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Original Research Article

Impact and Health Risk Assessment of Heavy metals on Contaminated Tomatoes (*Lycopersicum esculentum*) Consumed in Gombe Metropolis

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Abstract

Tomatoes consumed in Gombe are contaminated with traces and heavy metals due to accumulation of these metals in soil that absorbed by crop plants, which is the most serious environmental problem with significant implications on human health. This study focused on the comparative studies on concentrations of carcinogenic and non- carcinogenic heavy metals analyzed based on WHO Permissible limits. Sample T1 Tomatoes showed mean concentrations in decreasing order of Zn = 0.094 ± 0.045 mg/kg followed by Mn = 0.0744 ± 0.0031 mg/kg then Ni = 0.0394 ± 0.0014 mg/kg, Fe = 0.0163 ± 0.00113 mg/kg, Cd = 0.0063 ± 0.00106 mg/kg, Pb = 0.0031 ± 0.0062 mg/kg, Co = 0.00152 ± 0.00126 mg/kg, As = 0 respectively. Sample T2 showed mean concentrations of heavy metals with the highest of Ni = 0.2095 ± 0.27 mg/kg followed by Zn = 0.1761 ± 0.134 mg/kg, Mn = 0.0487 ± 0.0023 mg/kg, Fe = 0.0233 ± 0.00195 mg/kg, Cd = 0.0147 ± mg/kg, Pb = 0.0047 ± 0.0062 mg/kg, Co = 0.0075 ± 0.0065 mg/kg respectively with few above WHO limits of 0.002 – 0.005mg/kg. Sample T3 Tomatoes showed mean concentrations with highest in decreasing order of Mn = 0.0829 ± 0.017 mg/kg followed by Ni = 0.0809 ± 0.00412 mg/kg, Zn = 0.0504 ± 0.0031 mg/kg, Co = 0.0225 ±0.00080 mg/kg, Cd = 0.0179 ± 0.00243 mg/kg, Fe = 0.0143 ± 0.00057 mg/kg. As = 0.0011 ± 0.000265 mg/kg, Pb = 0.0004 ± 0.000058 mg/kg respectively. Hazard Index (HI) of non-carcinogenic Heavy metals analyzed in Tomatoes samples showed highest hazard index in all the three pathways with Co = 3.64 E+ 00 followed by Pb = 2.71E+00 then Cd = 5.51E-01, Ni = 1.07E-02, Mn = 6.81E-03, As = 2.16E-03, Zn = 7.79E-04, while the lowest Hazard index was shown by Fe = 5.62E-05 indicating HI > 1 with adverse health risk in decreasing order of Co > Pb > Cd > Ni > Mn > As > Zn > Fe respectively. Cancer risk effects of carcinogenic heavy metals investigated through ingestion showed the highest cancer risk of Cd = 4.10E-05 followed by As = 3.23E-07 then Pb = 7.14E-06 with order of Cd > As > Pb > Co while cancer risk through inhalation showed the highest in Co = 1.27E-11 followed by Cd = 7.06E-12 then As = 4.76E-13, the lowest of Pb = 4.41E-14 with order of Co > Cd > As > Pb indicating that some heavy metals contaminated the tomatoes analyzed were projecting while hazard and cancer risk on human health will persisted on body systems at certain prolong time, examining of these heavy metals levels will safeguard public health.

Keywords: Heavy metals, Contamination, Health risk.

INTRODUCTION

Tomato as fruit is commonly utilized for salads, cooked in sauces, soup or consumed as paste like ketch-up it can also be used in making tomato juice. It contains many nutrients, anti-oxidants and secondary metabolite such as vitamin C and E, b-carotene, lycopene, flavonoid organic acids, phenolic and chlorophyll, which are important for human health (Mulat *et al.*, 2019).

Heavy metals such as Hg, Pb, Cd, Ag, Cr and many others that are indirectly distributed as a result of human activities could be very toxic even at low concentrations when constantly consumed in edible plants like tomatoes. Heavy metals are abundant in the environment, as a result of both natural and anthropogenic activities, and humans are exposed to them through various pathways. Other metals like Fe, Sn, Cu, Mn and vanadium occur naturally in the soil as minute particles are trace metals serves as components of plant nutrients depending at various concentrations. These metals undergo decay and can fit into global ecological circles as reported by Bassey *et al.*, (2014). Contamination of soil by these heavy metals pose serious environmental hazards and has significant implications for human health. Soil is a vital environmental, ecological and agricultural resource that has to be protected, from further environmental degradation. Thus soil play important role for adequate supply of healthy food needed for the world's increasing population as reported by Bassey *et al.*, (2014).

Intake of heavy metals by vegetables in soil may pose a risk to the human health, this because heavy metals have the ability to accumulate in living organisms and at elevated levels they can be toxic. Prolong consumption of unsafe concentrations of heavy metals through foodstuffs may lead to the chronic accumulation of the metals in kidney, Liver and borne diseases that causes disruption of biochemical processes (Lawal and Audu, 2011).

MATERIALS AND METHODS

Sample Collection

Three different samples of Tomatoes commonly consumed in Gombe were collected all together. Samples were identified with local names and coded as T1 = Largo Red Cherry Tomato, T2 = Plum Tomato, T3= Beef Steak, from Gombe. These different samples of Tomatoes were collected from two major markets in Gombe Metropolis. Then two corresponding samples were mixed together to form representative fractions suitable for the analysis as adopted by Usman *et al.*, (2020) and Usman *et al.*, (2021).

Sample Preparation of Fruit Samples

Exactly 30 g of fresh Tomatoes samples were weighed separately and placed in 400 cm^3 beakers. Then 200 cm^3 of distilled water was added. The mixture was boiled for 1 hr over hot plate at several time intervals of 10 minutes lost molecules was replaced during evaporation. The solution was allowed to cooled and transferred into a volumetric flask, it was then stored in refrigerator for further analysis as adopted by Usman *et al.*, (2021).

Sample Preparation for AAS Analysis

Initially, 10 cm^3 of 1M HNO_3 was added to 1.00 g of Tomato sample in 25 x 150 mm glass digestion tube. The samples were then heated at 95 ± 10 °C for 15 minutes. When cool, 5 cm^3 of HNO_3 was added and heated for another 30 minutes. The digests were again allowed to cool, then 2 cm^3 of distilled water and 3 cm^3 of 30 % H_2O_2 was added and heated to 95 ± 5 °C. After the digests were cooled again, another 1 cm^3 of 30 % H_2O_2 was added. Heating continued until the sample volumes reduced to approximately 5 cm^3. The digests were then allowed to cool again before being diluted to 50 cm^3 with distilled water. Prior to analysis, the tomatoes digests were further diluted for analysis of metals content as adopted by (Usman *et al.*, 2020).

Study Area

Gombe is the City and the Headquarters of the Gombe State is located in the center part of north-eastern part of Nigeria latitude (10° 15' N, 10° 19' N) and between longitude (11° 07' E, 11° 15' E) and is known as one of the rapidly growing metropolitan areas of Nigeria. Gombe state has approximately 52 km^2 (20 Sq ml) land area and has the highest estimated population of about (261,536) people as at 2006 National Population census. It also has an important role as being the touristic, cultural and industrial Center.

RESULTS AND DISCUSSION

Mean Concentration of Heavy metals in All samples

Heavy metals concentrations shown in Figure 1 expressed that sample T1 Tomatoes showed Zn has the highest concentrations among all the heavy metals and their concentrations was expressed in decreasing order of; Zn with 0.094 ± 0.045 mg/kg followed by Mn with 0.0744 ± 0.0031 mg/kg then Ni has 0.0394 ± 0.0014 mg/kg, Fe showed 0.0163 ± 0.00113 mg/kg, Cd showed 0.0063 ± 0.00106 mg/kg, Pb showed 0.0031 ± 0.0062 mg/kg, Co showed 0.00152 ± 0.00126 mg/kg, Lastly As has zero concentrations. Except As metal most of the Heavy metals in sample T1 unveiled lowest concentrations below the FAO/WHO permissible limits of 0.001 to 0.05 mg/kg in vegetables as stated by Adedokun *et al*,. (2016). The heavy metals concentrations in T1 was expressed in decreasing order of; Zn > Mn > Ni > Fe > Cd > Pb > Co > As

On the other hand, heavy metal concentration in sample T2 showed Ni with the highest mean concentration of 0.2095 ± 0.27 mg/kg followed by Zn with the mean concentration of 0.1761 ± 0.134 mg/kg. Manganese has the concentration of 0.0487 ± 0.0023 mg/kg. Fe has the concentration of 0.0233 ± 0.00195 mg/kg, Cd has the concentration of 0.0147 ± mg/kg, Pb has concentration of 0.0047 ± 0.0062 mg/kg, Co has the concentration of 0.0075 ± 0.0065 mg/kg. Their concentrations are expressed decreasing order of; Ni > Zn > Mn > Fe > Cd > Co > Pb > As where Nickel as the highest concentration above them while As the lowest concentrations.

Heavy metals in Sample T3 showed concentration of in samples were Mn has the highest mean concentration of 0.0829 ± 0.017 mg/kg followed by Ni has the concentration of 0.0809 ± 0.00412 mg/kg, Zn has the concentration of 0.0504 ± 0.0031 mg/kg, Co has the concentration of 0.0225 ±0.00080 mg/kg, Cd has the concentration of 0.0179 ± 0.00243 mg/kg, Fe showed the concentration of 0.0143 ± 0.00057 mg/kg. Arsenic revealed the concentration of 0.0011 ± 0.000265 mg/kg while Pb showed the lowest mean concentration of 0.0004 ± 0.000058 mg/kg. Their concentrations were expressed as Mn > Ni > Zn > Co > Cd > Fe > As > Pb respectively. The result showed that Mn has the highest while Pb formed the lowest Heavy metals concentrations which were all below permissible limits of 0.001 tO 0.05 mg/kg as reported by Adedokun *et al*., 2016). The highest concentration of the Heavy metals could be attributed to nature of the irrigated water used, run-off water, excess Fertilizer, Herbicides, Pesticide from the farm lands, and random Organic dump waste used as a source of fertilizer.

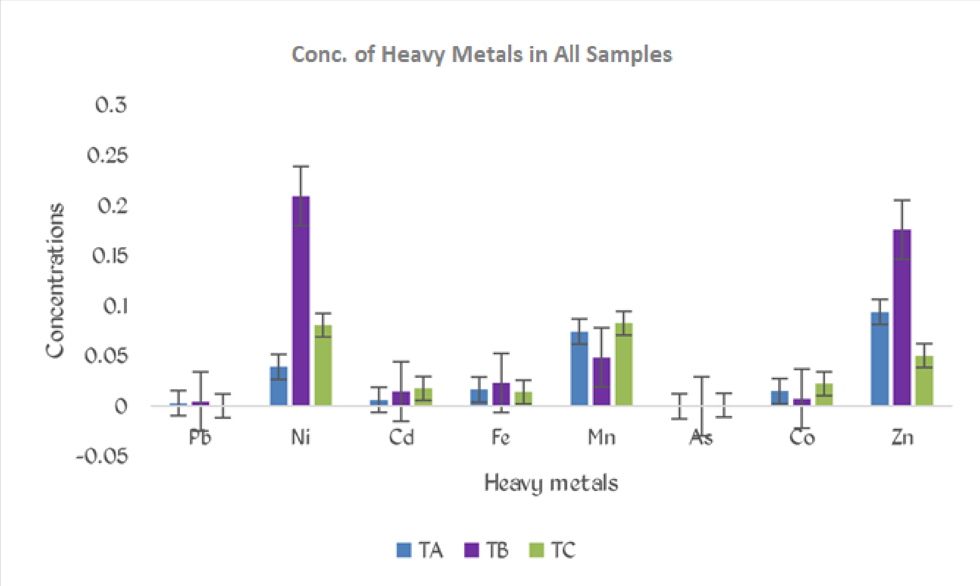

Figure 1: Mean Conc. of Heavy Metals in All Samples of Tomatoes (mg/kg)

Health Risks Assessment

Health risks assessment of carcinogenic and non-carcinogenic risk through Heavy metals present in some edible Tomatoes samples around Gombe has been determined using exposure pathways of inhalation, ingestion and dermal to determined health risk of human as evidence for taking decision, (Usman *et al*., 2020) and (Hu *et al*., 2017).

Methods adopted was through (Usman *et al*., 2020) which are mention below.

Ingestion

AD_{ing} (mg/kg^{-1} day^{-1}) = $\frac{CS \times IRing \times EF \times FI \times ED \times CF}{BW \times AT}$ (Usman *et al*., 2020)

Inhalation

AD_{inh} (mg/kg^{-1} day^{-1}) = $\frac{CS \times IR\ inh \times EF \times FI \times ED}{PEF \times BW \times AT}$ (Usman *et al*., 2020)

Dermal

AD_{der} (mg/kg^{-1} day^{-1}) = $\frac{CS \times SA \times AF \times ABS \times EF \times ED \times CF}{BW \times AT}$ (Usman *et al*., 2020)

Where AD (mg/kg^{-1} day^{-1}) is the absorbed dose of exposure to through ingestion (AD_{ing}), inhalation (AD_{inh}), and dermal contact (AD_{der})

CS = Chemical concentration in a sample (mg/kg)

IR_{ing} = Ingestion rate (mg soil/day): 100 mg/day (Usman *et al*., 2020)

FI = Fraction ingestion from contaminated source: 1 at reasonable maximum exposure(USEPA., 2011)

EF: Exposure frequency: 350 days for non-carcinogenic effect and (USEPA, 2011)

SA= Exposure skin area: 5700cm^3 (USEPA, 2011) and (Usman *et al*., 2020)

AF: Soil to skin adherence factor (mg/cm^3)0.07 mg/cm^3 $^($USEPA, 2011) and (Usman *et al*., 2020)

ABS: Absorption factor (mg/cm^3)0.03(As) 1 (USEPA, 2011) and (Usman *et al*., 2020)

BW: Body weight in (Kg); 70kg for adult average

PEF: Particle Emission factor: 1.36 x 10^9 m^3.kg^{-1} (Usman *et al*., 2020)

AT: Average. 365 x ED for non-carcinogenic effect and 365 x 70 for carcinogenic effect

CF: conversion factor (10^{-6}) (USEPA, 2011) and (Usman *et al*., 2020)

AD Ingestion Inhalation and Dermal Non-Carcinogenic Metals

Figure 2 showed daily dose of non - carcinogenic metals where Ni has the highest mean daily dose of all the three pathways of 3.17E-04 followed by Zn with 1.6E-04. Mn = 1.05E-04 then Pb = 8.17E-05, Fe = 3.93E -05, Co = 3.32E-05, Cd = 2.03E-05 and lastly As showed the least value of 5.62E-07. The result showed that the daily exposure dose of non-carcinogenic heavy metals of the sample Tomatoes analyzed within the Gombe metropolis were expressed in decreasing order of Ni >Zn > Mn >Pb> Fe > Co > Cd > As respectively.

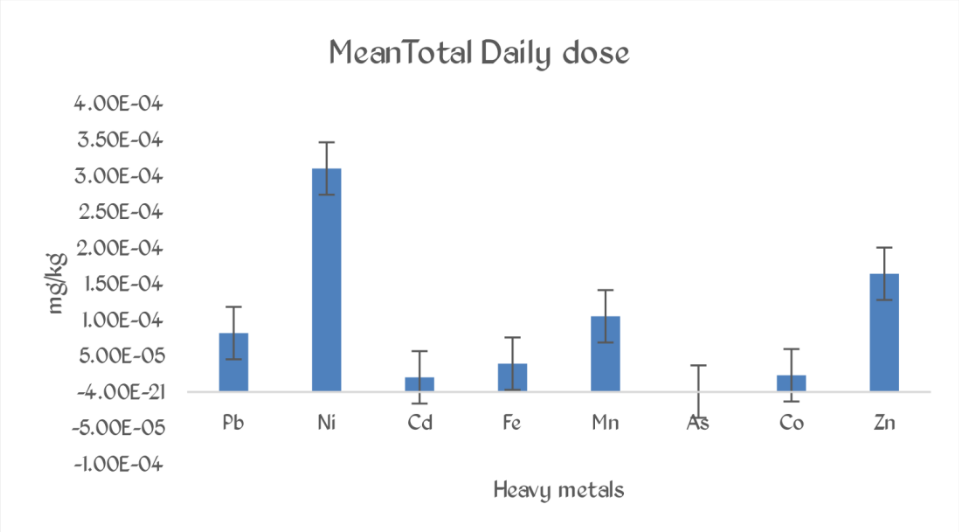

Figure 2: Mean total daily dose of non- carcinogenic Heavy metals

Mean Total Daily Dose of Carcinogenic Heavy metals

Figure 3 showed daily dose of Carcinogenic metals where Pb has the highest mean daily dose of all the three pathways of 7.14 E-06 followed by Cd with 6.50E-06. Ni = 6.45E-05 then Co = 4.85E-05 while the least amount of daily dose was shown by As = 2.15E-07. The result showed that the daily exposure dose of Carcinogenic heavy metals of the sample Tomatoes analyzed within the Gombe metropolis were expressed in decreasing order of Pb > Cd > Ni > Co > As respectively.

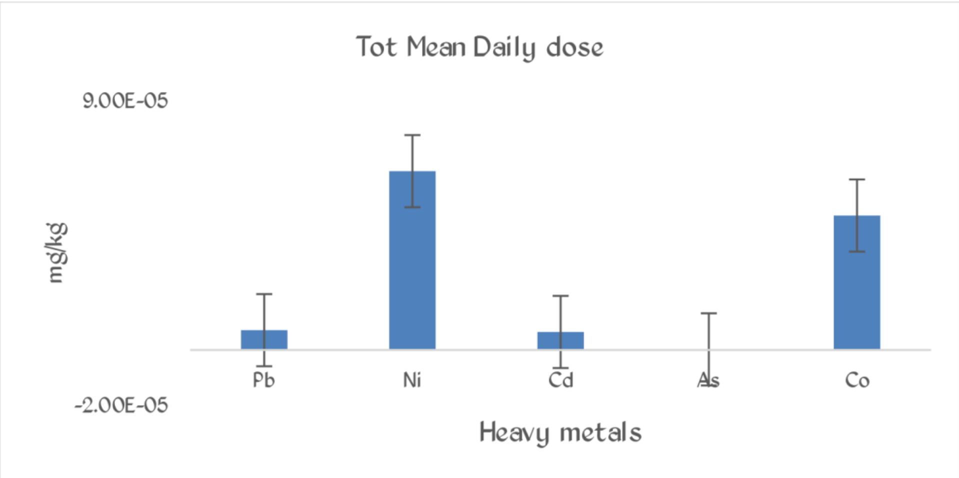

Figure 3: Mean total daily dose of Carcinogenic Heavy metals

Risks Assessment of Non-Carcinogenic Heavy metals and Hazard Quotient

The hazard quotient (HQ) represents the potential non- carcinogenic risk for an individual heavy metal. The HQ is the ratio of mean daily exposure dose (AD) to the reference dose (RfD) in mg/kg/day (Usman *et al.*, 2020) and (Koki *et al.*, 2015).

$$HQ = \frac{AD}{RfD}$$

Reference dose for ($RfD_{ing.}$) ingestion, ($RfD_{inh.}$) inhalation and ($RfD_{derm.}$) dermal constant values of heavy metals concentrations in tomatoes for this research have been estimated as;

The RfD_{ing} (mg/kg/day), of heavy metals values are; Cd = 1.00×10^{-3}, Cr = 3.00×10^{-3}, Co = 3.00×10^{-4} Cu = 4.00×10^{-2} Pb = 3.5×10^{-3}, Zn = 3.00×10^{-1} (Zheng *et al.*, 2015), Mn = 1.40×10^{-1}, As = 3.00×10^{-4} (Bortey-Sam et al., 2015) Ni = 2.00×10^{-2} (Caspah *et al.*, 2016) Fe = 7.00×10^{-1}(Usman *et al.*, 2020).

The RfD_{inh} (mg/kg/day), constant values are; Cd = 1.00×10^{-3}, Cr = 2.86×10^{-5}, Co = 5.71×10^{-6}, Cu = 4.02×10^{-2}, Pb = 3.52×10^{-3}, Zn = 3.00×10^{-1}, (Zheng *et al.*, 2015), Mn = 1.84×10^{-5}, As = 3.00×10^{-4}, Ni = 0 (Caspah *et al.*, 2016) Fe = 8.25 (Usman *et al.*, 2020).

The RfD_{derm}(mg/kg/day), constants values are; Cd = 1.00×10^{-5} Cr = 6.00×10^{-5}, Co = 3.00×10^{-2} Cu = 1.20×10^{-2} Pb = 5.25×10^{-4}, Zn = 6.00×10^{-2} (Zheng *et* *al.*, 2015), Mn = 1.84 x 10^{-3} ,As = 1.23 x 10^{-4} Ni = 5.6 x 10^{-3}(Caspah *et al.*, 2016). Fe = 7.00 x 10^{-1} (Usman *et al.*, 2020).

Hazard Index of Tomatoes Samples in Gombe Motropolis

Hazard Index (HI) represents the functional non- carcinogenic risk assessment of many heavy metals through major pathways present in the sample, which is given as; Total Hazard Index (Hit = HI ing. + HI inh. + HI derm.) Which is the sum of all HI in three pathways. HI = $\sum HQi$ where Q = Hazard Quotient, i = is the different heavy metals in the sample. HI ≤ 1 no adverse health risk, HI ≥ 1 there is likely adverse health risk effects. As reported by (Koki *et al.*, 2015).

Figure 4 showed Hazard Index (HI) of non-carcinogenic Heavy metals analyzed in Tomatoes samples consumed in Gombe metropolis, where Co has the highest hazard index in all the three pathways with 3.64E+ 00 followed by Pb = 2.71E+00 then Cd = 5.51E-01, Ni = 1.07E-02, Mn = 6.81E-03, As = 2.16E-03, Zn = 7.79E-04, while the lowest Hazard index was shown by Fe with 5.62E-05 respectively. The pathway rank of HI ≥ 1 indicated that all the heavy metals analyzed in tomatoes were prominent to likely adverse health risk effects as reported by (Usman *et al*,. 2020). The result showed that the hazard index of Non-Carcinogenic heavy metals of the sample Tomatoes analyzed within the Gombe metropolis were expressed in decreasing order of Co > Pb > Cd > Ni > Mn > As > Zn respectively.

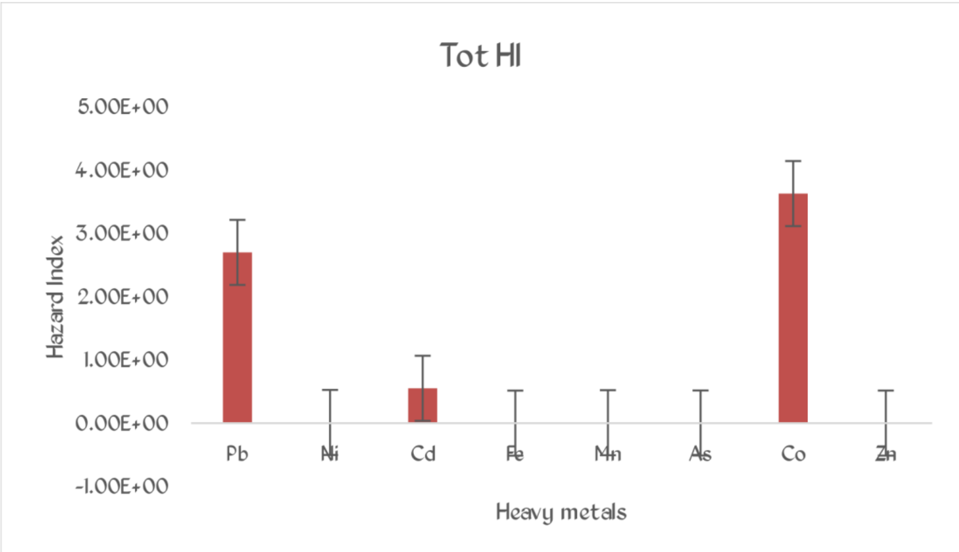

Figure 4: Hazard Index of Non- Carcinogenic Heavy metals

Figure 5 showed Hazard Quotient (HQ) of carcinogenic Heavy metals analyzed in Tomatoes samples consumed in Gombe metropolis, where HQ ingestion showed 6.35E+00 followed by HQ dermal with 5.55E-01, while HQ inhalation showed the lowest of1.29E-06 respectively.

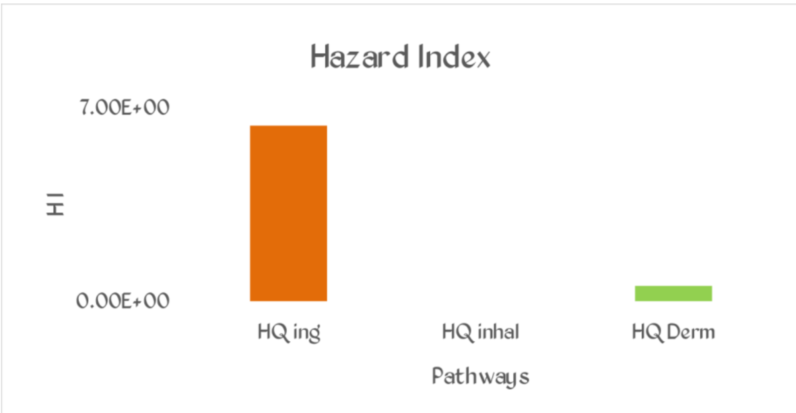

Figure 5: Hazard Quotient (HQ) of Non- Carcinogenic in three Pathways

Carcinogenic risk assessment of Tomatoes samples within Gombe Metropolis

Carcinogenic effects of risk assessment are determined through ingestion and inhalation while dermal pathways are neglected only for carcinogenic heavy metals such as Cd, Co, Cr, As and Pb as reported by (Caspah *et al*., 2016).

The carcinogenic cancer risk assessment was determined using multiplying daily exposure dose by either corresponding slope factor of individual carcinogenic heavy metals to arrive at cancer risk values. Slope factor for ingestion in mg/kgday^{-1} of As = 1.50E + 00, Pb = 8.50E -03, Cr = 5.0E – 01, Co = 0, while slope factor for inhalation of carcinogenic heavy metals are As = 1.50 E + 01, Pb = 4.20 E – 02, Cd= 6.30 E + 00, Cr = 4.10 E + 01 Co = 9.80 E + 00 (Caspah *et al*., 2016) and (Usman *et al*., 2020).

Figure 6 show that the cancer risk of carcinogenic heavy metals effects where by the prominent effects was shown by Cd has the highest cancer risk effects through ingestion with 4.10E-05 followed by As with 3.23E-07 then lead has 7.14E-06 cancer risk effect of heavy metal, while Co showed the lowest cancer risk of 0.00E+00. The order of decreasing cancer risk through ingestion is Cd > As > Pb > Co respectively. The result showed that cancer risk of carcinogenic heavy metals effects through inhalation revealed that Co has the highest of 1.27E-11 followed by Cd with 7.06E-12 then As has 4.76E-13 and Pb showed the lowest cancer risk of 4.41E-14. The order of decreasing cancer risk through inhalation is Co > Cd > As > Pb respectively. Which were contrary to cancer risk of Pb > Cd > Co >As > Cr as investigated by Usman *et al*., (2020).

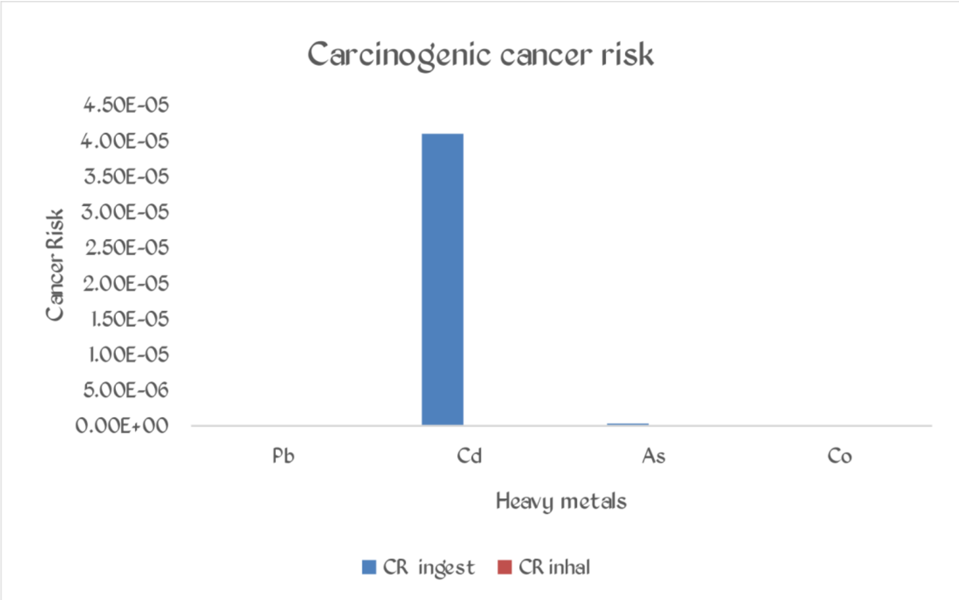

Figure 6: Cancer Risk of Carcinogenic Heavy metals in Tomatoes

CONCLUSION

Samples of tomatoes were found to be contaminated with the traces and heavy metals such as Pb, Ni, Cd, Fe Mn, As, Co and Zn this could be due to the presence of these heavy metals accumulation in soil that passed through crop plants by absorption. All concentrations obtained from this research were lower than the FAO/WHO permissible limits of 0.02 to 0.05 mg/kg of Heavy metals in foods and vegetables.

Sample T1 Tomatoes mean concentrations showed Zn = 0.094 ± 0.045 mg/kg followed by Mn = 0.0744 ± 0.0031 mg/kg then Ni = 0.0394 ± 0.0014 mg/kg, Fe = 0.0163 ± 0.00113 mg/kg, Cd = 0.0063 ± 0.00106 mg/kg, Pb = 0.0031 ± 0.0062 mg/kg, Co = 0.00152 ± 0.00126 mg/kg, As = 0 with order of Zn > Mn > Ni > Fe > Cd > Pb > Co > As respectively.

Sample T2 mean concentrations of heavy metals showed the highest to Ni = 0.2095 ± 0.27 mg/kg followed by Zn = 0.1761 ± 0.134 mg/kg, Mn = 0.0487 ± 0.0023 mg/kg, Fe = 0.0233 ± 0.00195 mg/kg, Cd = 0.0147 ± mg/kg, Pb = 0.0047 ± 0.0062 mg/kg, Co = 0.0075 ± 0.0065 mg/kg in decreasing order of Ni > Zn > Mn > Fe > Cd > Co > Pb > As accordingly.

Sample T3 Tomatoes mean concentrations showed the highest to Mn = 0.0829 ± 0.017 mg/kg followed by Ni = 0.0809 ± 0.00412 mg/kg, Zn = 0.0504 ± 0.0031 mg/kg, Co = 0.0225 ±0.00080 mg/kg, Cd = 0.0179 ± 0.00243 mg/kg, Fe = 0.0143 ± 0.00057 mg/kg. As = 0.0011 ± 0.000265 mg/kg, Pb = 0.0004 ± 0.000058 mg/kg with order of Mn > Ni > Zn > Co > Cd > Fe > As > Pb respectively. The order of decreasing mean concentration of heavy metals analyzed in all samples were in sequences (Zn > Mn > Ni > Fe > Co > Cd > Pb > As).

Hazard Index (HI) of non-carcinogenic Heavy metals analyzed in Tomatoes samples consumed in Gombe metropolis, where Co has the highest hazard index in all the three pathways with 3.64 E+ 00 followed by Pb = 2.71+00 then Cd = 5.51E-01, Ni = 1.07E-02, Mn = 6.81E-03, As = 2.16E-03, Zn = 7.79E-04, while the lowest Hazard index was shown by Fe with 5.62E-05. These were expressed in decreasing order of Co > Pb > Cd > Ni > Mn > As > Zn > Fe, indicating that HI > I with likely adverse health hazard as reported by (Koki *et al*., 2015). Cancer risk effects of carcinogenic heavy metals investigated through ingestion showed the highest cancer risk effects through ingestion with Cd = 4.10E-05 followed by As = 3.23E-07 then Pb = 7.14E-06 with order of Cd > As > Pb > Co while cancer risk through inhalation showed the highest of Co = 1.27E-11 followed by Cd = 7.06E-12 then As = 4.76E-13 and the lowest cancer risk of Pb = 4.41E-14 with order of Co > Cd > As > Pb respectively.

The levels of some Heavy metals of Pb, and Ni contamination in tomatoes analyzed were prominent to likely adverse Health Risk effects on prolong utilization in body systems of humans. Checking the levels of these heavy metals will ascertain safety to public health.

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