Transfer of Heavy Metals from Soil to Lettuce *(Lactuca sativa)* grown in irrigated farmlands of Kaduna Metropolis, Nigeria.

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ABSTRACT

This studied was carried out to investigate the amount of heavy metals (Fe, Cd, Zn,Cu and Pd) transferred from soil to lettuce so as to know the extent of contamination from Soil and lettuce samples collected from different irrigated farmlands of Kaduna metropolis and Rigachikun as control site. These heavy metals were determined from soil and lettuce with the use of atomic absorption spectrophotometer. The result obtained revealed that Zinc from Kabala and Iron from Kabala had the highest concentrations of 18.45 ± 28.39 µgg^{-1} and 18.20 ± 20.19µgg^{-1} respectively being the highest elements absorbed by the lettuce samples from the irrigated farmland of the Kaduna metropolis. This is because with soil being acidic, the solubility of Zn and Fe play a principal role in the retention of these metals in the soil thereby increasing their absorption by the plants especially in lettuce sample. All the transfer factor obtained are below 1 with the exception of samples from Rigasa (2.66 µgg^{-1}for Cd), Malali (1.01 µgg^{-1} for Cd, 1.03 µgg^{-1} for Fe and 1.17 µgg^{-1} for Cu),Kawo (1.48 µgg^{-1} for Cd) , Tudunwada(1.00 µgg^{-1} for Cd),Doka (1.09 µgg^{-1} for Cd) and Rigachikun (control) 1.18 µgg^{-1} for Cu.Result of this analysis also showed the transfer factor of soil to lettuce is in this order, Cadmium > Copper > Lead > Iron > Zinc. This because of atmospheric deposition of such heavy metal from their sources of contamination such as fertilizers, pesticides, sewage sludge and organic waste.

Keywords: Soil,lettuce, transfer factor, heavy metals, atomic absorption spectrophotometer, Kaduna Metropolis, Nigeria.

INTRODUCTION

Heavy metals have been excessively released into the environment due to rapid industrialization and have created a major global concern [1].

The sources of heavy metals in plants are their growth media from which heavy metals are taken up by roots. Although some heavy metals such as Cu, Zn, Mn, Fe etc are essential in plant nutrition, many heavy metals do not play significant role in the plants physiology. Plants growing in a polluted environment can accumulate the toxic metal at high concentration thereby causing serious risk to the human health when consumed[2,3]. When vegetable accumulates heavy metals at a proportion exceeding the tolerance limit and if consumed by man or other animals, then the excess proportion of these metals from the vegetables tend to accumulates gradually in animal tissues at a very high concentration where it becomes toxic and causes varieties of illness e.g. brain damage, tumor cell, miscarriage etc.

The main sources of lead pollution in the environment are: Industrial production processes and their emission, road traffic using leaded petrol, the smoke and dust emissions of coal and gas-fired power stations. Lead can trigger both acute and chronic symptoms of poisoning. Acute intoxication only occurs through the consumption of relatively large doses of soluble lead salts.

Chronic intoxication can arise through the regular consumption of foodstuffs slightly contaminated with lead. Lead is a typical cumulative poison.

Children are particularly at risk for lead consumption, both before and after birth as they absorb lead more rapidly than adults. Particularly affected are small children with their habit of placing dirty fingers and objects of all kinds into their mouth (or licking them which is refer to as mouth/hand activity) and in this way, swallowing dust and soil particles containing heavy metals, for example from lead – based paints[4].

Cadmium exists in low concentrations in all soil. It is actively extracted from its ores for commercial purposes and also emitted from industrial processes such as metal melting and refining, coal and oil-fired power stations, electroplating plants etc.

It is spread by air and water (sewage sludge) far over sea and land, but especially in the vicinity of heavy industrial plants. Cadmium is today regarded as the most serious contaminant of the modern age. It is absorbed by many plants and sea creatures and because of its toxicity; it presents a major problem for foodstuffs. Contamination through fertilizers becomes a serious problem.

Cadmium is toxic at extremely low level. In humans, long term exposure of cadmium result in renal dysfunction, which is characterized by tubular proteinuria. High exposure can lead to obstructive lung disease. Cadmium pneumonitis, resulting from inhaled dusts and fumes. It is characterized by chest pain, cough with foamy and bloody sputum and death of the lung tissues because of excessive accumulation of watery fluids, cadmium is also associated with bone defects, viz; Osteomalacia, Osteoporosis and Spontaneous fractures, increased blood pressure and myocardic dysfunction. Depending on the severity of exposure the symptoms of cadmium toxic effects also include nausea, vomiting, abdominal cramps, dysperia and muscular weakness. Severe exposure may result in pulmonary Odema and death[5,6,7,8].

The main source of zinc contaminations are metal plating factories, paper and calcium powder which contained zinc, catering equipment, roofing sheets etc. Zinc can also be present as alloys. It is used in rubber industries, manufacture of dry batteries, roofing and exterior fitting on building and pharmaceutical industries where it is used in ointment, shampoo[9].

High level of zinc can damage the pancreas and disturb the protein metabolism and cause liver cirrhosis. It can also be dangerous to the unborn and new born children[10]. High concentration of zinc cause eminent health problem such as stomach cramps, skin irritation, vomiting etc.

Copper also plays an important role in cellular respiration, hormones activation, intermediary metabolism, antioxidant defence, wound healing and tissue growth. Among enzymes utilizing, copper are cyclochrome oxidase intra and extra-cellular super oxide dimutase, tryosinase, phenyl alanine hydroxylase[11] .

Long-term exposure to copper can cause irritation of the nose, mouth and eyes and headaches, stomach pain, dizziness, vomiting and diarrhoea. High uptake of copper may cause liver and kidney damage and even death. Copper is carcinogenic[10] .

Acute copper intoxication is characterized by haemolytic anaemia, renal tubular injury and cellular damaged. [12] .

Copper poisoning results in Wilson's disease characterized by hepatic cirrhosis, brain damage, demyelisation, renal disease and copper deposition in the cornea[10] .

The absorbed iron is derived from two pools – the heame pool in which iron in complex with haemoglobin, myoglobin and other heme containing protein and the non heme pool representing the majority of dietary iron intake. As opposed to heme iron, non-heme iron absorption is subjected to interaction with variety of nutrients[10] .

Excessive iron intake result to a toxic effect. For instance iron acts as catalyst for free radical generating reaction. Consequently, an excess of free iron through the enhancement of cellular oxidative reaction as lipid peroxidation can lead to oxidative damage[5] .

Soil is made up of matter existing in three states such that the solid, liquid and the gaseous state are not regionalized but co-exist together. For plant growth, a proper balance of all the three states of matter is necessary. The entire soil could be segmented into the earth crust, the mantle and the core[13] . The crust is made up of the Sial and Sima. The Sial is composed of solid rocks like lignite with low density. Beneath the Sial is the sigma having dense rock materials and lying in the region of higher temperature, this is the substance from which the rocks on the surface of the earth are made, the rocks in the mantle region are denser than those in the Sial and Sima of the crust and are hotter. Because of heat, the material can flow and change its shape. The core region existing in the centre of the earth consists of an inner solid metallic part and an outer ring of lignite materials composed mostly of iron and nickel. [13,14] .

The accumulation of trace metals in agricultural and non-agricultural soils poses health hazards[15] . Some of the health effects of trace metals include skin irritation, damage to the liver, kidney circulatory and nerve – tissue resulting from acute or chronic exposure.

Heavy metals concentrations in soil are associated with biological and geological cycles and are influenced by anthropogenic activities such as agricultural practices, industrial activities and waste disposal methods[16, 17]. Major categories of soil pollutions include nutrients (fertilizers, sewage sludge), acids, heavy metals, radioactive elements and organic chemicals, herbicides, insecticides and other pesticides). Many of these pollutants are continuously discharged into the soil through land waste disposal, inputs from the atmosphere and irrigation by municipal waste water on a daily basis[18] .

Lettuce (Lactuca sativa) is a temperate annual or biennial plant of the daisy family asteracease. It typically eaten cold and raw in salads, hamburgers, tacos and many other dishes. The lettuce plant has short stem initially (a rosette growth habit), but when it blooms the stem lenthens and branches and it produce many flower heads that look like those of dandelions, but smaller, which is called botting. When grown to eat, lettuce is harvested before it bolt.

Plants take heavy metals from soil through different processes such as; absorption, ionic exchange, redox reaction, precipitation-dissolution etc. The solubility of trace elements depends on minerals in soil (carbonates, oxide, hydroxide etc), soil organic matter (humic acid, fulvic acids, polysaccharides and organic acids), redox potential, soil temperature and humidity[19].

The amount of element in soil solution is much lower than amount of elements absorbed by plant. A higher rate of bio available fraction is located in the solid phase.

In Nigeria the use of polluted water in the immediate surroundings of big cities for growing of vegetables is a common practice. Although this water is considered to be rich source of organic matter and plant nutrients, it also contains sufficient amounts of soluble salts and heavy metals like Fe, Mn, Cu, Zn, Pb, etc. When such water is used for cultivation of crops for a long period, heavy metals may accumulate in soil and may be toxic to the plants[20].

The type of irrigation system employed in the farmlands of the Kaduna metropolis is the surface irrigation where water is applied directly to the soil surface through channel which varies in size from individual furrow to large basin.

In some settlements within Kaduna metropolis, substantial amount of vegetables were produced. These farms are irrigated with waste water from Kaduna River and some other rivers and drainages within the metropolis. For the past several decades, the water from these rivers was clean. However, with the increase in the urban population and industrialization, the water has now become contaminated with various pollutants, among which are heavy metals.

In addition, vegetables could be contaminated as farmers wash their product with waste water before bringing them to market.

The aim of this research work is to investigate the amount of heavy metals transferred from soil to lettuce so as to know the extent of contamination if found extremely above concentrations stipulated by various agencies

MATERIALS AND METHODS

***Sample and Sampling*:**

Lettuce 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 lettuce 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

Lettuce samples

5g of the ground lettuce samples were 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 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 cabbage

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[21,22] .

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

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[23] plant uptake is one of the major

path ways by whichmetal 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 cabbage were shown in the below table 1.0 and 2.0 respectively

Table 1.0: Heavy metals in lettuce samples from different irrigation sites of the Kaduna Metropolis

Sampling sites	Cd ($\mu g g^{-1}$)			Fe ($\mu g g^{-1}$)			Zn ($\mu g g^{-1}$)			Cu ($\mu g g^{-1}$)			Pb ($\mu g g^{-1}$)		
KBL	0.09	±	0.10	18.2	±	20.19	18.45	±	28.39	2.41	±	2.33	3.44	±	3.14
DMN	ND		ND	2.57	±	2.23	18.33	±	15.92	1	±	0.87	0.96	±	0.84
RGS	0.09	±	0.07	14.63	±	24.01	11.16	±	18.13	2.5	±	4.048	3.57	±	1.71
BNW	0.47	±	0.41	5.47	±	4.74	7.03	±	4.32	2.47	±	2.19	1.51	±	0.37
MKR	0.73	±	0.23	9.7	±	1.54	6.17	±	3.93	2.67	±	0.47	2.37	±	0.24
KKR	0.03	±	0.06	12.09	±	5.03	0.57	±	0.49	0.27	±	0.31	3.81	±	2.97
BDK	0.47	±	0.42	12.07	±	2.34	4.62	±	3.21	2.5	±	2.18	ND		ND
NAS	0.47	±	0.46	8.67	±	5.15	5.7	±	1.37	4.07	±	1.53	2.88	±	1.70
MAL	1.27	±	0.23	12.87	±	0.42	8.43	±	1.09	4.77	±	0.75	2.33	±	0.31
KUD	1.13	±	0.31	13.13	±	2.30	6.4	±	1.06	3.87	±	0.83	3.67	±	0.92
KKN	1.13	±	0.42	9.07	±	2.99	5.27	±	0.83	3.7	±	1.13	1.73	±	0.76
KWO	0.8	±	0.4	9.2	±	3.70	5.03	±	1.44	2.67	±	0.72	2.13	±	1.01
URM	0.67	±	0.23	8.73	±	1.10	10.13	±	1.27	2.33	±	0.75	3.4	±	1.56
UNS	ND		ND	17.09	±	1.09	15.01	±	11.39	0.67	±	1.15	1.27	±	0.12
TDW	0.2	±	0.25	10.73	±	2.19	1.87	±	1.62	2.67	±	2.36	2.47	±	2.19
DKA	1.37	±	0.21	11.87	±	6.05	5.93	±	3.49	4.97	±	1.86	2.73	±	0.64
UDS	0.6	±	ND	6.6	±	1.44	7.6	±	1.64	3.2	±	0.89	1.8	±	0.35
CTA	0.53	±	0.58	9.33	±	2.02	8.83	±	2.84	3.53	±	1.70	1.8	±	0.35
KMS	0.67	±	0.31	8.73	±	3.72	8.2	±	0.35	3.47	±	0.55	2.17	±	0.85
ABK	1	±	0.2	7.6	±	1.71	5.73	±	2.50	3.43	±	1.19	3.33	±	1.97
RCK	0.63	±	0.47	9.26	±	4.63	4.23	±	3.67	4.2	±	3.64	3.27	±	1.90

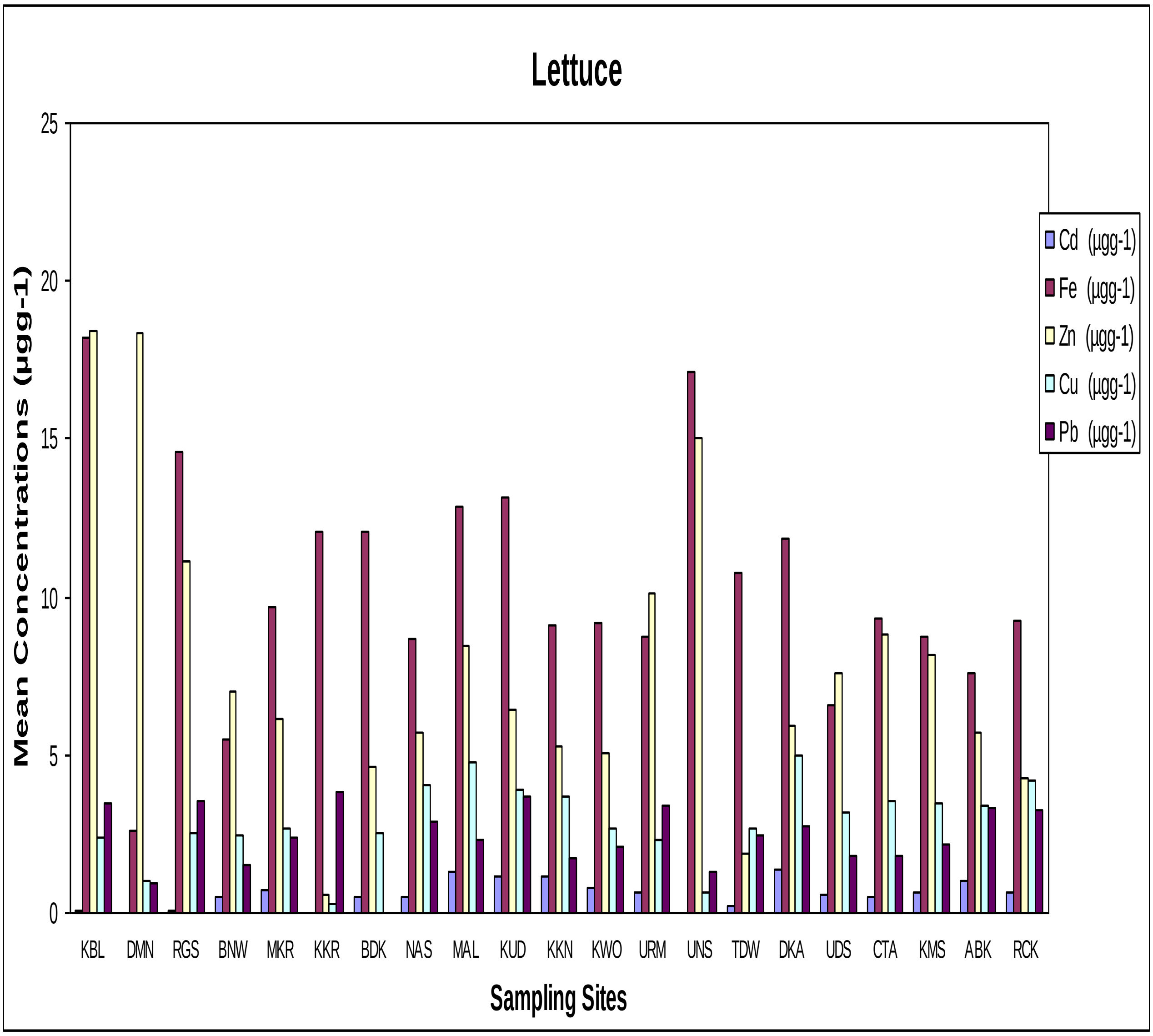

Fig.1.0: Heavy metal in Lettuce sample from different irrigation sites of the Kaduna Metropolis

Figure 1.0 showed that Zinc from KBL and Iron from KBL had the highest concentrations of 18.45 ± 28.39 and 18.20 ± 20.19µgg^{-1} respectively being the highest elements absorbed by the lettuce samples from irrigated farmland of the Kaduna metropolis. Copper from the DKA with 4.97 ± 1.86µgg^{-1} was the next and Lead from KKR had 3.81 ± 2.97µgg^{-1} Cadmium from MKR had concentration of 0.73 ± 0.23µgg^{-1} being the lowest among the most highly absorb element from the analyzed lettuce samples.

The absorption of heavy metals in lettuce are in the following increasing order: Zn (KBL) > Fe (KBL) > Cu (DKA) > Pb (KKR) > Cd (MKR).

Infact it has been revealed from this analysis that Zinc and Iron from KBL were predominantly absorbed than other metals. This is because with soil being acidic, the solubility of Zn and Fe play a principal role in the retention of these metals in the soil thereby increasing their absorption by the plants especially in lettuce sample.

Table 2.0: Transfer factor (TF) for each metal from soil to Lettuce

Sampling Sites	Cd (μgg^{-1})	Fe (μgg^{-1})	Zn (μgg^{-1})	Cu (μgg^{-1})	Pb (μgg^{-1})
Kabala	0.07	0.41	0.57	0.75	0.82
Danmani	ND	0.06	0.59	0.20	0.24
Rigasa	2.66	0.14	0.17	0.78	0.27
Barnawa	0.37	0.05	0.21	0.06	0.04
Makera	0.37	0.22	0.15	0.32	0.74
Kakuri	0.04	0.13	0.01	0.02	0.11
Badiko	0.37	0.26	0.19	0.55	ND
Nasarawa	0.26	0.19	0.18	0.54	0.61
Malali	1.01	1.03	0.31	1.17	0.61
Kudenda	0.51	0.28	0.16	0.49	0.74
Kinkinau	0.73	0.25	0.18	0.58	0.49
Kawo	1.48	0.09	0.11	0.13	0.05
Uuguwan Rimi	ND	0.08	0.16	0.11	0.21
Uuguwan Sanusi	ND	0.17	0.31	0.08	0.13
Tudunwada	1.00	0.11	0.05	0.11	0.48
Doka	1.09	0.16	0.19	0.34	0.09
Unguwan Dosa	0.38	0.41	0.30	0.63	0.49
Costain	0.34	0.32	0.31	0.89	0.71
Kurmi mashi	0.45	0.22	0.37	0.64	0.83
Abakpa	0.85	0.39	0.22	0.97	0.96
Rigachikun	0.48	0.43	0.24	1.18	0.89

Table 2.0 shows transfer factor of heavy metal from soil to lettuce. All transfer factor are below 1 with the exception of samples from Rigasa (2.66 for Cd), Malali (1.01 for Cd, 1.03 for Fe and 1.17 for Cu), Kawo (1.48 for Cd), Tudun wada (1.00 for Cd), Doka (1.09 for Cd) and Rigachikun (control) 1.18 for Cu. The obtain value for cadmium showed that its transfer factor is higher than 0.02 reported by Sani *et al*.,[24].

The value of Fe were high when compared with 0.90 observed by [24] and also higher than 0.90 reported by Uwah *et al*.,[25]. Sani *et al*.,[24] reported 0.23 lower than the obtained transfer factor for Zn values but there few exceptions with higher TF than the above mentioned values.

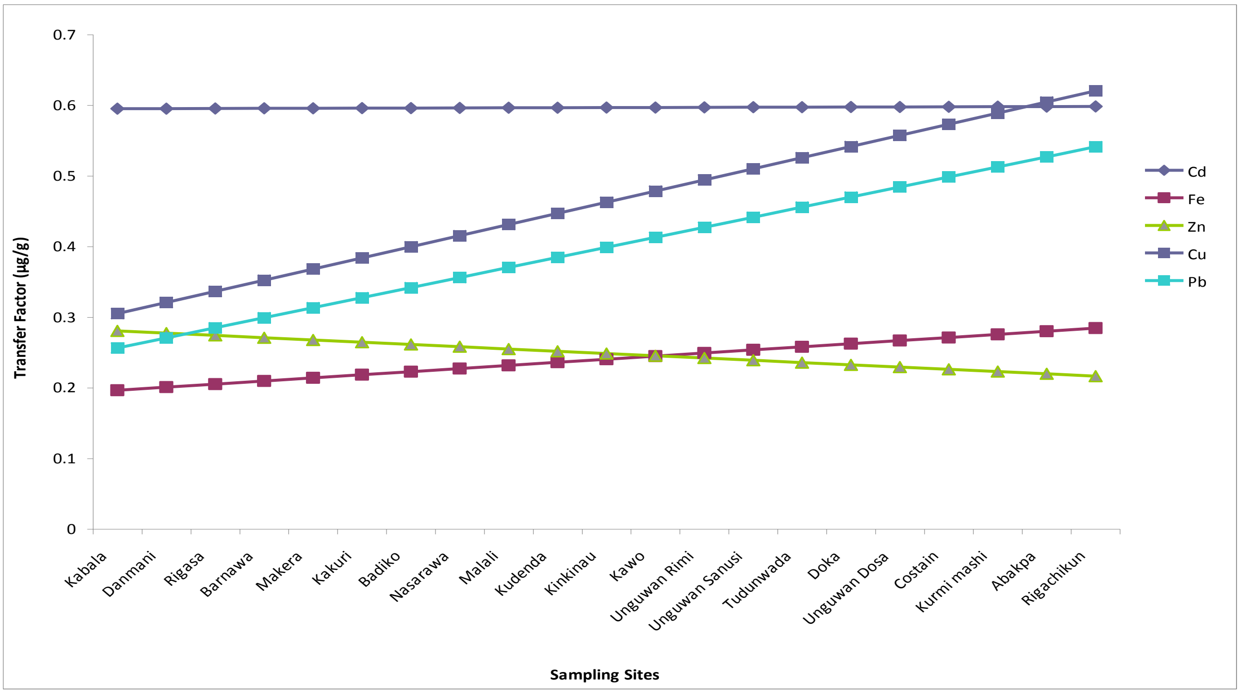

Fig. 2.0: A plot of transfer factor from soil to lettuce

Transfer factor obtained for most of Cu and Pb were lower than 0.5 and 0.17 respectively as observed by Sani *et al.*,[24]

This is to quantify the relative differences in bioavailability of metals to Plants or identify the efficiency of a plant species to accumulate a given heavy metal.

Figure 2.0 shows transfer factor of heavy metal from soil to lettuce. In this analysis cadmium was highly transferred than other elements. Next to this are copper, lead, iron and least is zinc. This showed that cadmium is more mobile than other metals[26]. have reported that Cd is retained less strongly by the soil and hence it is more mobile than other metals. This is also due to the atmospheric deposition of heavy metals from different sources such as: metaliferous metal smelting and industrial activities and other sources of contamination such as fertilizers, pesticides, sewage sludge and organic waste [27].

This transfer factor of soil to lettuce is summarized in the below order: -
Cadmium > Copper > Lead > Iron > Zinc.

CONCLUSION

In the present study, the transfer factor (soil to lettuce) of different irrigation sites of Kaduna metropolis were determined and found that Zinc from Kabala and Iron from Kabala had the highest concentrations of 18.45 ± 28.39 and 18.20 ± 20.19µgg^{-1} respectively being the highest elements absorbed by the lettuce samples from irrigated farmland of the Kaduna metropolis. In this analysis cadmium was highly transferred than other elements. Next to this are copper, lead, iron and least is zinc. This transfer factor of soil to lettuce is arranged in this order: Cadmium > Copper > Lead > Iron > Zinc This is because cadmium is retained less strongly by the soil and hence it is more mobile than other metals.

This is also due to human, industrial activities and other sources of contaminants such as fertilizers, pesticides, etc found in the soils which were eventually being absorbed by the lettuce samples. When vegetable such as lettuce accumulates heavy metals at a proportion exceeding the tolerance limit and if consumed by man or other animals, then the excess proportion of these metals from the vegetables tend to accumulates gradually in animal tissues at a very high concentration where it becomes toxic and causes varieties of illness e.g. brain damage, tumor cell, miscarriage etc.

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