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Health risk of some metals in maize grains cultivated close to Gosa and Gwagwalada solid waste dumpsites

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Abstract-- Maize is a vital nutritional cereal for the infants, young children and adults. The environment which they are cultivated in Africa could expose to metal accumulations from soils, thereby posing health risks to the consumers. The objectives of this study were determine metal accumulations in maize grains (*Zea mays* L.) cultivated close to Gosa and Gwagwalada solid waste dumpsites and their health risks via consumption. A total of 36 soil samples (12 each from dumpsite soil, farmland soil and maize grains) were collected and analyzed for some metals [cadmium (Cd), lead (Pb), zinc (Zn), cobalt (Co), copper (Cu), chromium (Cr), nickel (Ni) and mercury (Hg)] using standard atomic adsorption spectrophotometer. The transfer factors and metal health risks in adults (60 kg; 22-48.9 years), young children (35 kg; 6-15 years) and infants (15 kg; 1-6 years) were evaluated using mathematical models. The ranges of metal (mg/kg) detected were 10114.00 to 0.52, 10.45 to 0.001 and 13.62 to 0.001 for dumpsite, farmland and maize grains, respectively. Though, within FAO/WHO and EU safe limits, Zn was significantly ($p<0.05$) highest in both locations, while Cd, Cr and Hg (0.001 mg/kg) were the least. Only Zn had transfer factor value below 0.5, which indicates possibilities of anthropogenic elevations. The estimated daily intake from consumption of maize grains (57 g) were generally high for Zn and low for Ni, Cd, and Hg in exposed individuals. The hazard index was below 1, which indicates no significant non-carcinogenic risks in exposed populations. The incremental lifetime cancer risks was below 10^{-6} and this suggest potential lifetime cancer risks in the order infants > children > adults. This study concluded that daily consumption of maize cultivated closed to dumpsites poses potential lifetime cancer concern and thus maize farming around dumpsites needs to be discouraged for safety reasons.

Keywords: Dumpsite, Health Hazards, Heavy Metals and Maize Grains,

1. Introduction

Soil is one of the major natural resources which supports the growth and survival of microorganisms, plants, animals and human beings. It is infinite reservoir of diverse pollutants ranging from natural origins like rock weathering and volcanic emissions to anthropogenic activities such as waste dumpsites, incessant use of chemical/inorganic fertilizers and pesticides among other industrial waste products [1, 2]. The pollution of the environment by heavy metals has remained a serious threat to the ecosystem. In most cities, the key sources of heavy metals accumulation in soils are through metallic constructions, fabrications, chemical agents, wastewater, agricultural fertilizers, pesticides, crude oil spillage and refining [3]. Some of these pollutants are not-readily decomposed and transform

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to other less innocuous and environmentally friendly products. Hence, these pollutants accumulate and eventually impact directly on the ecosystem. Other pollutants such as heavy metals can persist and remain for years in soil, water and even bio-accumulate along food chains thereby posing serious health concerns to exposed humans and other animals [4, 5]. The ultimate goal of monitoring the level of waste management in the environment is to protect the pollution of agricultural lands and underground water bodies. Literature review have shown that waste dumpsites take the lead in the release of heavy metals into the surrounding soil, water and plants worldwide [6-10]. These are the commonest routes by which humans and animals get exposed to heavy metal contaminations. Apart from proper management of waste dumpsite, excessive use of agrochemicals such fertilizer in modern day framing to boost crop yields and productivity has been identified as a paramount source of different kinds of metals in agricultural soil [11-13]. Unknown to most of the framers, these unsafe practices can lead to accumulation of more metals in soil and crops which are cultivated in those lands [13]. The implications of such agricultural practices not only portends a short-term consequence but a long term effect on the soil chemistry, health, and other biological systems associated thereby [14]. Human beings are mostly the final recipients of environmental pollutants of agricultural soil through the consumption of plants that have accumulated and biomagnified the pollutants over a period of time [1, 15, 16].

Edible plants and water sources are the major exposure pathways for uptake and cellular accumulation of heavy metals by humans. Plant especially absorb the heavy from the soil via their roots and some of them are transferred to other parts of the plants where they accumulate to a significant threshold needed to exert toxicities and other health disorder in both humans and animals [2, 17]. Some of the reported toxicities of heavy metals ingested along with food include impairment of the immune defense system, psychosocial disorders, loss of essential nutrients, poor growth and other organ disorders [4, 16]. For instance, consumption of some cereals that were contaminated by lead (Pb), copper (Cu) and cadmium (Cd) have been linked to cancer, upper respiratory disorders, and renal failures [11]. The public health importance of crops contaminated by heavy metals in soil where they were grown have been documented in literature over the years to date [4, 11, 16-18]. Hence, it is important to monitor edible plants within the vicinities of major sources of heavy metals for public health concern. One of such edible, nutritional and annual flowering plants with widespread consumption rates by the young and the old is maize.

Zea mays L., commonly referred to as maize, is a flowering plant belonging to the Poaceae family. The grain is normally known as corn and ranked third after wheat and rice with reference to productivity and utilization. Due to its high nutritional value, maize is widely cultivated as human food, animal feeds and raw materials for food, pharmaceutical and other industrial products globally [19]. The proximate contents of maize grains were 71.9 %, 8.8 %, 4.6 %, 2.15 and 2.33 % for carbohydrates, crude proteins, crude fat, crude fat and crude ash respectively; useful minerals such as different classes of vitamins C and B have been reported [20]. Although, a nutritionally rich grain, studies have shown that maize possess the capacity to bio-accumulate certain heavy metals depending on the physiochemical properties of the soil [21-23]. In most towns and cities in Nigeria, maize are planted in old dumpsite areas or close to solid waste landfills and thus a serious health concerns to the consumers [24]. Beside, some farmers use wastewater from production processes as sources of irrigation for maize plants without recourse to their chemical wholesomeness [25]. The increasing rate of environmental pollution of soils by industrial and anthropogenic activities make plants cultivated in such areas a serious threat to health. The plants can bio-accumulate the heavy metals and translocate same to their edible fruits/grains. Therefore, this study was carried out to investigate the levels of accumulation of heavy metals by maize grains (*Zea mays* L.) cultivated around Gosa and Gwagwalada area councils solid waste dumpsites in Federal Capital Territory, Abuja, Nigeria and their health risks.

2. Literature Review

2.1 *Study area*

The study was carried out in Abuja, the Federal Capital Territory (FCT) of Nigeria. This study area is geographically located at coordinates' 9° 3′ 28.26″ N and 7° 29′ 42.29″ E and at 500 m above sea level. The land mass of FCT is about 8,000 km^2 with an estimated population 3,652,000 as at 2022 [26]. It has an average annual temperature range from 30-37 °C, with highest temperature experienced in the month of March and with total average rainfall of approximately 1,650mm per annum [27]. The four major States bordering the FCT are Kaduna (N), Niger (W), Nasarawa (E) and Kogi States (S) (Fig 1). This study was carried out at two of the major municipal area council, namely were Gosa (Abuja City) and Gwagwalada local government areas. Gosa area council harbors one of the largest municipal and industrial activites and thus has the largest solid waste dumpsites. Its geographical coordinates lie between latitudes 8° 53'N and 9° 13'N and longitudes 7° 00'E and 7° 30'E with a land area of 90.8 hectare [28]. On daily basis, 80 to 90 trucks visit Gosa dumpsite and waste management workers do their services of managing the solid wastes in districts using compacting trucks for municipal waste and tippers for garden waste [28]. The relevant government agency saddled with the responsibility of waste disposal in Abuja municipal is the Abuja environmental and protection board (AEPB). The second study location, Gwawalada area council lies on longitude 07°10'E and latitude 08° 59' N with elevation of about 610ft above the sea level. The town is heavily occupied as a result of the rinsing population of humans, farming, manufacturing and commercial activities [29]. Other municipal services such as vehicular activities, mini businesses, food vending among other metropolitan activities are prominent in area [29]. These activities generate tons of solid waste on daily and weekly basis, which are conveyed to the dumpsite within the town for disposal [29].

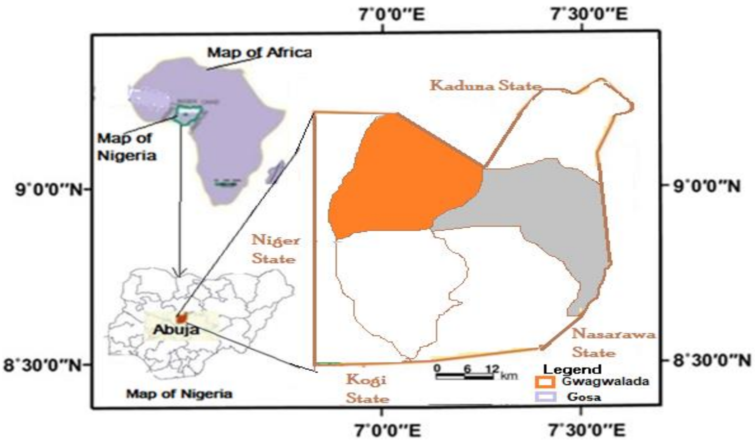

Figure 1. Location map of Federal Capital Territory, Abuja, showing study locations.

2.2. Collection of maize grains and surrounding soil samples

Maize grains, farmland soil and dumpsite soil samples (12 samples each) were collected using cluster random sampling methods in triplicates during the dry season from Gosa and Gwagwalada area councils. The selected farmlands used to cultivate the maize plants were situated at about 2 km from each dumpsite). The maize cobs were harvested manually, while the soil samples were collected using soil auger. All the samples were labeled using permanent maker and transported directed to the laboratory for preparation analysis.

2.3. Preparation of maize samples

The soil samples were air-dried at using hot air ovun at 35 °C for 3 days and then reduced to smaller size (2 mm) thereafter. The grains of the maize were manually separated and dried on crucibles for hours to reduce the moisture contents before digestion process.

2.4. Digestion and metals analyses of samples

The soil samples (dumpsite and farmland soils) were digested as reported previously (El-Hassanin *et al.*, 2020; Karimian *et al*., 2021) [30, 31]. Briefly, a mixture of three concentrated acids; HCl, $HClO_4$ and HNO_3 at ratio 3:3:1 v/v/v). The soil samples were weighed (0.5 g) and carefully mixed with digestion solution (25 mL) and for 4 h at 220 °C. After the digestions process, the final contents were filtered after cooling using Whatman filter paper (ashless). The final volume of the volume of the filtrate diluted up to the 50 mL by adding some quantities of HNO_3 (1 % v/v). Similarly, the dried maize grains (5 g) digested using the dry-ashing procedure and then further dissolved in conc. HCL (1 ml). The digested solution was diluted with HNO_3 (1 % v/v) to 25 ml before filtering using the Whatman filter paper (ashless). Metal analysis for cadmium (Cd), lead (Pb), zinc (Zn), cobalt (Co), copper (Cu), chromium (Cr), nickel (Ni) and mercury (Hg) were done according to their wavelengths using atomic absorption spectrophotometer (AAS Buck Scientific Model 210) in accordance with manufacturer's guidelines.

2.5. Transfer factor (TF) from soil to maize grains:

$$TF = \frac{C_{maize}}{C_{Soil}} \tag{1}$$

Where C_{maize} is the concentration of metals in maize grain samples, while C_{Soil} is the concentration of farmland soil samples [32]. If the calculated TF value is > 0.5, it shows higher possibilities of anthropogenic input in metal contaminations.

2.6. Health risk assessment (HIA)

The HIA was determined to estimate the health risk associated with metal consumption of maize grains using some standard equations 2-5 reported in previous studies for daily intake of metal (DIM), target hazard quotient (THQ) and hazard index (HI), respectively [32]. The exposed population were grouped based on age bracket and average body weight as 60 kg; 22-48.9 years (adult), 35 kg; 6-15 years (young children) and 15 kg; 1-6 years (infants) [33]. Average rate maize consumed in Nigeria was taken as 57 g/person/days [32]

2.6.1. Daily intake of metal (DIM) from maize consumption

$$DIM = \frac{C_{metal} \times C_{factor} \times C_{maize\ intake}}{B_{average\ weight}} \tag{2}$$

Where C_{metal} is concentration of metals in maize, C_{factor} is conversion factor to dry weight (0.085 was used), $C_{maize\ intake}$ daily intake of maize and $B_{average\ weight}$ is average body weight [32].

2.6.2 **Target hazard quotient (THQ)**

$$THQ = \frac{DIM \times E_D \times E_F}{T_A \times RfD \times 365} \times 10^{-3} = \frac{DIM}{RfD} \tag{3}$$

Where DIM is dietary intake of metal (mg/kg/day), E_D is exposure period (40 years for an average lifetime) (Afonne *et al.*, 2017), E_f is frequency of exposure (365 per year), T_A is average exposure period for non-carcinogen and numerically similar to E_D and RfD is the minimum acceptable oral dose without health issues. They are 1.0×10^{-3} (Cd), 4.0×10^{-3} (Pb), 3×10^{-1} (Zn), 4.0×10^{-3} (Co), 4.0×10^{-2} (Cu), 3.0×10^{-2} (Cr) 2.0×10^{-3} (Ni) and 3.0×10^{-4} (Hg) mg/kg body weight [32, 33]. If the calculated THQ is < 1, this indicates likelihood of adverse health non-carcinogenic risk in exposed individuals.

2.6.3. Hazard index (HI)

$$HI = \sum \text{THQs} \tag{4}$$

If the calculated value of HI ≤ 1, this shows no significant risk of non-carcinogenic effects. While HI > 1, indicates an increasing probability of non-carcinogenic effects occurring in the exposed individuals.

2.6.4. Incremental lifetime carcinogenic risk (ILCR)

$$ILCR = CSF \times EDI \quad (5)$$

Where, CSF is the carcinogenic slope factor for heavy metals (Cu, Cr, Ni, Cd and Pb used were 1.5, 0.41, 1.7, 0.38 and 0.0085 mg/kg/day, receptively) [32, 34] and EDI is the estimated daily intake of each metals (mg/kg/bw/day). Generally, an intolerable target range for carcinogen is between 10^{-4} to 10^{-6} [35].

2.7. Data analysis

The experimental data obtained were computed for one-way analysis of variance (ANOVA) at significance level of 0.05. Mean values that were significantly different were separated using Duncan Multiple Range Test.

3. Results

Generally, soil samples collected from dumpsite soils had the highest metal concentrations, followed by farmland soil except for Zn, which had greater concentrations in the maize grains than farm land soil samples in both study locations (Table 1). The metal, Zn (762-1014 mg/kg) was significantly ($p<0.05$) highest in all the sampling locations. The least metal concentrations were Cd (0.001 mg/kg), Cr (0.001 mg/kg), Hg (0.001 mg/kg). For the maize grain samples, the concentrations of metals were within the safe limit stipulated by the FAO/WHO [36] and EU [37].

The results of transfer of metal from farmland soil to the plant (maize) are shown in Figure 2. The transfer value for each metal was in the order: Zn > Pb >Cd > Co > Ni > Cu > Cr = Hg (Gosa maize grains) and Zn > Pb > Co > Cu >Ni > Cr = Cd = Hg. Of all the metal assayed, only Zn in both locations had TF that was greater than 0.5. This indicates the possibilities of anthropogenic inputs in the farm environments.

Table 1. Metal concentration (mg/kg) (mean ± SD) in soils (dumpsite and farmland) and maize grain samples

Sampling Area	Metal (mg/kg)	Dumpsite soil	Farmland soil	Maize grains	Safe Limit* [36, 37]
Gosa	Cd	16.11 ± 0.59^{de}	0.23 ± 4.21^{e}	0.011 ± 0.01^{f}	0.2
	Pb	16.12 ± 4.30^{de}	1.17 ± 0.24^{d}	0.11 ± 1.02^{c}	0.3
	Zn	1014.00 ± 647^{a}	10.45 ± 0.40^{a}	11.76 ± 1.19^{a}	99.4
	Co	38.15 ±15.7^{c}	1.56 ± 0.23^{cd}	0.024 ± 4.21^{e}	0.01
	Cu	85.42 ±13.10^{b}	2.35 ± 0.60^{c}	0.021 ± 0.11^{e}	73.3
	Cr	102.00 ± 49.21^{b}	0.001 ± 0.00^{g}	0.001 ± 0.14^{h}	2.3
	Ni	79.32 ± 17.34^{b}	0.210 ± 0.10^{e}	0.002 ± 0.10^{g}	67.9
	Hg	19.53 ± 5.03^{de}	1.12 ± 0.51^{d}	0.001 ± 1.10^{h}	0.03
Gwagwalada	Cd	0.52 ± 0.29^{f}	0.001 ± 0.00^{g}	0.001 ± 0.11^{h}	0.2
	Pb	10.94 ± 2.86^{e}	0.04 ± 0.60^{f}	0.01 ± 1.60^{f}	0.3
	Zn	762.00 ± 231^{a}	4.15 ± 0.94^{b}	13.62 ±2.26^{a}	99.4
	Co	62.00 ± 18.38^{b}	2.18 ± 1.71^{c}	0.27 ± 0.23^{b}	0.01
	Cu	83.16 ± 34.21^{b}	1.27 ± 0.81^{d}	0.05 ± 1.44^{d}	73.3
	Cr	23.00 ± 13.21^{d}	0.001 ± 0.02^{g}	0.001 ± 0.00^{h}	2.3
	Ni	41.94 ± 16.86^{c}	2.45 ± 0.04^{c}	0.02 ± 0.15^{e}	67.9
	Hg	14.83 ± 3.57^{de}	0.001 ± 0.10^{g}	0.001 ± 0.00^{h}	0.03

Data are expressed as mean ± standard deviation of triplicate (n = 3), values with different superscript down the column are significantly different (p<0.05).

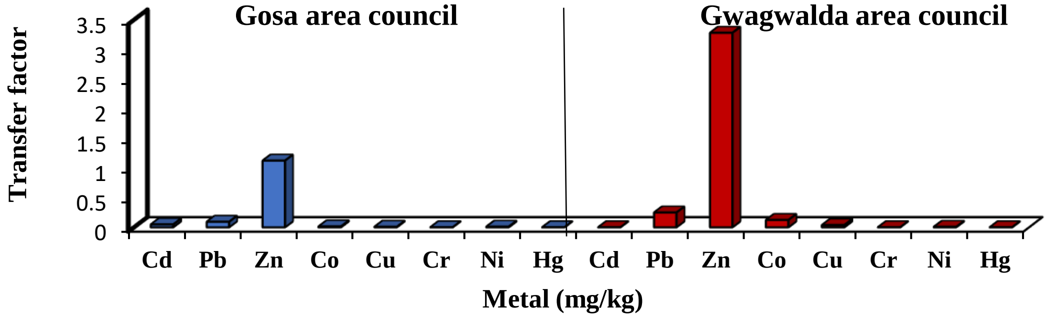

Figure 2. Transfer factors of metals from soil to maize grain (**TF > 0.5 indicates anthropogenic inputs)*

The estimated daily intake (mg/kg bw/day) from consumption of maize grains (57 g) in exposed individuals (infants, 15 kg; children, 35 kg; adults 60 kg) are presented in Table 2. For Gosa area council, the highest and lowest DIM for infants and children were both Zn and Ni, unlike in adults with Zn and Hg. Similarly, Gwagwalada area council had Zn as the highest DIM and the least were Ni, Cd, and Hg for infants and children. The adults also had Zn as the most DIM and Ni, Cd, and Hg as the least metals. When compared with the daily safe limit of each metal in food, they were all found to be below recommended dosages for each metals/elements.

Target hazard quotient for the metals, as shown in Table 3, revealed that consumption of maize grains (57 g) in exposed individuals (infants, 15 kg; children, 35 kg; adults 60 kg) revealed their HI (summation of individual THQ) as 0.03, 0.01, and 0.01 (Gosa area council) and 0.02, 0.02 and 0.01 (Gwagwalada area council). These HI values were below 1, which generally indicates no significant non-carcinogenic risk in exposed infants, children and adults.

The target cancer risks for each metals are presented in Table 4. The results showed that the calculated ILCR were generally below 10^{-6}. The cancer risks for exposure to each metal in infants, children and adults were Cu (10^{-2}, 10^{-3}, 10^{-3}), Cd (10^{-3}, 10^{-4}, 10^{-4}), Ni (10^{-3}, 10^{-4}, 10^{-4}), Pb (10^{-4}, 10^{-4}, 10^{-5}) and Cr (10^{-4}, 10^{-5}, 10^{-6}) (Gosa area council) and Cu (10^{-2}, 10^{-2}, 10^{-3}), Ni (10^{-2}, 10^{-3}, 10^{-3}), Cr (10^{-3}, 10^{-5}, 10^{-5}), Cd (10^{-4}, 10^{-5}, 10^{-5}), Pb (10^{-5}, 10^{-5}, 10^{-6}). The summation of the ILCR metals were 10^{-2}, 10^{-3}, 10^{-3} for infants, children and adults (Gosa area council) and 10^{-2}, 10^{-2}, 10^{-3} for infants, children and adults (Gwagwalada area council).

Table 2. Daily intake of metals (DIM) (mg/kg bw/day) from consumption of maize grains (57 g) for exposed individuals (infants, 15 kg; children, 35 kg; adults 60 kg) **sample**

Sampling area	Metal (mg/kg)	DIM Infants	DIM Children	DIM Adult	Daily safe limit
Gosa area council	Cd	4.00×10^{-3}	2.00×10^{-3}	8.88×10^{-4}	0.00-0.06
	Pb	3.60×10^{-2}	1.52×10^{-2}	8.88×10^{-3}	0.00-0.24
	Zn	3.81	1.64	0.954	8.00-40.00
	Co	7.79×10^{-3}	3.34×10^{-3}	1.95×10^{-3}	0.01
	Cu	6.81×10^{-3}	2.92×10^{-3}	1.70×10^{-3}	0.90-10.00
	Cr	3.25×10^{-4}	1.39×10^{-4}	8.11×10^{-5}	0.1
	Ni	6.49×10^{-4}	2.78×10^{-4}	1.62×10^{-4}	0.50-1.00
	Hg	3.25×10^{-4}	1.39×10^{-4}	8.11×10^{-5}	0.05
Gwagwalada area council	Cd	3.25×10^{-4}	1.39×10^{-4}	8.11×10^{-5}	0.00-0.06
	Pb	3.25×10^{-3}	1.39×10^{-3}	8.11×10^{-4}	0.00-0.24
	Zn	4.42	1.89	1.10	8.00-40.00
	Co	8.76×10^{-2}	3.75×10^{-2}	2.19×10^{-2}	0.01

	Cu	1.62×10^{-2}	6.95×10^{-3}	4.06×10^{-3}	0.90-10.00
	Cr	3.25×10^{-4}	1.39×10^{-4}	8.11×10^{-5}	0.1
	Ni	6.49×10^{-3}	2.78×10^{-3}	1.62×10^{-3}	0.50-1.00
	Hg	3.25×10^{-4}	1.39×10^{-4}	8.11×10^{-5}	0.05

Table 3. Target hazard quotient (THQ) of metals from consumption of maize grains (57 g) for exposed individuals (infants, 15 kg; children, 35 kg; adults 60 kg)

Sampling area	Metal (mg/kg)	THQ Infants	THQ Children	THQ Adult
Gosa area council	Cd	4.00×10^{-3}	2.00×10^{-3}	8.88×10^{-4}
	Pb	9.00×10^{-3}	3.80×10^{-3}	2.22×10^{-3}
	Zn	1.27×10^{-2}	5.47×10^{-3}	3.18×10^{-3}
	Co	1.95×10^{-3}	8.35×10^{-4}	1.95×10^{-3}
	Cu	1.70×10^{-4}	7.30×10^{-5}	4.25×10^{-5}
	Cr	1.08×10^{-5}	4.63×10^{-6}	2.70×10^{-6}
	Ni	3.25×10^{-4}	1.39×10^{-4}	8.10×10^{-5}
	Hg	1.08×10^{-3}	4.63×10^{-4}	2.70×10^{-4}
Non-carcinogenic risk (HI < 1)	$\sum$ THQs	0.03	0.01	0.01
Gwagwalada area council	Cd	3.25×10^{-4}	1.39×10^{-4}	8.11×10^{-5}
	Pb	8.13×10^{-4}	3.48×10^{-4}	2.03×10^{-4}
	Zn	1.47×10^{-2}	6.30×10^{-3}	3.67×10^{-3}
	Co	2.19×10^{-3}	9.38×10^{-3}	5.48×10^{-3}
	Cu	4.05×10^{-4}	1.74×10^{-4}	1.01×10^{-4}
	Cr	1.08×10^{-5}	4.83×10^{-6}	2.70×10^{-6}
	Ni	3.25×10^{-3}	1.39×10^{-3}	8.10×10^{-4}
	Hg	1.08×10^{-3}	4.63×10^{-4}	2.70×10^{-4}
Non-carcinogenic risk (HI < 1)	$\sum$ THQs	0.02	0.02	0.01

Table 4. Incremental lifetime carcinogenic risk (ILCR) of heavy metals from consumption of maize grains (57 g) for exposed individuals (infants, 15 kg; children, 35 kg; adults 60 kg)

Sampling area	Metal (mg/kg)	LCR Infants	LCR Children	LCR Adult
Gosa area council	Cd	1.52×10^{-3}	7.60×10^{-4}	3.37×10^{-4}
	Pb	3.06×10^{-4}	1.29×10^{-4}	7.55×10^{-5}
	Zn	ND	ND	ND
	Co	ND	ND	ND
	Cu	1.02×10^{-2}	4.38×10^{-3}	2.55×10^{-3}
	Cr	1.33×10^{-4}	5.70×10^{-5}	3.32×10^{-6}
	Ni	1.10×10^{-3}	4.73×10^{-4}	2.27×10^{-4}
	Hg	ND	ND	ND
Carcinogenic risk	$\sum ILCR$	**1.33×10^{-2}**	**5.80×10^{-3}**	**3.19×10^{-3}**
Gwagwalada area council	Cd	1.24×10^{-4}	5.28×10^{-5}	3.08×10^{-5}
	Pb	2.76×10^{-5}	1.18×10^{-5}	6.89×10^{-6}
	Zn	ND	ND	ND
	Co	ND	ND	ND
	Cu	2.43×10^{-2}	1.04×10^{-2}	6.09×10^{-3}
	Cr	1.33×10^{-3}	5.70×10^{-5}	3.33×10^{-5}

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	Ni	1.10×10^{-2}	4.73×10^{-3}	2.75×10^{-3}
	Hg	nd	nd	nd
Carcinogenic risk	$\sum$ ILCR	**$3.58 \times 10^{-2*}$**	**$1.53 \times 10^{-2*}$**	**$8.91 \times 10^{-3*}$**

ND: not determined,

4. Discussion

The activities of man are the major factors responsible for environment. There several pollutants in the environment, but due to their non-biodegradability, persistence, longevity, bioaccumulations and toxicity, among other factors, heavy metals been identified as a serious environmental hazard to the ecosystem and health of microbes, plants, animals and mans. Some metals are beneficial to man, while others are non-beneficial because of their toxicities to cells, tissues and organs which absorb them. Metals are generally toxic depending on the expose dosage, age and other physiological conditions of the exposed individuals [33]. One of the major routes by which humans gets exposed to heavy metals is via consumption with food, water and inhalation by air [32].

This study investigated the health risk of some metals (Zn, Pb, Cd, Co, Cu, Cr, Ni and Hg) in maize grains (*Zea mays* L.) cultivated close to Gosa and Gwagwalada solid waste dumpsites. Zn was detected as the most abundant metal in all the samples tested in both locations. Zn is one of the commonest and most widespread beneficial metals for all organisms, including humans because at the recommended dose it plays useful physiological roles such as metabolism, cell growth/development, enzyme co-factor, boost immune system and overall maintenance of a healthy system [38]. At relatively low nutritional intake, certain health disorders have been reported in infants, children and adults [38]. In this study, the mean concentration of Zn ranged from 11.76 mg/kg to 13.62 mg/kg in maize grains cultivated at Gosa and Gwagwalada area council farmlands. The daily maximum safe limit is about 99.4 mg/kg [36, 37]. Data analysis using one-way ANOVA revealed that Zn was significantly ($p<0.05$) highest in both locations. The mean level of Zn reported previously were 2.01 mg/kg from Kaduna, Nigeria [39], 0.122 mg/kg from Gishu Couny, Kenya [40], 0.113 mg/kg from Homabay County, Kenya [41], 0.66 mg/kg from Ethiopia [42] and 3.6 mg/kg in Bangladesh [43]. They were far lower than the levels of Zn this study. However, higher concentrations were reported from China (15 mg/kg) and Ethiopia (18.1 mg/kg) by Hongxing and Yu-Kui [44] and Nyachoti *et al*. [45], respectively. The significantly high level of Zn in both farmland could be attributed to human activities such as fertilizer applications and leachate from waste dumpsites around the farmlands.

Like Zn, the metals Co, and Cu are other useful biological micronutrients which are important for all cells. Copper (Cu) is also an essential enzyme components for active cellular metabolism and physiological processes such as good bone formations and production of haemoglobin, antioxidants, neurons protections and other oxidative stress-associated enzymes [46]. Similarly, Co is an important micronutrient needed for production of vitamins and other co-factors for enzymes [47]. On the other hand, living cells require the less toxic biological usable form (Cr^{3+}) for the production of tolerance factors of glucose for carbohydrate, proteins and fat metabolisms [46]. The other form which is toxic to the cells usually occur as chromium IV can lead to poor metabolism, diabetes, skin disorder, renal failure and respiratory tract challenges [46]. The levels of Co and Cu observed in this study ranged between 0.024 - 0.27 mg/kg and 0.05 - 0.021 mg/kg, respectively. Akenga *et al.* [41] reported a comparable level of 0.042 mg/kg for Co and a higher content of Cu (0.122 mg/kg) in maize grains. On the other hand, higher concentrations of 007 – 0.5 mg/kg and 0.23 mg/kg were reported for Cr in maize grains irrigated using wastewater by Huma *et al*. [48] and Lu *et al.* [49].

The presence of Ni, Pb, Hg and Cd are important in the maize grain because of their public health relevance. In this study, the range of Ni, Pb, Hg and Cd (mg/kg) were 0.001 – 0.002, 0.001 –

0.11, 0.001, and 0.001 – 0.011. The present results were lower than to those reported by previous workers who studied heavy metal accumulations in maize grains. For instance, 0.48 - 0.23 and 0.04 – 0.11 mg/kg were reported for Pb and Cd [49]. Similarly higher contents of Cd (0.223 mg/kg) and Pb (0.324 mg/kg) were reported by Akenga *et al*. [41]. While a higher level of Ni (0.18 mg/kg) was documented [49], a substantially lower content of Hg (<0.001 mg/kg) was however reported another study [50]. Although, the levels of Ni, Pb, Hg and Cd were relatively lower than the safe limit stipulated by the FAO/WHO [36] and EU [37], there is need to reduce farming in < 2 km away from dumpsites so as to reduce continuous exposure, accumulation and possible bio-magnification along the food chains. The commonest toxicities of heavy metals reduction in immune system, psychosocial disorders, skin disorders, gastrointestinal and respiratory damages as well as impairments of normal roles tissues and other organ disorders depending of the age of exposed persons, route of contact and dosages available [4, 16, 46].

Metals, particularly the trace or micronutrients, are important to plants and animals for health growth and development. Plants derive their elemental nutrients from soil via the root system. From thus location, some are stored or bio-accumulate due to non-degradability, while others are utilize by the cells of the plants for optimal physiological and biochemical processes. Some of the non-essential metals, also termed heavy metals (Cd, Pb and Hg, among others) are absorbed through the roots to other part of the plants. Those with potential phyto-extracts mechanism have devised a safer way of transforming or concerting these heavy into cell tolerable forms. In order the assess the concentrations of accumulated metals in plants organs from soil, environmentalists determine the transfer factor of such metals by estimating the ratio of the concentration of the metal in question to the concentration in soil [51]. If the calculated TF value is greater than 0.5, it suggests a greater chance of anthropogenic input in metal contaminations and accumulation in the plant [32]. In this study, all the metal assayed had TF values of less than 0.5 with the exception of only Zn in both locations. This indicates that the anthropogenic activities such as irrigations, fertilizer application and leachates from waste dumpsites must have enhanced the level (above the farmland soil content) of Zn in the maize grains. This result is agrees with the study of [32]. The variations could be attributed to the differences in properties of the physical and chemical compositions of vse-a-vis human inputs [31].

The health risk associated with exposure of humans to harmful metals is of public and environmental concerns. The parameters used to assess health risks of metals in food are the estimated daily intake of metals with food, analysis of target hazard quotient (also known as the non-carcinogenic index) and the incremental lifetime carcinogenic risks (Ogu and Akinnibosun, 2019; Ojiego *et al.*, 2022) [52, 53]. The results of the estimated daily intake from consumption of maize grains (57 g) were generally high for Zn and low for Ni, Cd, and Hg in exposed individuals. All the metals were below the maximum daily intake of metals in food, suggesting little or no health issues for daily consumption of 57 g of maize by infants (15 kg), young children (35 kg) and adults (60 kg). Our result concurs with previous report [31]. This result from this study further revealed that all the metals had THQ and HI of less than 1. This indicates that there is no significant non-carcinogenic risk in exposed infants, children and adults. The target cancer risks for each metals were generally below 10^{-6}. According to nutritionists and food scientists, the severity of ILCR is classified as low risk ($\leq 10^{-6}$), moderate risk (10^{-5} to 10^{-3}) and high risk (10^{-3} to 10^{-1}) of cancer [35, 54, 53]. Hence, less than 10^{-6} value of target cancer risk obtained in this study indicates potential lifetime cancer concern in exposed individual. Specifically, the infants appears to be the most exposed individuals, followed the young children and adults who are continuous feeding on maize grains harvested from the study locations. Exposure to daily consumption of Gwagwalada maize grains with Cu, Ni, Cr and Cd poses high cancer risks in infant unlike the other (young children and adults) target populations.

5. Conclusion

Based on the findings from this study, this study has shown that maize grains cultivated close Gosa and Gwagwalada area council dumpsites have varying amounts of metal (mg/kg) which ranged from 13.62 (Zn) to 0.001 (Cr, Hg and Cd). The metals were however below the permissible limits indicating that their concentrations are relatively safe. The transfer factor of Zn, being above 0.5, indicates inputs from dumpsite leachates and probably human activities during the farming processing. Daily consumption of the maize grains (57 g) showed no significant non-carcinogenic risks in all the exposed populations investigated. However, target cancer risks ($< 10^{-6}$) indicate potential lifetime cancer risks especially in infants and children who constantly consume the maize. Hence, this study concluded that daily consumption of maize cultivated closed to dumpsites poses potential incremental lifetime cancer concern and thus maize farming around dumpsites needs to be discouraged for safety reasons. Other safety measures against pollution and leachates of heavy metals within the study areas could be adopted.

References

[1] J. Kormoker, R. Proshad, M. S. Islam, S. Ahmed, S. Chandra, M. Uddin, and M. Rahman, "Toxic metals in agricultural soils near the industrial area of Bangladesh: ecological and human health risk assessment," Tox Rev, 2019, doi: https://doi.org/10.1080/15569543.2019.1650777

[2] E. C. Mmaduakor, C. T. Umeh, J. E. Morah, D. O. Omokpariola, A. A. Ekwuofo and S. O. Onwuegbuokwu, "Pollution status, health risk assessment of potentially toxic elements in soil and their uptake by *Gongronema latifolium* in Peri-urban of Ora-Eri south-eastern Nigeria," Heliyon, vol. 8, no. 8, e10362, 2022, doi: https://doi.org/10.1016/j.heliyon.2022.e10362

[3] R. A. Wuana and F. E. Okieimen, "Heavy metals in contaminated soil: a review of sources, chemistry, risks and best available strategies for remediation," Int Schol Res Not, 2011, doi: https://doi.org/10.5402/2011/402647

[4] J. E. Emurotu and P. C. Onianwa, "Bioaccumulation of heavy metals in soil and selected crops cultivated in Kogi State, north central Nigeria. Environ Syst Res, vol. 6, p. 21, 2017, doi: https://doi.org/10.1186/s40068-017-0098-1

[5] R. Li, Y. Yuan, C. Li, W. Sun, M. Yang and X. Wang, "Environmental health and ecological risk assessment of soil heavy metal pollution in the coastal cities of estuarine Bay- A case study of Hhangzhou Bay China," Tox, vol. 8, no. 3, p. 75, 2020, doi: https://doi.org/10.103390/toxicss8030075

[6] B. R. Issa, G. B. Birma, F. A. Muhammed, J. E. Ikpesu and P. Tawari–Fufeyin, "Index model approach of heavy metals pollution assessment in soil quality of some selected solid waste dumpsites in Warri and Environs, Delta State, Nigeria. Dir. Res. J. Pub. Health Environ Technol, vol. 7, no. 1, pp. 1-8, 2020, doi: https://doi.org/10.26765/DRJPHET871635105

[7] S. O. Oluwole, S. O. Makinde, M. L. Ogu and I. R. Nwachukwu, "Evaluation of heavy metal concentrations and proximate compositions of *Amaranthus spinosus* L. and *Talinum triangulare* J. and soils collected from dumpsites in some selected areas in Lagos State, Nigeria. World Environ, vol. 10, pp. 16-26, 2020, doi: https://doi.org/10.5923/j.env.20201001.03

[8] Y. Wang, W. Sun, Y. Zhao, P. He, L. Wang and L. T. T. Nguyen, "Assessment of heavy metal pollution characteristics and ecological risk in soils around a rare earth mine in Gannan," Sci. Program, 2020. DOI: https://doi.org/10.1155/2022/5873919

[9] V. I. Onwukeme and V. C. Eze, "Identification of heavy metals source within selected active dumpsites in southeastern Nigeria," Environ Anal Health Toxicol, vol. 36, e2021008, 2021, doi: https://doi.org/10.5620/eaht.2021008

[10] B. K. Mavakala, P. Sivalingam, A. Laffite, C. K. Mulaji, G. Giuliani, P. T. Mpiana and J. Potéa, "Evaluation of heavy metal content and potential ecological risks in soil samples from wild solid waste dumpsites in developing country under tropical conditions," Environ Challenges, vol. 7, p. e100461, 2022, doi: https://doi.org/10.1016/j.envc.2022.100461

[11] F. O. Ugbede, O. D. Osahon, A. F. Akpolile and B. B. Oladele, "Assessment of heavy metals concentrations, soil-to-plant transfer factor and potential health risks in soil and rice samples from Ezillo rice fields in Ebonyi State, Nigeria," Environ Nanotechnol Monitor Manag, vol. 16, e100503, 2021, doi: https://doi.org/10.1016/j.enmm.2021.100503

[12] W. A. Iyama, K. Opkara and K. Techato, "Assessment of heavy metals in agricultural soils and plants (*Vernonia amydalina* Delile) in Port Harcourt Metropolis, Nigeria. Agric, vol. 12, no. 1, p. 27, 2021, doi: https://doi.org/10.3390/agriculture12010027

[13] E. A. Okoye, A. N. Eejiofor, I. L. Nwaogazie, C. Frazzoli and O. Orisakwe, "Heavy metals and arsenic in soil and vegetation of Niger Delta: ecological risk assessment," Case Study Chem Environ Eng, vol. 6, p. 100222, 2022, doi: https://doi.org/10.1016/jcscee.2022.100222

[14] O. H. Adedeji, O. O, Olayinka, O. O. Tope-Ajayi and A. S. Adekoya, "Assessing the spatial distribution, potential ecological and human health risks of soil heavy metal contamination around Trailer Park in Nigeria," Sci Afri, vol. 10, e00650, 2020, doi: https://doi.org/10.1016/j.sciaf.2020.e00650

[15] B. Mekonnen, A. Haddis and W. Zeine, "Assessment of the effect of solid waste dumpsite on surrounding soil and river water quality in Tepi Town, Southwest Ethiopia," J Environ Pub. Health, online pp. 1-9, 2020, doi: https://doi.org/10.1155/2020/5157046

[16] E. Atikpo, E. S. Okonofua, N. O. Uwadua and A. Michael, "(2021). Health risks connected with ingestion of vegetables harvested from heavy contaminated farms in Western Nigeria. Heliyon, vol. 7, no. 8, e07716, 2021, doi https://doi.org/10.1016/j.heliyon.2021.eo7716

[17] B. K. Lere, I. Basira, S. Abdulkadir, S. M. Tahir, H. A. Ari and A. Y. Ugya, "Health risk assessment of heavy metals in ingested fruits and vegetables cultivated in selected farmlands around Kaduna metropolis, Nigeria," Egyptian J. Basic Appl Sci, vol. 8, no. 1, pp. 317-329, 2021, doi: https://doi.org/10.1080/2314808X.2021.1992956

[18] R. Proshad, M. S. Islam, T. Kormoker, M. S. Bhuyan, M. A. Hanif, N. Hossain, Y. Roy and A. C. Sharma, "Contamination of heavy metals in agricultural soil: ecological and human health risk assessment," J Nanochem Nanotechnol, vol. 2, no. 1, e1012, 2019.

[19] A. P. Soji, "The potential importance of maize (*Zea mays* L.) in Nigeria (A case study of 2,800 farmers sampled at different location)," Adv Biochem, vol. 8, no. pp. 1-10, 2019, doi: https://doi.org/10.11648/j.ab.20200801.11

[20] T. Rouf-Shah, K. Prasad and P. Kumar, "Maize- a potential source of human nutrition and health: a review," Cogent Food Agric, vol. 2, no. 1, e1166995, 2016.

[21] C. Nakiguli, B. Namakula, J. Odda, J. Wasswa and E. Ntambi, "Heavy metal accumulation in maize (*Zea mays* L.) grown on chromated copper arsenate (CCA) contaminated soil amended with treated composted sewage biosolid," J Environ Prot, vol. 9, pp. 1196-1204, 2018, doi: https://doi.org/10.4236/jep.2018.911075

[22] O. T. Aladesanmi, J. G. Oroboade, C. P. Osisiogu and A. O. Osewole, "Bioaccumulation factor of selected heavy metals in *Zea mays,"* J Health Poll, e191207, 2019, doi: https://doi.org/10.5696/2156-9614-9.24-191207

[23] E. A. Ruiz-Huerta, M. A. Armienta-Hernandez, J. G. Dubroksy and J. M. Gomez-Bernal, "Bioaccumulation of heavy metals and As in maize (*Zea mays* L.) grown close to mine tailing strongly impacts plant development," Ecotoxicol, vol. 31, pp. 447-467, 2022, doi: https://doi.org/10.1007/s10646-022-02522

[24] G. Sagbara, N. Zabbey, K. Sam and G. N. Nwipie, "Heavy metal concentration in soil and maize (*Zea mays.* L.) in partially reclaimed refused dumpsite 'burrow pit' in Port Harcourt, Nigeria," Environ Technol Innov, vol. 4: e100745, 2020, doi: https://doi.org/10.10165/j.eti.2020.100745

[25] E. A. Abdelrahman, S. A, Alkhamisi, M. Ahmed and H. Ali, "Effects of treated wastewater irigateion on element concentrations in soil ad maize plants. Commun Soil Sci Plant Anal, vol. 42, no. 17, e596236, 2011, doi: https://doi.org/10.1080/000103624.2011.596236

[26] Anonymous, "Abuja, Nigeria metro area population 1950-2022," 2022. Available: https://www.macrotrends.net/cities/21976/abuja/population

[27] B. R. Mohammed, O. C. Jegede, S. K. Malang, S. S. Obeta, C. E. Ojiofor, L. N. Onyekanihu, B. T. Farimoyo and D. N. Onah, "Awareness of the public health importance of singeing of

slaughtered goat uing spent tyres ta Gwagwalada abattoir, Abuja – Nigeria," J Foodborne Zoo Dis, vol. 3, no. 3, pp. 34-48, 2015.

[28] K. Saidu, I. D. Muhammad and I. I. Ozigis, "Characterization of Gosa municipal solid waste at Abuja, Nigeria," FUOYE J. Eng. Technol., vol. 6, no. 1, pp. 72 – 76, 2021

[29] H. O. Sawyerr, A. T. Adeolu, A. S. Afoabi, O. O. Salami and B. K. Badmos, "Impact of dumpsites on the quality of soil and ground water in satellite towns of the Federal Capital Territory, Abuja, Nigeria," J. Health Pollut., vol. 7, no. 14, pp. 15 – 22, 2017

[30] A. S. El-Hassanin, M. R. Samak, G. N. Abdel-Rahman, Y. H. Abu-Sree and E. M. Saleh, "Risk assessment of human exposure to lead and cadmium in maize grains cultivated in soil irrigated either with low-quality water or freshwater," Toxicol Rep, vol. 7, pp. 10-15, 2020, doi: https://doi.org/10.1016/j.toxrep.2019.11.018

[31] S. Karimian, S. Shekoohiyan and G. Moussavi, "Health and ecological risk assessment and simulation of heavy metal-contaminated soil of Tehran landfill," Royal Soc Chem Adv, vol. 11, pp. 8080-8095, 2021, doi: https://doi.org/10.1039/d0ra08833a

[32] O. J. Afonne, E. B. Ehigiator and U. U. Ezeani, "Health risk potentials of some metals via consumption of some food crops at Irueken, Southern Nigeria," Toxicol. Int, vol. 24, no. 2, pp. 140-149, 2017, doi: https://doi.org/10.22506/ti/2017/v24/i2/162411

[33] O. E. Arigbede, G. O. Olutona and M. O. Dawodu, "Dietary intake and risk assessment of heavy metals from selected biscuit brands in Nigeria," J. Heavy Metal Tox. Dis, vol. 4, no. 2, p. 3, 2019, doi: https://doi.org/10.21767/2473-6457.10027

[34] M. Alsafran, K. Usman, M. Riizwan, T. Ahmed and H Al-Jabri, "The carcinogenic and non-carcinogenic health risks of metal(oids) bioaccumulation in leafy vegetables: a consumption advisory. Front. Environ Sci, vol. 9, e742268, 2021, doi: https://doi.org/10.3389/fenvs.2021.742268

[35] USEPA, "United States Environmental Protection Agency Regional screening levels (RSLs)-generic tables. Washington, D.C.: 2018. Accessed in the March, 2022 from: https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

[36] FAO/WHO, *"Codex Alimentarius Commission Food additives and contaminants. Joint FAO/WHO Food Standards Programme, & World Health Organization. Codex Alimentarius*," General requirements (food hygiene). ALINORM 01/12A: 1-289, 2001.

[37] FDA (Food and Drug Administration) *"Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc,"*Report of the Panel on Micronutrients. National Academy Press, Washington, DC Food and Drug Administration, Dietary supplements, Center for Food Safety and Applied Nutrition, 2001.

[38] R. B. Saper and R. Rash, "(2010). Zinc: an essential micronutrient," Am Farm Physician, vol. 79, no. 9, p.768, 2010.

[39] Y. I. Sulyman, S. Abduralzak, Y. A. Oniwapele and A. Ahmad, "Concentration of heavy metals in some selected cereals source within Kaduna State, Nigeria," IOSR J Environ Sci Toxicol Food Technol, vol. 9, no. 10, pp. 17-19, 2015.

[40] T. Akenga, V. Sudoi, W. Machuka, E. Kerich and E. Ronoh, "Heavy metal uptake in maize grains and leaves in different agro-ecological zones with Uasin Gishu County," J Environ Prot, vol. 9, no. 24, pp. 1435-1444, 2017, doi: https://doi.org/10.4236/jep.2017.812087

[41] T. Akenga, V. Sudo, E. Kerich, W. Machuk and E. Ronoh (2020). Selected heavy metal concentrations in maize grains and leaves in Homahills, Homabay County," Afr J Edu Sci and Technol, vol. 4, no. 4, pp. 50-58, 2018.

[42] W. A. Tegegne, "Assessment of some heavy metals concentrations in selected cereals from local market of Ambo City, Ethiopia. J Cereal Oilseeds, vol. 6, no. 2, pp. 8-13, 2015.

[43] M. S. Islam, M. K. Ahmed and H. Al-Mamun, "Heavy metals in cereals and pulses: health implications in Bangladesh," J Agric Food Chem, vol. 62, no. 44, pp. 10828-10835, 2014, doi: https://doi.org/10.1021/jf502486q

[44] Z. Hongxing and R. Yu-Kui, "Determination of trace metals, heavy metals and rare earth metals in corn seed from Beijing by ICP-MS simultaneously," J Chem, 8, 2011, doi: https://doi.org/10.1155/2011/152713
[45] S. Nyachoti, S. Adebayo and T. R. Godebo, "Elemental composition of teff (a gluten-free grain), maize and wheat: staple crops in the main Ethiopian Rifte Valley. J Food Comp. Anal, vol. 100, p. 103660, 2020, doi: https://doi.org/10.1016/j.jfca.2020.103660
[46] M. Jaishankar, T. Tseten, N. Anbalagan, B. B. Mathew and K. N. Beeregowda, "Toxicity, mechanism and health effects of some heavy metals," Interdiscipl Toxicol, vol. 7, pp. 60–72, 2012, doi: https://doi.org/10.2478/intox-2014-0009
[47] K. Yamada, "Cobalt: its role in human and disease," Metal Ions Life Sci, vol. 13, pp. 295-320, 2013, doi: https://doi.org/10.1007/978-94-007-7500-8_9
[48] Z. Huma, Z. I. Khan, I. R. Noorka, K. Ahmad, K. Wajid, M. Nadeem, M. Munir, I. S. Malik, M. Kiran, T. Hussain, M. F. Qamar, T, Ahmad, S. U. Rehman and M. F. Ullah, "Appraisal of chromium in chicken reared on maize irrigated with sewage water," Environ Sci Pollut Res, Int, vol. 28, pp. 11509-11517, 2021, doi: https://doi.org/10.1007/s11356-020-11393-9
[49] Y. Lu, Y, Yao, D. Shan, Y. Jiang, S. Zhang and J. Yang, "Heavy metal accumulation in maize at long-term waste water irrigation area in Tongliao, China," J Chem, vol 2015, p. 628280, 2015, doi https://doi.org/10.1155/2015/628280
[50] G. Sun, X. Feng, R. Yin, H. Zhao, L. Zhang, J. Sommar, Z. Li and H. Zhang, "Corn (*Zea mays* L.): a low methylmercury staple cereal source and an important biospheric since of atmospheric mercury, health risk assessment," Environ Challenges, vol. 131, e104971, 2019, doi: https://doi.org/10.1016/j.envint.2019.104971
[51] D. S. Prabasiwi, S. S. Murniash and K. Rozana, "Transfer factor as indicator of heavy metal content in plants around Amidala Steam Power Plants," J Phys Conf Ser, vol 1436, e012133, 2020.
[52] G. I. Ogu and F. I. Akinnibosun, "Health Risks Associated With Heavy Metals in Commercial Chicken Meat via Consumption within Southern Nigeria," Afr. J. Health, Safety and Environ, vol.1, no.1, pp. 22-37, 2020, doi: https://doi.org/10.1052417/ajhse.v1i1.29
[53] B. O. Ojiego, G. I. Ogu, F. Dantanko, J. C. Okolo, and K. E. Audu, "Health risk assessment for selected heavy metals in *Telfairia occidentalis* (fluted pumpkin) leaf retailed in markets within Lokoja metropolis," SUV Int J Agric Sci, vol. 4, no. 3, pp.125-134, 2022, doi: https://doi.org/10.21608/SUVJAS.2022.154693.1225