentration in spinach leaves was obtained in point 1 of plot C (0.055 mg/kg) of Minna (Figure 12).

Average cadmium distribution in soil per plot/farm site is presented in Table 4. The results showed that plot A in Kontagora had the highest concentration of cadmium (0.084 mg/kg) which is higher had the 0.05 mg/kg reported as plot average for Soje area [5] but lower than 3.05 mg/kg obtained for irrigated farm land in Makera area of Kaduna [6] and the 0.2 mg/kg threshold value for agricultural soil by the Federal Environmental Protection Agency [7].

The average cadmium concentration in spinach leaves per plot as presented in Table 5 shows that sample from plot A in Bida area had the lowest average (0.008 mg/kg) while plot B in Minna area had the highest average concentration (0.053 mg/kg) for plot B in Minna area. The 0.008 mg/kg obtained for plot A in Bida is lower than the 0.013 and 2.12 mg/kg obtained for different plots in Makera area of Kaduna, Nigeria. The minimum (0.008 mg/kg) and maximum (0.053 mg/kg) cadmium concentration obtained in spinach sample studied are higher than 0.00134 mg/kg obtained for spinach by Ali and Al-Qahtani [8] but lower than 0.1 mg/kg WHO safe limit for heavy metals in vegetables [9]. The results also showed that the concentration of cadmium in spinach produced in the studied areas is low and cannot be considered dangerous to human health.

Tables 4 and 6 present the average heavy metals concentration in soil per plot and the average metal concentration per town. Results showed no significant difference at 0.05 for concentration of cadmium in Bida and Minna soils. Mean values of the plots are within range of each other. This is corroborated by values in appendix I. Plots A and C from Kontagora showed significant difference in cadmium but differ from result of plot B. Similar trends were observed for chromium and manganese concentrations.

Considering towns, there is no correlation between cadmium concentration in Bida, Minna and Kontagora. Cadmium concentration in Kontagora soil is higher (0.08078 mg/kg) than that of Minna (0.07022 mg/kg) and Bida (0.0414 mg/kg), hence no correlation exists between them (see Table 6).

Cadmium concentration in spinach leaves of different plots in Minna showed correlation. Similar observation was made for Kontagora (see Table 5). The average concentration of cadmium in spinach leaves from Bida, Minna and Kontagora did not show correlation at 0.05 significant level as shown in Table 7. The high concentration of cadmium in spinach leaves obtained from Kontagora (0.0510 mg/kg) compared to those from

Minna (0.0369 mg/kg) and Bida (0.0124 mg/kg) could be due to high concentration of same metal in soil were the spinach is grown. These values are lower than the maximum 1.014 mg/kg obtained for *Amaranthus retroflexus* grown in Kaduna, Nigeria [10].

The results chromium concentration in soils and spinach leaves from each of the plots in Bida, Minna and Kontagora are presented in Tables 1 – 3 and in Figures 4 – 6, 13 – 15 and 22 – 24.

It was observed in all irrigation farm sites (plots) that the chromium concentration in spinach leaves is lower than that in soil sample. This is expected as the plant samples obtain their nutrients from the soil. The highest soil concentration of chromium (1.921 mg/kg) was obtained from point 5 in farm site (plot) B in Kontagora (Table 3 and Figure 23) and point 5 plot B in Minna had the lowest chromium concentration (0.167 mg/kg). These values are lower than the 21.35 mg/kg reported for *Amaranthus retroflexus* [10].

The highest correlation coefficient (R^2) value of 0.9383 was obtained for soil sample from plot C (Figure 6) while that of spinach leaves was 0.9851 from plot B (Figure 5) all from Bida area. The maximum chromium concentration (0.409 mg/kg) in spinach leaves was obtained from plot A, sample point 3 while the minimum value was 0.108 mg/kg from plot B, sampling point 3. The values are lower than the 1.30 mg/kg WHO/FAO limit for the metal [11].

At 0.05 significance, correlation exists in chromium concentration in soils of the various irrigation farm sites (plots) in Minna and Kontagora areas (see Table 4). This is corroborated by results of chromium concentration in spinach leaves from the same plots (Table 5).

Figures 7 – 9, 16 – 18, 25 – 27 and Tables 1 – 3 present the concentration of manganese in soils and spinach leaves at each plot. The results indicate that soil sample from point 8 of plot C in Minna area had the highest manganese concentration (2.972 mg/kg) and the same point had the highest concentration in leaves (2.044 mg/kg) as seen in Table 2 and Figure 18. Correlation coefficient (R^2) of 0.5802 was the highest for soil sample (Figure 25) and 0.6162 was obtained for spinach leaves (Figure 27).

Tables 4 - 5 present the average concentration of manganese for soils and leaves. Results indicate that plot C in Minna had the highest soil concentration (1.9327 mg/kg) while leaves from same plot had the highest manganese concentration (0.8787 mg/kg). The maximum concentration of manganese in the spinach leaves studied is lower than the 6.60 mg/kg WHO critical level [12].

Conclusion

The concentration levels of cadmium, chromium and manganese in soils and spinach leaves of irrigation farm sites (plots) in Bida, Minna and Kontagora are low compared to the critical limits prescribed by FEPA and WHO, implying that vegetables cultivated in the study areas are safe for human consumption. The concentration of these heavy metals in soil is in the order: manganese (Mn) > chromium (Cr) > cadmium (Cd) for Minna area while Cr > Mn > Cd was the concentration order for Bida and Kontagora areas. Trend observed in leaves was Mn > Cr > Cd in all study areas.

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