*FUDMA Journal of Sciences (FJS)*
*ISSN online: 2616-1370*
*ISSN print: 2645 - 2944*
*Vol. 6 No. 4, August, 2022, pp 6 - 11*
*DOI: https://doi.org/10.33003/fjs-2022-0604-1035*

# DETERMINATION OF HEAVY METALS (Co, Cu,Cd,Fe, Pb, Zn) IN SOME EDIBLE INSECTS AND FINGERLINGS IN DUTSIN-MA TOWN

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## ABSTRACT

Assessment of some carcinogenic (Cd and Pb) and non-carcenogenic (Co, Cu, Fe and Zn) heavy metals elements was carried out on fingerling, grasshopper, locust and termite. These organisms were selected for this study because they are regarded as alternative source of protein and recently as traditional medicine. Hence it became imperative to assess their human health risk. The result analyzed show that cobalt level ranges from 1.85±0.16 mg/kg to 9.03±0.54 mg/kg, copper from 18.56±0.01 mg/kg to 78.02±2.35 mg/kg, iron from is 176±12.55 mg/kg to 390.37±10.95 mg/kg, cadmium1 from74±0.00 mg/kg to 7.11±0.89 mg/kg, lead from 0.04±0.08 mg/kg to 1.14±0.49 mg/kg and zinc 244.15± 10.30 mg/kg to 281.48 ± 45.52 mg/kg. These were determined using atomic absorption spectrophotometer (AAS) and were compared with FAO/WHO standards. And all were above the recommended level except lead (Pb). Fingerling which is the only aquatic organism among the samples was found to contain higher amount of Co, Cu, Fe and Pb. It could be attributed to more interaction with its habitat and usually improper disposal of waste, use of fertlizers and manure among other things may be responsible for that. Hazard indices (HI) were all high and ranges from 5 to 9 and 16 to 31 for adults and children respectively. Cancer risk (TR) assessments of Cd and Pb were categorized as moderate and low respectively according NYSDOH. Public should therefore avoid eating these organisms because the heavy metals in them may bioaccumulate and manifest adversely.

**Keywords:** fingerling, grasshopper, heavy metal, locust, termite, carcinogenic, carcinogenic

## INTRODUCTION

Heavy metals are persistent as contaminant in the air, water and soil and come to forefront of dangerous substances causing health hazard in human. Mining and smelting ferrous ores, the surface finishing industry, energy and fuel production, fertilizer and pesticide industries and applications are artificial causes of these problem (ZL He *et al.,* 2005). Hence, the need to provide guidelines and specifications on many industrial activities so as to checkmate heavy metal pollution in the environment. This could be achieved through the use of cleaner technology which may involve change in raw material input, product formulation and the manufacturing technology. Banning the use of substances that are pollutants or their precursors should be enforce by international community.

Heavy metal pollution was less pronounced prior to the technological age, it is mainly due to bush burning, flooding, weathering and volcanic eruptions (Tchounwou *et al,* 2012). Human activities contribute very little. The pollution that occurs due to it is less and affects only soil, being essential for agriculture. Plants grown in that soil as well as the animals including man that feeds on them tends to accumulate the heavy metals in their tissues with subsequent adverse effect being manifested.( Bradl H, 2005).

Some heavy metals like Cu, Co, Zn, Fe, and Mn are essential metals for enzymatic activity and many biological processes but only when they are present at low concentration (Tchounwou *et al*., 2012). However, Cd and Hg have no any beneficial role in the body of living organisms and even at low concentrations are toxic (Balali-Mood *et al.*, 2021).

Insects are the most widely spread group of organisms in the animal kingdom, making about 76% of known species of living animals (Ajai *et al.*,2013).Insects appear to be attractive, apart from being a source of food to many vertebrae animals, such as birds, reptiles, amphibians, insectivorous plant and other mammals (Banjo *et al.*, 2010). Historically, they are traditionally part of human diet in Africa, Colombia, Venezuala, Asia and Latin America (Ruddle, 2006; Chavunduka, 2010). Grasshopper, termites, caterpillars and beetle grubs constitute the most important class of insects used as poor man protein in different parts of Nigeria (Banjo et al., 2006; Ifie and Emeruwa, 2011). Butterflies and grasshoppers also have ecological fidelity and are sensitive to environmental changes and quality. According to Chen and co-workers, 2008 these insects have been successfully used as bioindicators for environmental pollution and heavy metal contaminations near industrial states and even within urban areas.

High amount of protein, vitamins and mineral contents are the main reasons for high consumption of insects as food (Ledger,2010).They also reduce serum cholesterol and serve as haemostatic agent which helps in tissue repairs and for accelerating the healing of wounds due to its chitin content (Defoliart, 2007; Goodman,2011). Even though insects consumption has many benefits but care must be taken in their processing to checkmate toxic, pathogens and other antinutritional substances present (Birgit and Oliver, 2013).

Bioaccumulation of heavy metals in tissues mostly occurs from direct ingestion in food from the digestive tract. Depending on the toxicity and concentration of the metal present, this leads to malfunctioning of the affected organ or tissue. Some metals are highly toxic even in relatively low doses (Polechonska *et al.*, 2007). The adverse effects caused are ionic and mineral imbalance, induce oxidative damage to cell structures, produces injury to DNA and induce cancer transformation (Tchounwou *et al,* 2012).

## MATERIALS AND METHODS

### Study Area

Dutsin-ma town is on the latitude of 12.4545$^0$N and a longitude of 7.4977$^0$E with altitude of 543.267m. It has a dam called Dutsin-Ma Dam apart from having tributaries to Zobe Dam which is very close. Hence farming, fishing and irrigation are the main agricultural activities in the area. Cattle rearing by Fulani along the river bank is also very common.


Figure 1: Map of study area

**Chemicals and Reagents**

All the chemicals and reagents were of analytical grade and were purchased from Sigma Aldrich or Merck (Germany).

**Materials**

Perkin-Elmer Pinacle 900 H Atomic Absorption Spectrophotometer (AAS) was used for this analysis. Certified Atomic Absorption Spectroscopic standard stock solutions (1000 mg/L) of Pb, Co,Cd, Zn, Cu and Fe were prepared using Lead (II) chloride ($PbCl_2$), Cobalt (II) chloride ($CoCl_2$), Cadmium (II) chloride ($CdCl_2$), Zinc (II) chloride ($ZnCl_2$), Copper (II) chloride dihydrate ($CuCl_2.2H_2O$) and Iron (II) chloride hexahydrate ($FeCl_2.6H_2O$). Working standard solutions of 2, 4, 6, 8 and 10 mg/L were prepared by appropriate dilutions of the stock solution. Deionized water was used in the preparation of all the solutions.

**Sample Collection**

Three samples each of fingerling (*Oreochromis niloticus*), grasshopper (*Zonocerus variegatus*), locust (*Schisocerca gregaria*) and termite (*Macrotermes bellicosus)* were collected randomly from four different sites in Dutsin-Ma town of Katsina State between months of March and June,2021 viz: Gangare, Dan Rimi, Unguwar Kashe Naira and Unguwar Yan Daka; and were labelled before preparation.

**Sample preparation**

Samples were dried to a constant weight in an oven before been pounded to powdered form using a porcelain pestle and mortar, and then sieved, labelled and stored (Sadi, et al 2021). It was further treated by taken 1 g each of the powdered sample into 100ml beaker followed by the addition of concentrated $HNO_3$, $H_2SO_4$ and 37% $HClO_4$. The mixture was placed on a hot plate at $80^0$C and heated in a fume cupboard (Blessing *et al.*, 2020). The heating was stopped after the appearance of white fumes and when the solution became clear, signaling complete digestion (Ahmed *et al*, 2015). It was then allowed to cool, and then filtered using Whatman No.1 filter paper into a 100 ml standard flask, and then added up to the mark with deionsed water, and then taken for AAS analysis.

**Statistical Analysis**

The data obtained was analyzed using IBM SPSS Statistics Software Version 23 and the results were expressed as Mean ± Standard deviation (SD). Average concentration of the metal in the samples was compared using one-way analysis of variance (ANOVA), confidence level of 95% and significance level of 0.01 ( Sadi *et al*.,2021).

**Health risk assessment**

The long term effects of these heavy metals due to consumption of these edible insects and the fingerling was evaluated by calculating Estimated Daily Intake of metals (EDI), Hazard index( HI ) and Target Hazard Quotient( THQ ). Carcinogenic and non-carcinogenic health risk was also calculated using the relationship below (Blessing *et al.*, 2020):

**Table 1: Description of Factors Involved in Health risk assessment.**

| Risk exposure factors | Symbols | Values | Units |
|---|---|---|---|
| Exposure frequency | EF | 365 | Days/year |
| Exposure duration | ED | 30 | Years |
| Insects/fingerling ingestion rate | IIR | 54.8 | g/person/day |
| Average body weight adult | WABa | 70 | Kg |
| Average body weight Child | WABc | 20 | Kg |
| Average time, carcinogens | ATc | 25, 550days | Years |
| Carcinogenic potency slope | CPSo | $\mu g^{-1} day^{-1}$ | mg/Kg b w-day |
| HM concentration | CM | | mg/Kg |
| Conversion factor | CF | | Kg/mg |

$$THQ = \frac{EF \times ED \times IIR \times CF \times CM \times 10^{-3}}{WAB \times ATn \times RfD} \quad (1)$$

$$HI = THQ(Cd) + THQ(Co) + THQ(Pb) + THQ(Cu) + THQ(Fe) + THQ(Zn) \quad (2)$$

$$TR = \frac{EF \times ED \times IIR \times CF \times CM \times CSP_O \times 10^{-3}}{WAB \times AT_C} \quad (3)$$

$$EDI = \frac{CM \times IIR}{WAB \times 10^{-3}} \quad (4)$$

$CPS_O$ = 0.6 and 0.0085 for Cd and Pb; ATc = 365 days/years for 70 years; ATn = EF ×ED for 30 years; Conversion Factor is 0.208 for insects and 0.175 for fingerling to convert fresh to dry weight; HI = Hazard Index; THQ = Target Hazard Quotient; TR = Target cancer risk; Reference oral dose = RfD for Zn, Pb, Cd,Co, Fe and Cu are $3.0 \times 10^{-1}$, $4 \times 10^{-3}$, $1.0 \times 10^{-3}$, $3.0 \times 10^{-2}$, $7.0 \times 10^{-3}$, $4.0 \times 10^{-2}$ mg/kg/day, respectively (USEPA,2012 ).

## RESULTS AND DISCUSSION

The concentrations of the heavy metals determined were carried out in triplicate and presented in mg/kg as mean ± SD in Table 1 below:

**Table 2: Concentrations of the metals in Grasshopper samples**

| Samples | Element mg/kg $\pm \mu$ | | | | | |
|---|---|---|---|---|---|---|
| | Co | Cu | Fe | Cd | Pb | Zn |
| Grasshopper | 2.56±0.67 | 42.66±0.17 | 305.10±155.45 | 7.11±0.89 | 0.7±0.58 | 281.48 ± 45.52 |
| Fingerling | 9.03±0.54 | 78.02±2.35 | 390.37±10.95 | 5.78±0.75 | 1.14±0.49 | 244.15± 10.30 |
| Termite | 1.85±0.16 | 37.06±10.95 | 176.00±12.55 | 1.74±0.00 | 0.23±0.06 | 259.34±16.10 |
| Locust | 4.92±0.76 | 18.56±0.01 | 300.43±62.95 | 3.51±1.62 | 0.04±0.08 | 274.74±79.39 |
| *FAO/WHO | - | 30 | 48 | 1 | 2 | 60 |

*FAO/WHO Maximum permissible limits of the elements in foods (mg/kg) dry weight.

As can be seen from Table 2, above the mean and standard deviation gotten from ANOVA, confidence level of 95% and significance level of 0.01 were displayed. The concentration of cobalt varies from 1.85±0.16 to 9.03±0.54 mg/kg. Fingerling samples have the highest value (9.03±0.54 mg/kg) with termite being the least (1.85±0.16 mg/kg). This is due to higher transfer factor in aquatic habitat than in soil and air. The same trend was also observed in copper. Here it ranges from 18.56±0.01 to 78.02±2.35 and it is quite lower than that reported by Ajai (2013). Copper despite being an essential micronutrient that is used by human body for production of blood but when in an amount greater than recommended by WHO/FAO cause adverse effects to kidney, liver, stomarch and aneamia (Raymond A.Wuana1 and Felix E. Okieimen,2011).

Concentration of iron in termite and fingerling are 176±12.55 and 390.37±10.95 mg/kg respectively. It is lower compared to those reported by Ajai (2013) and Bodenheimer (2005) which was 574.75±30.75 to 205.30±32.45 mg/kg and 320 to 747 mg/kg respectively. Iron is an essential micronutrient needed by the body for oxygen transportation as a component of hemoglobin molecule in red blood cells but tends to be harmful when present above the FAO/WHO recommended limit, due to the formation of free radicals which damage the liver (Ekpo *et al.*, 2010).

Cadmium concentrations were found to be 1.74±0.00 to 7.11±0.89 mg/kg. Grasshopper has the highest value, while that of fingerling is slightly lower that the value reported by Blessing et al 2020. Differences in the habitat and feeding mode may be responsible for these variation as rightly pointed out by Ajai *et al*., 2013. Cadmium despite having uses such as in batteries, pigments, metal coatings, electroplating and effects (Sabine Martin and Wendy Griswold 2009); rarely occurs naturally in soil and minerals such as sulphide, sulphate, carbonate, chloride, and hydroxide salts as well as in water. High levels of Cd in water, air, and soil can occur following industrial activities which may result in substantial human exposure to Cd (Mahdi Balali-Mood, 2021). Moreover, the ingestion of contaminated food will cause major exposure to Cd. International Agency for Research on

Cancer (IARC) categorized it as human carcinogenic (Group 1) (Kim *et al*, 2020). The mechanism of its toxicity is through production of dispositional tolerance by binding to metallothionein (MT) protein (Mahdi Balali-Mood, 2021). This complex formed is very toxic for the kidney. Cadmium also mimic the function and behaviour of essential metals such as zinc and iron in the body (Schaefer *et al*, 2020). Cd-induced liver injury may be associated with the disturbance of calcium (Ca) homeostasis(Chen *et al.*,2019).

Like cadmium, lead is also carcinogenic (Sultana et al., 2017). Its concentration ranges from 1.14±0.49 to 0.04±0.08 mg/kg. As can be seen from Table2, fingerling samples were found to contain the highest amount of detected heavy metals. These values are lower than those reported by Blessing *et al*.,2020. Lead can adversely affect every organ and system in the body. Acute effects in adults include decreased performance in some tests that measure functions of the nervous system; weakness in fingers, wrists, or ankles; small increases in blood pressure; and anemia.While chronic effects damage brain and kidney, miscarriage and even death (Sabine Martin and Wendy Griswold ,2009).

Zinc is one of the nutrient elements needed by human body for proper functioning when present in small amount (Sadi *et al.*,2021).Grasshopper contains 281.48 ± 45.52 mg/kg, locust 274.74±79.39 mg/kg, termite 259.34±16.10 mg/kg and fingerling with the least value of 244.15± 10.30 mg/kg. They were higher than that reported by Ajai *et al.,* 2013. Among these, only zinc concentration show very little variation in all the four insects. This could be associated with the abundant amount of zinc present in the soil of the studied area. Differences in the geographical locations is the main attribute of these variations apart from inter-elemental interactions (Quin,2005).

**Human health risk assessment**

Estimated daily intake (EDI), Target hazard quotient (THQ), Hazard index (HI) and Target cancer risk (TR) values of metals through the consumption of these insects and fingerling are given in Table 3 below:

**Table 3: Estimated Daily Intake (EDI),Target Hazard Quotient (THQ) ,Hazard Index ( HI ) and Target cancer risk( TR ) of heavy metals from Consumption of Insects and fingerling from Dutsin-ma Town.**

| Samples | Elements | EDI | | THQ | | HI=ΣTHQ | | TR | |
|---|---|---|---|---|---|---|---|---|---|
| | | Adult | children | Adult | Children | Adult | Children | Adult | Children |
| Grasshopper | Co | 2.00 | 7.01 | 0.01 | 0.05 | **9** | **30** | **2.98E-4**<br>**4.15E-7** | **1.04E-3**<br>**1.45E-6** |
| | Cu | 33.40 | 116.89 | 0.17 | 0.61 | | | | |
| | Fe | 238.85 | 835.94 | 7.10 | 24.84 | | | | |
| | Cd | 5.57 | 19.48 | 1.16 | 4.05 | | | | |
| | Pb | 0.548 | 1.92 | 0.03 | 0.10 | | | | |
| | Zn | 220.36 | 771.26 | 0.15 | 0.53 | | | | |
| Fingerling | Co | 7.07 | 24.74 | 0.04 | 0.14 | **9** | **31** | **2.04E-4**<br>**5.69E-7** | **7.13E-4**<br>**1.99E-6** |
| | Cu | 61.07 | 213.77 | 0.27 | 0.94 | | | | |
| | Fe | 305.60 | 1069.61 | 7.64 | 26.74 | | | | |
| | Cd | 4.52 | 15.84 | 0.79 | 2.77 | | | | |
| | Pb | 0.89 | 3.12 | 0.04 | 0.14 | | | | |
| | Zn | 191.13 | 668.97 | 0.11 | 0.39 | | | | |
| Termite | Co | 1.45 | 5.07 | 0.01 | 0.04 | **5** | **16** | **7.29E-5**<br>**1.36E-7** | **2.55E-4**<br>**4.78E-7** |
| | Cu | 29.01 | 101.54 | 0.15 | 0.53 | | | | |
| | Fe | 137.78 | 482.24 | 4.09 | 14.33 | | | | |
| | Cd | 1.36 | 4.77 | 0.28 | 0.99 | | | | |
| | Pb | 0.18 | 0.63 | 0.01 | 0.03 | | | | |
| | Zn | 203.03 | 710.59 | 0.14 | 0.49 | | | | |
| Locust | Co | 3.85 | 13.48 | 0.03 | 0.09 | **8** | **27** | **1.47E-4**<br>**2.37E-8** | **5.14E-4**<br>**8.30E-8** |
| | Cu | 14.53 | 50.54 | 0.08 | 0.26 | | | | |
| | Fe | 235.19 | 823.18 | 6.99 | 24.46 | | | | |
| | Cd | 2.75 | 9.62 | 0.57 | 2.00 | | | | |
| | Pb | 0.03 | 0.11 | 0.00 | 0.01 | | | | |
| | Zn | 215.08 | 752.79 | 0.15 | 0.52 | | | | |

**Estimated daily intake ( EDI )of heavy metals**

The daily intake of heavy metals by human beings determine their toxicity level .The EDI of carcinogenic and non-carcinogenic heavy metals for samples of the study area is listed in Table 3.The values computed were very for all samples and all metals except Pb. Iron as the element with the highest EDI value and in all cases fingerling contains the highest value. Besides EDI of heavy metals in children was found to be higher than in adult as observed. Hence, the need for health risk concern for consuming these insects and the fingerling.

**Target Hazard Quotient (THQ )**

THQ takes care of only one heavy metal despite the fact that many heavy metals could be present in a particular food as shown by the result of this study. This necessitate the need to evaluate hazard index(HI), which the summation of all metals THQs (Javed and Usmani, 2016).The non-cancer risk ( THQ and HI ) values should be less than 1 otherwise there is need for alerting for public health concern. (Islam *et al.,* 2014; Zodape 2014). From the table 3 all the samples show a high risk level ( HI >1 ) for both adults and children. Iron, zinc and copper contributed greatly to this high level.

**Target Cancer Risk ( TR )**

This parameter measures the cancer risk of the concerned of the heavy metal.Cd and Pb are potent carcinogenic agents according USEPA,2012.The TR is low if are described as low if ≤ $10^{-6}$, moderate ranges from $10^{-4}$ to $10^{-3}$ , high $10^{-3}$ to $10^{-1}$ and very high is ≥ $10^{-1}$( NYSDOH,2007).TR is similar to THQ as an estimated lifetime cancer risk but not an exact estimate of expected cancers(Javed and Usmani *,2016)*.It is an upper limit probability that individuals exposed to the toxicant may develop cancer(Sultana *et al*.,2017).From the results of TR all the samples shown low chances of having cancer due to lead(Pb).Whereas for cadmium(Cd) moderate chances were seen for both adults and children.

## CONCLUSION

The findings of this study carried out on grasshopper, fingerling, termite and locust collected in areas of Dutsin-ma Town revealed that cobalt level ranges from 1.85±0.16 mg/kg to 9.03±0.54 mg/kg, copper from 18.56±0.01 mg/kg to 78.02±2.35 mg/kg, iron from is 176±12.55 mg/kg to 390.37±10.95 mg/kg, cadmium1.74±0.00 mg/kg to 7.11±0.89 mg/kg, lead from 0.04±0.08 mg/kg to 1.14±0.49 mg/kg and zinc 244.15± 10.30 mg/kg to 281.48 ± 45.52 mg/kg.They are all above the standard recommended value except for lead, which is below the baseline of 2.00 mg/kg. The non-cancer risk hazard indices (HI) for adults and children were (9,30),(9,31),(5,16) and (8,27) in grasshopper,fingerling,termite and locust respectively. These values are high and indicated the consumption of the insects/fingerling is not safe. Similarly the cancer risk due to cadmium and lead in those samples were 2.98E-4, 1.04E-3, 4.15E-7, 1.45E-6, 2.04E-4, 7.13E-4, 5.69E-7, 1.99E-6, 7.29E-5, 2.55E-4, 1.36E-7 and 4.78E-7 for adult and children respectively. These lead poses low risk and cadmium poses moderate cancer risk. Therefore, the community members should be enlighten on the threat of bioaccumulation due to consumption of these insects. However, more critical studies should be focused on the transfer factor due to interaction with the environment.

## REFERENCES


Ahmed M.K., M. Habibullah-Al-Mamun, M.S. Islam, S. Masunaga and M. Raknuzzaman(2015). Metal speciation in sediment and their bioaccumulation in fish species of three urban rivers in Bangladesh. *Arch. Environ. Contam. Toxicol.,* 68 (1):92–106.doi: 10.10 07/s0 0244- 014- 0079- 6 .

Ajai A. I., Bankole M., Jacob J. O. and Audu U. A. (2013). Determination of some essential minerals in selected edible insects. *African Journal of Pure and Applied Chemistry.* 7(5):194-197.

Banjo A D, Lawal O A, Fasunwon B T and Alimi G O (2010). Alkali and heavy metal contaminants of selected edible arthropods in southern Nigeria. *Am . Ewras. J. Toxicol. Sci*. 2(1):25-29.

Birgit AR, Oliver KS (2013). Nutritional composition and safety aspects of edible insects. *Mol. Nutr. Food Res.* 57(5):802-823.

Blessing Edogbo, Emmanuel Okolocha, Betty Maikai ,Tagang Aluwong and Chidiebere Uchendu (2020).Risk assessment of heavy metal contamination in soil, vegetables and fish around Challawa area in Kano state.*Scientific African* ,7 (2020) e00281.

Bradl H. (2005). Heavy Metals in the Environment: Origin, Interaction and Remediation. *Elsevier/Academic Press, London* pp6.

Chavunduka DM (2010). Insects as a source of protein to the African. *Rhodesian Sci. News* 9:217-220.

Chen X, Feng Y, Zhang H, Chen Z (2008). Review of the nutritive value of edible insects.*Food and Agricultural Organization of the United Nations(FAO)*,pp85-92.

Chen, X., Wang, Z., Zhu, G., Nordberg, G. F., Jin, T., and Ding, X. (2019). The association between cumulative cadmium intake and osteoporosis and risk of fracture in a Chinese population. *J. Expo. Sci. Environ. Epidemiol.,*29 (3):435–443. doi:10.1038/s41370-018-0057-6.

Defoliart GR (2007). The human use of insects as food and as animal feed. *Bull. Entomol. Soc. Am*. 35:22-35.

Ekop EA, Udoh AI, Akpan PE (2010). Proximate and Anti-nutrient composition of four edible insects in Akwa Ibom state, Nigeria. *World J. Appl. Sci. Technol.* 2(2):224-231.

Goodman WG (2011). Chitin: a magic bullet. *Food Insects Newslett.* 2(3):6-7.

He Z L, Yang X E and Stoffella P J(2005).Trace Elements in Agroecosystems and Impacts on the Environment. *J Trace Elem Med Biol*,19(2–3):125–140.

Ifie I, Emeruwa CH (2011). Nutritional and anti-nutritional characteristics of the larva of *Oryctes monoceros. Agric. Biol. J. N. Am*. 2(1):42-46.

Islam MS, Ahmed MK, Al-Mamun MH, Islam KN, Ibrahim M, Masunaga S (2014). Arsenic and lead in foods: a potential threat to human health in Bangladesh. Food Add Contam Part A. doi:10.1080/19440049.2014.974686.

Javed Mehjbeen and Usmani Nazura (2016). Accumulation of heavy metals and human health risk assessment via the consumption of freshwater fish *Mastacembelus armatus* inhabiting, thermal power plant effluent loaded canal. *SpringerPlus, 5:776* DOI 10.1186/s40064-016-2471-3.

Kim, T. H., Kim, J. H., Le Kim, M. D., Suh, W. D., Kim, J. E. and Yeon, H. J.(2020). Exposure assessment and safe intake guidelines for heavy metals in consumed fishery products in the Republic of Korea. *Environ. Sci. Pollut. Res.Int.*,27,33042–33051. doi:10.1007/s11356-020-09624-0.

Ledger J (2010). The eight plague returneth: The locusts are coming! *AFR. Wildl.*, 41:201-210.

Mahdi Balali-Mood, Kobra Naseri, Zoya Tahergorabi, Mohammad Reza Khazdair and Mahmood Sadeghi (2021).Toxic Mechanisms of Five Heavy Metals: Mercury, Lead, Chromium,Cadmium, and Arsenic. *Frontiers in Phamocology,* volume 12PPP.

NYSDOH (New York State Department of Health) (2007).Hopewell precision area contamination: appendix C-NYS DOH.Procedure for evaluating potential health risks for contaminants of concern. *http://www.health.ny.gov/environmental/ investigations/hopewell/appendc.htm.*

Polechonska L, M. Dambiec, A. Klink and A. Rudecki (2015). Concentrations and solubility of selected trace metals in leaf and bagged black teas commercialized in Poland.*Journal of Food and Drug Analysis*,23(3):486-492.

Quin PJ (2005). Foods and Feeding Habits of the Pedi:Witwatersrand University,Johannesburg, South Africa.

Raymond A.Wuana1 and Felix E. Okieimen (2011). Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation, *International Scholarly Research Network ISRN Ecology Volume*, Article ID 402647,20 pages doi:10.5402/2011/402647.

Ruddle K (2006). The human use of insects examples from the Yukpa*. Biotropica* 5:94-101.

Sabine Martin and Wendy Griswold (2009). Environmental Science and Technology Briefs for Citizens.Center for Hazardous Substance Research Kansas State University • 104 Ward Hall • Manhattan KS 66506 • 785-532-6519 • www.engg.ksu.edu/CHSR/

Sadi A. H., Suleiman A. K., Idris M. I. And Abubakar A. A.(2021).Assessment of some heavy metals in selected vegetables grown in Tudun Fulani, Ungogo, Kano - Nigeria and potential risk to human health. *Nigerian Research Journal of Chemical Sciences.*9(2):178-187.

Schaefer, H. R., Dennis, S., and Fitzpatrick, S. (2020). Cadmium: mitigation strategies to reduce dietary exposure. *J. Food Sci*., 85 (2):260–267. doi:10.1111/1750-3841.14997.

Sultana S. Mahfuza ,S. Rana, S. Yamazaki, T. Aono & S. Yoshida | (2017).Health risk assessment for carcinogenic and non-carcinogenic heavy metal exposures from vegetables and fruits of Bangladesh. *Cogent Environmental Science*,3:1, 1291107, DOI:10.1080/23311843.2017.1291107.

Tchounwou Paul B, Clement G. Yedjou, Anita K. Patlolla and Dwayne J. Sutton (2012). Heavy Metal Toxicity and the Environment. Molecular, Clinical and Environmental Toxicology: Environmental Toxicology. *Springer*, (3):133-164.

USEPA (2012). Waste and Cleanup Risk Assessment. http://www2.epa.gov/risk/ waste- and- cleanup- risk-assessment .

Wen-Si Zhong,Ting Ren, Li-Jiao Zhao (2016). Determination of Pb (Lead), Cd (Cadmium), Cr(Chromium), Cu (Copper), and Ni (Nickel) in Chinese tea with high-resolution continuum source graphite furnace atomic absorption spectrometry. *Journal of Food and Drug Analysis.*24(1):46-55.

WHO (2013). Tech. Rep., "Guidelines for the safe use of waste water and food stuff". Report of
the joint WHO/FAO Volume 2 No. 1, World Health Organization (WHO) and Food and Agriculture Organization (FAO), Geneva, Switzerland.

Zodape GV (2014). Metal contamination in commercially important prawns and shrimps species collected from Kolaba market of Mumbai (west coast) India. *Int J Agrisci.* 4:160–169.