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# Assessment of Heavy Metals Concentration and Health Hazard Indices in Soil and Plants from Kokona Local Government Area of Nasarawa State, Nigeria

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## Abstract
*Human dependence, on the plants grown on soil and the threat posed by contaminated soil to the ecosystem and general public has become a source of concern. The health risks caused by heavy metals concentration to the study area were evaluated. Fifteen (15) plant samples and soil samples each from the study area were collected and analyzed using an Energy Dispersive X-ray Fluorescence Spectroscopy (EDXRF) for Lead (Pb), Cadmium (Cd), Chromium (Cr), Nickel (Ni), Copper (Cu), and Zinc (Zn). The Measured concentrations of these heavy metals were in the order of Cd>Ni>Cu>Zn>Pb>Cr for the plant samples and Cr>Cd>Ni>Cu>Pb for soil samples with Cd and Cr as the highest contributors to cancer risk in term of the carcinogenic risk estimate. The Health Hazard Index value for all pathways were found to be* $7.34\ x\ 10^{-1}$*, making non-carcinogenic risk component less significant to the adult population and in case of children, the Hazard Index value was 1.21, a value greater than unity (1), which present a severe non-carcinogenic risk component to children living in the study area. The carcinogenic risk was found to be* $8.68\ x\ 10^{-6}$ *implying that 1 person in every 5882 adults may be affected and 1 in 2725 children may be affected (*$9.6\ x\ 10^{-5}$*). These carcinogenic risk values were both higher than acceptable values.*

**Keywords:** Heavy Metals Concentration, Non-Carcinogenic, Carcinogenic risk.

## INTRODUCTION
Heavy metals have been present in the environment and People have been exposed to them directly through consumption of crops grown in contaminated soils (Machiwa, 2010). Higher concentrations of heavy metals in the environment due to anthropogenic activities such as agriculture, industry, among others, have become a major source of concern to the world (Mundi *et al*., 2019). Some metals are essential to life and play irreplaceable roles as sources of vitamins, and minerals in the functioning of body organs (Brandy, 2009). All living organisms require varying amounts of metals, but become toxic at higher concentrations (Lane & Morel,

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2000). Other metals have no useful role in the human physiology. Lead, mercury, and arsenic are a few examples of these elements. Even at low exposure levels, they could be harmful. After being ingested by the body, heavy metals can remain in critical organs such as the kidneys, liver, brain, and bones for years or decades, leading to detrimental effects on health. Arsenic, lead and mercury are the first, second and third hazards on the priority list of heavy metal pollutants as designated by the United States Agency for Toxic Substances and Disease Registry (ATSDR, 1999). Arsenic, for instance, is regarded a human carcinogen from extremely low levels of exposure (ATSDR, 2015). Acute exposure to arsenic compounds may cause nausea, vomiting, abdominal pain, muscle cramps and diarrhea (NRC, 1999) while chronic exposure is associated with peripheral nerve damage causing diabetes (UN, 2002). Lead on the other hand, is regarded as a human mutagen and probable carcinogen (Podsiki, 2005). The exploitation of the study area, especially mining and agricultural activities makes it vulnerable to heavy metals pollution and other human induced imbalances. The soils from the study area are prone to heavy metals pollution through surface runoff or leaching, groundwater and atmospheric mediated transport of contaminants from car exhausts and agro-chemicals inputs sources (Machiwa, 2010). The study was undertaken in order (i) to assess the concentrations of heavy metals in plants and soils of the study area (ii) to estimate the soil-to-plant heavy metals from sampling locations (iii) to estimate the heavy metals carcinogenic and non-carcinogenic risks in the study area.

## MATERIALS AND METHODS

### Study Area

The Kokona local government area in Nasarawa state is the study area. The town of Garaku is home to Kokona local government headquarters. As of the 2006 census, its area was 1,844 km², and its population was 109,749. It is located at latitude 08003'0"E and longitude 0900'0"N. From Abuja, the region is reachable by the main road. The map of the study area is shown below.

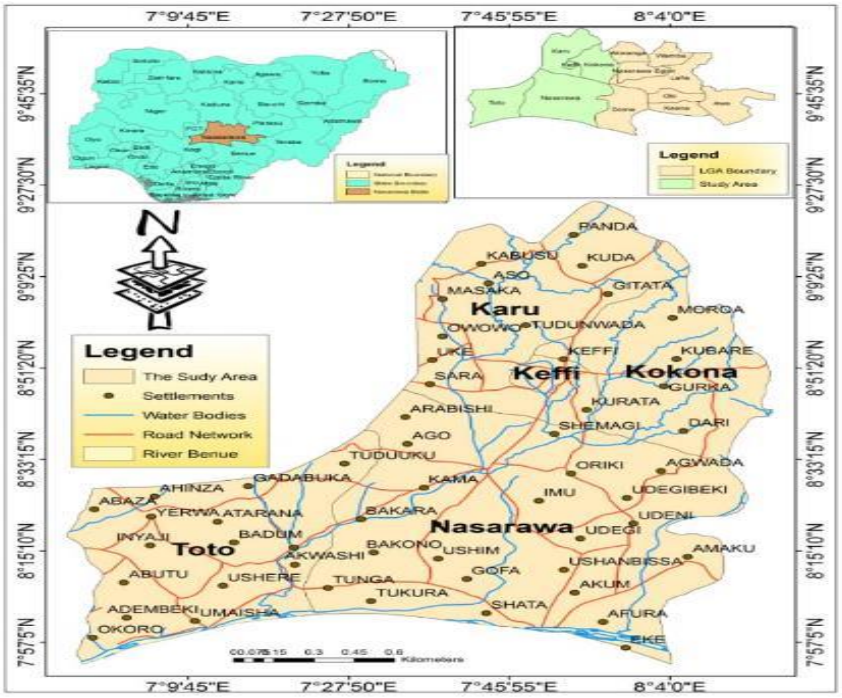


**Figure 1: A Map showing the study area.**

**Sample Collection**

A purposive sampling technique was used to collect both soil and plant samples from the study. A total of fifteen (15) samples for soil and plants each were collected differently from the study area using knife and hand trowel and the samples collected were packaged in well labeled plastic containers with its unique codes for soil and plants. A Global Positioning System (GPS) to obtain the geo-coordinates points of sampling locations.

**Samples Preparation**

The obtained samples (soil and Plants) were air – dried at an ambient temperature to remove the moisture contents, then pulverized using agate mortar and pestle, and subject to a 2.00mm sieve so as to obtain a uniform representative sample sizes for analysis.

**Samples Analysis**

A 10.0g of each sample by mass measured from the representative samples of soil and plant were pelletized with steel molds, pellets and a hydraulic press, using aluminum foil as the binder to hold the sample particles together after the removal from the molds. The representative soil and plant samples were irradiated using a high performance thermoelectrically cooled Si– PIN photodiode coupled ECLIPSE III Energy Dispersive X – Ray Fluorescence (EDXRF) spectrometer (XR – 100 CR) with a Preamplifier. The XRF-FP Quantitative Analysis Software package was used to perform the quantitative analysis of the samples. Elemental concentrations and/or film thickness are obtained by converting elemental peak intensities. The sample chamber holds the samples that will be exposed to radiation. The Si-PIN photodiode detector and the source X-ray tube are connected to the sample chamber at a 45° angle, respectively. Each sample is exposed to radiation for duration of 1000 seconds while the source X-ray tube is kept at a voltage of 25 kV and a current of 50 µA. Quality control procedures were used to guarantee the accuracy of the findings. Care was taken when handling the samples to prevent contamination. The XRF equipment was used to perform a recovery test using spike analyses. After each sample was exposed to radiation twice, the average data were used to determine the mass concentration of heavy metals.

**Data Analysis**

In order to produce the result in $mg.kg^{-1}$, the element concentrations as determined by the X-Ray Florescence Spectrometric Analysis, which uses weight percent (w.t %) as its unit, were coded in an Excel software program. As the globally accepted measure for soil analysis, the weight percent (wt %) unit of the raw data was transformed to milligram per kilogram (mg.kg-1) by multiplying the wt% values by 10,000 (1ppm or 1mg.kg-1 =10,000 wt%)(WHO, 2014).

**Measurement of Transfer Factor from Soil to Plant.**

Transfer Factors (TF) will be determined using the equation as expressed by (UNSCEAR, 2000) as:

$$TF = \frac{Activity Concentration of radionuclide in dry weight of soil \left(\frac{Bq}{kg}\right)}{Activity Concentration of radionuclide in dry weight of soil \left(\frac{Bq}{kg}\right)} \quad (1)$$

**Measurement of Average Daily Intake (Ingestion, Inhalation and Dermal Pathways)**

$$ADI_{ing} = \frac{C \times IR \times EF. \times ED \times CF}{BW \times AT} \quad (2)$$

$$ADI_{inh} = \frac{C_s \times IR_{air} \times EF \times ED}{BW \times AT \times PEF} \quad (3)$$

$$ADI_{dems} = \frac{C_s \times SA \times FE \times AF \times ABS \times EF \times ED \times CF}{BW \times AT} \quad (4)$$

Where $ADI_{ing}$, $ADI_{inh}$, $ADI_{der}$ are the average daily intake of heavy metals ingested, inhalation and dermal from soil in mg/kg-day, $C$ = concentration of heavy metal in mg/kg for soil. $IR$ in mg/day is the ingestion rate, $EF$ in days/year is the exposure frequency, $ED$ is the exposure duration in years, $BW$ is the body weight of the exposed individual in kg, $AT$ is the time period over which the dose is averaged in days. $CF$ is the conversion factor in kg/mg (US, EPA, 1989).

**Non-Carcinogenic Risk Assessment**

A unitless quantity known as the "hazard quotient" (HQ) represents the likelihood that a person would experience a negative outcome. It is defined as the quotient of the acute lead-ionization dose (ADI) or dose divided by the toxicity threshold value, also known as the chronic reference dose (RfD) of a particular heavy metal in milligrams per kilogram day.

$$HQ = \frac{ADI}{RfD} \quad (5)$$

$$HI = \sum_{k=1}^{n} HQ_k = \sum_{k=1}^{n} \frac{ADI_k}{RfD_k} \quad (6)$$

It is unlikely that the exposed population will suffer negative health impacts if the HI value is less than one. Potential non-carcinogenic consequences may be of concern if the HI value is greater than one(Capah, 2016).

**Carcinogenic risk assessment**

The equation for calculating the excess lifetime cancer risk is:

$$Risk_{pathway} = \sum_{k=1}^{n} ADI_k CSF_k \quad (7)$$

where Risk is the likelihood that a person will get cancer in their lifetime.
For a given number of heavy metals, ADIk (mg/kg/day) and CSFk (mg/kg/day)-1 represent the average daily intake and cancer slope factor, respectively, for the kth heavy metal. The anticipated daily intake of the heavy metal averaged over the course of a lifetime of exposure is immediately converted to the incremental risk of cancer development for a person by the slope factor (Capah, 2016).

## RESULTS AND DISCUSSION

The obtained heavy metals concentration for plants and soil were presented in Table 1 and 2 below. The soil-to-plant Transfer factors of heavy metals is presented in Table 3.

**Heavy Metals Concentration**

Table 1: Concentration of Heavy Metals in plant Samples from Kokona L.G.A. in Nasarawa West ($mgkg^{-1}$).

| Samples | **Cd** | **Cr** | **Cu** | **Ni** | **Pb** | **Zn** |
|---|---|---|---|---|---|---|
| PS1 | 31.341 | 0.097 | 0.354 | 0.384 | 0.155 | 0.247 |
| PS2 | 34.192 | 0.121 | 0.355 | 0.445 | 0.168 | 0.252 |
| PS3 | 30.281 | 0.089 | 0.336 | 0.411 | 0.093 | 0.243 |
| PS4 | 30.559 | 0.086 | 0.284 | 0.354 | 0.179 | 0.207 |
| PS5 | 37.296 | 0.123 | 0.394 | 0.469 | 0.174 | 0.306 |
| PS6 | 48.669 | 0.129 | 0.610 | 0.708 | 0.392 | 0.471 |
| PS7 | 36.321 | 0.047 | 0.407 | 0.464 | 0.213 | 0.268 |
| PS8 | 36.811 | 0.141 | 0.409 | 0.537 | 0.179 | 0.303 |
| PS9 | 28.516 | 0.063 | 0.265 | 0.360 | 0.138 | 0.189 |
| PS10 | 27.343 | 0.107 | 0.242 | 0.316 | 0.152 | 0.194 |
| PS11 | 36.320 | 0.117 | 0.305 | 0.380 | 0.164 | 0.224 |
| PS12 | 31.085 | 0.106 | 0.277 | 0.336 | 0.171 | 0.208 |
| PS13 | 28.044 | 0.091 | 0.258 | 0.308 | 0.171 | 0.192 |
| PS14 | 30.479 | 0.082 | 0.280 | 0.376 | 0.151 | 0.219 |
| PS15 | 34.903 | 0.063 | 0.341 | 0.450 | 0.208 | 0.250 |
| Mean | 33.477 | 0.097 | 0.341 | 0.420 | 0.181 | 0.252 |
| Max | 48.669 | 0.141 | 0.61 | 0.708 | 0.392 | 0.471 |
| Min | 27.343 | 0.047 | 0.242 | 0.308 | 0.093 | 0.189 |

The concentration of Cd, Cr, Cu, Ni, Pb and Zn in plants samples were shown in Table 1 above. PS6 was found to have the highest activity concentration of 48.669$mgkg^{-1}$ and PS10 with the lowest activity concentration of 27.343$mgkg^{-1}$ for Cd, PS8 has highest activity concentration of 0.141$mgkg^{-1}$ and PS7 with the lowest concentration of 0.047 for Cr, PS6 was found to have the highest concentration of 0.61$mgkg^{-1}$ and PS10 with the concentration of 0.242$mgkg^{-1}$ for Cu. PS6 was found to have the highest concentration of 0.707$mgkg^{-1}$ and PS13 with the lowest concentration of 0.308$mgkg^{-1}$ for Ni, PS6 was found to have the highest concentration of 0.392$mgkg^{-1}$ and PS3 with the lowest concentration of 0.093$mgkg^{-1}$ for Pb, finally, PS6 was found to have the highest concentration of 0.471$mgkg^{-1}$ and PS9 with the lowest concentration of 0.189$mgkg^{-1}$ for Zn.

Table 2: Concentration of Heavy Metals in Soil Samples from Kokona L.G.A. in Nasarawa West ($mgkg^{-1}$)

| Sample | Cd | Cr | Cu | Ni | Pb | Zn |
|---|---|---|---|---|---|---|
| SS1 | 42.9850 | 1270 | 0.0460 | 0.4790 | 0.3880 | 0.3890 |
| SS2 | 40.8530 | 2.0010 | 0.4430 | 0.4540 | 0.2500 | 0.7230 |
| SS3 | 20.5920 | 0.2080 | 0.4380 | 0.4290 | 0.1420 | 0.3430 |
| SS4 | 20.0680 | 0.2330 | 0.3260 | 0.4990 | ND | 0.4290 |
| SS5 | 25.0500 | 1.1170 | 0.4440 | 0.5420 | 0.2850 | 0.3970 |
| SS6 | 23.0990 | 5.8190 | 0.4490 | 0.5230 | 0.2940 | 0.2550 |
| SS7 | 40.0230 | 0.4830 | 0.3220 | 0.6800 | 0.5490 | 0.6070 |
| SS8 | 15.4330 | 0.3020 | 0.5350 | 0.5920 | 0.3190 | 0.6810 |
| SS9 | 14.9380 | 0.2030 | 0.1350 | 0.4730 | 0.1060 | 0.2790 |
| SS10 | 29.3440 | 0.7030 | 0.0380 | 0.0780 | 0.2490 | 0.1030 |
| SS11 | 25.9480 | 0.4540 | 0.4430 | 0.1310 | 0.2570 | 0.3240 |
| SS12 | 37.8330 | 0.3420 | 0.3510 | 0.1320 | 0.2270 | 0.1120 |
| SS13 | 30.8690 | 0.2920 | 0.2220 | 0.2790 | 0.2650 | 0.4140 |
| SS14 | 34.9600 | 0.4320 | 0.3640 | 0.3570 | 0.2340 | 0.2380 |
| SS15 | 35.9330 | 0.2120 | 0.4520 | 0.4770 | 0.1370 | 0.2250 |
| MEAN | 29.1952 | 85.5200 | 0.3338 | 0.4083 | 0.2644 | 0.3679 |
| Maz | 42.9850 | 1270 | 0.5350 | 0.6800 | 0.5490 | 0.7230 |
| Min | 14.9380 | 0.203 | 0.0380 | 0.0780 | 0.1060 | 0.1030 |

The concentration of Cd, Cr, Cu, Ni, Pb and Zn, in the soil samples collected from the study area were presented in table 2. SS1 was found to have the highest concentration of 42.985mgkg$^{-1}$ (SS9 with 14.938mgkg$^{-1}$ as the lowest concentration) for Cd, SS1 has highest activity concentration of 1270mgkg$^{-1}$ (SS9 with 0.203mgkg$^{-1}$ as the lowest concentration) for Cr, SS8 was found to have the highest concentration of 0.535mgkg$^{-1}$ (SS10 with 0.242mgkg$^{-1}$, lowest concentration) for Cu. SS7 was found to have the highest concentration of 0.68mgkg$^{-1}$ (SS13 with 0.308mgkg$^{-1}$, lowest concentration) for Ni, SS7 was found to have the highest activity concentration of 0.549mgkg$^{-1}$ (SS9 with 0.106mgkg$^{-1}$: lowest concentration) for Pb, while, SS7 was found to have the highest activity concentration of 0.723mgkg$^{-1}$ and SS10 with the lowest concentration of 0.103mgkg$^{-1}$ for Zn.

**Transfer factor**

Table 3: Soil-to-Plant transfer factors of heavy metals for this study

| Sample ID | Estimated fSoil-to-Plant (no unit) | | | | | |
|---|---|---|---|---|---|---|
| | Cd | Cr | Cu | Ni | Pb | Zn |
| TF1 | 0.7291 | 7.6378E-05 | 7.6956 | 0.8017 | 0.3995 | 0.6349 |
| TF2 | 0.8369 | 0.0605 | 0.8013 | 0.9801 | 0.6720 | 0.3485 |
| TF3 | 1.4705 | 0.4279 | 0.7671 | 0.9580 | 0.6549 | 0.7085 |
| TF4 | 1.5227 | 0.3690 | 0.8712 | 0.7094 | NA | 0.4825 |
| TF5 | 1.4889 | 0.1101 | 0.8874 | 0.8653 | 0.6105 | 0.7707 |
| TF6 | 2.1069 | 0.0221 | 1.3585 | 1.3537 | 1.3333 | 1.8470 |
| TF7 | 0.9075 | 0.0973 | 1.2639 | 0.6824 | 0.3879 | 0.4415 |
| TF8 | 2.3852 | 0.4668 | 0.7645 | 0.9071 | 0.5611 | 0.4449 |
| TF9 | 1.9089 | 0.3103 | 1.9629 | 0.7611 | 1.3019 | 0.6774 |
| TF10 | 0.9318 | 0.1522 | 6.3684 | 4.0512 | 0.6104 | 1.8835 |
| TF11 | 1.3997 | 0.2577 | 0.6885 | 2.9007 | 0.6381 | 0.6914 |
| TF12 | 0.8216 | 0.3099 | 0.7892 | 2.5454 | 0.7533 | 1.8571 |
| TF13 | 0.9084 | 0.3116 | 1.1622 | 1.1039 | 0.6452 | 0.4638 |
| TF14 | 0.8718 | 0.1898 | 0.7692 | 1.0532 | 0.6453 | 0.9202 |
| TF15 | 0.9713 | 0.2972 | 0.7544 | 0.9434 | 1.5182 | 1.1111 |

The soil-to-plant transfer factor (TF) were calculated from heavy metals concentration of soil and corresponding heavy metals concentration of plants using equation 1 and are presented in Table 3 above. The highest and lowest transfer factor values for Cd, Cu, Cr, Pb, Zn and Ni were TF8 & TF1 (2.3852, 0.7291), TF8 & TF1 (0.4669, 7.6378E-05), TF1 & TF11 (7.6957, 0.6885), TF10 & TF7 (4.0513, 0.6824), TF15 & TF1 (1.5182, 0.3995), TF10 & TF2 (1.8835, 0.3485) respectively. Cr and Pb are the most accidentally released heavy metals into the agricultural environment.

**Health Risk Assessment**

Table 4: Estimated Mean daily intake (ADI) values for adult and children in the study area for carcinogenic risk assessment

| Receptor pathway | | Average Daily Intake (ADI) values for Heavy Metals (mg/kg) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Cd | Cr | Cu | Ni | Pb | Zn | total |
| Ingestion | Child | 3.19E-05 | 9.37E-05 | 3.66E-07 | 4.47E-07 | 2.89E-07 | 4.03E-07 | 1.27E-04 |
| Inhalation | Child | 1.23E-09 | 3.60E-09 | 1.41E-11 | 1.72E-11 | 1.11E-11 | 1.55E-11 | 4.89E-09 |
| Dermal | Child | 4.09E-06 | 1.20E-05 | 4.69E-08 | 5.73E-08 | 3.71E-08 | 5.17E-08 | 1.63E-05 |
| | Total | 3.61E-05 | 1.06E-04 | 4.13E-07 | 5.05E-07 | 3.27E-07 | 4.55E-07 | 1.44E-04 |
| Ingestion | Adult | 1.7E-05 | 5.02E-05 | 1.96E-07 | 2.39E-07 | 1.55E-07 | 2.16E-07 | 6.82E-05 |
| Inhalation | Adult | 2.64E-09 | 7.72E-09 | 3.02E-11 | 3.69E-11 | 2.39E-11 | 3.32E-11 | 1.05E-08 |
| Dermal | adult | 4.24E-06 | 1.24E-05 | 4.85E-08 | 5.94E-08 | 3.84E-08 | 5.35E-08 | 1.69E-05 |
| | Total | 2.14E-05 | 6.26E-05 | 2.45E-07 | 2.99E-07 | 1.94E-07 | 2.69E-07 | 8.50E-03 |

The excess lifetime cancer risks for adults and children are calculated separately from the average contribution of the individual heavy metals in soil for all the pathways using equation 4 and 5. Based on the carcinogenic risk values of the calculated *ADI* values presented in Table 4.4, the results of the excess lifetime cancer risks were presented in Figures 3 and 4 below. The carcinogenic risk estimated based on Cd, Cu, Cr, Pb, Zn and Ni. Cd and Cr concentrations were found to be the highest contributors to the cancer risk. The US Environmental Protection Agency considered acceptable for regulatory purposes a cancer risk in the range of $1x10^{-6}$ to $1x10^{-4}$ (U.S. Environmental Protection Agency, 2004). On the other hand, South Africa, considers the Individual cancer risk limit to be $5x10^{-6}$ (Government of South Africa, 2006). The cancer risk for adults was found to be $8.68x10^{-6}$ (1 in 5882 individuals) and $9.6x10^{-5}$ (1 in 2725 individuals) for children, which were both higher than acceptable values. In the study area, children are therefore more at risk than adults. The ingestion route seems to be the major contributor to excess lifetime cancer risk followed by the dermal pathway.

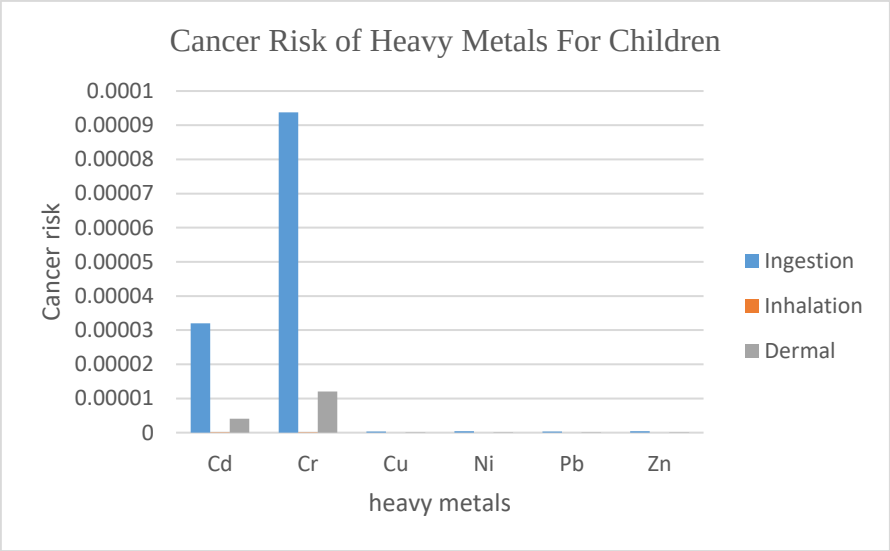


Figure 1: Cancer risk values of heavy metals for children in soil samples from study area

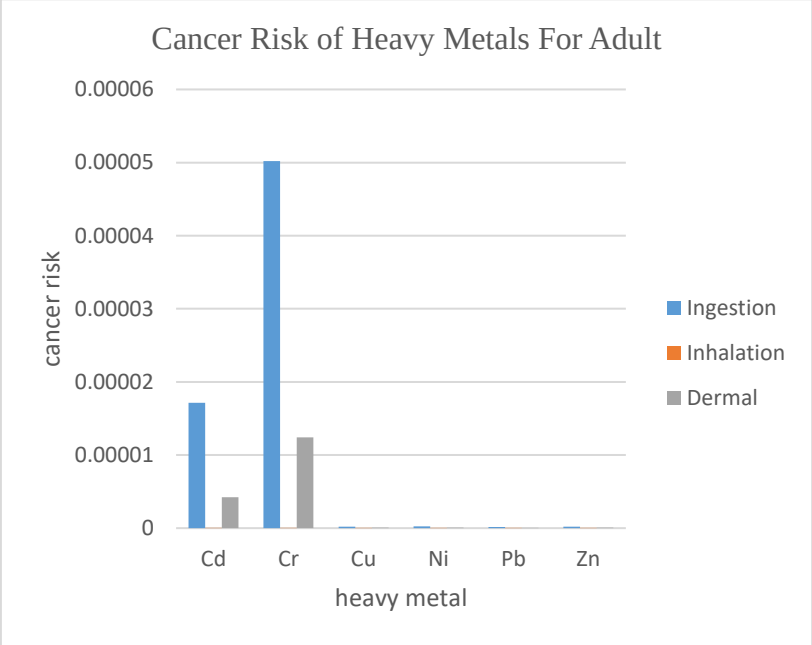


Figure 2: Cancer risk values of heavy metals for adults in soil samples from the study area.

Table 5: Estimated mean daily intake (ADI) values for adult and children in the study area for non-carcinogenic risk assessment.

| Receptor | Pathway | Average Daily Intake (ADI) values for Heavy Metals (mgkg-1) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Cd | Cr | Cu | Ni | Pb | Zn | Total |
| Ingestion | Child | 3.73E-04 | 1.094-03 | 4.27E-06 | 5.22E-06 | 3.38E-06 | 4.70E-06 | 1.48E-03 |
| Inhalation | Child | 1.44E-08 | 4.21E-08 | 1.64E-10 | 2.01E-10 | 1.30E-10 | 1.81E-10 | 5.71E-08 |
| Dermal | Child | 4.78E-05 | 1.404-04 | 5.47E-07 | 6.69E-07 | 4.33E-07 | 6.03E-07 | 1.90E-04 |
| | Total | 4.21E-04 | 1.23E-03 | 4.82E-06 | 5.89E-06 | 3.81E-06 | 5.31E-06 | 1.67E-03 |
| Ingestion | Adult | 2.39E-04 | 7.03E-04 | 2.74E-06 | 3.36E-06 | 2.17E-06 | 3.02E-06 | 9.54E-04 |
| Inhalation | Adult | 6.31E-09 | 1.85E-08 | 7.21E-11 | 8.82E-11 | 5.71E-11 | 7.95E-11 | 2.51E-08 |
| Dermal | Adult | 9.90E-06 | 2.90E-05 | 1.13E-07 | 1.39E-07 | 8.97E-08 | 1.25E-07 | 3.94E-05 |
| | Total | 2.49E-04 | 7.32E-04 | 2.86E-06 | 3.49E-06 | 2.26E-06 | 3.15E-06 | 9.94E-04 |

When *HQ* and *HI* values are less than 1, there is no obvious risk to the population, but if these values exceed one, there may be concern for potential non-carcinogenic effects (U.S. Environmental Protection Agency, 2004). For the children population, calculated values of *HQ* were less than one in inhalation and dermal pathways. However, *HI* for all the pathways was equal to 1.21, a value greater than one due to the ingestion pathway. This meant that the children population was at risk of non-carcinogenic effects. For adults, the ingestion inhalation and dermal pathways had *HQ* and *HI* values all less than 1 giving a total *HI* of $7.34x10^{-1}$ for all the pathways. This low value indicated heavy metal pollution that may pose a very low non cancer health risk to adults living around the area. The results also indicate that, children, the ingestion pathway contributes the greatest to non-carcinogenic risk followed by the dermal pathway. Inhalation is the least contributor to the risk as shown in Figure 5 and 6 below.

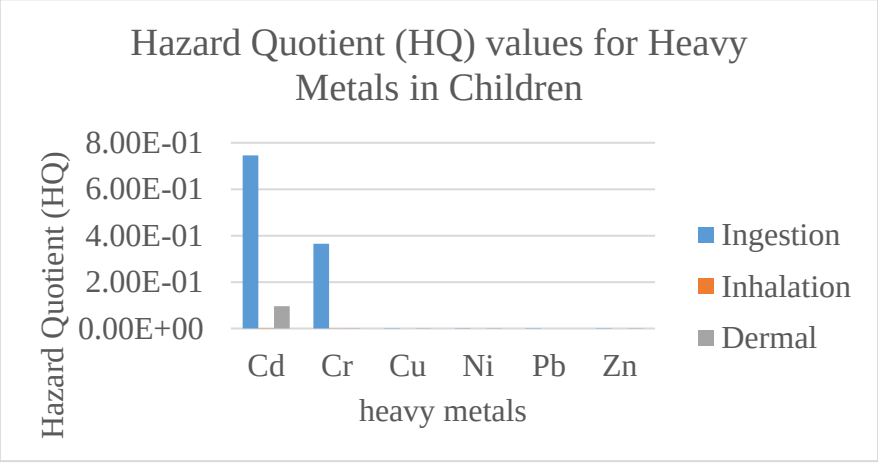


Figure 3: Hazard Quotient (HQ) values for heavy metals in Children for soil samples from study area.

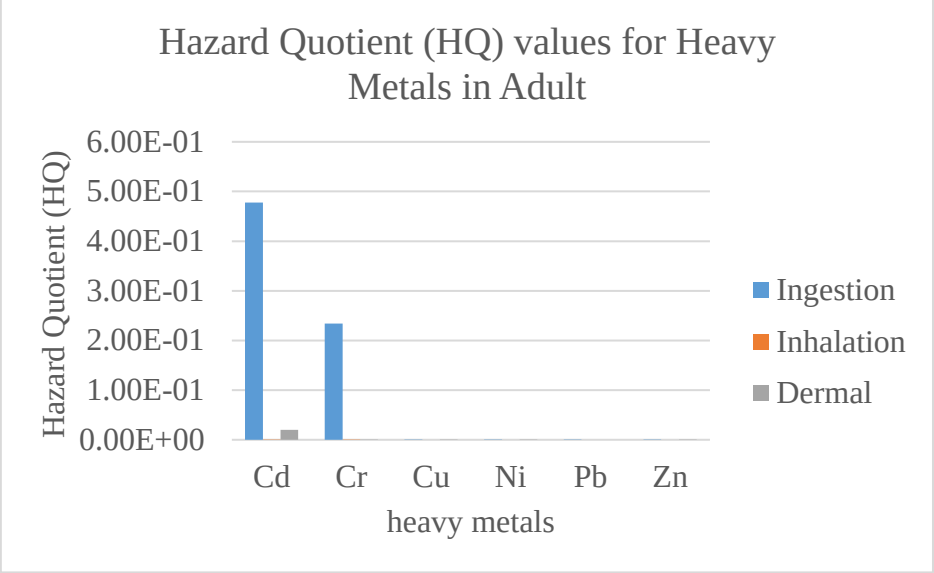


Figure 4: Hazard Quotient (HQ) values for heavy metals adult for soil samples from study area.

## DISCUSSION

Average concentrations of heavy metals in mg/kg for soil and plant samples from the study area are presented in Tables 1 and 2. The soil concentrations were used to calculate average daily intakes for non-carcinogenic and carcinogenic risk assessment. The results presented showed that the average concentrations of the heavy metals in rice sample from the study area varied significantly and decreased in the order Cd>Ni>Cu>Zn>Pb>Cr. The mean values of activity concentration of Cd, Cr, Cu, Ni, Pb and Zn, in the rice samples collected from the study area ranged from 27.343mgkg$^{-1}$ to 48.669mgkg$^{-1}$ with mean value of 33.477mgkg$^{-1}$, 0.047mgkg$^{-1}$ to 0.141mgkg$^{-1}$ with mean value of 0.097mgkg$^{-1}$, 0.242mgkg$^{-1}$ to 0.61mgkg$^{-1}$ with mean value of 0.341mgkg$^{-1}$, 0.308mgkg$^{-1}$ to 0.708mgkg$^{-1}$ with mean value of 0.420mgkg$^{-1}$, 0.093mgkg$^{-1}$ to 0.392mgkg$^{-1}$ with mean value of 0.818mgkg$^{-1}$, and 0.189mgkg$^{-1}$ to 0.471mgkg$^{-1}$ with mean value of 0.252mgkg$^{-1}$ respectively.

The soil samples from the study area had a varying concentrations of the heavy metals, which dropped significantly in order of Cr>Cd>Ni>Cu>Pb. The mean values of heavy metals concentration of Cd, Cr, Cu, Ni, Pb and Zn, in the plants samples collected from the study area ranged from 14.938mgkg$^{-1}$ to 42.985mgkg$^{-1}$ with mean value of 29.1952mgkg$^{-1}$, 0.203mgkg$^{-1}$ to 1270mgkg$^{-1}$ with mean value of 85.52007mgkg$^{-1}$, 0.038mgkg$^{-1}$ to 0.535mgkg$^{-1}$ with mean value of 0.333867mgkg$^{-1}$, 0.078mgkg$^{-1}$ to 0.68mgkg$^{-1}$ with mean value of 0.408333mgkg$^{-1}$, 0.106mgkg$^{-1}$ to 0.549mgkg$^{-1}$ with mean value of 0.264429mgkg$^{-1}$, and 0.103mgkg$^{-1}$ to 0.723mgkg$^{-1}$ with mean value of 0.367933mgkg$^{-1}$ respectively.

Comparison of the mean concentration of heavy metals in soil samples from the study area and maximum allowable limit of heavy metals concentrations in soil for different countries and FAO/WHO guidelines in the study conducted by (Ahmed, 2024) showed that the concentration of Cu, Pb, Ni, Zn, and Cr were below the maximum allowable limit while this study showed that the concentration of Cu, Pb, Ni, Zn , were lower than the maximum allowable limits set by FAO/ WHO , Cd was higher than the maximum allowable limit of heavy metals concentrations in soil for the different countries and this agrees with a study conducted by Abdelhafez *et al*. (2015) which states that Cadmium precipitation is more likely to occur in the form of Cd under anoxic paddy conditions. The study reveals that Cr was higher than the FAO/WHO guidelines for other countries like Germany, Australia, Bulgaria and South Africa but lower for some countries guideline like Taiwan, Poland and the UK.

The soil-to-plant transfer factor (TF) for this study was estimated from concentration of heavy metals in soil and corresponding concentration of heavy metals in plants. The mean transfer factors of Cd, Cu, Cr, Pb, Zn and Ni were 1.284112, 0.22552263 and 1.793639, 1.374464, 0.715465, and 0.885549, and ranged from 0.729115 to 2.385214, 7.6378E-05 to 0.46688742, 0.688488 to 7.695652, 0.682353 to 4.051282, 0.399485 to 1.518248, and 0.348548 to 1.883495 respectively.

The carcinogenic estimates were based on Cd, Cu, Cr, Pb, Zn and Ni concentrations in soil samples from the study area. The result obtained shows that Cd and Cr were the highest contributors to the cancer risk. The US Environmental Protection Agency considered acceptable for regulatory purposes a cancer risk limit in the range of $1x10^{-6}$ to $1x10^{-4}$ (US, EPA 2004). On the other hand, South Africa, considered the Individual cancer risk limit to be $5x10^{-6}$(Government of South Africa, 2006). The cancer risk for adults was found to be $8.68x10^{-6}$ (1 in 5882 individuals) and $9.6x10^{-5}$ (1 in 2725 individuals) for children, which were both greater than acceptable values. In the study area, children are therefore prone to cancer risk than adults. The ingestion route presents the major contributor to excess lifetime cancer risk followed by the dermal absorption pathway.

According to the Hazard Quotient data, children's non-carcinogenic risk is primarily contributed by the ingestion pathway, with the dermal absorption pathway following closely behind. The least amount of risk is associated with inhalation. In adults, the HQ and HI values for the dermal absorption and ingestion pathways were all less than unity (1), resulting in a total HI of $7.34\ x\ 10^{-1}$ for all the pathways. This low value indicated heavy metal pollution that may pose a very low non-cancer health risk to adults living around the area.

**CONCLUSION**

The findings demonstrated that the average heavy metal concentrations in soil and plant (rice) samples from the research region varied greatly and dropped in the following orders: Cr>Cd>Ni>Cu>Pb>Cr and Ni>Cd>Zn>Pb>Cr. The uptake of minerals by plants from contaminated soil which is an important step for heavy metals transport into the human food chains with Cr >Pb>Cd>Ni>Zn>Cu in a decreasing order. The results also indicated that the non-carcinogenic risk in both adults and children was primarily contributed by the ingestion pathway, which is followed by the dermal pathway. The inhalation pathway contributed the least proportion of non-cancer risk. In a carcinogenic risk terms, the dermal absorption pathway present a significant factor influencing the cancer risk occurrence. The results indicate that the soils in study area have been seriously contaminated by heavy metals, from leaching of top soils and rocks with Cd, Cr and Pb into the agricultural soils and practice of mineral fertilizer application which has called for a great concern. Tasrina *et al*. (2015) highlighted that long term low level body accumulation of heavy metals and the detrimental impact becomes apparent only after several years of exposure.

Comparing the concentrations of Cu, Pb, Ni, and Zn with standard results, the concentrations were below the maximum allowable limits; however, the concentrations of Cd were higher than the maximum allowable limit of heavy metals in soil for each country, and the concentrations of Cr were higher than the FAO/WHO (2002) guidelines for some countries (such as Germany, Australia, Bulgaria, and South Africa) but lower for others (such as Taiwan, Poland, and the UK). This study provides an important baseline reference data to the government decision-making on environment improvement/impact assessment.

**References**


Abdelhafez , A. A., Abbas, M. H. H. & Attia, T. M. S. (2015). Environmental monitoring of Heavy-Metals Status and human Health Risk Assessment in the Soil of Sahl El-Hessania Area,Egypt. *Pol. J. Environ. Stud*., 24(2), 459-467.

Abdullahi Abubakar Mundi, Umar Ibrahim & Idris Mohammed Mustapha (2019). Contamination and Pollution Risk Assessment of Heavy Metals in Rice Samples (*Oryza sativa*) from Nasarawa West, Nigeria. *Asian Journal of Advanced Research and Reports,* 3(4), 1-8. DOI: 10.9734/AJARR/2019/v3i430097. http://www.journalajarr.com/index.php/AJARR/article/view/30097

Agency for Toxic Substances and Disease Registry (1999). *Lead: Toxicological Profiles*; Centers for Disease Control and Prevention: Atlanta, GA, USA.

Agency for Toxic Substances and Disease Registry (2015). Guidance for the Preparation of a Twenty First Set Toxicological Profile. 2007. Available online: http://www.atsdr.cdc.gov/toxprofifiles/guidance/set_21_ guidance.pdf (accessed on 12 May 2015).

Ahmed, M. W., Afrin, S., Alam, M. K., Parven, A., Jubayer, M. F., Megharaj, M. & Khan, M. S. I. (2024). Determination and probabilistic health risk assessment of heavy metals in widely consumed market basket fruits from Dhaka city Bangladesh. *International Journal of Environmental Analytical Chemistry*, *104*(1), 215-230.

Brady, N., Nyle, C. & Ray, R. W. (2009). *Elementos da natureza e propriedades dos solos*. Bookman Editora.

Caspah, K., Manny, M. & Morgan, M. (2016). Health Risk Assessment of Heavy Metals in Soils from Witwatersrand Gold Mining Basin, South Africa. *International Journal of Environmental Research and Public Health*, *663*(13), 132 – 143.

Duffus, J. H. (2002). "Heavy metals" a meaningless term (IUPAC Technical Report). *Pure and applied chemistry,* 74 (5) 793-807.

Government of South Africa (2006). *Regulation Gazette: 490(*8454*).* Government of South Africa: Pretoria, South Africa.

Lane, T. W. & Morel, F. M. (2000). A biological function for cadmium in marine diatoms. *Proceedings of the National Academy of Sciences*, 97(9), 4627-4631.

Machiwa, J. F. (2010). Heavy Metal Levels in Paddy Soils and Rice (*Oryza Sativa* (L) from Wetlands of Lake Victoria Basin, Tanzania. *Tanz. J. Sci.,* 36(1), 59 – 72.

National Research Council (1999). *Arsenic in Drinking Water*; National Research Council: Washington, DC, USA; 251–257.

Podsiki, C. (2008). Heavy metals, their salts, and other compounds: a quick reference guide from AIC and the Health & Safety Committee. *AIC news,* 3(6), 1-4.

Tasrina, R. C., Rowshon, A., Mustafizur, A. M. R, Rafiqul, I. & Ali, M. P. (2015). Heavy metals contamination in vegetables and its growing soil. *J. Environ. Anal. Chem*., 2(3),1-6. DOI:10.4172/2380-2391.1000142

United Nations Environmental Programme (2002). *Global Mercury Assessment*; United Nations: Geneva, Switzerland.

UNSCEAR (2000). United Nations Scientific Committee on the Effects of Ionizing Radiation. Report to the General Assembly, United Nations. *I, 223*, New York

U.S. Environmental Protection Agency (2007). Framework for Determining a Mutagenic Mode of Action for Carcinogenicity: Review Draft. Available online: http://www.epa.gov/osa/mmoaframework/pdfs/MMOA-ERD-FINAL-83007.pdf (accessed on 3 October 2015).

U.S. Environmental Protection Agency (1989). *Risk Assessment Guidance for Superfund Volume1: Human Health Evaluation Manual (Part A)*; Office of Emergency and Remedial Response: Washington, DC, USA.

U.S. Environmental Protection Agency(2004). Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment); USEPA: Washington, DC, USA.

WHO (2014). Summary Results, Sensitivity Analyses, and Future Directions. *Bulletin of the World Health Organization, WHO,* 72**,** 495 - 508.