American Journal of Open Research, 1(2), November, 2022, 30-47
E-ISSN: 2834-7668

HEALTH RISK ASSESSMENT OF SOME HEAVY METALS IN IRRIGATED *BRASSICA OLERACEA L.*AND *LACTUCA SATIVA* VEGETABLES OF BARKIN-LADI LGA OF PLATEAU STATE, NIGERIA

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Abstract : The objectives of the present study were to investigate heavy metal (Cd, Cr, Mn and Pb) accumulation in Cabbage (*Brassica oleracea L.*) and Lettuce (*Lactuca sativa)* vegetable samples, which were freshly harvested within 7 different vegetable farm location grown around Barkin Ladi LGA of Plateau State, Nigeria. Heavy Metals concentrations in the vegetable samples were analyzed using Atomic Absorption Spectrophotometer (Bulk Scientific Model 210 VGP). Concentration of Chromium in Cabbage ranged from0.32mg/kg - 0.05mg/kg and Lettuce was between 0.23mg/kg-0.04mg/kg. Cadmium level of vegetables from the analysis of Cabbage ranged between 0.65mg/kg - 0.15mg/kg, and Lettuce was between 0.60mg/kg-0.13mg/kg. Mn level of vegetables from the analysis of Cabbage ranged between 0.37mg/kg-0.04mg/kg and the range for Lettuce was between 0.45mg/kg-0.10mg/kg. Pb level of vegetables from these the analysis of Cabbage ranged between 0.35mg/kg-0.08mg/kg and the range for Lettuce was between 0.51mg/kg-0.05mg/kg. The calculated mean and standard deviation for Cabbage sample for Cd, Cr, Mn and Pb were 0.353±0.162, 0.144±0.066, 0.165±0.087 and 0.156±0.075 respectively, while Lettuce samples were 0,327±0.140, 0.119±0.062, 0.258±0.095 and 0.2300.122 respectively. In general, the concentration trends of heavy metal investigated were on the order Cd > Mn > Pb > Cr in all the sample matrices of both vegetables. Risk analysis parameters for both sample matrices computed using standard methods for both adult and children were HRI, HQ, DIM, EDIM, MPI. Different methods of health risk assessment of the heavy metals concentration also revealed although the vegetable may be safe for consumption, bioaccumulation risk index showed that there could be potential danger of consumption over a long period of time. This study concludes that different vegetables accumulate and translocate variable amount of heavy metals from the soil into their tissues. Hence, it is not advisable to consume vegetable samples collected from this site based on the permissible limits as recommended by World Health Organization (WHO).

Keywords: safety practices; hotel accommodation barkin-ladi; *brassica oleracea l; lactuca sativa*; health risks; heavy metals.

DOI:
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INTRODUCTION

Vegetables play important roles in human nutrition and health, particularly as sources of vitamin C, thiamine, niacin, pyridoxine, folic acid, minerals, and dietary fiber (Siegiel *et al.,* 2014). Generally, Vegetables are common diet taken by various human populations throughout the world due to their richness in vitamins, minerals, fibers and anti-oxidative effects (Mohammed and Khamis, 2012; Cobb *et al.,* 2000). However, vegetables cultivated on contaminated soils or irrigated with contaminated water take up heavy metals in quantities large enough to cause potential health risks to the consumers (Singh *et al.,* 2010; Yang *et al.,* 2007; Lăcătuşu and Lăcătuşu, 2008).

Leafy vegetables grown in heavy metals contaminated soils accumulate higher amounts of metals in their edible and non-edible parts than those grown in uncontaminated soils (Muhammad *et al.,* 2008). Leafy vegetables such as amaranth and cabbage have particularly been reported to be good absorber of heavy metals from soil (Arora *et al.,* 2008). Cabbage (*Brassica oleracea*) and lettuce (*Lactuca sativa)* are leafy green biennial plants grown as annual vegetable crop for its dense leaved heads and nutritive values. They consist of soft, light green or whitish inner leaves covered and are good sources of vitamin K, vitamin C and dietary fiber.

Consumption of contaminated cabbage and lettuce have been linked to cases of food-borne illness in humans. The vegetables are reported to have therapeutic properties that are well known from ancient times and high vitamins contents which give it an excellent nutritional value. Both vegetable are known to have low levels of saturated fat and cholesterol and has been recognized as a good source of thiamine, calcium, iron, magnesium, phosphorus, potassium, dietary fiber, folate (vitamin B9) and manganese (Siegiel *et al.,* 2014; Radulescu *et al.,* 2013). Its enormous benefits notwithstanding, it can be a prolific accumulator of heavy metals from soil, providing an easy entry into food chain (Radulescu *et al.,* 2013), this of course is a real matter for serious concern. Cabbage as it is commonly called, is a highly cultivated leafy vegetable in most northern Nigerian states and adequately consumed all over the country. This study was aimed at assessing Pb, Cr, Ni and Mn in edible tissues of cabbage harvested from River Galma basin around Dakace Industrial layout, Zaria.

In a recent work by Liang *et al*. (2017), a two ANOVA analysis of data revealed that there was a significant difference in heavy metal concentrations between leafy vegetables and non-leafy vegetables. The heavy metals investigated include Cr, Ni, Cd, Fe and Pb for their bioaccumulation factor to provide baseline data regarding environmental safety and suitability of the vegetables for human consumption. Ologundudu *et al*. (2019; Udiba *et al.,* 2015) undertook a risk analysis studies in Corchorus olitorius L. (*Malvaceae*) and Amaranthus hybridus L. (*Amaranthaceae*) obtained from a selected dump site in Akure, Nigeria in which risk factors such as Translocation factor, Daily Intake of Metal (DIM), Health Risk Index (HRI) and Oral Refrence Dose (RFD) were calculated following standard methods. This study concludes that different vegetables accumulate and translocate variable amount of heavy metals from the soil into their tissues. They advised that vegetable samples collected from this site were not suitable for consumption based on the permissible limits as recommended by World Health Organization (WHO).

Environmental pollution can have detrimental effects on crop yield and its consumers. Health hazard indices are derived to assess the human health risks that result from the dietary intake of food crops contaminated with various types of heavy metals. In a study on health risks, especially heavy metal–induced cancer, Cr, Pb, As, Hg, and Cd had target hazard quotient (THQ) values>1 in food crops, and Pb and Hg were found to cause gastric and liver cancers, respectively ((Somda *et al.,* 2019; Mafuyai *et al.,* 2019; Patrick-Iwuanyanwu and Chioma, 2017; Zhao *et al.,* 2014). Health risk studies on the intake of food crops in a developing country were conducted to assess 30 agro-ecological zones in terms of health indices. The results revealed that the consumption of vegetables contaminated by heavy metals (especially Mn and Cu) was more deleterious to human health than the consumption of contaminated fruits (Mafuyai *et al.,* 2019; Shaheen *et al.,* 2016). Obiora et al (2016; Udiba *et al.,* 2015) reported that vegetables grown near Pb-Zn mine were contaminated with heavy metals, especially Pb and Mn, which can lead to Alzheimer's disease and manganism. In a study that emphasized the systematic health risks of a mixture of Pb and Cd, rather than the effects of specific metals in isolation, Cui et al (2005) found renal dysfunction in a population of people who ingested foods contaminated with multiple metals. Also, in recent decades, adverse effects of unexpected contaminants on crop quality have threatened both food security and human health. Heavy metals and metalloids (e.g., Hg, As, Pb, Cd, and Cr) can disturb human metabolomics, contributing to morbidity and even mortality (Rai *et al.,* 2019). According to Ametepey *et al.,* 2018, the individual hazard index of vegetables for both children and adults were below 1, indicating no potential risk to the public except for cadmium, chromium and manganese. The study also revealed that the hazard index of heavy metals studied were above 1, indicating non-acceptable level of non-carcinogenic adverse health effect (Patrick-Iwuanyanwu and Chioma, 2017)

Information on the concentration levels of heavy metals in crops in this area that will lead to the assessment of the risks involved in their consumption is scarce. Therefore there is the need to examine the concentration levels of Cd, Cr, Mn and Pb in the locally irrigated Cabbage (*Brassica Oleracea*) and Lettuce (*Lactuca sativa*) vegetables grown around the abandoned mining sites in Barkin Ladi, Pleateau State, Nigeria in other to sensitize people against long time exposure effects of heavy metals via consumption of these vegetables. The current study was designed to investigate the potential human health risks associated with the consumption of lettuce and cabbage vegetables contaminated with toxic heavy metals such as Cd, Cr, Mn and Pb.

Martials and Method

Farms 1, 2, 3, 4, 5, 6 and 7 have both cabbage and lettuce; and the locations are Lokojoro (Kassa), GonanYashi and Marit, Maraban Kantoma, Rakung, Ngwetti, and Boyi respectively. At each farms, vegetable samples were collected and washed with tap water and then properly rinsed with distilled water. The vegetables samples were divided into leave, stem and root.

Table 1. Geographical Locations of sampling sites

S/No.	Sample Site	Latitude	Longitude	Altitude (M)
1	Lokojoro (Kassa)	09°33.907’	008°54.030’	1299
2	Gonan Yashi	09°31.748’	008°54.091’	1295
3	Marit	09°32.966’	008°53.173’	1287
4	Mararaban Kantoma	09°30.869’	008°59.997’	1297
5	Rakung	09°32.877’	008°53.115’	1289
6	Ngwetti	09°33.009’	008°53.270’	1291
7	Boyi	09°33.097’	008°54.230’	1294

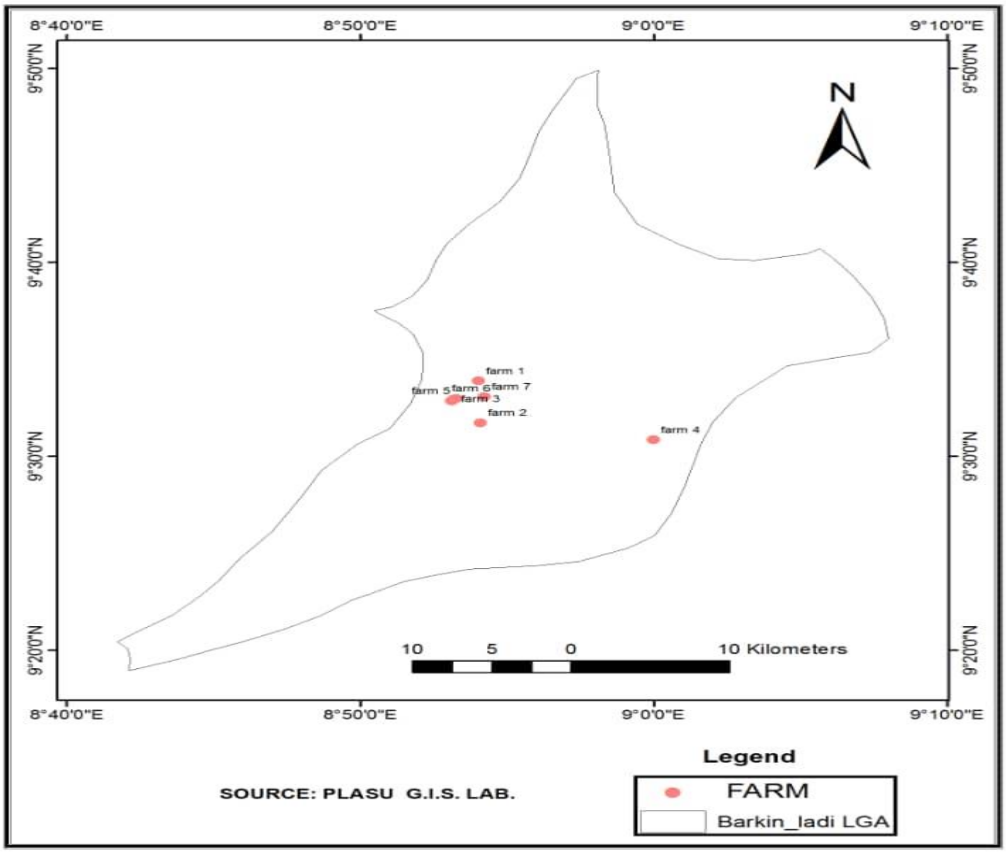


Fig 1. Map of Barkin Ladi showing Sample Sites

Digestion of Vegetable samples for Heavy Metals Determination

a. Vegetable Sampling

The vegetables selected for heavy metal analysis were Cabbage and Lettuce, each with its Leave, Stem and Root. Cabbage and Lettuce were collected from 7, 7 sites respectively during the dry season and stored in polyethylene bags. All the collected vegetables were washed with tap water to remove the soil particles and then uneatable parts were removed. The edible part was sliced into pieces and dried separately on sheet of filter paper, then dried in oven at 105°C for 24 h and then crushed with a porcelain mortar and pestle; the resulting powder was sieved with a 2MM mesh size sieve at room temperature and digested.

b. Digestion of Samples

1gm of each sample of vegetable was placed in 100 mL beaker separately and digested with 9 mL of concentrated HCl, 3 mL of concentrated HNO_3 and 15 mL at 3:1:5 ratios at 80°C on an oven plate till the solution becomes transparent. The solution thus obtained was filtered through a Whatman Number 1 filter paper into a 100 mL volumetric flask and rinsed with 0.1M HNO_3 acid and finally topped to the mark with distilled water.

MATERIALS AND METHODS

Elemental Analysis of Samples

The resulting solutions were stored in plastic sample bottles in the Chemistry Laboratory, Plateau State University Bokkos at room temperature before been taken to Engineering Laboratory ATBU, Bauchi for the determination of Pb, Cd, Cr and Mn which were made directly on each final solution using a 210 VGP (AAS) Scientific Atomic Absorption Spectrophotometer.

RESULTS AND DISCUSSION

a. Results

Levels of heavy metals in the Roots, Stems and Leaves of the vegetable samples (Cabbage and Lettuce) from the seven different farms in Barkin Ladi LGA are as displayed in table 1 and 2

Table 2. Analysis Result for Cabbage Vegetable Samples

Sample	**Element Concentration (mg/kg)**			
	Cd	**Cr**	**Mn**	**Pb**
CKSR	0.59±0.03	0.14±0.02	0.24±0.02	0.17±0.01
CKSS	0.15±0.01	0.15±0.01	0.10±0.02	0.19±0.03
CKSL	0.37±0.00	0.13±0.01	0.04±0.00	0.18±0.05
CGYR	0.24±0.01	0.19±0.02	0.20±0.01	0.10±0.01
CGYS	0.46±0.01	0.20±0.02	0.08±0.00	0.10±0.00
CGYL	0.24±0.01	0.08±0.02	0.06±0.01	0.14±0.01
CMRR	0.64±0.01	0.05±0.00	0.37±0.01	0.35±0.05
CMRS	0.56±0.02	0.09±0.01	0.30±0.03	0.28±0.03
CMRL	0.65±0.04	0.14±0.02	0.26±0.02	0.29±0.02
CMKR	0.22±0.00	0.13±0.01	0.25±0.05	0.21±0.02
CMKS	0.45±0.01	0.12±0.02	0.18±0.02	0.09±0.01
CMKL	0.38±0.02	0.22±0.03	0.07±0.01	0.16±0.02
CRKR	0.43±0.01	0.13±0.02	0.19±0.01	0.11±0.01
CRKS	0.45±0.00	0.08±0.00	0.11±0.00	0.14±0.03
CRKL	0.29±0.00	0.14±0.01	0.10±0.02	0.12±0.02
CNGR	0.33±0.02	0.09±0.01	0.20±0.01	0.09±0.01
CNGS	0.21±0.02	0.10±0.01	0.12±0.01	0.08±0.01
CNGL	0.18±0.01	0.08±0.01	0.10±0.02	0.09±0.02
CBOR	0.23±0.02	0.32±0.04	0.20±0.02	0.18±0.03
CBOS	0.18±0.02	0.26±0.02	0.18±0.03	0.12±0.02
CBOL	0.17±0.03	0.18±0.02	0.11±0.02	0.09±0.01
Average	**0.35±0.03**	**0.14±0.02**	**0.17±0.02**	**0.16±0.03**
WHO STD	**0.1**	**0.05**	**0.2 - 0.4**	**0.3**

Table 3. Analysis Result for Lettuce Vegetable Samples

Sample	**Element Concentration (mg/L)**			
	Cd	**Cr**	**Mn**	**Pb**
LKSR	0.5±0.00	0.15±0.00	0.23±0.02	0.14±0.00
LKSS	0.35±0.00	0.15±0.01	0.10±0.02	0.15±0.03
LKSL	0.27±0.00	0.13±0.00	0.14±0.00	0.17±0.05

LGYR	0.24±0.01	0.19±0.00	0.20±0.01	0.10±0.01
LGYS	0.26±0.01	0.20±0.00	0.28±0.00	0.10±0.00
LGYL	0.34±0.01	0.18±0.02	0.36±0.01	0.24±0.01
LMRR	0.24±0.01	0.15±0.00	0.37±0.01	0.35±0.05
LMRS	0.26±0.02	0.19±0.01	0.30±0.00	0.28±0.03
LMRL	0.35±0.00	0.14±0.00	0.16±0.00	0.22±0.02
LMKR	BDL	0.11±0.01	0.17±0.05	0.25±0.02
LMKS	0.13±0.01	0.15±0.00	0.18±0.02	0.22±0.01
LMKL	0.57±0.02	0.23±0.02	0.18±0.01	0.05±0.02
LRKR	0.33±0.01	0.07±0.02	0.25±0.01	0.23±0.02
LRKS	0.60±0.00	BDL	0.45±0.00	0.21±0.02
LRKL	0.41±0.00	0.05±0.02	0.37±0.02	0.05±0.00
LNGR	0.48±0.02	0.11±0.02	0.20±0.02	0.17±0.02
LNGS	0.39±0.02	0.04±0.02	0.21±0.02	0.51±0.03
LNGL	0.34±0.02	0.08±0.02	0.40±0.02	0.45±0.02
LBOR	0.33±0.02	0.06±0.01	0.34±0.03	0.38±0.01
LBOS	0.28±0.01	0.07±0.01	0.29±0.02	0.32±0.02
LBOL	0.20±0.02	0.05±0.00	0.23±0.01	0.24±0.03
Average	**0.33±0.02**	**0.12±0.01**	**026±0.01**	**0.23±0.02**
WHO/FDA STD (2011)	**0.2**	**0.3**	**0.2-0.4**	**0.3**

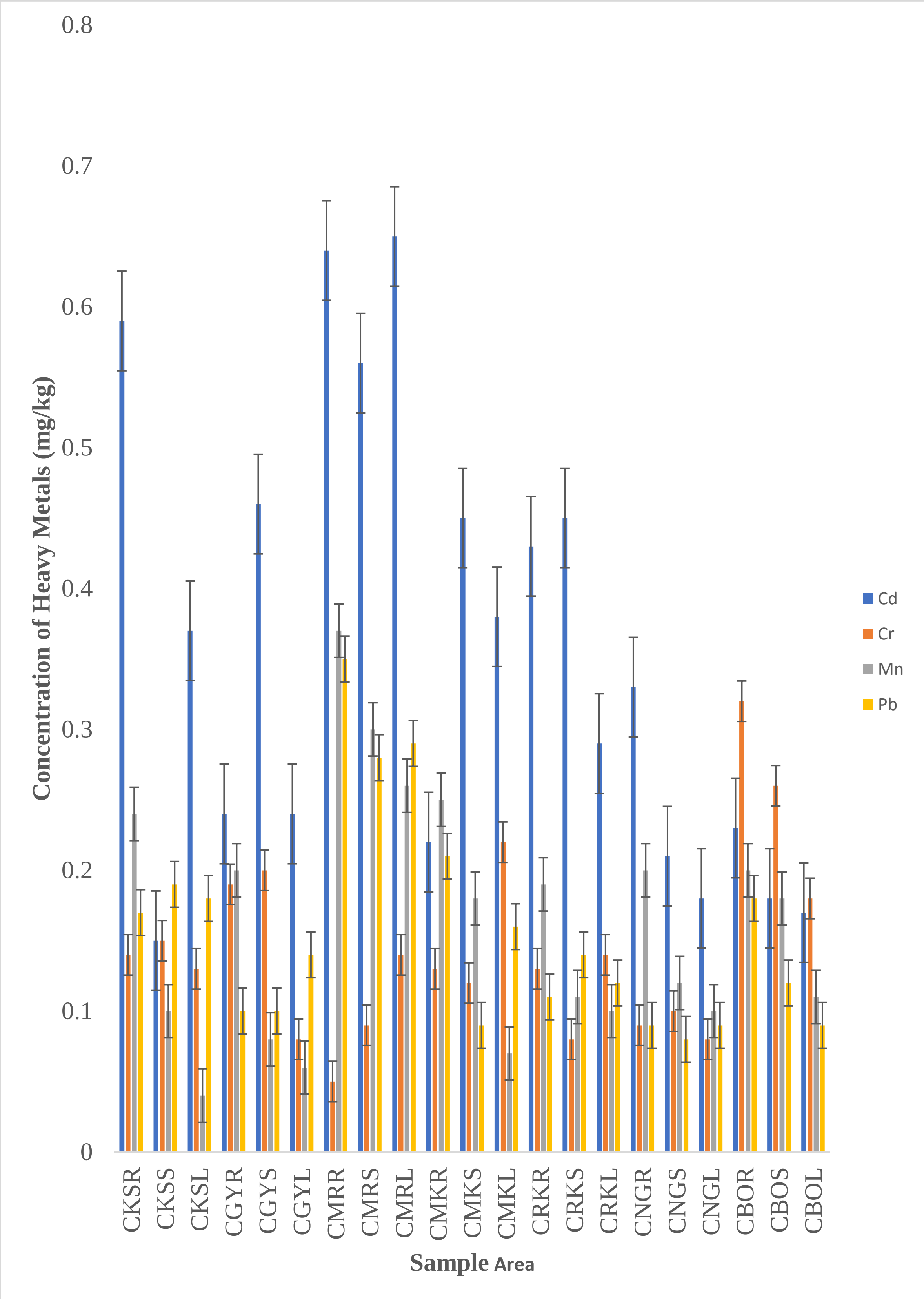
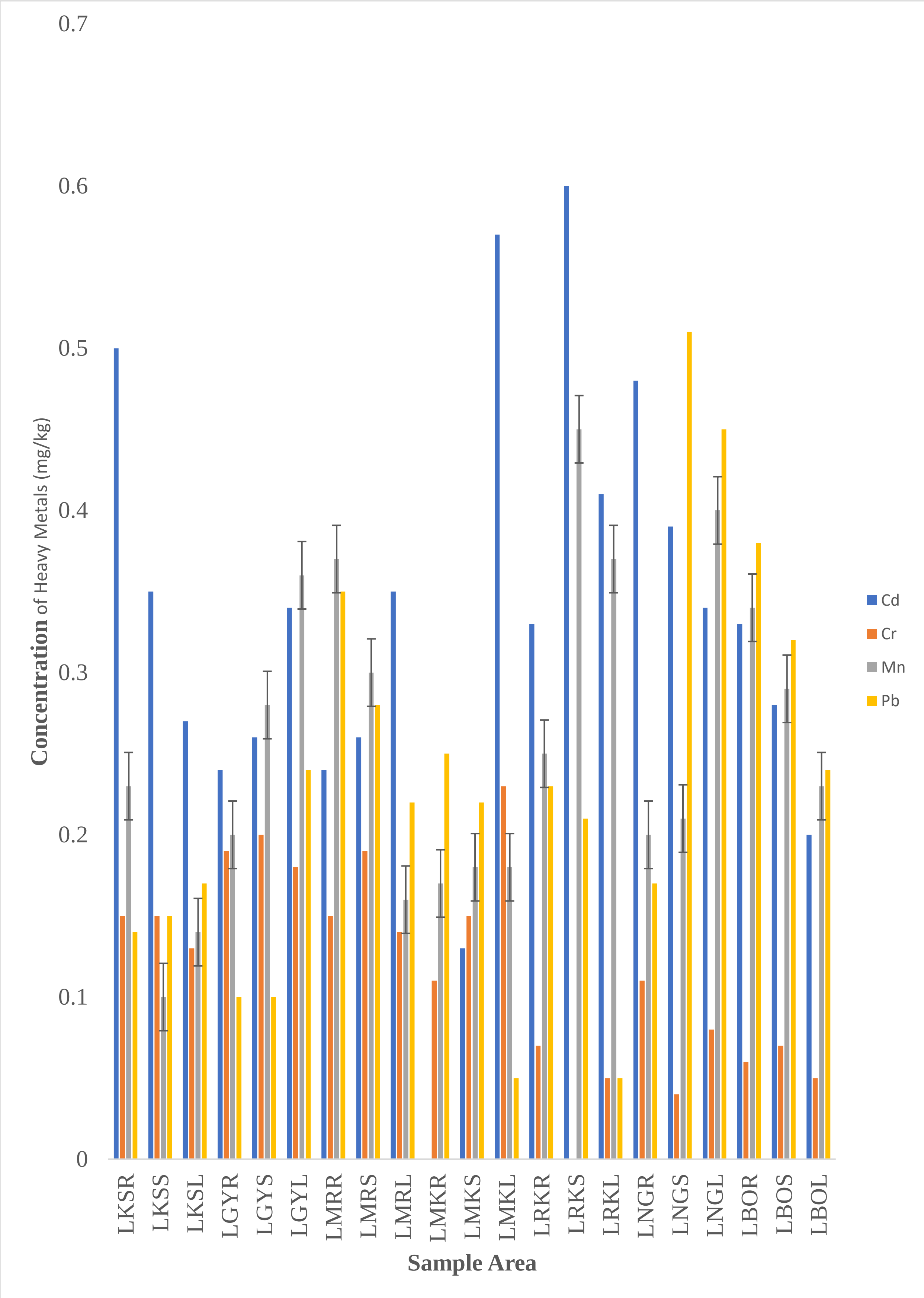


Fig 2. Bar chat representation of heavy metal concentration of cabbage in sample areas



0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Concentration of Heavy Metals (mg/kg)
LKSR
LKSS
LKSL
LGYR
LGYS
LGYL
LMRR
LMRS
LMRL
LMKR
LMKS
LMKL
LRKR
LRKS
LRKL
LNGR
LNGS
LNGL
LBOR
LBOS
LBOL
Sample Area
Cd
Cr
Mn
Pb

Fig 4. Bar chat representation of heavy metal concentration of lettuce in sample areas

Calculated MPI for Cabbage and Lettuce Leave Sample

Sample sites	Cabbage	Lettuce
KSL	$8.65×10^{-5}$	$2.09×10^{-4}$
GYL	$8.06×10^{-5}$	$1.32 ×10^{-3}$
MRL	$1.71×10^{-3}$	$4.31×10^{-4}$
MKL	$2.34×10^{-4}$	$2.34×10^{-4}$
RKL	$1.21×10^{-4}$	$1.21×10^{-4}$
NGL	$3.24×10^{-5}$	$3.24×10^{-5}$
BOL	$7.57×10^{-5}$	$7.57×10^{-5}$

Table 5. Calculated EDIM for Adult from Sample Sites

Sample sites	Cabbage				Lettuce			
	Cd	Cr	Mn	Pb	Cd	Cr	Mn	Pb
KSL	$1.43×10^{-4}$	$5.02×10^{-5}$	$1.55×10^{-5}$	$6.95×10^{-5}$	$1.0×10^{-4}$	$5.0×10^{-5}$	$5.4×10^{-4}$	$6.6×10^{-5}$
GYL	$9.27×10^{-5}$	$3.09×10^{-5}$	$2.31×10^{-5}$	$5.41×10^{-5}$	$1.3×10^{-4}$	$6.9×10^{-5}$	$1.4×10^{-4}$	$9.3×10^{-5}$
MRL	$2.51×10^{-4}$	$5.40×10^{-5}$	$1.0×10^{4}$	$1.10×10^{-4}$	$1.4×10^{4}$	$5.4×10^{-5}$	$6.2×10^{-5}$	$8.5×10^{-5}$
MKL	$1.47×10^{-4}$	$8.50×10^{-5}$	$2.7×10^{-5}$	$6.18×10^{-5}$	$2.2×10^{4}$	$8.9×10^{-5}$	$6.9×10^{-5}$	$1.9×10^{-5}$
RKL	$1.1×10^{-4}$	$5.4×10^{-5}$	$3.86×10^{-5}$	$4.6×10^{-5}$	$1.6×10^{-4}$	$1.9×10^{-5}$	$1.4×10^{-4}$	$1.9×10^{-5}$
NGL	$6.9×10^{-5}$	$3.1×10^{-5}$	$3.9×10^{-5}$	$3.5×10^{-5}$	$1.3×10^{-4}$	$3.1×10^{-5}$	$1.5×10^{-4}$	$1.7×10^{-4}$
BOL	$6.6×10^{-5}$	$6.9×10^{-5}$	$4.3×10^{-5}$	$3.3×10^{-5}$	$7.7×10^{-5}$	$1.9×10^{-5}$	$8.9×10^{-5}$	$9.3×10^{-5}$

Table 6. Calculated EDIM for Children from Sample Sites

Sample sites	Cabbage				Lettuce			
	Cd	Cr	Mn	Pb	Cd	Cr	Mn	Pb
KSL	$1.34×10^{-4}$	$4.7×10^{-5}$	$1.5×10^{-5}$	$6.5×10^{-5}$	$9.9×10^{-5}$	$4.7×10^{-5}$	$5.1×10^{-5}$	$6.2×10^{-5}$
GYL	$8.7×10^{-5}$	$2.9×10^{-5}$	$2.1×10^{-5}$	$5.1×10^{-5}$	$1.2×10^{-4}$	$6.6×10^{-5}$	$1.3×10^{-4}$	$8.7×10^{-5}$
MRL	$2.37×10^{-4}$	$5.1×10^{-5}$	$9.5×10^{-5}$	$1.1×10^{-4}$	$1.3×10^{-4}$	$5.1×10^{-5}$	$5.8×10^{-5}$	$8.0×10^{-5}$
MKL	$1.4×10^{-4}$	$8.0×10^{-5}$	$2.6×10^{-5}$	$5.8×10^{-5}$	$2.1×10^{-4}$	$8.4×10^{-5}$	$6.6×10^{-5}$	$1.8×10^{-5}$
RKL	$1.1×10^{-4}$	$5.1×10^{-5}$	$3.6×10^{-5}$	$4.4×10^{-5}$	$1.4×10^{-4}$	$1.8×10^{-5}$	$1.3×10^{-4}$	$1.8×10^{-5}$
NGL	$6.6×10^{-5}$	$2.9×10^{-5}$	$3.6×10^{-5}$	$3.3×10^{-5}$	$1.2×10^{-4}$	$2.9×10^{-5}$	$1.5×10^{-4}$	$1.6×10^{-4}$
BOL	$6.2×10^{-5}$	$6.6×10^{-5}$	$4.0×10^{-5}$	$3.3×10^{-5}$	$7.3×10^{-5}$	$1.8×10^{-5}$	$8.4×10^{-5}$	$8.7×10^{-5}$

Table 7. Calculated DIM for Adult from Sample Sites

Sample sites	Cabbage				Lettuce			
	Cd	Cr	Mn	Pb	Cd	Cr	Mn	Pb

KSL	1.7×10^{-3}	5.9×10^{-4}	1.9×10^{-4}	8.2×10^{-4}	1.2×10^{-3}	5.9×10^{-4}	6.4×10^{-4}	7.7×10^{-4}
GYL	1.1×10^{-3}	3.6×10^{-4}	2.7×10^{-4}	6.4×10^{-4}	1.5×10^{-3}	8.2×10^{-4}	1.6×10^{-3}	1.1×10^{-3}
MRL	2.9×10^{-3}	6.4×10^{-4}	1.2×10^{-3}	1.3×10^{-3}	1.6×10^{-3}	6.4×10^{-4}	7.3×10^{-4}	1.0×10^{-3}
MKL	1.7×10^{-3}	1.0×10^{-3}	3.1×10^{-4}	1.1×10^{-3}	2.6×10^{-3}	1.0×10^{-3}	8.1×10^{-4}	2.3×10^{-4}
RKL	1.3×10^{-3}	6.4×10^{-4}	4.5×10^{-4}	5.5×10^{-4}	1.9×10^{-3}	2.3×10^{-4}	1.6×10^{-3}	2.3×10^{-4}
NGL	8.1×10^{-4}	3.6×10^{-4}	4.5×10^{-4}	4.1×10^{-4}	1.5×10^{-3}	3.6×10^{-4}	1.8×10^{-3}	2.0×10^{-3}
BOL	7.7×10^{-4}	8.2×10^{-4}	5.0×10^{-4}	4.1×10^{-4}	9.0×10^{-4}	2.3×10^{-4}	1.0×10^{-3}	1.1×10^{-3}
STD	0.001	0.003	0.140	0.0035	0.001	0.003	0.140	0.0035

Table 8. Calculated DIM for Children from Sample Sites

Sample sites	Cabbage				Lettuce			
	Cd	Cr	Mn	Pb	Cd	Cr	Mn	Pb
KSL	1.6×10^{-3}	5.6×10^{-4}	1.7×10^{-4}	7.7×10^{-4}	1.1×10^{-3}	5.6×10^{-4}	6.0×10^{-4}	7.3×10^{-4}
GYL	1.0×10^{-3}	3.4×10^{-4}	2.6×10^{-4}	6.0×10^{-4}	1.5×10^{-3}	7.7×10^{-4}	1.5×10^{-3}	1.0×10^{-3}
MRL	2.8×10^{-3}	6.0×10^{-4}	1.1×10^{-3}	1.2×10^{-3}	1.5×10^{-3}	6.0×10^{-4}	6.9×10^{-4}	9.4×10^{-4}
MKL	1.6×10^{-3}	9.4×10^{-4}	3.0×10^{-4}	6.9×10^{-4}	2.4×10^{-3}	9.9×10^{-4}	7.7×10^{-4}	2.1×10^{-4}
RKL	1.2×10^{-3}	6.0×10^{-4}	4.3×10^{-4}	5.1×10^{-4}	1.8×10^{-3}	2.1×10^{-4}	1.5×10^{-3}	2.1×10^{-4}
NGL	7.7×10^{-4}	3.4×10^{-4}	4.2×10^{-4}	3.9×10^{-4}	1.4×10^{-3}	3.4×10^{-4}	1.7×10^{-3}	1.9×10^{-3}
BOL	7.3×10^{-4}	7.7×10^{-4}	4.7×10^{-4}	3.9×10^{-4}	8.6×10^{-4}	2.1×10^{-4}	9.9×10^{-4}	1.0×10^{-3}
STD	0.001	0.003	0.140	0.0035	0.001	0.003	0.140	0.0035

Table 9. Calculated HRI for Adult from Sample Sites

Sample Sites	Health Risk Index (HRI)							
	Cabbage				Lettuce			
	Cd	Cr	Mn	Pb	Cd	Cr	Mn	Pb
KSL	1.70	0.19	1.4×10^{-3}	0.23	1.2	0.19	4.6×10^{-3}	0.22
GYL	1.1	0.12	1.9×10^{-3}	0.18	1.5	0.27	0.01	0.31
MRL	2.9	0.21	8.6×10^{-3}	0.37	1.6	0.21	5.2×10^{-3}	0.29
MKL	1.7	0.33	2.2×10^{-3}	0.31	2.6	0.33	5.8×10^{-3}	0.07
RKL	1.3	0.21	3.2×10^{-3}	0.16	1.9	0.08	0.01	0.07
NGL	0.81	0.12	3.2×10^{-3}	0.12	1.5	0.12	0.01	0.57
BOL	0.77	0.27	3.6×10^{-3}	0.12	0.9	0.08	7.1×10^{-3}	0.31

Table 10. Calculated HRI for Children from Sample Sites

Sample sites	Health Risk Index (HRI)							
	Cabbage				Lettuce			
	Cd	Cr	Mn	Pb	Cd	Cr	Mn	Pb
KSL	1.6	0.18	1.2×10^{-3}	0.22	1.1	0.18	4.3×10^{-3}	0.21
GYL	1.0	0.11	1.9×10^{-3}	0.17	1.5	0.26	0.01	0.29
MRL	2.8	0.20	7.9×10^{-3}	0.34	1.5	0.20	4.9×10^{-3}	0.26
MKL	1.6	0.31	2.1×10^{-3}	0.19	2.4	0.33	5.5×10^{-3}	0.06
RKL	1.2	0.20	3.1×10^{-3}	0.15	1.8	0.07	0.01	0.06
NGL	0.77	0.11	3.0×10^{-3}	0.11	1.4	0.11	0.01	0.54
BOL	0.73	0.26	3.4×10^{-3}	0.11	0.86	0.07	7.0×10^{-3}	0.29

Table 11. Calculated HQ for Adults

Sample sites	Hazard Quotient (HQ)							
	Cabbage				Lettuce			
	Cd	Cr	Mn	Pb	Cd	Cr	Mn	Pb
KSL	6.73	0.79	5.19×10^{-3}	0.94	4.91	0.79	0.02	0.88
GYL	4.36	0.48	7.8×10^{-3}	0.73	6.36	1.09	0.05	1.25
MRL	11.81	0.85	0.03	1.51	6.36	0.85	0.02	1.14
MKL	6.91	1.33	9.1×10^{-3}	0.83	10.36	1.39	0.02	0.24
RKL	5.27	0.85	0.01	0.62	7.45	0.30	0.05	0.26
NGL	3.27	0.48	0.01	0.47	6.18	0.48	0.05	2.34
BOL	3.09	1.09	0.01	0.47	3.64	0.30	0.03	1.25

Table 12. Calculated HQ for Children

Sample sites	Hazard Quotient (HQ)							
	Cabbage				Lettuce			
	Cd	Cr	Mn	Pb	Cd	Cr	Mn	Pb
KSL	10.57	1.24	8.16×10^{-3}	1.47	7.71	1.24	0.03	1.39
GYL	6.86	0.76	0.01	1.14	9.71	1.71	0.07	1.96
MRL	18.57	1.33	0.05	2.37	10.00	1.33	0.03	1.79
MKL	10.86	2.09	0.01	1.31	16.29	2.19	0.04	0.41
RKL	8.29	1.33	0.02	0.98	11.71	0.48	0.08	0.41
NGL	5.14	0.76	0.02	0.73	9.71	0.76	0.08	3.67
BOL	4.86	1.71	0.02	0.73	5.71	0.48	0.05	1.96

Table 13. Descriptive statistics and Correlation tables for Lettuce

Descriptive Statistics

	Mean	Std. Deviation	N
Cadmium	.32714	.139755	21
Chromium	.11905	.062041	21
Manganese	.25762	.095284	21
Lead	.23000	.121614	21

Table 14. Correlations

		Cadmium	Chromium	Manganese	Lead
Cadmium	Pearson Correlation	1	-.132	.253	-.207
	Sig. (2-tailed)		.569	.268	.368
	N	21	21	21	21
Chromium	Pearson Correlation	-.132	1	-.380	-.449*
	Sig. (2-tailed)	.569		.089	.041

	N	21	21	21	21
Manganese	Pearson Correlation	.253	-.380	1	.301
	Sig. (2-tailed)	.268	.089		.185
	N	21	21	21	21
Lead	Pearson Correlation	-.207	-.449*	.301	1
	Sig. (2-tailed)	.368	.041	.185	
	N	21	21	21	21
*. Correlation is significant at the 0.05 level (2-tailed).					

Descriptive statistics and Correlation tables for Cabbage

Table 15. Descriptive Statistics

	Mean	Std. Deviation	N
Cadmium	.35333	.161967	21
Chromium	.14381	.065915	21
Manganese	.16476	.086754	21
Lead	.15619	.074530	21

Table 16. Correlations

		Cadmium	Chromium	Manganese	Lead
Cadmium	Pearson Correlation	1	-.323	.537*	.592**
	Sig. (2-tailed)		.154	.012	.005
	N	21	21	21	21
Chromium	Pearson Correlation	-.323	1	-.153	-.189
	Sig. (2-tailed)	.154		.508	.411
	N	21	21	21	21
Manganese	Pearson Correlation	.537*	-.153	1	.651**
	Sig. (2-tailed)	.012	.508		.001
	N	21	21	21	21
Lead	Pearson Correlation	.592**	-.189	.651**	1
	Sig. (2-tailed)	.005	.411	.001	
	N	21	21	21	21
*. Correlation is significant at the 0.05 level (2-tailed).					
**. Correlation is significant at the 0.01 level (2-tailed).					

Discussion

The levels of Lead (Pb), Cadmium (Cd), Chromium (Cr) and Manganese (Mn) were analyzed in the Roots, Stems and Leaves of Cabbage and Lettuce. The sampling locations were Kassa, GonanYashi, Marit, Maraban Kantoma, Rakung, Ngwetti, and Boyi of BarkinLadi LGA of Plateau State. All analyses were performed in triplicate and compared with the World Health Organization (WHO, 2014).

Cr level of vegetables from the analysis of Cabbage was within the range of 0.32 mg/kg in Boyi Roots (BOR) and 0.05 mg/kg in MRR. The recommended maximum limit of Cadmium for vegetables by

FAO/WHO (2011) is 2.3 mg/kg. All the elements investigated in the samples were within the range of the permissible limit. Cr level of vegetables from the analysis of Lettuce was within the range of 0.23 mg/kg in MKL and 0.04 mg/kg in Ngwetti Stems (NGS). All the samples were within the range of the permissible limit, except for RKS which was Below Detection Limit (BDL).

Mn level of vegetables from the analysis of Cabbage was within the range of 0.37 mg/kg in Marit Roots (MRR) and 0.04 mg/kg in KSL. The recommended maximum limit of Manganese for vegetables by FAO/WHO (2011) is 1.50 mg/kg. All the samples were within the range of the permissible limit. Mn level of vegetables from the analysis of Lettuce was within the range of 0.45 mg/kg in RKS and 0.10 mg/kg in KSS. All the samples were within the range of the permissible limit. As low level of manganese intake are essential for human health but exposure to high level of manganese are toxic. Inhaled manganese is directly transported to brain before metabolized to liver. Permanent neurological disorder known as magnetism is a result of manganese toxicity and symptoms of that is tremors, difficulty walking and facial muscle spasms. High level of manganese inhalation can cause series of serious and disabling neurological effects in humans (ATSDR).

Pb level of vegetables from these the analysis of Cabbage ranged between 0.35 mg/kg in MRR and 0.08 mg/kg in NGS. The recommended maximum limit of Lead for vegetables by FAO/WHO 2011 is 0.2 mg/kg. All the samples were within the range of the permissible limit, except MRR which was detected to have exceeded the permissible limit. Pb level of vegetables from these the analysis of Lettuce ranged between 0.51 mg/kg in NGS and 0.05 mg/kg in MKL & RKL. Most of the samples were within the range of the permissible limit, except MRR, NGS, NGL, BOR and BOS were dictated to have exceeded the permissible limit. The Lead poisoning mainly affects Nervous system. It can causes weakness in fingers, wrists or ankles. Small increases in blood pressure especially in middle aged and can cause anemia. High levels of lead cause brain and kidney damage leading to death. In case of pregnant woman higher lead levels cause miscarriage and in men they destroy sperm producing organ. The harmful effects of Pb to unborn children include smaller babies, premature births and decreased memory of infants and growth problems (ASTDR).

Tab 3 is the calculated Metal Pollution Index (MPI) for the samples, in the table; the calculated MPI is low indicating that the samples are safe for consumption since the index of pollution is below the maximum acceptable limits of each element investigated.

Tab 4 and Tab 5 is the calculated Estimated Daily Intake for Adult and Children respectively. The results also showed low metal intake in the vegetable samples, thus the samples can be said to be safe for consumption.

Tab 6 and Tab 7 is the calculated Daily Intake of Metals for Adult and Children respectively. Comparing these results with the permissible limits of daily intake, all the investigated heavy metals concentration indicated low intake, and thus the samples are safe for consumption. These results showed some agreement with previous studies showing levels of heavy metals in edible part of food crops irrigated with wastewater (Oluwole *et al.,* 2013; Adesuyi *et al.,* 2015; Singh *et al.,* 2010)

Tab 8 and Tab 9 is the calculated Health Risk Index for Adult and Children respectively, which was computed as described by Jan et al.(2010). The HRI less than 1 means exposed population said to be safe (US-EPA IRIS, 2006). In this table, Cd in both samples shows a high risk index, particularly for samples Kassa Leaves (KSL), Boyi Leaves (BYL), Marit Leaves (MRL), Mararaban Kantoma Leaves (MKL), Rakung Leaves (RKL) and Gonan Yashi Leaves (GYL) for Lettuce sample. This shows that the accumulated intake of samples over time could pose serious heavy metal health risk upon consumption as reported by other researchers (Achakzai *et al.,* 2011; Khan *et al.,* 2010; Waalkes, 2000). The HRI less than 1 for Cr, Mn and Pb through consumption of all the vegetables of the studied area suggest that vegetables collected from all the sample sites in respect to Cr, Mn and Pb are safe for consumption and the result is in agreement with those reported by Achakzai et al (2011) and Islam et al 2014;

Tab 10 and Tab 11 is the calculated Hazard Quotient (HQ) for Adult and Children respectively, in each sample, Cd, Cr and Pb pose potential hazard upon consumption over time. The health protection standard of life time risk for HQ is 1.0 (Islam *et al.,* 2014; Wong *et al.,* 2009). These results showed that the vegetables in these sites could cause health threat upon consumption, particularly for Cd, Cr and Pb with calculated Hazard Quotient greater than 1 for both adults and children (Adesuyi *et al.,* 2015; Divrikli *et al.,* 2006)

The charts for each sample showing the relative index of concentration in Cabbage are as shown in Appendix 3 – Appendix 9, whereas, that of the Lettuce is displayed in Appendix 10 – Appendix 16.

In Kassa Cabbage, the root shows high concentration in Cd, followed by the leaf and stems, whereas for Mn the roots was high followed by the stems then the leaf, this is probably because Mn is a micro element and transportation is low, for Cr and Pb the 3 parts of the samples show relatively equal concentration of the elements, giving concordance with the work of Oluwale *et al.,* 2013.

In Gonan Yashi Cabbage, the stem shows high concentration in Cd while leaf and root show relatively equal concentration. For Cr, the root and stem are relatively equal, while the leaf has a low concentration. For Mn, the root has a high concentration, followed by the stem and leaf in a relatively equal concentration. For Pb, the leaf is high, followed by the root and stem which are equal in concentration.

In Marit Cabbage, the root and leaf are high and relatively equal concentration in Cd, followed by the stem. Cr, Mn and Pb have relatively equal concentration of the elements.

In Maraban Kantoma Cabbage, stem and leaf are relatively equal followed by root for Cd. For Cr, leaf is high followed by root and stem which are relatively equal in concentration. For Mn, the root is high followed by the stem and leaf respectively. For Pb, the root and leaf are in relatively equal concentration followed by the stem.

In Rakung Cabbage, the root and stem showed high levels of heavy metals and are in a relatively equal concentration followed by the leaf. For Cr, Mn and Pb the 3 parts are relatively equal concentration of the elements.

In Ngwetti Cabbage, the root shows a high concentration, followed by the stem and leaf which are in a relatively equal concentration for Cd. For Mn, the root has an average concentration followed by the stem and leaf which have a relatively high concentration. Cr and Pb, have relatively equal concentration of elements.

In Boyi Cabbage, the root has a high concentration followed by the stem and the leaf respectively for Cr. Cd, Mn and Pb are in a relatively equal concentration for all the 3 parts.

In Kassa Lettuce, the root has a high concentration followed by stem and leaf for cd. Cr, Mn and Pb are in relatively equal concentration of elements for all the 3 parts.

In Gonan Yashi Lettuce, the leaf for Cd and the leaf for Mn have a relatively high concentration followed by their roots and stems. Cr is in relatively equal concentration for all the 3 parts. For Pb, the leaf is high followed by the root and stem which are equal in concentration.

In Marit Lettuce, Cd, Mn and Pb are in relatively equal concentrations in all the 3 parts. For Cr the stem is at an average concentration, followed by the root and leaf. For Cr, the stem has an average concentration, while the root and leaf are in a relatively high concentration.

In Maraban Kantoma Lettuce, the leaf sample matrix showed high concentration, while the stem is low and the root is below detectable limit for Cd. Cr, Mn and Pb are in relatively equal concentration in all the 3 parts.

In Rakung Lettuce, the stem of Cd and Mn is high followed by the leaf and root respectively for Cd. For Pb, root and stem are at an average concentration and are relatively equal in concentration followed by the leaf. For Cr, the root and leaf are low and relatively equal, while the stem is below detectable limit.

In Ngwetti Lettuce, Cd is high in the root, followed by the stem and leaf respectively, while Pb is high in the stem, followed by leaf and root respectively. For Mn, the leaf is high, followed by the stem and root which have equal concentration of the element. For Cr, the concentration is low in the stem, followed by the leaf and root respectively.

In Boyi Lettuce, the root is high followed by the stem and root respectively for Cd, Mn and Pb in all the 3 parts of the sample and the concentrations are relatively equal. While Cr is low and has a relatively equal concentration of elements. This study concludes that different vegetables accumulate and translocate variable amount of heavy metals from the soil into their tissues. Hence, it is not advisable to consume vegetable samples collected from this site based on the permissible limits as recommended by World Health Organization, WHO (2014). This concurred with the works of many other researchers (Mafuyai *et al.,* 2019; Aytekin *et al.,* 2019; Adesuyi *et al.,* 2015; Zheng *et al.,* 2015; Zhao *et al.,* 2014; Ahmed *et al.,* 2012). Generally, the trend of metal bioaccumulation showed that Cd > Mn > Pb > Cr in all sample matrices.

Correlation

Table 12 is the descriptive statistic and correlation tables for Lettuce samples, the result shows that Cd and Cr have a good correlation, while Pb and Mn show significant correlation, this implies that elements are from the same sample or species. Generally, correlation is significant at 2-tailed 95% confidence level. For lettuce vegetable, only chromium has a significant negative correlation with lead. This indicates that the metals have variant sources and the concentration inversely proportionate. Table 13 is the descriptive statistic and correlation tables for cabbage samples. This table indicated that Cd correlated significantly at 2-tailed 99% confidence level with Mn and Pb and are strongly correlated, while Mn shows strong correlation with Cr and Pb at 2-tailed 95% confidence level. It indicates that the elements could be from the same source or species (Adesuyi *et al.,* 2015; Oluwole *et al.,* 2013; Nangbes *et al.,* 2013; Singh *et al.,* 2010).

Conclusion

The research has brought to bear the heavy metal pollution levels of the elements investigated and showed that their high level of potential heavy metal pollution either in the agricultural soil or the abandoned tin mining ponds. This study concludes that different vegetables accumulate and translocate variable amount of heavy metals from the soil into their tissues. Hence, it is not advisable to consume vegetable samples collected from this site based on the permissible limits as recommended by World Health Organization (WHO).

This could pose high health risk upon consumption of agricultural products produced from these natural resources over time. Thus the need for a practical and deliberate remediation action to be taken so as to avert the pending consequential health effects of heavy metal pollution on the biotic lives in and around these resources.

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