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Discovery

Transfer of heavy metals from soil to spinach (Spinacea Oleracea) grown in irrigated farmlands of Kaduna metropolis

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This present research work was carried conducted in order to investigate the concentration of heavy metals such as Fe, Cd, Zn, Cu and Pd transferred from soil to spinach so as to know the extent of contamination from Soil and lettuce samples collected from different irrigated farmlands of Kaduna metropolis. Rigachikun was selected to be the control site. These heavy metals were determined from soil and spinach with the use of atomic absorption spectrophotometer. The result obtained revealed that Copper was highly absorbed in Kinkinau sample with 23.00 ±32.74 μgg^{-1} then Zinc from Rigasa sample with 18.49 ± 1.91μgg$^{-1.}$ All transfer factor are below 1 with the exception of samples from Kawo (2.45 μgg^{-1} for Cd) and Tudun wada (1.00 μgg^{-1} for Cd), Unguwan dosa (1.00 μgg^{-1} for Cu), Abakpa (1.00 μgg^{-1} for Pb) and Rigachikun (1.11 μgg^{-1} for Cu). This is as result of application of cadmium containing phosphate fertilizer. Result of this analysis also showed the transfer factor from soil to lettuce is in this order, cadmium > copper > lead > zinc > iron. The highest transfer factor was observed in cadmium. Next to this are copper, lead, zinc and the least is iron.

INTRODUCTION

The movement of trace metals and metalloid between the soil, plant and even atmosphere is part of a complex and intricately interrelated biogeochemical cycling processes in nature and is affected by several factor that are both natural and anthropogenic. In addition to the natural activities, anthrapogenic activities are also responsible for elevated trace metals concentrations in soils (Devkota and Schmidt, 2000; Frost and Ketchum, 2000; Singh et al., 2004; Mapanda et al., 2005) The pollution of the ecosystem by toxic metals during man's activities poses serious concern, this is because, metals are non-degradable and are persistent in the ecosystem. Physical, chemical and biological processes may combine under certain circumstances to concentrate metal rather than dilute them. Some of these metals are essential at low concentration for normal life. Human being releases more of metals by burning fossil, mining, discharging industrial effluent, agricultural and domestic wastes (Smith et al, 1996).

Actually, some of the toxic metals are being released to the environment in increasing amounts, because of change in gasoline formulation. All are daily ingested by human either through air, food, water and soil. Irrespective of their source, toxic elements can reach the soil where they became part of the food chain, thus,

Soil → Plant → Animal → Humus

Unfortunately, once the elements become part of this cycle, they may accumulate in animal and human body tissue, (Daniel and Edward, 1998).

Soil is a vital resource for sustaining basic human needs, a quality food supply and a liveable environment (Wild, 1995). It serves as a sink and recycling factory for both liquid and solid waste. Municipal solid waste has been found to contain appreciable quantity of heavy metals such as Cd, Zn, Pb and Cu all which may eventually end – up in the soil (Alloway and Aryes 1997). Other identifiable sources include atmospheric depositions, manure and fertilizers, pesticides and industrial discharge (Holgate, 1979).

Heavy metal in soil is either from pedogenic or anthropogenic sources. Studies of heavy metals in soil have tended to concentrate on sewage sludge and aerosol deposition source with limited attention being given to municipal solid waste source. Most often the levels of heavy metal in soil reflect the level of industrialization of the area (Ferlex, 2005).

Spinach (Spinach Oleracea) is an edible flowering plant that belongs to the members of the genus Amaranthus and the family of Amaranthaceae. It is native to central and south-western Asia. It is an annual plant (rarely biennial), may survive over winter in temperate regions. The leaves are alternate, simple, ovate to triangular based, very variable in size from about 2-30 cm long and 1- 15 cm broad, with larger leaves at the base of the plant and small leaves higher on the flowering

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stem. Spinach has a nutritional value and is extremely rich in antioxidant especially when fresh, steamed or quickly boiled it is a rich source of vitamin A, vitamin C, vitamin E, vitamin K, manganese, magnesium, iron calcium, potassium copper etc.

The aim of this research work is to determine the amount of heavy metals transferred from soil to spinach so as to ascertain the level of toxic metal accumulation in such vegetable.

MATERIAL AND METHOD

Sample and Sampling

Spinach samples were collected from twenty one (21) different irrigation site of the farmlands of the Kaduna metropolis where they were irrigated with water from the river or pond which are sometimes contaminated. Soil samples were also randomly collected from the farm where these vegetables were grown and irrigated with water. These samples were then stored in polythene bags and taken to the laboratory and dried in an oven at 100^0c. The dried samples were ground with mortar and pestle and sieved with 2mm sieve.

Sampling sites and their codes

Soil samples and spinach samples for heavy metal determination were collected from twenty one (21) irrigation sites of the Kaduna metropolis. These sites were shown in the below table. Table of the sampling sites and their codes,

s/no	Sampling Sites	Codes
1.	Kabala	KBL
2.	Danmani	DMN
3.	Barnawa	BNW
4.	Makera	MKR
5.	Badiko	BDK
6.	Nasarawa	NAS
7.	Malali	MAL
8.	Kudenda	KUD
9.	Kinkinau	KKN
10.	Kawo	KWO
11.	Unguwan Rimi	URM
12.	Unguwan Sanusi	UNS
13.	Tudun Wada	TDW
14.	Doka	DKA
15.	Unguwan Dosa	UDS
16.	Costain	CTA
17.	Kurmin Mashi	KMS
18.	Abakpa	ABK
19.	Kakuri	KKR
20.	Rigasa	RGS
21.	Rigachikun (Control)	RCK

Sample preparation

Spinach samples

5g of the ground spinach samples was ashed in a muffle furnace at a temperature of 550^0c for five hours and digested with $20cm^3$ of HNO_3/H_2O_2 (2:1). The digested residues were dissolved with $50cm^3$ of distilled water and filtered in $50cm^3$ volumetric flask.

Soil sample

20g of the finely ground soil samples was mixed with $60cm^3$ (5:5:1) $H_2SO_4/HNO_3/HCl$ acid mixtures and the content were refluxed for 12 hours. The sample was washed with 1M HNO_3 and $100cm^3$ of deionized water was also added and centrifuged. The elements (Fe, Zn,Cu,Cd & Pb) were determined using bulk scientific model VPG 210 model atomic absorption spectrophotometer (AAS).

Transfer of Heavy metals from soil to spinach

In order to determine the ratio of the concentration of heavy metal in a plant to the concentration heavy metal in soil, the transfer factor was calculated based on the method described by Oyedele et al, 1995 and Harrison and Chirgawi, 1989).

$$TF = Ps\ (\mu gg^{-1}/ St\ (\mu gg^{-1})$$

Where Ps is the plant metal content originating from the soil and St is the total metal content in the soil.

According to Rasheed and Awadallah (1998) plant uptake is one of the major path ways by which metal in soil enter the food chain. The food chain plants might absorb enough amounts of heavy metals to become a potential health hazard to consumers. The transfer factor is an index for evaluating the transfer potential of a metal from soil to plant.

RESULTS AND DISCUSSION

The mean concentration of some heavy metals and that of the transfer factor from soil to spinach were shown in the below table 1 and 2 respectively. Figure 1 showed that among all the Spinach samples analyzed for heavy metals. Copper was highly absorbed in KKN sample with 23.00 ±32.74 μgg^{-1} then Zinc from RGS sample with 18.49 ± 1.91μgg^{-1} next to this is Iron from KMS sample with 14.47 ± 3.42μgg^{-1}, followed by Copper from NAS sample with 6.23 ± 1.11μgg^{-1} Lead from KKR sample with 5.01 ± 1.72μgg^{-1} and Cadmium from KWO with 1.33 ± 0.23μgg^{-1}. This also shows the rate of absorption of heavy metals from Spinach samples obtained from irrigation sites of the Kaduna metropolis are in the below increasing series:-

Cu (KKN) >Zn (RGS) > Fe (KMS) >Cu >(NAS) > Pb (KKR) > Cd (KWO)

Table 2 shows transfer factor for heavy metal from soil to spinach. All transfer factor are below 1 with the exception of samples from Kawo (2.45 for Cd) and Tudun wada (1.00 for Cd), Unguwan dosa (1.00 for Cu), Abakpa (1.00 for Pb) and Rigachikun (1.11 for Cu) The obtained value for cadmium show transfer factor higher than 0.02 as reported by Sani *et al*., (2001). The value of Fe (0.56) was higher than 0.5 transfer factor for spinach observed by Sani *et al.*, (2001) and also 0.50 reported by Uwa *et al*. Sani *et al.*, (2001) reported 0.30 lower than the obtained transfer factor for Zn in this work with the exception of samples from Kabala and Tudunwada. Transfer factor obtained for Cu in the present study were lower than 0.2 observed by Kashif *et al.*, (2009). Pb had higher transfer factor than 0.13 for Spinach as reported by Sani *et al.*, (2001). Figure 2 shows the mean plot of transfer factor from soil to spinach where cadmium is being absorbed immensely from soil to spinach. That is to say, the highest transfer factor is observed in cadmium. Next to this are copper, lead, zinc and the least is iron. This is as result of application of cadmium containing phosphate fertilizer and other sources of heavy metal pollutant such as road traffic using leaded petrol, catering equipment containing zinc, and rusted iron in the soil. The order of arrangement follow the series:-

cadmium > copper > lead > zinc > iron.

Table 1 Heavy metals in spinach samples from different irrigation sites of the Kaduna Metropolis

Sampling sites	Cd (μgg^{-1})			Fe (μgg^{-1})			Zn (μgg^{-1})			Cu (μgg^{-1})			Pb (μgg^{-1})		
KBL	0.16	±	0.06	13.61	±	16.13	13.16	±	4.36	1.33	±	2.31	3.65	±	1.43
DMN	0.10	±	0.14	9.39	±	3.60	5.48	±	0.42	ND		ND	3.22	±	0.54
RGS	ND		ND	5.32	±	0.29	18.49	±	1.91	ND		ND	1.53	±	0.16
BNW	0.04	±	0.05	1.84	±	1.60	1.97	±	1.73	ND		ND	1.61	±	0.53
MKR	1.00	±	0.35	9.33	±	8.21	7.07	±	3.78	3.2	±	1.99	1.60	±	0.35
KKR	0.67	±	0.61	4.13	±	1.50	15.39	±	7.64	3.67	±	3.33	5.01	±	1.72
BDK	ND		ND	10.19	±	4.22	0.57	±	0.49	ND		ND	1.37	±	0.48
NAS	1.27	±	0.12	5.2	±	0.72	5.23	±	0.76	6.23	±	1.11	ND		ND
MAL	0.73	±	0.46	8.2	±	3.98	7.07	±	0.47	3.5	±	0.23	1.83	±	0.15
KUD	1.27	±	0.31	10.33	±	1.14	9.97	±	2.24	4.1	±	2.1	1.53	±	0.42
KKN	0.73	±	0.50	8.07	±	3.41	6.77	±	1.31	23	±	32.74	1.93	±	0.70
KWO	1.33	±	0.23	6.13	±	1.10	9.37	±	1.79	4.57	±	0.81	2.67	±	1.29
URM	0.97	±	0.40	6.00	±	2.00	6.53	±	2.40	2.8	±	0.69	3.73	±	2.05
UNS	0.60	±	0.35	8.07	±	5.78	5.00	±	0.8	2.77	±	0.51	2.20	±	0.69
TDW	0.20	±	0.35	8.12	±	5.47	12.48	±	14.34	3.83	±	3.33	1.77	±	0.50
DKA	1.20	±	0.53	8.16	±	2.63	6.28	±	1.64	4.58	±	0.84	3.80	±	1.59
UDS	1.00	±	0.20	8.93	±	4.92	6.63	±	1.52	5.07	±	2.16	3.13	±	0.50
CTA	0.73	±	0.61	9.87	±	2.27	7.27	±	6.19	1.93	±	0.31	1.90	±	0.26
KMS	0.53	±	0.42	14.47	±	3.42	6.20	±	4.36	3.63	±	2.09	2.53	±	0.12
ABK	0.8	±	0.4	8.93	±	2.27	5.1	±	2.59	2.57	±	0.81	3.47	±	1.50
RCK	0.47	±	0.23	8.87	±	2.73	3.07	±	1.42	3.93	±	1.30	2.47	±	1.55

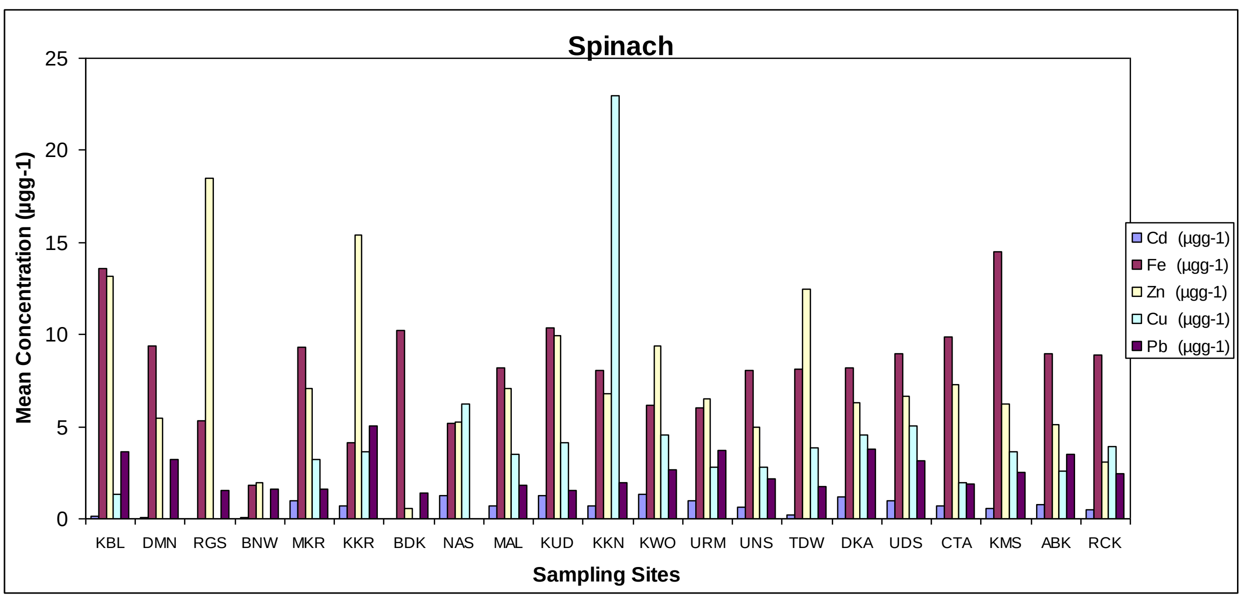

Figure 1 Heavy metal in Spinach sample from different irrigation sites of the Kaduna Metropolis

Table 2 Transfer factor (TF) for each metal from soil to Spinach

Sampling Sites	Cd (μgg^{-1})	Fe (μgg^{-1})	Zn (μgg^{-1})	Cu (μgg^{-1})	Pb (μgg^{-1})
Kabala	0.12	0.30	0.41	0.41	0.88
Danmani	0.09	0.21	0.18	0.00	0.81
Rigasa	0.00	0.05	0.27	0.00	0.12
Barnawa	0.01	0.11	0.06	0.00	0.05
Makera	0.51	0.22	0.18	0.38	0.50
Kakuri	0.92	0.05	0.30	0.51	0.14
Badiko	0.00	0.22	0.02	0.00	0.63
Nasarawa	0.71	0.12	0.16	0.83	0.00

Malali	0.58	0.65	0.26	0.86	0.48
Kudenda	0.58	0.22	0.25	0.52	0.31
Kinkinau	0.47	0.23	0.23	3.63	0.56
Kawo	2.46	0.06	0.19	0.23	0.07
Unguwan Rimi	0.73	0.06	0.10	0.13	0.23
Unguwan Sanusi	0.80	0.08	0.10	0.34	0.23
Tudunwada	1.00	0.08	0.31	0.16	0.34
Doka	0.96	0.11	0.21	0.31	0.13
Unguwan Dosa	0.64	0.56	0.26	1.00	0.85
Costain	0.47	0.34	0.26	0.48	0.75
Kurmi mashi	0.36	0.37	0.28	0.67	0.97
Abakpa	0.68	0.46	0.19	0.73	1.00
Rigachikun (control)	0.36	0.41	0.18	1.11	0.67

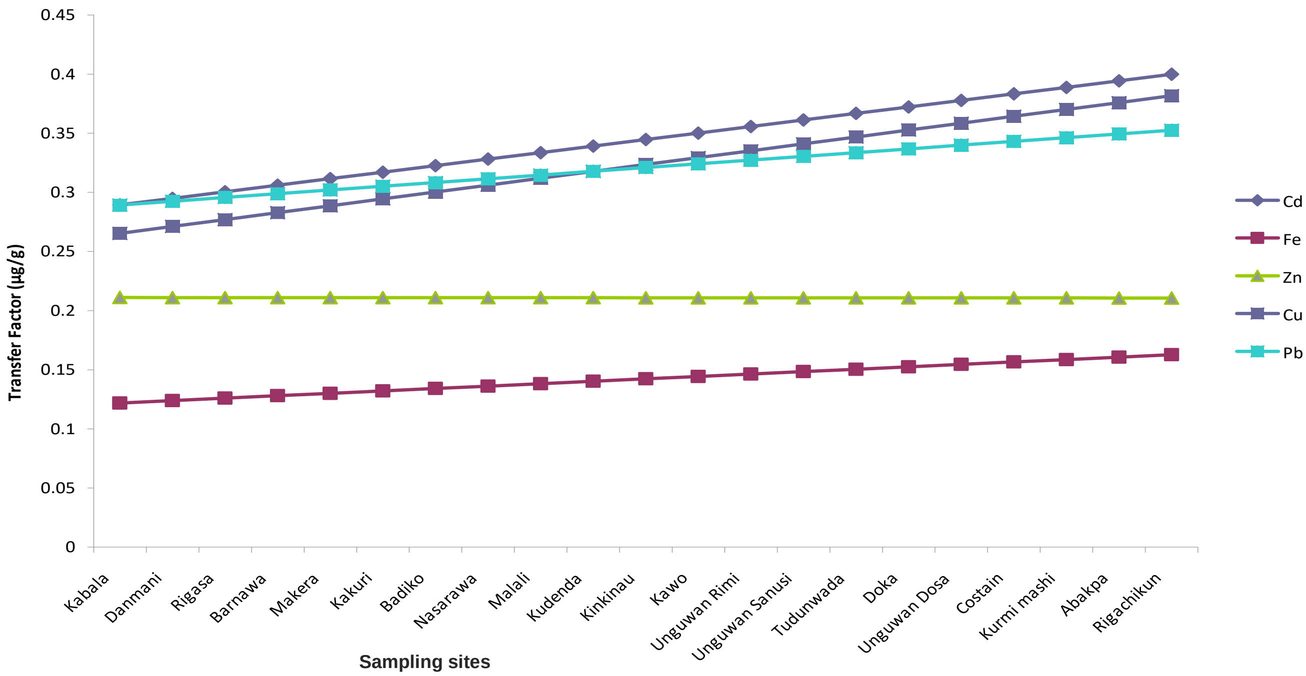

Figure 2 Plot of transfer factor from soil to spinach

CONCLUSION

The results obtained in this analysis showed the transfer of heavy metal from the soil to the spinach is in the following increasing order:- cadmium > copper > lead > zinc > iron. This also showed that samples absorbed much cadmium metal than any of the analyzed metals. This is because of the use of fertilizer, manures, pesticides, herbicides and other agro chemicals as well as use of wastewater by irrigating the soil leading to the increase in concentrations of such heavy metals in spinach samples via its growing medium which is soil. From the result it be deduced that consumption of spinach from these irrigation sites might exposed the consumers with danger of heavy metals especially cadmium metals. This is because some of these heavy metals are likely to be above tolerable limits stated by various health organizations. As a result of this, consumption of vegetables might be toxic and hazardous to humans as at the time of this research work.

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