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Health risk assessment of heavy metals in some vegetables grown along Kilange river of Adamawa State, Nigeria

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Abstract:
One major route heavy metal accumulation/expose to humans is via vegetables consumption. The main objective of this research work was to assess heavy metals in some vegetables grown along the Kilange River. A total of sixteen (16) plants samples were collected and analyzed for heavy metals (Zn, Mn, Fe, Cr, Ni, Cd, Pb, Hg, Se, Ag, and As.) using X-ray Fluorescence spectrophotometry, following standard procedures. Results were found to contain all the analysed heavy metals (except As, Hg, Se, and Ag) at different levels. Plants: Amaranthus Fe (0.514±0.001 - 2.41±0.002 mg/kg) are all below standard permissible limit of 100 mg/kg, Cd (0.356±0.002 – 0.605±0.314 mg/kg) which are above standard acceptable value. Rossele: Fe (0.2011±0.002 -3.924±0.003 mg/kg), Cd (0.005 ±0.315-0.551±0.00151mg/kg) and Zn (0.05±0.01-s0.094±0.002 mg/kg) are all below permissible limit, except Cd above WHO/FAO standard of (0.02 mg/kg), Onion: Fe (2.02±0.01 -5.01±0.01 mg/kg) Mn (0.07±0.02-0.57±0.02 mg/kg), Cr (0.1±0.01-0.15 ±0.01mg/kg), Zn (0.1 ±0.217-0.21±0.01 mg/kg), all were below WHO/FAO acceptable standard limits. Pb, Cd, Ni, Hg, and Ag are below detection limit in both dry and wet season. Tomatoes: Fe (3.20±0.1-4.57±0.02 mg/kg), Mn (0.10±0.01-2.61±0.02 mg/kg), Cr (0.02±0.144- 0.07±0.01 mg/kg) and Zn (0.05±0.01 -0.19±0.01 mg/kg). Health quotient and health index are below one (1) which all values agreed with WHO/FAO standard permissible limits. Other heavy metal were below detection limits. These vegetables are safe for human consumption.

Keywords: *Health risk Assessment, Kilange River, Heavy metals, Vegetables*

1. Introduction

According to World Health Organization (WHO), food security is achieved when "everyone and always" have access to "sufficient and safe" food. Fruits and vegetables are important components of healthy diet. Reduced fruit and vegetable consumption are linked to poor health and increased risk of communicable diseases. An estimated 9.9 million deaths worldwide were attributed to inadequate fruit and vegetable consumption [1]. Vegetables are important component of human diet because of high nutritional value and antioxidants. However, Leafy and tuberous vegetables tend to accumulate higher concentration of heavy metals than grains and fruits. Some studies across the globe have revealed that high content of heavy metals in vegetables cultivated with waste water [2]. Water can percolate and infiltrate from wastewater drain to the adjoining areas and the content of metals in plants growing in the vicinity of wastewater drain can also be significantly elevated which can cause serious problems to the society. Heavy metals are considered as hazardous chemicals in the environment. Nonessential heavy metals are toxic to plants, animals, and humans at very low concentrations. Even the essential heavy metals also cause adverse health effects at high concentrations [3].

Heavy metals pollution is threat to our environment as they are most prominent contaminating agents of our food supply, especially vegetables [4]. Metals being tenacious, keep accumulating and magnifying with increase in trophic level of food chain. Heavy metals in soil contains a potential threat to the environment and can cause damage to human health through various absorption pathways such as direct ingestion, dermal contact, and diet through the soil–food chain, inhalation, and oral intake [5]. Heavy metal pollutants most common in the environment are Cr, Mn, Ni, Cu, Zn, Cd, and Pb [6]

Accumulation of heavy metals beyond permissible limits affects vital organs like, kidneys, bones, liver and blood, causing serious health hazards. Health effects associated with heavy metals like, cadmium, copper, lead and chromium include gastrointestinal effects, renal impairment, neurological disorders, cardiovascular troubles, bone problems, convulsions, paralysis etc. Metals, because of their solubility in water, are toxic and the toxicity can be acute or chronic dependent upon exposure-time [7]

The soil-to-plant transfer of heavy metals is a very important step in the trophic transfer of such metals in food chains. These metals are taken up by plants from polluted soil and subsequently transferred to herbivorous animals along the food chain [8]. Despite contamination of the human food chain, contamination of crops such as cereals and vegetables are another serious issue. Consumption of vegetables and cereals contaminated with toxic heavy metals may cause risk to human health [9].

2. Materials and methods

2.1 Study Area

The Kilange river catchment covers an area of 4955 km^2 encompassing parts of Fufore, Song, Gombi, and Hong, Local Government Areas of Adamawa state, Nigeria. It is located between latitudes 9° 23′ 26'' N to 10° 19′ 00'' N and longitudes 12° 15′ 00' E to 13° 17′ 25'' as shown in Figure 1 below. This research work was carried out in some selected farmlands of villages along Kilange River in four (4) local government areas of Adamawa state.

2.2 Samples collection, treatment and preservation

The Sampling and preservation of samples were carried out as prescribed by APHA method [10]. In the field, some vegetable samples were collected from eight different farm locations along Kilange river in Adamawa state. These farms were located at Wuro-bokki (WB), Wuro-yolde (WY), Geleng (GE), Muleng (MU), Guriki (GU), Wuro Alhaji (WA), Zhyidinyi (ZY) and Dhirwachilla (DW) sampling plots as shown in Figure 1. Between (January and March 2020), for dry season in each plot, and from (July and September 2020) for Wet Season in each plot.

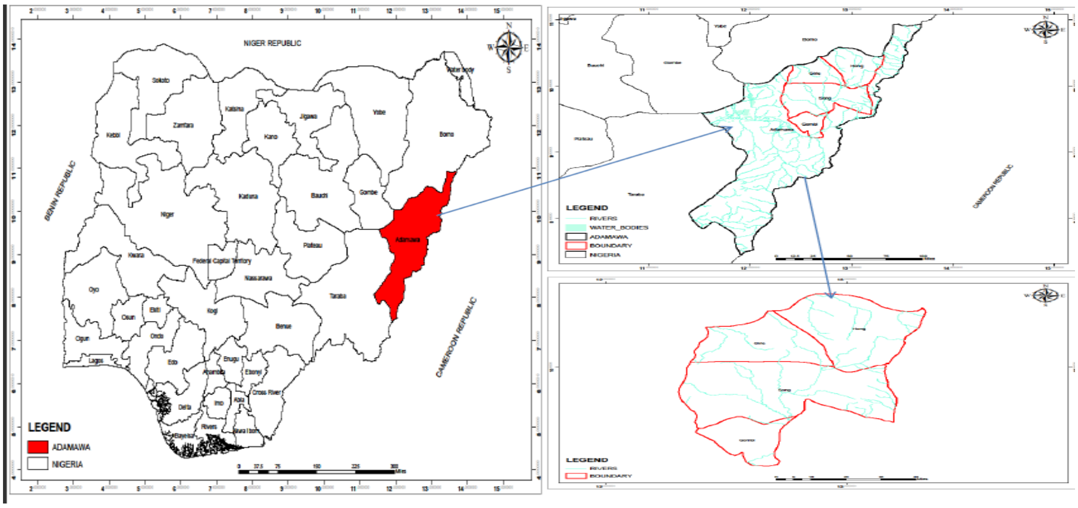

Figure 1: Map of the study area showing sample location

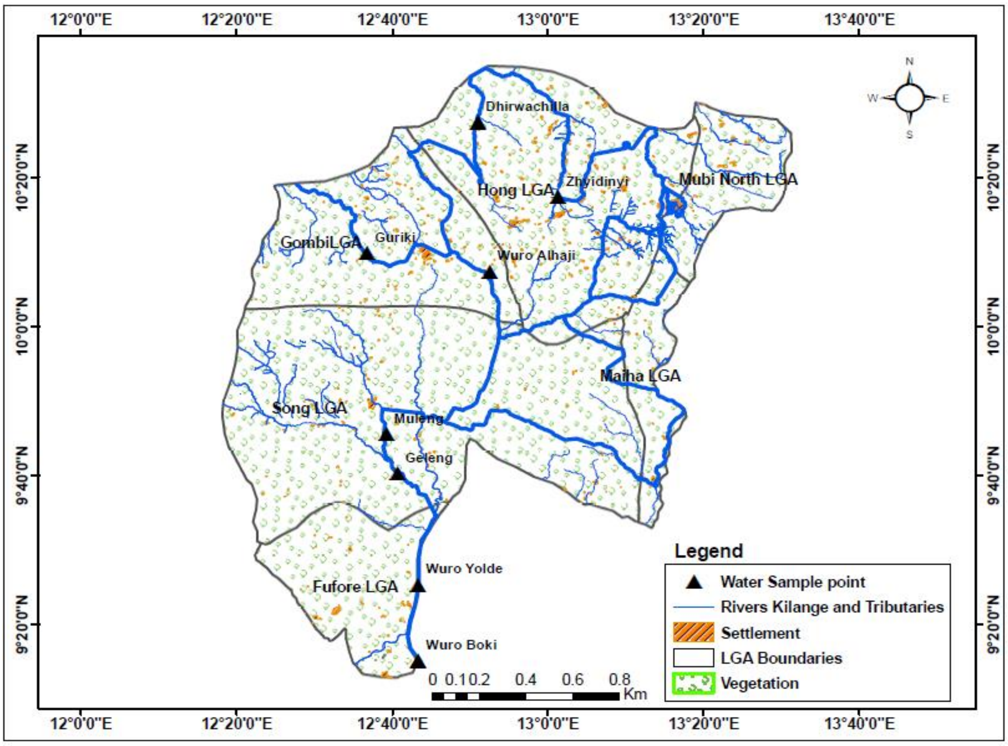

Figure 2: Map of the sampling area

Vegetables were sampled at each point, in both dry season and wet season, (*Amaranthus cruentus,* Rossele *(hibiscus sabdariffa),* onion *(Allium cepa) and* Tomatoes (*Solanum lycapersicum*) from the farmlands along Kilange river site was freshly harvested from eight farmlands and package into labeled paper bags, and transport to the Chevron Biotechnology Centre Moddibo Adama University, yola laboratory. The vegetable samples were washed with running tap water to removed sand and debris and followed by Distilled water, and air dried in the laboratory, collected samples are then divided into roots and leaf. Air dried samples were (roots and leaves) are crushed, ground into fine powder by using mortar and pistil, which pass through 2mm mesh sieve. The samples were stored in polyethylene zip -type bags and label for further analysis. Vegetables samples (roots and leaves) were analyzed for the essential elements and heavy metals.as reported by [11].

2.3 X-Ray fluorescence spectrometry (XRF)

X-Ray Fluorescence Spectrometer (XRF) was used for the determination of heavy metals and essential elements contents of the plants samples as described by [12]. Where 2.0g of powdered samples was fused with 0.40g of stearic acid in 20ml platinum crucible and it was pressed with hydraulic press to obtain soil pellets. The plants pellets formed were exposed to short wave length x-ray radiation. Ionization takes place and ejection of inner electron shell takes place. Electron from outer electron shells falls into the lower shells to fill the space left behind and fluorescence radiation (energy) is released. The energy of which is equal to or characteristics of the atom present. The fluorescence radiation (energy) released is then evaluated by a detector.

2.4 Health risk and calculations

Health risks assessment has to do with evaluating the risk to a particular organism or population following exposure to certain chemical agent(s) by taking into consideration the characteristics of the agent and the target system it affects. The model for health risk assessment begins with formulation of a problem followed by identification of hazard, characterization of hazard, assessment of exposure and then risk characterization [13]. Food crops like vegetables, tubers, fruits and nuts cultivated in contaminated lands can amass toxic heavy metals. The soil in these areas is the principal source of these toxicants. Human exposure to toxic heavy metals is via inhalation of dust, contact with the soil, and intake of contaminated water and food crops. Heavy metals via food accumulate in the several organs causing altered metabolism in liver and kidney, cardiovascular, nervous and bone disorders [14].

2.5 Daily intake rate (DIR)

The Daily Intake Rate (DIR) is calculated as the average metal content in each vegetable multiplied by the respective consumption rate. Daily Intake Rate (DIR) is determined by the following equation 1:

$$DIR = C\,(Metal\ conc.) \times C\,(Factor) \times D\,(Vegetable\ intake) \qquad (1)$$

Where, C (Metal conc.) = Heavy metal concentration in vegetables (mg/kg); C (Factor) = conversion factor (0.085); D (Vegetable intake) = Daily Intake of Vegetable (kg person-1day-1 FW) Calculations were made with reference to the standard assumption for an integrate USEPA risk analysis, considering adults and children with average body weights of 60 kg and 32.7 kg respectively. Average daily consumption of vegetables, fruits and nuts for adults and children was considered to be 0.345 kg person-1 day-1 and 0.173 kg person-1 day-1 respectively. Average daily consumption of tubers for adults and children was considered to be 0.418 kg person-1 day-1 and 0.209 kg person-1 day-1 respectively [15].

2.6 Estimated daily intake of heavy metals

The estimated or average daily vegetable intake rate (ADI) (mg kg-1) will be calculated by assuming the average body weight (BW) of 60 kg and 32.7 kg adult and child and the average daily intake for adults and children were set to 0.345Kg and 0.173kg person-1day-1 (expressed as fresh weight), as in equation 2:

$$EDIM = \frac{C\ X\ IR\ X\ Cf}{BW} \qquad (2)$$

Where: *C* = Contaminant concentration in vegetable (mg kg-1), *IR* = Ingestion rate per unit time or Event (kg day^{-1}), *Cf* = conversion factor, *BW* = Body weight.

2.7 Hazardous Quotient (HQ)

Hazardous Quotient (HQ) for the locals (consumers) through the consumption of contaminated vegetables was assessed by the ratio of Daily Intake Rate (DIR) to the oral reference dose (Rf Do) for each metal. If the value of HQ is less than 1, then the exposed local population (consumers) is said to be safe, if HQ is equal to or higher than 1, is considered as not safe for human health, therefore potential health risk occurred, and related interventions and protective measurements should be taken. An estimate of risk to human health (HQ) through consumption of vegetables grown in metal contaminated soil was calculated by the following equation 3:

$$HQ = \frac{EDIM}{RfDO} \qquad (3)$$

Where, *RfDo* is the oral reference dose. Rf Do is an estimate of a daily oral exposure for the human population, which does not cause deleterious effects during a lifetime [16].

2.8 Hazard index (HI)

An exposure to more than one pollutant results in additive effects. Thus, hazard index (HI) is a vital index that assesses overall likely impacts that can be posed by exposure to more than one contaminant. When the HI is >1, this suggests that there are significant health effects from consuming pollutants contained in a foodstuff. The HI is calculated as an arithmetic sum of the hazard quotients for each pollutant as shown in the following equation 4:

$$HI = \sum HQ\ Where, HI = hazard\ index, \sum = Summation \qquad (4)$$

HQ = hazard quotient of a heavy metal [16]

Carcinogenic risk and slope factors (CSF)

As described by [17], ingestion cancer slope factors are used to evaluate the lifetime (average of 70 years) probability of contracting cancer due to certain levels of exposure to a potential carcinogen. The carcinogenic risk is expressed as in equation 5 and 6:

$$CR = EDIM * CSFing \qquad (5)$$

$$TCR = \sum EDIM * CSFing \qquad (6)$$

Where CR, EDIM and CSFing TCR, are the carcinogenic risk, estimated daily intake of heavy metals and ingestion cancer slope factor, Total carcinogenic risk respectively. Carcinogenic risk index between 10^{-6} (1 in 1,000,000) and 10^{-4} (1 in 10,000) indicates an interval of allowable predicted lifetime risks for cancer a causing agent. Thus, chemicals having risk factors less than 10^{-6} may not be treated as chemicals for further concern [13].

3. Result and discussion

The result of daily intake of heavy metals from some plant and leaves species (Rossele leaves, Amaranthus leaves, Tomatoes and Onions) grown in wet and dry season along Kilange River in adults and children were shown in Table 1 to 8.

From the current investigation Tables 1 and 8 it can be seen that the health risk assessment of heavy metals in plants samples range of the estimated daily intake of Fe for adults and children in the vegetables in dry season were: Rossele leaves; 5.91E-05 to 1.24E-03 and 5.44E-05 to 1.14E-03, Tomato; 2.71E-04 to 2.23E-03 and 1.31E-03 to 2.06E-0; Onion; 9.87E-04 to 2.47E-03 and 9.08E-04 to 2.16E-03 respectively which were slightly higher than the corresponding wet season with values: Rossele leaves; 1.24E-04 to 4.45E-04and 1.14E-04 to 4.09E-04, Tomato; 1.60E-03 to 2.20E-03 and1.40E-03 to 2.01E-03; Onion; 1.32E-03 to 2.84E-03 and 1.22E-03 to 2.25E-03. The Fe intake is slightly higher in adults than in children.

Table 1a: Estimated daily intake of heavy metals (mg/kg/day) of adult in Rossele leaves in dry season

Sampling site	Dry season	Fe	Mn	Pb	Cr	Cd	Co	Zn	Ni	Hg
WB	R. leaves	1.24E-03	0	0	0	2.69E-04	0	0	0	0
WY	R. leaves	7.69E-05	0	0	0	1.88E-04	0	3.47E-05	0	0
GE	R. leaves	1.19E-04	0	0	0	1.68E-04	0	2.44E-05	0	0
MU	R. leaves	1.54E-04	0	0	0	2.44E-06	0	0	0	0
GU	R. leaves	1.24E-04	0	0	0	0	0	0	0	0
WA	R. leaves	5.91E-05	0	0	0	2.93E-07	0	1.52E-05	0	0
ZY	R. leaves	9.82E-05	0	0	0	1.47E-06	0	7.33E-06	0	0
DW	R. leaves	1.19E-03	0	0	0	5.96E-05	0	0	0	0

Table 2b: Estimated daily intake of heavy metals (mg/kg/day) of children in Rossele leaves in dry season

Sampling site	Dry season	Fe	Mn	Pb	Cr	Cd	Co	Zn	Ni	Hg
WB	R. leaves	1.14E-03	0	0	0	2.48E-04	0	0.00E+00	0	0
WY	R. leaves	7.07E-05	0	0	0	1.73E-04	0	3.19E-05	0	0
GE	R. leaves	1.09E-04	0	0	0	1.55E-04	0	2.25E-05	0	0
MU	R. leaves	1.42E-04	0	0	0	2.24E-06	0	0.00E+00	0	0
GU	R. leaves	1.13E-04	0	0	0	0.00E+00	0	0	0	0
WA	R. leaves	5.44E-05	0	0	0	5.39E-03	0	1.39E-05	0	0
ZY	R. leaves	9.03E-05	0	0	0	2.69E-03	0	6.75E-06	0	0
DW	R. leaves	1.09E-03	0	0	0	1.09E-01	0	0	0	0

Table 3a: Estimated daily intake (mg/kg/day) of heavy metals of adult in Rossele leaves in wet season

Sampling site	Wet season	Fe	Mn	Pb	Cr	Cd	Co	Zn	Ni	Hg
WB	R. leaves	1.97E-04	1.03E-5	0	0	0	0	4.89E-06	0	0
WY	R. leaves	2.83E-04	9.78E-06	0	0	0	0	4..89E-06	0	0.00E+00
GE	R. leaves	1.24E-04	3.08E-05	0	0	0	0	0	0	0.00E+00
MU	R. leaves	2.49E-04	1.12E-05	0	0	0	0	4.89E-06	0	0
GU	R. leaves	2.59E-04	2.98E-05	0	0	0	0	0	0	0
WA	R. leaves	4.45E-04	1.56E-05	0	0	0	0	9.78E-06	0	0.00E+00
ZY	R. leaves	1.51E-04	1.03E-05	0	0	0	0	4.89E-06	0	0.00E+00
DW	R. leaves	2.79E-04	1.56E-05	0	0	0	0	0.00E+00	0	0.00E+00

Table 4b: Estimated daily intake (mg/kg/day) of heavy metals of children in Rossele leaves in wet season

Sampling site	Wet season	Fe	Mn	Pb	Cr	Cd	Co	Zn	Ni	Hg
WB	R. leaves	1.81E-04	9.44E-06	0	0	0	0	4.49E-06	0	0
WY	R. leaves	2.61E-04	8.99E-06	0	0	0	0	4.49E-06	0	0.00E+00
GE	R. leaves	1.14E-04	2.83E-05	0	0	0	0	0	0	0.00E+00
MU	R. leaves	2.29E-04	1.03E-05	0	0	0	0	4.49E-06	0	0
GU	R. leaves	2.38E-04	2.74E-05	0	0	0	0	0	0	0
WA	R. leaves	4.09E-04	1.44E-05	0	0	0	0	8.99E-06	0	0.00E+00
ZY	R. leaves	1.39E-04	9.44E-06	0	0	0	0	4.49E-06	0	0.00E+00
DW	R. leaves	2.57E-04	2.57E-04	0	0	0	0	0	0	0.00E+00

Table 5a: Estimated daily intake of heavy metals (mg/kg/day) of adult in Amaranthus leaves in wet season

Sampling site	Wet season	Fe	Mn	Pb	Cr	Cd	Co	Zn	Ni	Hg
WB	Am leaves	2.94E-04	1.08E-05	0	0	0	0	4.89E-08	0	0
WY	Am leaves	2.30E-04	1.81E-06	0	0	0	0	0	0	0.00E+00
GE	Am leaves	1.76E-04	8.79E-07	0	0	0	0	0	0	0.00E+00
MU	Am leaves	2.05E-04	4.89E-08	0	0			0	0	0
GU	Am leaves	2.64E-04	1.27E-06	0	0		0	0	0	0
WA	Am leaves	2.30E-04	1.22E-05	0	0			0	0	0.00E+00
ZY	Am leaves	2.45E-04	1.52E-06	0	0	0	0	0	0	0.00E+00
DW	Am leaves	5.65E-04	4.39E-07	0	0	0	0	5.38E-06	0	0.00E+00

Table 6b: Estimated daily intake of heavy metals (mg/kg/day) of children in Amaranthus leaves in wet season

Sampling site	Wet season	Fe	Mn	Pb	Cr	Cd	Co	Zn	Ni	Hg
WB	Am leaves	2.71E-04	9.94E-06	0	0	0	0	4.49E-08	0	0
WY	Am leaves	2.12E-04	1.66E-06	0	0	0	0	0	0	0.00E+00
GE	Am leaves	1.62E-04	8.09E-07	0	0	0	0	0	0	0.00E+00
MU	Am leaves	1.89E-04	4.49E-8	0	0	0	0	0	0	0
GU	Am leaves	2.43E-04	1.17E-06	0	0	0	0	0	0	0
WA	Am leaves	2.12E-04	1.12E-05	0	0	0	0	0	0	0.00E+00
ZY	Am leaves	2.26E-04	1.39E-06	0	0	0	0	0	0	0.00E+00
DW	Am leaves	1.67E-04	4.05E-07	0	0	0	0	4.95E-06	0	0.00E+00

Table 7a: Estimated daily intake of heavy metals (mg/kg/day) of adult in Amaranthus leaves in dry season

Sampling site	Dry season	Fe	Mn	Pb	Cr	Cd	Co	Zn	Ni	Hg
WB	Am leaves	5.73E-04	0	0	0	0	0	0	0	0
WY	Am leaves	1.38E-03	0	0	0	2.96E-04	0	0	0	0.00E+00
GE	Am leaves	1.18E-03	0	0	0	2.89E-04	0	0	0	0.00E+00
MU	Am leaves	6.09E-04	0	0	0	0		0	0	0
GU	Am leaves	4.50E-04	0	0	0	2.45E-04	0	0	0	0
WA	Am leaves	5.82E-04	0	0	0	2.19E-04		0	0	0.00E+00
ZY	Am leaves	3.93E-04	0	0	0	0	0	0	0	0.00E+00
DW	Am leaves	5..65E-04	0	0	0	1.74E-04	0	0	0	0.00E+00

Table 8b: Estimated daily intake of heavy metals (mg/kg/day) of children in Amaranthus leaves in dry season

Sampling site	Dry season	Fe	Mn	Pb	Cr	Cd	Co	Zn	Ni	Hg
WB	Am leaves	5.27E-04	9.94E-06	0	0	0	0	0	0	0
WY	Am leaves	1.27E-03	1.66E-06	0	0	2.72E-04	0	0	0	0.00E+00
GE	Am leaves	1.08E-03	8.09E-07	0	0	2.66E-04	0	0	0	0.00E+00
MU	Am leaves	5.60E-04	4.49E-8	0	0	0	0	0	0	0
GU	Am leaves	4.14E-04	1.17E-06	0	0	2.25E-04	0	0	0	0
WA	Am leaves	5.35E-04	1.12E-05	0	0	2.02E-04	0	0	0	0.00E+00
ZY	Am leaves	3.62E-04	1.39E-06	0	0	0	0	0	0	0.00E+00
DW	Am leaves	5..19E-04	4.05E-07	0	0	1.60E-04	0	0	0	0.00E+00

In human, excess ingestion of Fe can result in deposition of iron in tissues (siderosis) in adrenals, liver, pancreas, thyroid, pituitary among others [18]. To assess the health risk of inhabitants of these crops in the study area, the daily intake rates of metal (DIM) and the health risk index were estimated. The degree of toxicity of heavy metals to human is function of body weight and intake.

The Estimated daily intake (EDI) estimated for the consumption of the vegetables for both adults and children. The EDI did not show for many elements at different sites because either they were not detected or their values were negligible. Cr was only detected in tomato and onion with EDI values for adults and children as 9.78E-06 and 8.99E-06 for tomato from Muleng (MU) and 1.00E-04 and 3.14E-05 for onion from the same area. Chromium is crucial for insulin activity and deoxyribonucleic acid transcription in living organism particularly human beings. However, an intake less than 0.02 mg per day could lessen cellular responses to insulin. Hence, the concentrations of Cr in the vegetables are suitable for proper cellular response to insulin [18].

The estimated daily intake of Cd for adults and children from Rossele leaves in dry season ranged from 2.93E-07 to 2.69E-04 $mgkg^{-1}day^{-1}$ and 0.00E+00 to 1.09E-01 $mgkg^{-1}day^{-1}$ respectively. The content of Cd intake found was lower than that reported in literature, which ranged between 0.008 and 0.052 mg per day [18]. The greatest contribution of Cd intake in Rossele leaves came from DM (1.09E-01 mg per day). Cd was not detected in tomato and onion from all locations. It could be that vegetables are excluders of the metal. Cd was not also detected in all the vegetables grown in the wet season. This could be due to the high mobility of the metal in soil. The presence of the metal could be attributed to the application of fertilizers. Cadmium is a dangerous element because it can be absorbed via the alimentary tract; penetrate through placenta during pregnancy, and damage membranes and DNA. Once in the human body, it may remain in the metabolism from 16 to 33 years and is connected to several health problems, such as renal damages and abnormal urinary excretion of proteins. Vegetables may contribute to about 70 % of Cd intake by humans, varying according to the level of consumption [18].

Table 9a: Estimated daily intake of heavy metals (mg/kg/day) of adult in Tomatoes in dry season

Sampling site	Dry season	Fe	Mn	Pb	Cr	Cd	Co	Zn	Ni	Hg
WB	Tomatoes	1.92E-03	5.87E-05	0	0	0	0	7.82E-05	0	0
WY	Tomatoes	1.83E-03	4.39E-05	0	0	0	0	1.22E-04	0	0.00E+00
GE	Tomatoes	1.56E-03	6.35E-05	0	0	0	0	3.42E-04	0	0.00E+00
MU	Tomatoes	2.15E-03	1.03E-05	0	9.78E-06	0	0	5.87E-05	0	0
GU	Tomatoes	2.02E-03	2.29E-05	0	0	0	0	2.93E-05	0	0
WA	Tomatoes	1.43E-03	1.23E-04	0	0	0	0	4.40E-05	0	0.00E+00
ZY	Tomatoes	1.42E-03	1.32E-04	0	0	0	0	8.80E-05	0	0.00E+00
DW	Tomatoes	2.23E-03	9.29E-05	0	0	0	0	4.39E-05	0	0.00E+00

Table 10b: Estimated daily intake of heavy metals (mg/kg/day) of children in Tomatoes in dry season

Sampling site	Dry season	Fe	Mn	Pb	Cr	Cd	Co	Zn	Ni	Hg
WB	Tomatoes	1.48E-03	5.39E-05	0	0	0	0	7.20E-05	0	0
WY	Tomatoes	1.69E-03	4.05E-05	0	0	0	0	3.15E-05	0	0.00E+00
GE	Tomatoes	1.44E-03	5.85E-05	0	0	0	0	3.15E-04	0	0.00E+00
MU	Tomatoes	1.98E-03	9.44E-05	0	8.99E-06	0	0	5.40E-05	0	0
GU	Tomatoes	1.86E-03	2.11E-04	0	0	0	0	2.70E-05	0	0
WA	Tomatoes	1.31E-03	1.13E-04	0	0	0	0	4.05E-05	0	0.00E+00
ZY	Tomatoes	1.31E-03	1.21E-04	0	0	0	0	8.54E-05	0	0.00E+00
DW	Tomatoes	2.06E-03	8.54E-05	0	0	0	0	4.05E-05	0	0.00E+00

Table 11a: Estimated daily intake of heavy metals (mg/kg/day) of adult in Tomatoes in wet season

Sampling site	Wet season	Fe	Mn	Pb	Cr	Cd	Co	Zn	Ni	Hg
WB	Tomatoes	2.01E-03	1.00E-04	0	0	0	0	1.00E-04	0	0
WY	Tomatoes	2.20E-03	1.00E-04	0	0	0	0	1.00E-04	0	0.00E+00
GE	Tomatoes	2.20E-03	1.00E-04	0	0	0	0	2.44E-05	0	0.00E+00
MU	Tomatoes	1.60E-03	2.00E-04	0	1.00E-04	0	0	2.44E-05	0	0
GU	Tomatoes	1.60E-03	2.00E-04	0	0	0	0	4.39E-05	0	0
WA	Tomatoes	1.70E-03	2.00E-04	0	0	0	0	6.35E-05	0	0.00E+00
ZY	Tomatoes	1.60E-03	1.00E-04	0	0	0	0	4,89E-05E-05	0	0.00E+00
DW	Tomatoes	1.90E-03	1.00E-04	0	0	0	0	9.29E-05	0	0.00E+00

Table 12b: Estimated daily intake of heavy metals (mg/kg/day) of children in Tomatoes in wet season

Sampling site	Wet season	Fe	Mn	Pb	Cr	Cd	Co	Zn	Ni	Hg
WB	Tomatoes	1.76E-03	4.95E-05	0	0	0	0	2.70E-05	0	0
WY	Tomatoes	1.97E-03	2.65E-05	0	0	0	0	3.15E-05	0	0.00E+00
GE	Tomatoes	2.01E-03	4.49E-05	0	0	0	0	2.25E-05	0	0.00E+00
MU	Tomatoes	1.45E-03	1.17E-04	0	3.14E-05	0	0	2.45E-05	0	0
GU	Tomatoes	1.40E-03	1.58E-04	0	0	0	0	4.05E-05	0	0
WA	Tomatoes	1.54E-03	1.17E-04	0	0	0	0	5.85E-05	0	0.00E+00
ZY	Tomatoes	1.40E-03	7.64E-05	0	0	0	0	4.50E-05	0	0.00E+00
DW	Tomatoes	1.74E-03	7.02E-05	0	0	0	0	8.54E-05	0	0.00E+00

Mn was not detected in Russel in the dry season but the ranges of the estimated daily intake of Mn for adults and children in the other vegetables were: Tomato; 1.03E-05 to 1.32E-04 and 4.05E-05 to 2.11E-04; Onion; 3.42E-05 to 2.20E-04 and 3.15E-05 to 2.02E-04 respectively which were slightly higher than the corresponding wet season with values as: Rossele leaves; 4.39E-07 to 1.22E-05 and 4.05E-07 to 1.12E-05, Tomato; 1.00E-04 to 2.00E-04 and 2.65E-05 to 1.58E-04; Onion 2.65E-05 - 1.58E-04and 1.96E-05 - 2.79E-04. The Mn intake is also slightly higher in adults than in children. Adverse effects of Mn can result from both deficiency and overexposure, causing neurological effects, which can cause tremor, gait disorders (seen in primate), psychological symptoms such as irritability, and emotional liability the decreased intake of Mg or Mn leads to a decreased ability to store and use thiamin (vitamin B) [19].

Zincs was not detected in *amaranthus* leaves in the dry season but the ranges of the estimated daily intake of Mn for adults and children in the other vegetables were: Rossele leaves; 7.33E-06-3.47E-05 and 6.75E-06-3.19E-05 As shown in the table 4.5 to 4.8 below, tomato; 2.93E-05-3.42E-04 and2.70E-05- 3.15E-04; Onion; 2.44E-05- 9.78E-05 and 4.45E-05-8.99E-06 respectively, which were slightly higher than the corresponding wet season with values as: Rossele leaves; 4.89E-06- 9.78E-06and 4.49E-06- 8.99E-06 *Amaranthus* leaves; 4.89E-08 - 5.38E-06and 4.49E-08- 4.95E-06; Tomato; 2.44E-05 - 1.00E-04, 5.87E-05- 1.22E-04; Onion 0.87E-05 - 1.22E-04 and 1.12E-041.12E-04. The Zn intake is also slightly higher in adults than in children. Generally, Zn, which are important nutrients for humans, are considered a much lower health risk to humans than Pb, Cd, and As. Poor health can be caused by a lack of these required elements, but excessive ingestion can also have adverse effects on human health [20].

Table 13a: Estimated daily intake of heavy metals (mg/kg/day) of adult in Onions in dry season

Sampling site	Dry season	Fe	Mn	Pb	Cr	Cd	Co	Zn	Ni	Hg
WB	Onion	1.57E-03	3.42E-05	0	0	0	0	2.44E-05	0	0
WY	Onion	9.87E-04	8.30E-05	0	0	0	0	5.87E-05	0	0.00E+00
GE	Onion	2.19E-03	2.20E-04	0	0	0	0	0	0	0.00E+00
MU	Onion	1.76E-03	1.12E-04	0	4.89E-05	0	0	3.91E-05	0	0
GU	Onion	1.23E-03	6.84E-05	0	0	0	0	9.78E-05	0	0
WA	Onion	2.47E-03	7.82E-05	0	0	0	0	0	0	0.00E+00
ZY	Onion	2.13E-03	6.84E-05	0	0	0	0	0	0	0.00E+00
DW	Onion	2.35E-03	8.31E-05	0	1.47E-05	0	0	4.89E-06	0	0.00E+00

Table 14b: Estimated daily intake of heavy metals (mg/kg/day) of children in Onions in dry season

Sampling site	Dry season	Fe	Mn	Pb	Cr	Cd	Co	Zn	Ni	Hg
WB	Onion	1.85E-03	3.15E-05	0	0	0	0	4.45E-05	0	0
WY	Onion	9.08E-04	7.64E-05	0	0	0	0	5.40E-05	0	0.00E+00
GE	Onion	2.02E-03	2.02E-04	0	0	0	0	0	0	0.00E+00
MU	Onion	1.62E-03	1.03E-04	0	4.50E-05	0	0	8.99E-06	0	0
GU	Onion	1.13E-03	6.30E-05	0	0	0	0	0	0	0
WA	Onion	1.24E-03	7.20E-05	0	0	0	0	0	0	0.00E+00
ZY	Onion	1.96E-03	6.30E-05	0	0	0	0	0	0	0.00E+00
DW	Onion	2.16E-03	7.64E-05	0	1.35E-05	0	0	4.50E-05	0	0.00E+00

Table 15a: Estimated daily intake of heavy metals (mg/kg/day) of adult in Onions in wet season in wet season

Sampling site	Wet season	Fe	Mn	Pb	Cr	Cd	Co	Zn
WB	Onion	2.15E-03	7.33E-05	0	0	0	0	5.87E-05
WY	Onion	1.54E-03	1.22E-04	0	0	0	0	1.22E-04
GE	Onion	2.30E-03	1.52E-04	0	0	0	0	0
MU	Onion	1.82E-03	2.79E-04	0	7.33E-05	0	0	1.03E-04
GU	Onion	1.32E-03	4.39E-05	0	0	0	0	9.78E-06
WA	Onion	2.84E-03	3.42E-05	0	0	0	0	0
ZY	Onion	2.00E-03	1.96E-05	0	0	0	0	0
DW	Onion	2.45E-03	3.91E-05	0	0	0	0	7.33E-05

Table 16b: Estimated daily intake of heavy metals (mg/kg/day) of children in Onions in wet season in wet season

Sampling site	Wet season	Fe	Mn	Pb	Cr	Cd	Co	Zn
WB	Onion	1.98E-03	6.75E-05	0	0	0	0	5.39E-05
WY	Onion	1.42E-03	1.12E-04	0	0	0	0	1.12E-04
GE	Onion	2.12E-03	1.39E-04	0	0	0	0	0
MU	Onion	1.67E-03	2.56E-04	0	6.75E-05	0	0	9.44E-05
GU	Onion	1.22E-03	4.05E-05	0	0	0	0	8.99E-06
WA	Onion	2.61E-03	3.15E-05	0	0	0	0	0
ZY	Onion	2.12E-03	1.79E-05	0	0	0	0	0
DW	Onion	2.25E-03	3.59E-05	0	0	0	0	6.75E-05

Estimated daily intakes of heavy metals for both adults and children through the consumption of vegetables in this study were less than tolerable daily intake limit set by the US-EPA, IRIS. This showed that no risk would be associated with the consumption of the studied vegetables grown along Kilange River in both dry and wet seasons.

According to Tables 1 Hazard cautions (HQs) for individual vegetables were all below 1.0 for all HMs, regardless the population type. HQ for Fe, Mn, Cr, Cd and Zn ranged from 0 to 0.314; 0 to 0.0157; 0 to 0.331 0 to 0.538 and 0 to 0.0033 respectively for adults and 0 to 0.287; 0 to 0.0184; 0 to 0.0105, 0 to 0.495 and from 0 to 0.0011 respectively for children. When the consumption habit of adults and children in this study area were analyzed, HQs for all HMs were below 1.0. So, the consumption of these vegetables can be considered safe with no risk to human health. This was in agreement with the works of [21] and [22] that found the values of heavy metals in tomatoes from Umuahia Metropolis of Abia State Nigeria were below the dietary intake in tomato.

The hazard index (HI) of all the metals from the four vegetables and from all locations were less than 1.0 indicating that, there is no concern for potential health effects [20]. Even though there was no apparent risk when each metal was analyzed individually, the potential risk could multiplied when considering all HMs. HI for adults and children were 0.715 and 0.658 in Rosselle leaves respectively were highest in the study. These results suggested that, the potential health risks of heavy metals through consumption of leafy vegetables were the highest among all vegetable types. Although HI was slightly higher for adults, neither population could suffer from ingestion of vegetables contaminated with HM s. However, chronic low-level intake of toxic metal elements has a negative effect on human health, and the detrimental impact becomes apparent after several years of exposure [20].

4. Conclusion

This study stipulated that the health risk assessment of this investigation shows that, estimated daily intake of heavy metals for both adults and children through the consumption of vegetables in this study were less than tolerable daily intake limit set by the WHO, US-EPA, IRIS. This showed that no risk would be associated with the consumption of the studied vegetables grown along Kilange river in both dry and wet seasons HQs for individual vegetables were all <1.0 for all HMs, regardless the population type. HQ for Fe, Mn, Cr, Cd and Zn ranged from 0 to 0.314; 0 to 0.0157; 0 to 0.331 0 to 0.538 and 0 to 0.0033 respectively for adults and 0 to 0.287; 0 to 0.0184; 0 to 0.0105, 0 to 0.495 and from 0 to 0.0011 respectively for children. When the consumption habit of adults and children in this study area were analyzed, HQs for all HMs were below.

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