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Probabilistic health risk assessment in the consumption of toxic metal polluted zea mays and *talinum fruticosum* from farms near mining sites in southwest of Nigeria

[Health Risk in Toxic Metal Polluted Farm Produce]

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Abstract
Toxic metals found in food chain are due to plants intakes. This research work identifies and quantifies the amount of toxic metals (Pb, Co, and Zn) in samples of Zea Mays and Talinum Fruticosum widely cultivated and consumed in a locality near a limestone mining company and estimated daily dose (EDD). Three Farms in the neighborhoods of limestone mining site were identified for both Zea Mays and Talinum Fruticosum; samples were collected, digested and prepared for analysis using Atomic Absorption Spectrophotometer (AAS) model S4 series, Model (GBC 906) (USA). The mean concentrations of Zn from Zea Mays and Talinum Fruticosum farms are in the range of 9.38±1.63 mg/kg to 13.95±1.02 mg/kg and 0.30±0.10 mg/kg to 59.41±3.02 respectively. Pb, concentration in Zea Mays in the range of 0.20±0.05 mg/kg - 79.45±3.08 mg/kg and for Talinum Fruticosum in the range of 3.04±1.01 mg/kg - 3.82±1.01 mg/kg; and of Ni is between 0.03±0.01 mg/kg – 0.22±0.06 mg/kg and 0.04±0.01 mg/kg – 0.80±0.06 mg/kg for Zea Mays and Talinum Fruticosum respectively. Health risk index (HI) value of 1.51 and 2.18 for the adult and children respectively from Talinum Fruticosum; Zea Mays HI value is 3.13 for the adults and 2.49 for children these values exceeded recommended value of HI < 1 thus adults is more prone to health related problems than the children. The total toxic metal pollution index (TTMPI) in the environment is lower in Zea Mays farms than Talinum Fruticosum farms. Probability of carcinogenic cases in adult is 20% higher than in children taking Zea Mays; while in Talinum Fruticosum the probability of cancer related sickness is 91% in adult than children.
Keywords: Toxic; spectrophotometer; pollution index; hazards; environment

1. Introduction

Vegetables are part of the essential food recommended for healthy growth in human, so they are generally consumed by everybody. These vegetables are available round the year in the markets from different farm sources. In some farms they are produced through irrigations in general, while in some they are produced during the raining season, no matter the method of production, the soil still remains a major concern because of the pollutions. This work considers farms near a busy limestone mining area because of the possibility of soil pollutions in the area. This area is rich in solid minerals and so the possibility of heavy metals pollution of the vegetables planted in the nearby farms is of interest. Zea Mays and Talinum Fruticosum were among the commonly planted farm produce in Ewekoro and they are either irrigated or planted during the raining season. Some metals are generally essential for human health at a recommended amount for a period of time. However; if these amounts are exceeded for a long while then the metals become toxic to the human body and at this point, we call them heavy metals contamination.

Toxics metals are harmful to human kinds, once liberated to find their ways into human body through the food chain. They get into the human body through various ways such as ingestion, inhalation and through the skin by absorption. Release of heavy metals to the environment may occur through a wide range of processes and pathways, which may include the air during combustion, extraction and industrial processing (Ogungbemi et al., 2022), or surface waters such as runoff and releases from storage, wastewater and transport and the soil (agricultural processes and planting of crops (Duran et al., (2007)). Accumulation of heavy metals is toxic to humans and other living organism; therefore, exposure to toxic metals is normally chronic if the exposure is over a longer period of time, especially in the food chains.

Heavy metal contamination is one of the major problems on the environment especially of growing medium sized urban areas in developing countries, primarily as a result of uncontrolled pollution levels driven by causative factors like industrial growth etc. (Ogungbemi et al., 2022). Heavy metal contaminated crops could aggravate human health risk when consumed along with heavy metal contaminated drinking water. Heavy metal contamination may occur due to factors including irrigation with contaminated water (Kato et al., 2019), the addition of fertilizers and metal-based pesticides, industrial emissions, transportation, harvesting process and storage (Fithians et al., 2019). Toxic metals polluted ecosystem constitutes a serious health problem to mankind. Most of these toxic metals were either used in compound forms for one chemical reason or the other, for example lead compounds such as lead nitrates, lead acetate tri-hydrate etc. are generally used in the manufacturing industries for various purposes such as in sugar analysis and clarification of solutions of organic substances (HSDB, 2009; Radian & Salaam, 2006). Toxic metals are generally not separable from the plumes even after the treatment of lime stones at cement plants and thus, cause risk of heavy metal contamination of the soil and subsequently to the food chain (Oyinloye, 2015).

In addition to the naturally available sources, the quantity of heavy metals entering the environment through anthropogenic activities ranging from coal driven power plants to waste incinerators has increased tremendously. For these reasons, risk of human exposure to such harmful metals continues to increase. Some of the most frequently reported heavy metals with regards to potential hazards and the occurrence in contaminated soils are ^{55}Fe, ^{60}Co, ^{63}Ni, ^{90}Sr, 210Pb, 137Cs, ^{112}Cd, ^{51}Cr, ^{65}Zn, and ^{64}Cu (Karaca et al., (2010). Thus, heavy metal pollution of the soil is caused by various metals, especially Cu, Ni, Cd, Zn, Cr and Pb (Duruibe et al., (2007). Few metals such as Fe, Zn, Ca and Mg, have been reported to be of bio-importance to man and their daily medicinal and dietary allowances had been recommended.

However, metals such as As, Cd, Pb, and Hg have been reported to have no known bio-importance in human biochemistry and physiology and consumption even at very low concentrations can be toxic (Ashraf et al., 2007). Heavy metals exert toxic effects on soil microorganism hence results in the change of the diversity, population size and overall activity of the soil microbial ecosystem (USEPA, (2012). Heavy metal crops uptakes from the soil in high concentrations can result in general health problem in the food webs. Studies have shown that vegetables and staple food stuffs contain traces of metals (Al Mutairi et al., 2019; Saeed et al., 2014) and as a result of this, farming close to mining sites has been a place of concern and a liable reservoir of heavy metals in such an environmental; thus a place of health concern. Small scale farming activities like the cultivation crops and vegetables in farms around the mining sites are throughout the year. Thus, the transportation of heavy metals and other emerging pollutants in soil from around the mining site are possible via root-uptake in plants and hence, higher possibility of human absorption through ingestion (food path way) and inhalation (dust in the air).

Therefore, the aim of this present study was to identify and quantify Ni, Pb and Zn in samples of Zea Mays and Talinum Fruticosum, estimate daily dose intakes in humans and determine whether it is safe to consume Zea Mays and Talinum Fruticosum from the selected farms near the mining site. At the time of this study, Zea Mays and Talinum Fruticosum were readily available in the market places, consumed by almost everyone within and outside the area and Nigeria at large but our area of study is in the southwest Nigeria. There are many studies on several sources of heavy metals accumulation in the soils that are well documented, but; little attention has not been focused on individual consumable vegetables around a mining site.

2.0 Material and methods

Samples were collected from three farms that produce Zea Mays in the eastern direction to the mining site, while another three farms were identified in the southern direction to the mining site for the production of Talinum Fruticosum and the collection points are as coded in Table 1 below. All the farms for sample collections were located from between 1 km - 3 km away from the mining factory.

Table 1: Zea Mays and Talinum Fruticosum sampling locations and distances around the study area

Zea Mays Sampling Locations to East	Talinum Fruticosum Sampling Locations to South	Distances from the mining Company (meters)
ZEA1	TSA1	500
ZEA2	TSA2	
ZEA3	TSA3	
ZEB1	TSB1	1500
ZEB2	TSB2	
ZEB3	TSB3	
ZEC1	TSC1	2800
ZEC2	TSC2	
ZEC3	TSC3	

2.1 Sample Collection

The study area Ewekoro is one of the developing suburbans with agricultural produce as one of the major occupations of the dwellers, this area is a local government in Ogun state Nigeria. Ewekoro River as in Figure 1 forms the natural boundary between Ewekoro local government and a few of the neighboring Local Government Areas so the area is made up of a fertile land. Ewekoro is located on latitude 6º 55' 59.99" N and longitude 3º 12' 60.00" E. It has a land area of about 631.5 km^2 with a growing population of about 55,093 as a result of the industries that were established in the area (Oyinloye, (2015).

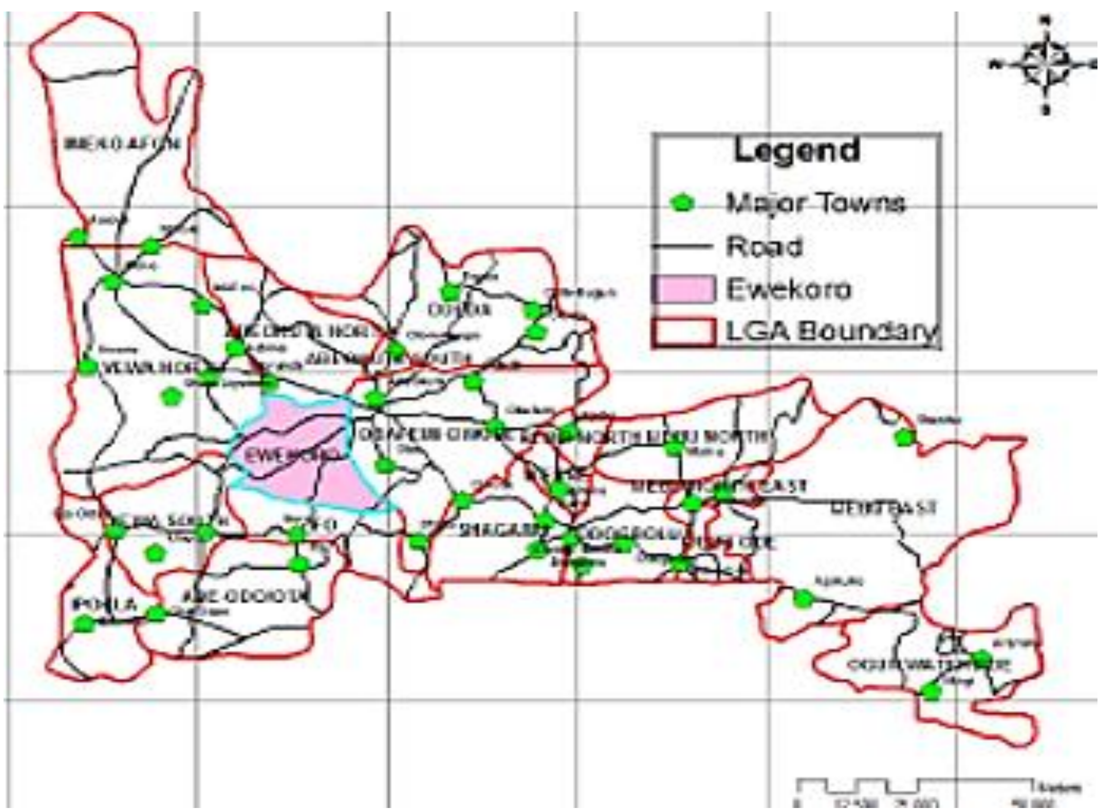

Figure 1: Map of Ogun State from Administrative perspective showing Ewekoro location in the State

Zea Mays and Talinum Fruticosum are available all year round, because they are produced through the irrigation system of farming. There were several farms around the area but our focus is on the nearest farms of about 1 km -3 km for the purpose of this study. The farms were coded ZEA, ZEB, and ZEC this implies Zea Mays from eastern part of the company Farm A; Farm B and Farm C; so also, the same was done for Talinum Fruticosum in the south part of the company: TSA, TSB, and TSC as shown in Table 1 above.

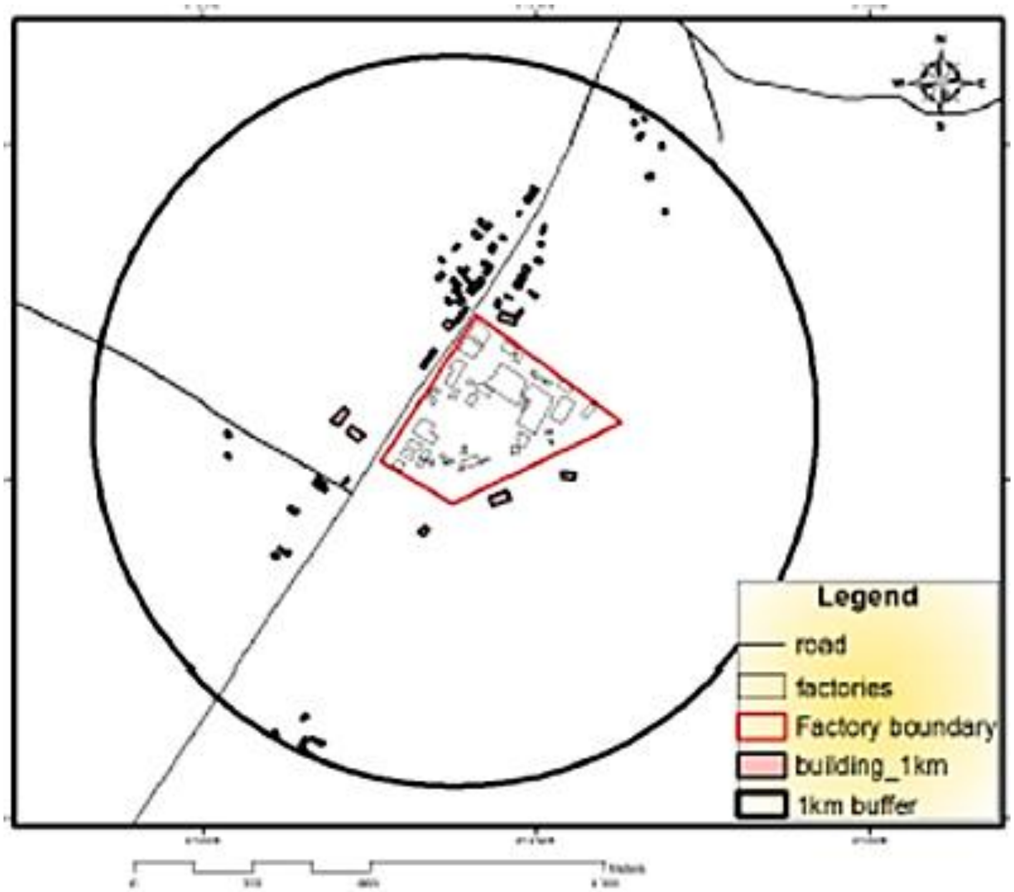

Figure 2: The Cement Producing Company Environs within 1 km from the farm

Zea Mays and Talinum Fruticosum were collected from various farms within a reasonable radius of about 1- 3 km from the cement manufacturing company at for sampling as in Figure 2. Glass wares were cleaned in detergent, rinsed with tap water and deionized water, soaked in 10% nitric acid overnight this is to remove heavy metals stains, rinsed with deionized water because of its oxidizing ability and dried in an oven. For the analysis of the selected metals, all samples were air dried until constant weight was obtained from the samples. A pestle and mortar was used in grinding the samples until homogenous powders of the samples were obtained this were then sieved through a 2-mm mesh.

Afterwards, 0.5 g of each sample was separately weighed into a glass 100 ml round flash and to this 10 ml of deionized water was added, followed by 7.5 ml of concentrated hydrochloric acid and 2.5 ml of concentrated nitric acid. The samples (Talinum Fruticosum and Zea Mays as shown in Figure 3a and b respectively) were digested at room temperature overnight prior to being placed into a digestion block system (of about 40 spaces) connected to a Gerhardt Turbos scrubber unit (filled with 10% w/v sodium hydroxide). The samples were then refluxed at 120°C for some hours. After cooling to ambient temperature, the digests were filtered into volumetric flasks, diluted with deionized water, made up to a volume of 50 ml and mixed. Thus, the samples were taken to Atomic Absorption Spectrophotometer (AAS) model S4 series, Model (GBC 906) (USA) for the identification and quantification of the metals.

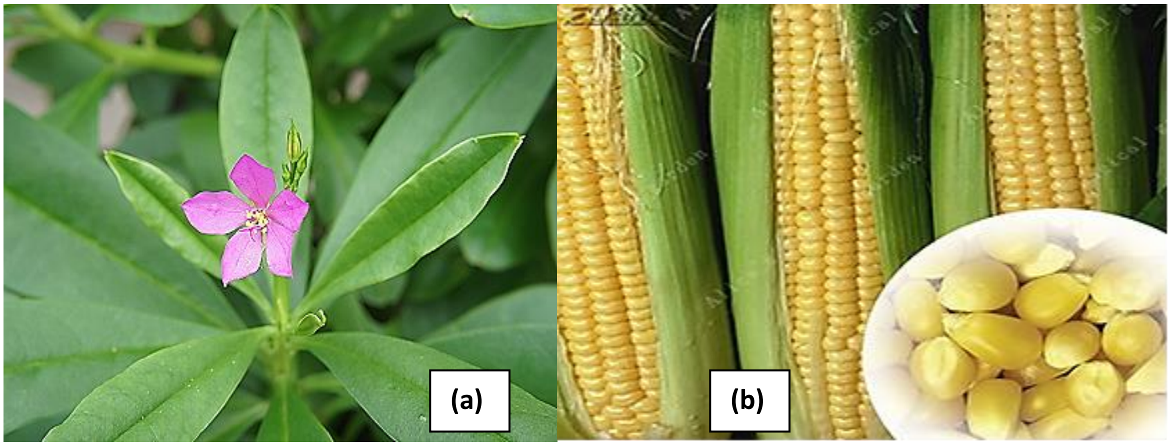

Figure 3: Harvested Talinum Fruticosum (a) and Zea Mays (b)

2.2 Health Risk Analysis Of Zea Mays And Talinum Fruticosum

Toxic metals in Zea Mays and Talinum Fruticom may be accumulated in the body if these vegetables are consumed for period of times, thus to estimate the health risk over a life time we used the following assessment parameters: daily estimated intake of metals (DEI), target hazard quotients (THQ), target cancer risk (TR) and hazard index (HI) for both the targeted consumers of different ages thus we consider both the adult and the children. It should be noted here that cooking of Zea Mays and Talinum Fruticosum has no effects of the samples.

2.2.1 Daily Estimated Intake (DEI)

DEI is one of the parametric quantities used in analyzing the health risk in consumable items and this is used for all ages as in equation 1 below.

$$DEI = \frac{ER \times PE \times IR \times MC \times CF}{HW \times T_A} \times 10^{-3} \qquad (1)$$

where ER is the exposure rate (365 days/year), PE is the exposure period (30 years for non-cancer risk metal pollutants as used by USEPA (USEPA, 2011) ; MC is the mean concentrations of toxic metals (mg/kg wet weight), IR is average ingestion rate (g/day); for Talinum Fruticosum is 0.45 kg, 0.35kg for adult and children respectively, while for the Zea Mays the value is about 0.25kg for the adult and 0.15kg for the children; CF is the conversion factor value 0.208 in converting from fresh weight to dry weight with above 79% moisture, HW is average body weight of adult 65kg for adult, 35 kg for children of about 15 years old and T_A is the average exposure time (70 x 365 days for adult and for the children 35 x 365days) (USEPA, 2011)

2.2.2 Target Hazard Quotient (THQ)

Target hazard quotient for both carcinogenic metals and non-carcinogenic metals are required to estimate the risk that may come from consuming Zea Mays and Talinum Fruticosum for a period of time; as in the equation 2 below [USEPA 2011]. THQ is dimensionless.

$$THQ = \frac{DEI}{RfD} \qquad (2)$$

where DEI (mg\day\kg bodyweight) = estimated daily metal intake of the population and
R*f*D is the reference dose values as in table 2 below for individual metal (mg/kg/day) (USEPA, 2011; Pirsaheb et al., 2019; Sadeghi et al., 2015) .

Table 2: Shows the reference dose (R_fD) and Cancer Slope factor (CPSo) values used for different metals

Element	Reference dose (RfD) (mg\kgBw\day)	Cancer Slope Factor (CPSo) (mg\kgbw\day)$^{-1}$
Zn	0.300	------
Pb	0.0035	8.5 x 10^{-3}
Ni	0.02	1.7

2.2.3 Hazard Risk Index (HI)

This study assess the overall potential health risk posed by more than one metal, therefore; HI of the individual metals sought in this work has been evaluated in the equation 3 below (Azari *et al.*, 2017; Dobaradaran *et al.*, 2017). For non-serious health concern HI value is less than 1, while for health risk concern HI will have to be greater than unity.

$$HI = \sum_{i=1}^{k} THQ_i \ ; \ \ i = 1, 2, \dots, k \tag{3}$$

2.2.4 Target Cancer Risk (TR)

Target cancer risk (TR) normally shows the level of the carcinogenic risk in the ingestion of carcinogenic metals for a given population of consumers.

$$TR = \sum_{i=1}^{j} \left(DEI_{(i)} + CPSo_{(i)} \right) \tag{4}$$

Where TR = cancer risk over lifetime due to specific toxic metal intake,
DEI = estimated daily metal ingestion of the populace in mg\day\kg body weight;
CPSo = cancer Slope Factor values as in Table 2 above (mg\kgbw\day)$^{-1}$ (Rattan *et al.*, 2005; Naghipour *et al.*, 2017; Arora *et al.*, 2008)

2.2.5 Total Toxic Metal Pollution Index (TTMPI)

The TTMPI is normally used to assess the total metal content found in Toxic metals in Zea Mays and Talinum Fruticom and this is one of the effective tools in assessing metal pollution and can be used to predict the environmental impact of such metal pollutions.

$$TTMPI = \left(C_{f1} \times C_{f2} \times C_{f3} \times \dots \times C_{fn} \right)^{\frac{1}{n}} \tag{5}$$

Where C_{fn} Concentration of n^{th} metal in the sample

3.0 Results and Discussions

From the analysis of the samples using AAS the concentration level of Zn, Pb and Ni was obtained for nine different locations each for Zea Mays and Talinum Fruticom and the mean values were as reported in Tables 3 and 4.

Table 3: Concentration levels (mg/kg) of Talinum Fruticosum from sampling locations

Talinum Fruticosum Sampling Locations	Mean Concentration of Heavy Metals in the Samples (mg/kg)		
	Zn	Pb	Ni
TSA1	17.421±1.101	3.065±0.112	0.471±0.012
TSA2	14.224±4.045	3.319±1.028	0.085±0.005
TSA3	16.109±3.075	3.399±1.071	0.337±0.143
TSB1	14.878±3.061	3.041±1.009	0.804±0.061
TSB2	28.139±2.039	3.253±0.074	0.041±0.008
TSB3	17.318±4.181	3.219±0.095	0.094±0.004
TSC1	59.406±3.015	3.733±1.106	0.234±0.086

TSC2	24.365±2.032	3.403±0.077	0.181±0.043
TSC3	0.302±0.104	3.818±1.011	0.315±0.023

Table 3 is the results obtained from the three farms sampling locations, farms A, B and C south of the mining company. The highest concentration levels are found in Zn, thus; giving in the following, trends of Zn concentrations in the farms:

TSA1 > TSA3 > TSA2;

TSB2 > TSB3 > TSB1;

TSC1 > TSC2 > TSC3.

For the Pb concentrations in these farms, the highest is 3.399±1.071 mg/kg and from farm A; 3.253±0.874 mg/kg from farm B while from farm C is 3.733±1.196, hence the Pb concentration levels are in the following trends:

TSA3 > TSA2 > TSA1;

TSB2 > TSB3 > TSB1;

TSC3 > TSC1 > TSC2

So also, the highest concentration level of Ni is 0.804±0.061 mg/kg from farm B1 and the lowest is 0.041±0.008 mg/kg from farm B2. Therefore, the trend of Ni concentration levels is:

TSA1 > TSA3 > TSA2;

TSB1 > TSB3 > TSB2;

TSC3 > TSC1 > TSC2

Sampling of Zea Mays was done in the eastern part of the mining company, the results of the concentration levels are as shown in table 4 below. The range of the Ni concentration from farm A is 0.062±0.008 mg/kg to 0.215±0.055 mg/kg, from farm B, Zn concentration ranges between 0.033±0.007 mg/kg and 0.188±0.022 mg/kg, in farm C the range is 0.037±0.004 mg/kg - 0.079±0.006 mg/kg.

Tables 4: Concentration levels (mg/kg) of Zea Mays from sampling locations.

Zea Mays Sampling Locations	**Mean Concentration of Heavy Metals in the Samples (mg/kg)**		
	Ni	Pb	Zn
ZEA1	0.215±0.055	1.681±0.190	13.882±1.021
ZEA2	0.062±0.008	1.284±0.012	10.201±1.009
ZEA3	0.122±0.005	1.092±0.017	9.899±1.001
ZEB1	0.188±0.022	0.196±0.047	13.946±2.162
ZEB2	0.048±0.009	0.807±0.016	10.714±1.019
ZEB3	0.033±0.007	0.376±0.101	10.492±1.191
ZEC1	0.079±0.006	79.446±3.081	9.376±1.630
ZEC2	0.043±0.001	0.611±0.118	10.256±1.016
ZEC3	0.037±0.004	1.236±0.014	12.649±3.911

The trend of the Ni concentration each Zea Mays sampling farms is as given below:

ZEA1 > ZEA3 > ZEA2;

ZEB1 > ZEB2 > ZEB3;

ZEC1 > ZEC2 > ZEC3

Pb concentrations are in the range of 1.092±0.017 mg/kg to 1.681±0.190 mg/kg; 0.807±0.016 mg/kg to 0.196±0.047 mg/kg; and 0.611±0.218 mg/kg to 79.446±7.881 mg/kg from farms A, B and C respectively. Thus, the trend is as follows:

ZEA1 > ZEA2 > ZEA3;

ZEB2 > ZEB3 > ZEB1;

ZEC1 > ZEC3 > ZEC2

Therefore, the Zn concentrations level is the other of:

ZEA1 > ZEA2 > ZEA3;

ZEB1 > ZEB2 > ZEB3;

ZEC3 > ZEC2 > ZEC1

The estimated daily intakes (*EDI*) obtained from each farm from both Talinum Fruticosum and Zea Mays samples are as shown in table 5 and table 6 respectively. The *EDI* values for both adult and the children have been shown for Talinum Fruticosum in table 5. Farm TSC1 shows higher *EDI* than all other farms both for the adult and children across the three pollutants of Talinum Fruticom. Thus, the mean of the overall in Zn for all the farms in southern direction of the company is slightly greater in children than the adult.

Table 5: The mean daily estimated intake of metals (DEI) from Talinum Fruticom consumption (mg\day\kg bodyweight) from sampling locations

Talinum Fruticom sampling locations	**Mean daily estimated intake of metals (DEI) from Talinum Fruticom consumption (mg\day\kg bodyweight)**					
	Adult			Children		
	Zn	Pb	Ni	Zn	Pb	Ni
TSA1	2.51E-02	4.14E-03	6.78E-04	3.62E-02	6.38E-03	9.80E-04
TSA2	2.05E-02	4.78E-03	1.22E-04	2.96E-02	6.90E-03	1.77E-04
TSA3	2.32E-02	4.90E-03	4.85E-04	3.35E-02	7.07E-03	7.01E-04
TSB1	2.14E-02	4.38E-03	1.16E-03	3.10E-02	6.33E-03	1.67E-03
TSB2	4.05E-02	4.68E-03	5.90E-05	5.85E-02	6.77E-03	8.53E-05
TSB3	2.50E-02	4.64E-03	1.35E-04	3.60E-02	6.70E-03	1.96E-04
TSC1	8.55E-02	5.38E-03	3.37E-04	1.24E-01	7.77E-03	4.87E-04
TSC2	3.51E-04	4.90E-03	2.61E-04	5.07E-02	7.08E-03	3.77E-04
TSC3	4.35E-04	5.50E-03	4.54E-04	6.28E-04	7.94E-03	6.55E-04

However, the EDI obtained due to Pb have a mean of 4.84E-03 mg\day\kg bodyweight for adult and 6.99E-03 mg\day\kg bodyweight for the children. Also the EDI obtained due to Ni has been recorded as for adult is 1.16E-03 mg\day\kg bodyweight and 1.67E-03 mg\day\kg bodyweight for the children. This implies that from this a farming areas, children received more EDI than the adult in Zn, Pb and Ni.

Table 6: The mean daily estimated intake of metals (DEI) from Zea Mays consumption (mg\day\kg bodyweight) from sampling locations

Zea Mays sampling locations	Mean daily estimated intake of metals (DEI) from Zea Mays consumption (mg\day\kg bodyweight)					
	Adult			Children		
	Zn	Pb	Ni	Zn	Pb	Ni
ZEA1	1.56E-02	1.88E-03	2.41E-04	1.24E-02	1.50E-03	1.92E-04
ZEA2	1.14E-02	1.44E-03	6.94E-05	9.09E-03	1.15E-03	5.53E-05
ZEA3	1.11E-02	1.22E-03	1.37E-04	8.82E-03	9.73E-04	1.09E-04
ZEB1	1.56E-02	2.20E-04	2.16E-04	1.24E-02	1.75E-04	1.68E-04
ZEB2	1.20E-02	9.04E-04	5.38E-05	9.55E-03	7.19E-04	4.28E-05
ZEB3	1.18E-02	4.21E-04	3.70E-05	9.35E-03	3.35E-04	2.94E-05
ZEC1	1.05E-02	8.90E-02	8.85E-05	8.36E-03	7.08E-02	7.04E-05
ZEC2	1.15E-02	6.84E-04	4.82E-05	9.14E-03	5.45E-04	3.83E-05
ZEC3	1.42E-02	1.38E-03	4.14E-05	1.13E-02	1.10E-03	3.30E-05

The mean daily estimated intake of metals (DEI) in Zea Mays consumption from the farms in the eastern part of the mining company have been computed as shown in table 6 above. From all the nine sampling locations in three different farms, the value of DEI in Zn range between 1.05E-02 mg\day\kg bodyweight and 1.56E-02 mg\day\kg bodyweight in the adult and for the children the range is 8.36E-03 mg\day\kg bodyweight - 1.24E-02 mg\day\kg bodyweight. While for Pb in adult the values of EDI are in the range of 2.20E-04 mg\day\kg bodyweight and 8.90E-02 mg\day\kg bodyweight, the children EDI of Pb is in the range 1.75E-04 mg\day\kg bodyweight to 7.08E-02 mg\day\kg bodyweight. From the Ni, the adult EDI is found to be in the range of 3.70E-05 mg\day\kg bodyweight - 2.41E-04 mg\day\kg bodyweight and that of the children is in the range of 3.30E-05 mg\day\kg bodyweight and 1.92E-04 mg\day\kg bodyweight. From this farm, adult received more EDI in Zn than the children, while in both Ni and Pb, adult received more than the children.

4.0 Target Hazard Quotient For Adult And Children

Target hazard quotient (THQ) is one of the parametric quantities for measuring the probabilistic health risk, even though; this quantity is a function of the reference dose (R*f*D) values of each of the carcinogenic and non-carcinogenic toxic metals intake individually. The THQ due to each samples collected from the farms have been evaluated as indicated in Figure 4 below. The THQ due to consumptions Zn present in Talinum Fruticosum samples for both the adult and children in case of the, non-carcinogenic pollutant.

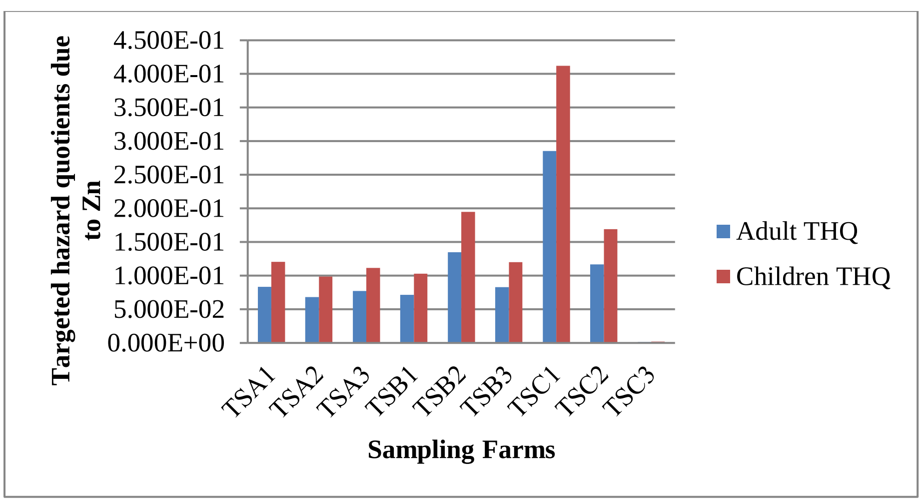

Figure 4: Targeted hazard quotients of both the adult and children due to Zn in Talinum Fruticosum farms

THQ due to Zn for adult is in the range of 1.45E-03 – 1.17E-01 while that of the children is within the range of 2.09E-03 – 4.12E-01. Farm TSC1 have the highest value for both children and adult, with that of the children been higher than that of the adult. The lowest THQ here is found in the farm TSA2. On the average the THQ for children is greater than for the adults. THQ values are used for making a major decision between the situation of either the produce studied will give an health over a period or not, however; the results, shows that over the period of life time, children that consume Talinum Fruticom from the farms here will likely have cancer related health issues than the adults. For the adult in Talinum Fruticom farm the THQ due to Zn is in order of; TSC1 > TSB2 > TSC2 > TSA1 > TSB3 > TSA3 > TSB1 > TSA2 > TSC3, and for the children in Talinum Fruticom farm the THQ due to Zn is in order of; TSC1 > TSB2 > TSC2 > TSA1 > TSB3 > TSA3 > TSB1 > TSA2 > TSC3. Figure 5 shows the THQ from Talinum Fruticosum due to Pb, the range for the adult is between 1.25E+00 and 1.57E+00, while that of the children is between 1.81E+00 and 2.23E+00. This indicates that theTHQ values obtained for the children are greater than that of the adult as indicated in Figure 5 thus; children that consume Talinum Fruticosum regularly are likely to have health related issues early than the adults. The average value for the adult is 1.38E+00, while that of the children is 2.00E+00. The locations TSA2, TSA3, TSC2 and TSC3 are the main locations from different farms that give high values for THQ in adult, so also; the children follows the same trends but the values for the children were higher than that of the adult from the same sampling locations in the same farm.

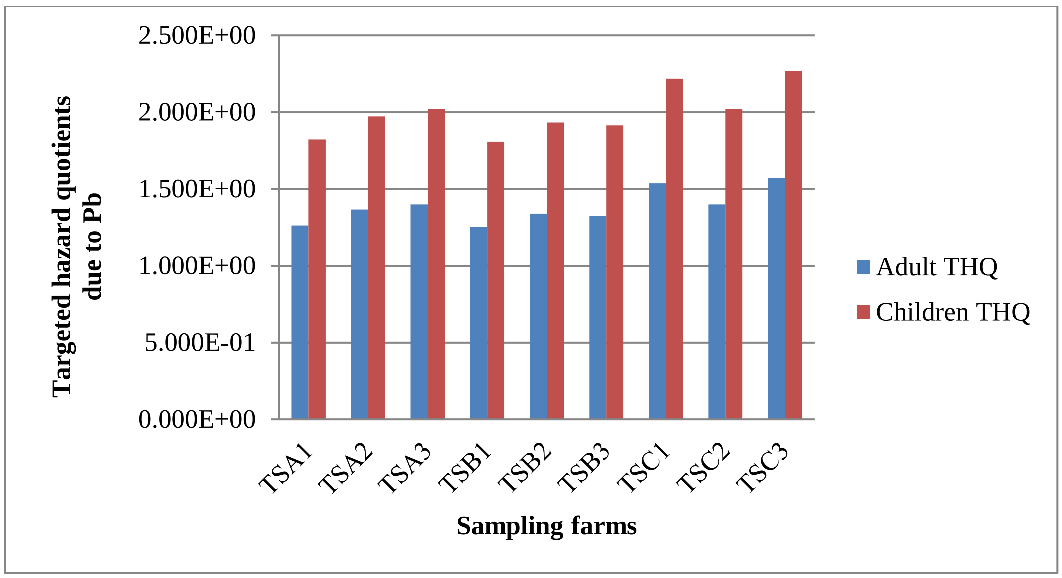

Figure 5: Targeted hazard quotients of both the adult and children due to Pb in Talinum Fruticosum farms

This implies that Pb is on the high side in this farm generally and this may be a serious concern to look into. For the adult in Talinum Fruticom farm the THQ due to Pb is in order of; TSC1 > TSB2 > TSC2 > TSA1 > TSB3 > TSA3 > TSB1 > TSA2 >TSC3. For the children in Talinum Fruticom farm the THQ due to Pb is in order of; TSC1 > TSB2 > TSC2 > TSA1 > TSB3 > TSA3 > TSB1 > TSA2 > TSC3. The target quotients due Ni intake from Talinum Fruticom farms for both the adult and children are as shown in Firgure 6. THQ for the children is significant than that of the adult in all the sampling locations from the farms. In all the average THQ values due to Ni for both the adult and children are 2.05E-02 and 2.96E-02 respectively.

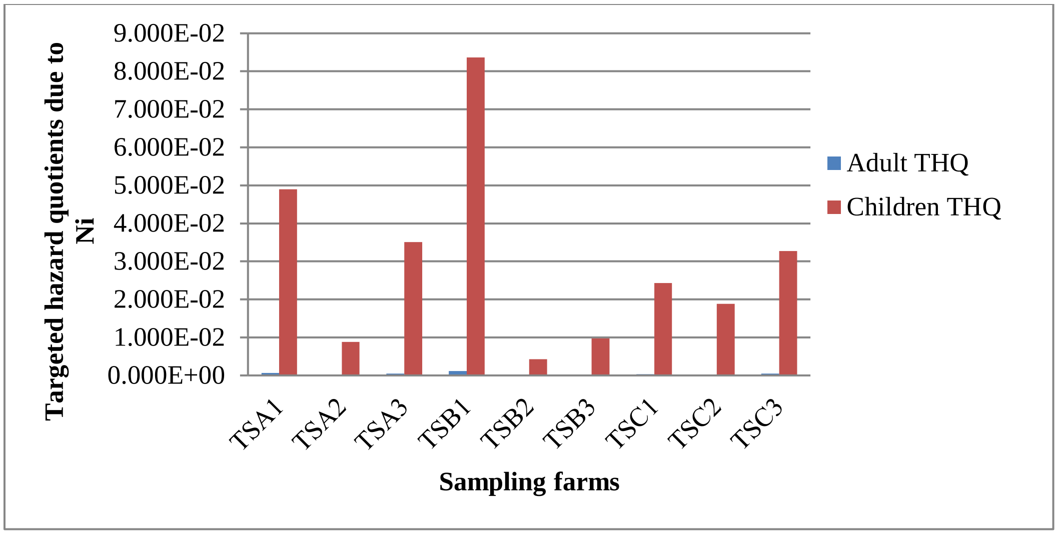

Figure 6: Targeted hazard quotients of both the adult and children due to Ni in Talinum Fruticosum farms

For the children the range of the THQ due to Ni is 4.26E-03 to 8.36E-02 that of the adult is between the range of 2.95E-03 and 3.39E-02. Considering each sampling locations for the farms then the THQ ; for the adult in Talinum Fruticosum farm due to Ni is in order of; TSB1 > TSA1 > TSB2 > TSA3 > TSC3 > TSC2 > TSC1 > TSB3 > TSA2. For the children in Talinum Fruticom farm due to Ni is in order of; TSB1 > TSA1 > TSA3 > TSC3 > TSC1 > TSC2 > TSB3 > TSA2 > TSB2. From figure 7, the THQ of both the adult and children from the Zea Mays sampling locations in all the farms studied from the eastern part of the mining company. THQ due to Ni from different sampling locations of Zea Mays farms have been obtained.

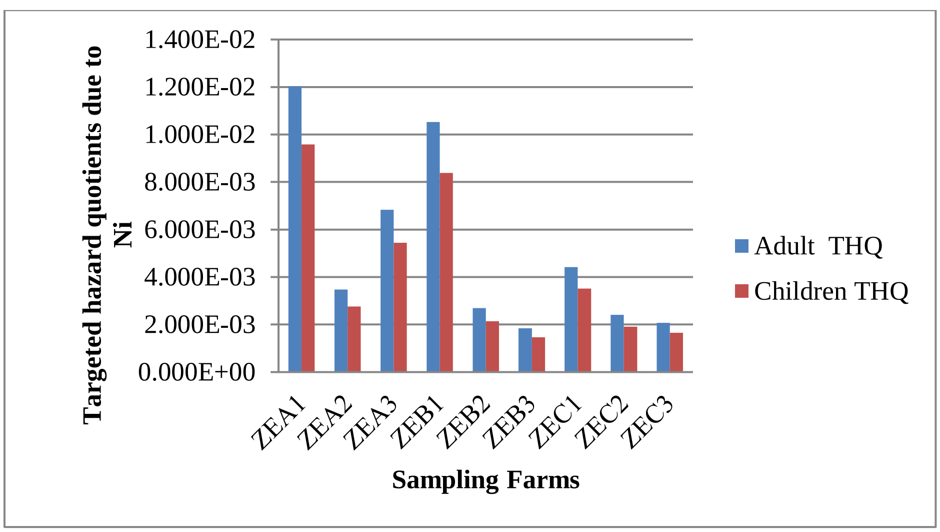

Figure 7: Targeted hazard quotients of both the adult and children due to Ni in Zea Mays farms

The average THQ in both the adult and children is 5.15E-03 and 4.10E-03 respectively from the farms in the eastern part of the mining company. For the adult in Zea Mays farm due to Ni is in order of; ZEA1 > ZEB1 > ZEA3 > ZEC1 > ZEA2 > ZEB2 > ZEC2 > ZEC3 > ZEB3. For the children in Zea Mays farm due to Ni is in order of; ZEA1 > ZEB1 > ZEA3 > ZEC1 > ZEA2 > ZEB2 > ZEC2 > ZEC3 > ZEB. In figure 8, the THQ due to Pb as shown in figure 8 above, THQ is more significant from sampling location ZEC1 in both the adult and children with values of 2.54E+01 and 2.02E+01 respectively as compared to the overall average of 3.08E+00 in adult and 2.45E+00 in children from the farms.

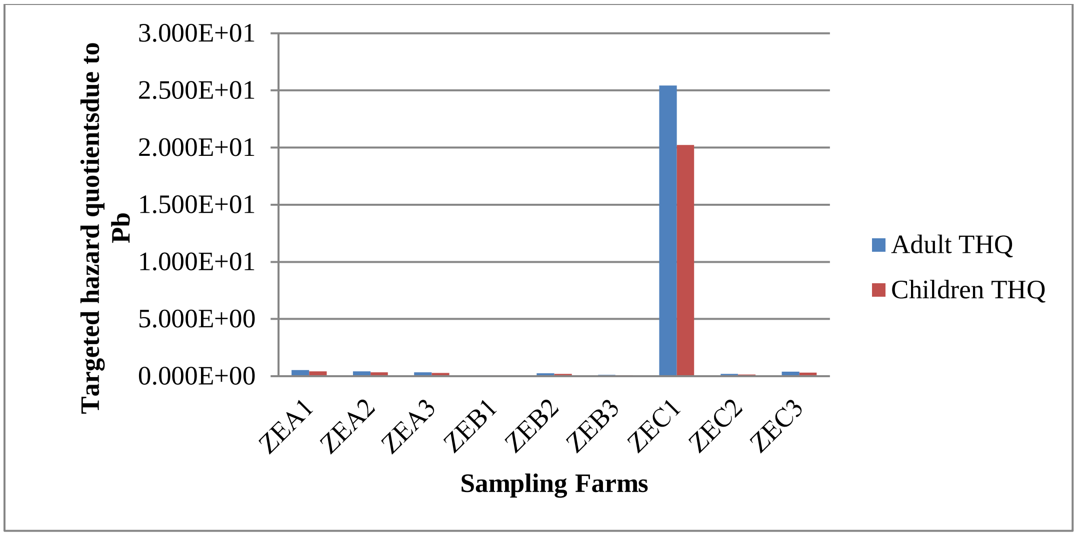

Figure 8: Targeted hazard quotients of both the adult and children due to Pb in Zea Mays farms

For the adult in Zea Mays farm due to Pb is in order of; ZEC1 > ZEA1 > ZEA2 > ZEC3 > ZEA3 > ZEB2 > ZEC2 > ZEB3 > ZEB1. For the children in Zea Mays farm due to Pb is in order of ZEC1 > ZEA1 > ZEA2 > ZEC3 > ZEA3 > ZEB2 > ZEC2 > ZEB3 > ZEB1 as shown in figure 8 above. Location ZEC1 is may be a great concern because of the very high value of THQ that is greater than unity. Values of THQ greater than unity may cause health issues for those that may be consuming Zea Mays from this location.

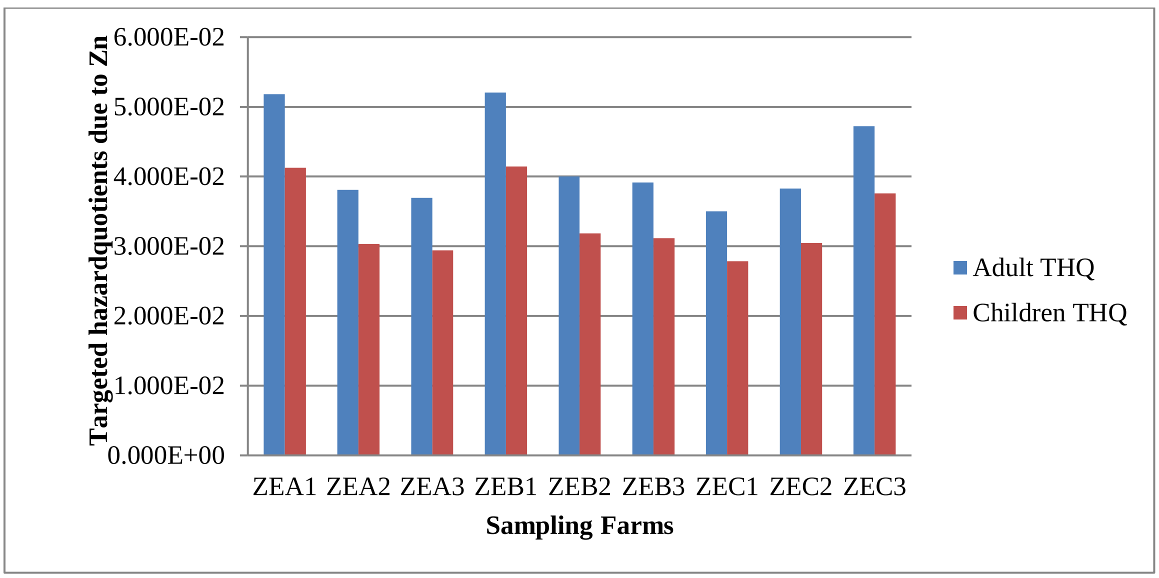

Figure 9: Targeted hazard quotients of both the adult and children due to Zn in Zea Mays farms

The figure 9 above show THQ due to Zn in both the adult and the children from Zea Mays sampling points in the farms. The average THQ obtained for the adult and children is 4.21E-02 and 3.35E-02 respectively, however the highest in adult is 5.21E-02 and the lowest is 3.50E-02 which indicates that the likeliness of cancer related health issues may not happened for sometimes; while the highest in the children is 4.14E-02 and the lowest is 2.79E-02 this implies that the hazard may be in adult here than the children. Sampling location ZEA1, ZEB1 and ZEC3 are higher for adult and this trend is observed for the children also in these locations.

5.0 Health Risk Index For Adult And Children

In accessing the overall health risk related issues from multi-metal pollutants point of view, figure 10 illustrates the health risk in each the locations in all the farms sampled for Talinum Fruticosum. The average health risk index of 1.51E+00 in adult and 2.18E+00 in children may cause health issues.

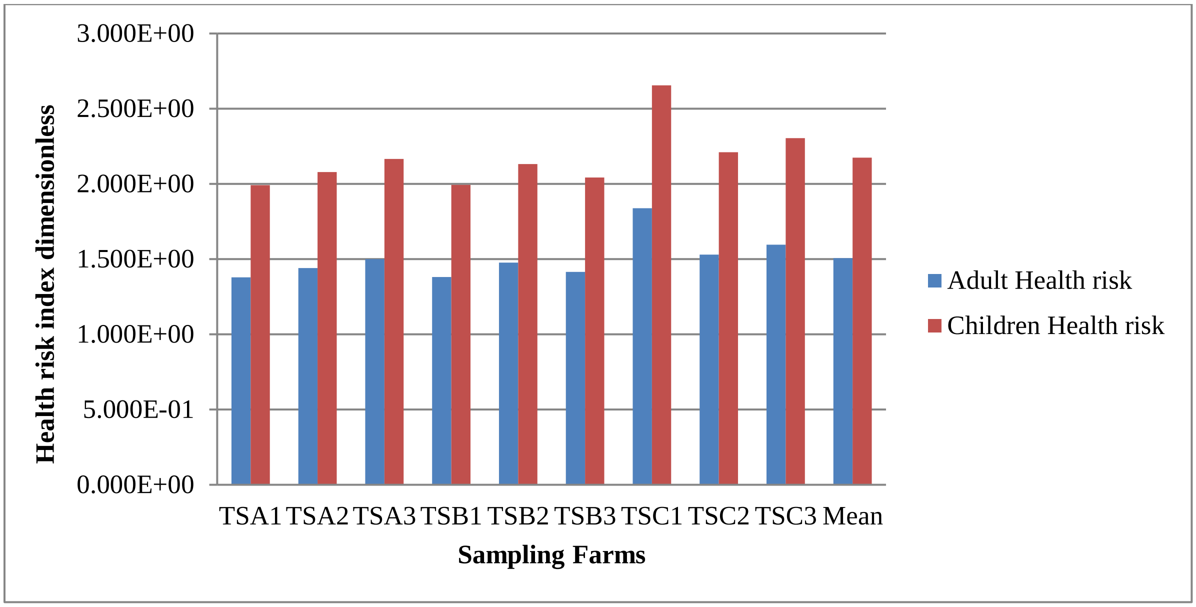

Figure 10: Health risk index for both the adult and children from Talinum Fruticosum farms

The highest value of 1.83E+00 and 2.66E+00 are obtained from sampling location TSC1 for both the adult and children respectively and these values were higher that the recommended value of one (HI < 1) for no health issues, while the lowest values of 1.38E+00 for adult and 1.99E+00 for the children both at the sampling location TSA1. Considering the Zea Mays farms the trend is quite different in the case health risk as it is illustrated in figure 11.

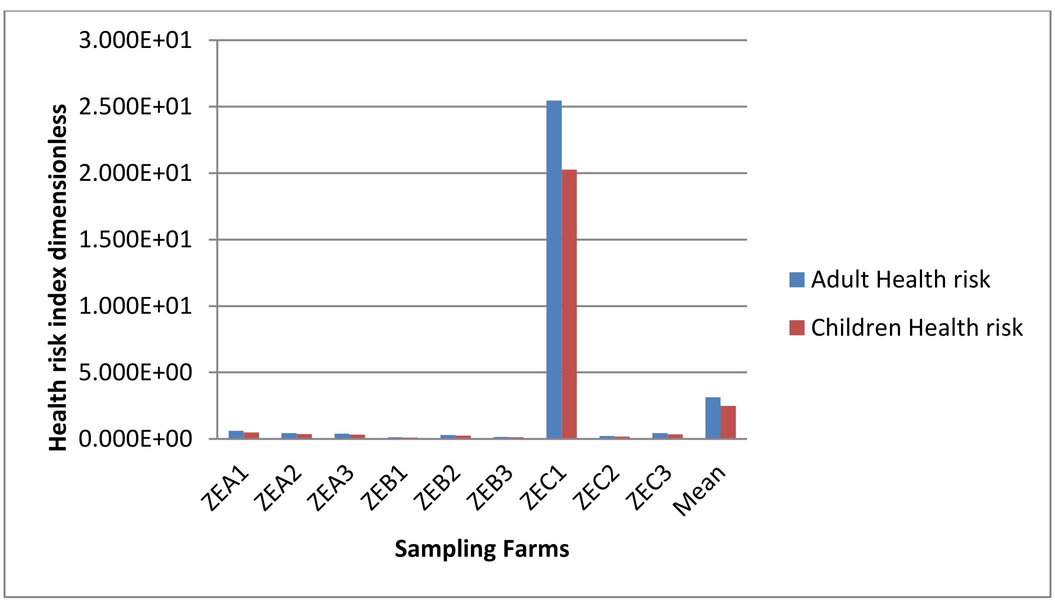

Figure 11: Health risk index for both the adult and children from Zea Mays farms

The average HI obtained from Zea Mays farm is 3.13E+00 for adult and 2.49E+00 for the children, however most of the sampling locations have lower values of HI in both cases apart from the location ZEC1 that has a value of 2.55E+00 for adult and 2.03E+00 for the children. These values are greater than the average value as it is obtained from the whole farm and most the values obtained from other locations were lower than the average. Therefore, locations ZEC1 is the only probable health risk issue location in the eastern part of the mining company; whereas, for the Talinum Fruticosum the HI value is generally greater than unity in all the sampling locations that may be a concern. Health issues in all the sampling locations for the consumers Talinum Fruticosum form the southern part of the mining company. In a life time period, the dwellers that constantly consumed Talinum Fruticosum may have cancer related health issues because of the high values of health risk (> 1) in the farms in the southern part of the mining company. For the targeted cancer risk, Pb and Ni were used to determine the probabilistic cancer risk from each of the farms. Figure 12 show the comparison between the targeted cancer risk (TR) in adult and the children from consuming Talinum Fruticosum in the farms of study.

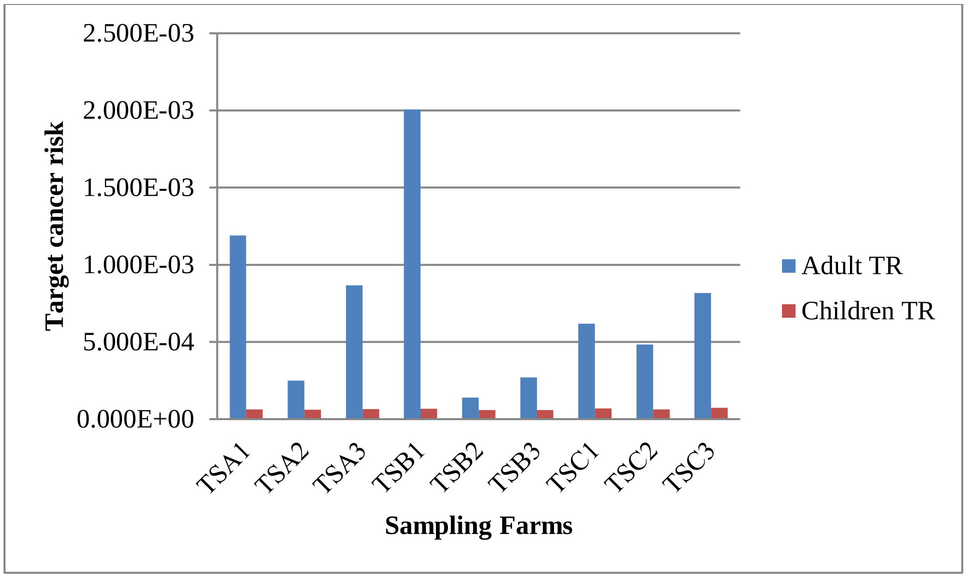

Figure 12: Targeted cancer risk for both the adult and children from Talinum Fruticosum farms

For non-health issues, the range of 10^{-6} and < 10^{-4} are the permissible limits for a single carcinogenic metals and multi-carcinogenic metals; however, in this study we considered multi-carcinogenic metals in Pb and Ni. Therefore, in the Talinum Fruticosum farms the range of TR due to Pb is 3.75E-05 – 4.67E-05 while for Ni, the TR range is between 1.00E-04 and 1.97E-03 for the adult. But for the children, TR due to Pb is in the range of 5.38E-05 to 6.75E-05 as indicated in figure 12. Considering each sampling locations, for the adult consuming Talinum Fruticosum from the farm, the multi-carcinogenic metals TR are in the order of TSB1 > TSA1 > TSA3 > TSC3 > TSC1 > TSC2 > TSB3 > TSA2 > TSB2; and for the children in the same farm, the TR are in the order of TSC3 > TSC1 > TSB1 > TSA3 > TSC2 > TSA1 > TSA2 > TSB3 > TSB2. Adults from this farm with average of (7.38×10^{-4}) were more prone to carcinogenic risk (TR) than children (6.45×10^{-5}) when Talinum Fruticosum is consumed**.** The TR obtained due to Pb in Zea Mays farms for adult is between 1.87E-06 and 7.56E-04 and for the children is between 1.49E-06 and 6.02E-04 as in figure 13 above. Also, the TR due to Ni in adult is in the range 7.05E-05 – 4.09E-04 and that for the children is within the range of 5.00E-05 and 3.26E-04. Adult consuming Zea Mays from the study farms, the multi-carcinogenic metals TR are in the order of ZEC1 > ZEA1 > ZEB1 > ZEA3 > ZEA2 > ZEB2 > ZEC2 > ZEC3 > ZEB3; for the children in the same farm, the TR are in the order of ZEC1 > ZEA1 > ZEB1 > ZEA3 > ZEA2 > ZEB2 > ZEC2 > ZEC3 > ZEB3. From figure 13, the results shows that Adults from this farm with average of (2.67E-04) were more prone to carcinogenic risk (TR) than children (2.12E-04).

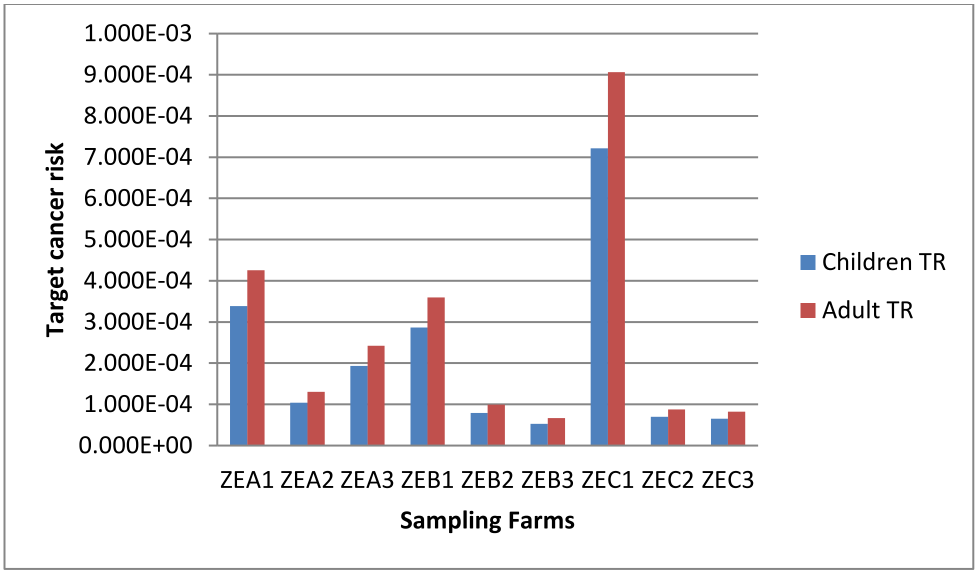

Figure 13: Targeted cancers for both the adult and children from Zea Mays farms

6.0 Total Toxic Metal Pollution Index

In figure 14 above the TTMPI in each sampling locations from the Talinum Fruticosum farms studied, this is used to assess the total metal content in soils and the level of toxic metal pollution found in the soils of the farm of the investigated. Therefore, the trend of the toxic metal pollution (TTMPI) is in the following trend in the Talinum Fruticosum farms studied, and this trend described the ways the vegetable is affected right from the soils TSC1 > TSB1>TSA1> TSA3 > TSC2 >TSB2 >TSA2 >TSB2 >TSC3.

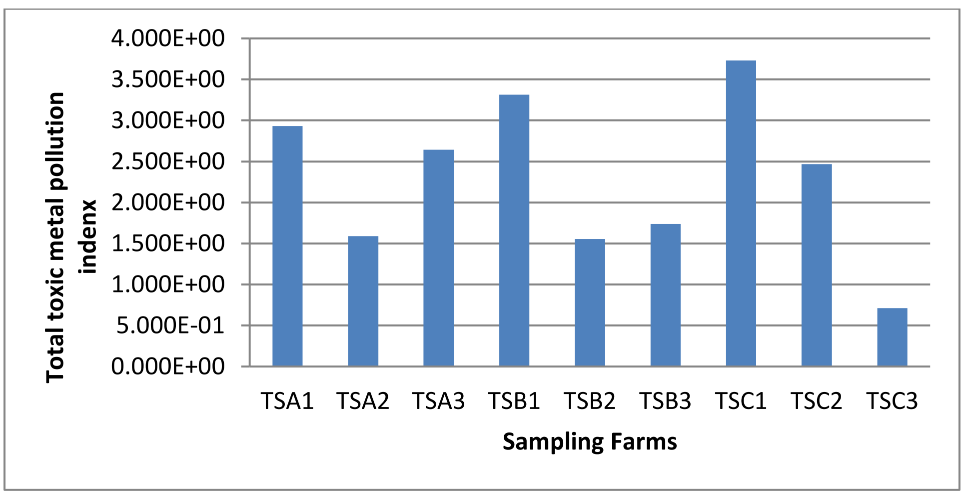

Figure 14: Total toxic metal pollution indexes from Talinum Fruticosum farms

From the Zea Mays farms, the highest TTMPI is found in ZEC1 and the lowest from sampling location ZEB1. Zea Mays sampling location TTMPI is in the following order: ZEC1 > ZEA1 > ZEA3 > ZEA2 > ZEC3 > ZEB1 > ZEB2 > ZEC2 > ZEB3. However, the TTMPI is generally lower in Zea Mays farms when compared with that of the Talinum Fruticosum farms

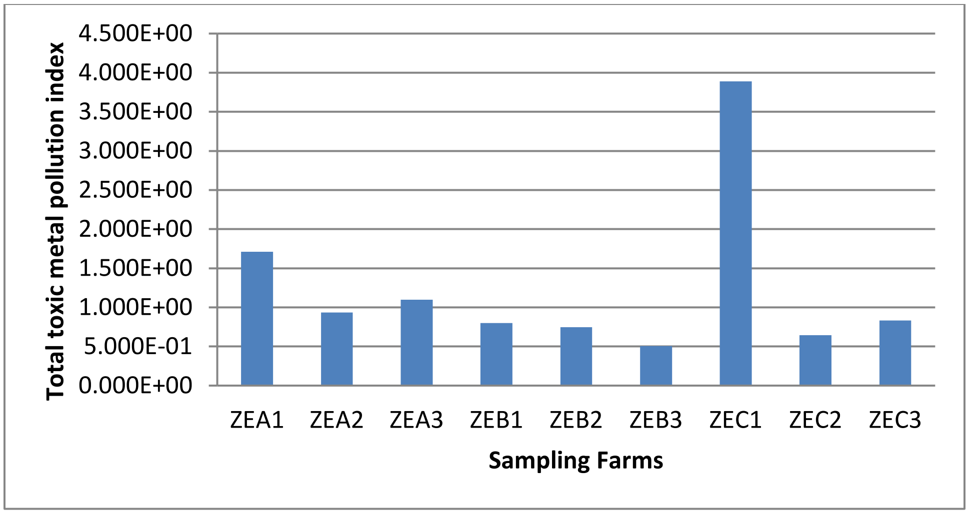

Figure 15: Total toxic metal pollution indexes from Zea Mays farms

7.0 Conclusions

From nine sampling locations from three farms that produces Zea Mays in the eastern direction of a mining site and also from the farms in southern direction that produces Talinum Fruticosum Ni, Pb and Zn have been detected in the samples. The Ni, Pb and Zn detected are in various concentrations in different locations of the farm. The estimated daily intake of detected toxic metals have been obtained from each farms. There is an indication that people consuming Talinum Fruticosum and Zea Mays may be affected in one's lifetime. The health risk index has been evaluated in each farm for both the adults and the children that may be consuming Zea Mays and Talinum Fruticosum. This indicates that both the adults were more prone to carcinogenic risk (TR) than children in consuming Talinum Fruticosum and the children are more prone to health-related problems in Zea Mays than adults.

TTMPI is generally lower in Zea Mays farms when compared with that of the Talinum Fruticosum farms which may be caused by the rate of Zn, Pb and Ni pollutions from the environment. Both the Zea Mays and Talinum Fruticosum consumed from these farms should be consumed with cautions because of the level of the toxic metal pollution in that environment

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