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# Assessment of Natural Radionuclides and Some Toxic Metals in Vegetables Cultivated Around Ibese and Ewekoro Cement Industries in Ogun State, Southwest Nigeria

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**Abstract:** Absorption of natural radionuclides and heavy metals (HM) contents from wastes is a possible way of soil contamination which subsequently adversely affects the plants cultivated in the area and human health when consumed. Therefore, this study aimed to measure NORMs and some toxic metals in five types of vegetable; *Telfairia occidentalis*, *Corchorus olitorius*, *Solanum Lycopersicum*, *Amaranthus hybridus, and*, *Talinum fruticosum* around two cement industries in Ogun state using Sodium Iodide detector and Atomic Absorption Spectrometer. The mean concentrations of radionuclide ($^{226}$Ra, $^{228}$Ra, and $^{40}$K) in the samples were 21.31±2.40, 10.62±2.52 and 220.71±14.32, respectively in *Telfairia occidentalis* and lower in all other samples. The metals analyzed (Pb, Cd, Cu, Ni and Zn) have their average concentrations as 0.08, 0.18, 3.21, 0.45 and 2.15 mg kg$^{-1}$ respectively in *Telfairia occidentalis*; 0.11, 0.07, 4.29, 0.58 and 2.84 mg kg$^{-1}$ in *Corchorus olitorius*; 1.00, 0.18, 4.20, 0.34 and 3.60 mg kg$^{-1}$ in *Solanum Lycopersicum*. The hazard indices obtained were 1.47, 1.69, 2.21, 1.71 and, 1.29, respectively, meaning hazard is probable from consuming the vegetables. The committed doses (0.4 and 0.38 µSv y$^{-1}$) and the cancer risks (0.41 ×10$^{-6}$ in Ibese and 0.37 × 10$^{-6}$) estimated are well below the United Nation Scientific Committee on Energy and Atomic Research.

**Keywords:** Heavy metals, vegetables, absorbed dose, effective dose, radionuclide, transfer factor, cancer risk

## 1. Introduction

Human beings are exposed to natural radioactivity everywhere in the world. Naturally Occurring Radioactive Material (NORMs) is present in considerable amount in every constituent of the environment; food, water, soil, and building materials. The origin of natural radioactivity is from the earth's crust while, the radioactivity in soils depends on the concentration of $^{238}$U and $^{232}$Th series, and the radioactive isotope of $^{40}$K (Turhan, 2008). The level of exposure to radioactivity from NORM in any sample depends on the local geology, geographical locations and chemical composition of the area (UNSCEAR, 2000). The $^{40}$K, $^{226}$Ra and $^{232}$Th are the causes of external exposures,

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while the inhalation of $^{222}$Rn, $^{220}$Rn and their short-lived progeny leads to internal exposure of the respiratory tract due to alpha particles (UNSCEAR, 2000). Cement is produced from some unprocessed materials like limestone, shells, chalk shale, clay, slate, silica sand, and iron ore which are natural and contain many natural radionuclides. Some of the wastes generated from cement industries after processing include dust, fumes, used oil and lubricant, silica, and alumina compounds with other trace elements (Lamas, Palau and Camargo). These waste products must be carefully disposed of to avoid detrimental health implications to public health (Adedokun et al., 2019).

Toxic metals enter the environment through natural and human activities involving agrochemicals, mining, sewage disposal, industrial activities, municipal wastes and automobile exhaust (Oti, 2015). The passage of contaminants into non-contaminated areas through dust or leachate through the soil spread heavy metals into the environment. Excessive accumulation of heavy metals in soils alters the characteristics, disturbs crop production and plants and poses risks to human health (Granero and Domingo, 2002). Toxic metals are a threat to human beings and the food chain because of their ability to amass in different body parts. The bioaccumulation factor of metal in plants is the ratio of metal concentration in plants to the concentration in soil. The factor of which must be less than one (bioaccumulation) or greater than one (hyperaccumulation) (Zakka, Omoniyi and Musa, 2014). Therefore, bioaccumulation of metals in plants is a function of the concentration of metal in the soil and their forms, pH and growth stage (Suruchi and Pankaj, 2011). There are differences in the ability to accumulate, transfer and uptake heavy metals by plant species. According to (Souri, Hatamian and Tesfamariam, 2019), seedlings generally have a higher uptake rate than mature plants, and the roots have the highest concentration of heavy metals than other plant tissues due to their direct contact with heavy metals in the soil.

Several published studies are available locally and internationally on the assessment of radioactivity in vegetables and food crops. From Iraq, research on vegetables and fruits in Najaf Governate, Iraq (Abojassim, Hady and Mohammed, 2016) concluded that the annual doses to adults, children, and infants are below the WHO recommendation limit (WHO, 2007). A study on radioactivity in vegetables was carried out in 30 bunches of leafy vegetables in the Manyoni district, Tanzania (Nyada and Nkuba, 2017). The study recorded a high concentration of radionuclides values than UNSCEAR recommendation (UNSCEAR, 2008). In Lagos State, Nigeria, a study on leafy vegetables cultivated through surface water irrigation recorded mean activities concentration of $^{226}$Ra and $^{232}$Th that were 40 and 56 times higher than the WHO recommendation (Adedokun et al., 2019).

Also, there are some published studies on the potential toxicity of metals in vegetables and food; a field study on the relationship between toxic metals and growth in some leafy vegetables in Bangladesh was reported and concluded that heavy metal was highest at the earlier stage and decreased in the later stages (Naser, Sultana and Nashir, 2011). In Uganda, the risk of consuming some organ meats in Kampala City was conducted, and a high hazard index >1 was recorded for Lead (Pb) in all the samples (Ogwok et al., 2014). Therefore, organs meats are contaminated with Pb and dangerous for human health. In Kano, Nigeria, a study of heavy metals in vegetables grown around Sharada, Kwakwachi, and Jakara concluded that metals were within the NAFDAC's permissible limit (Lawal and Audu, 2011). Doherty et al., 2012 investigated heavy metals concentration in vegetables selected from farms and market in Lagos State, Nigeria. The study revealed that heavy metals were detected in a low concentration below the World Health Organization (WHO) and Food and Agriculture Organization (FAO) safe limit (FAO/WHO, 2014). A study in Rivers and Enugu state on heavy metals levels in some vegetables cultivated in crude oil and non-crude-oil areas recorded higher concentrations much above the acceptable limits (Okonkwo et al, 2018).

Cultivation of vegetables is a common practice around Ibese and Ewekoro cement factories in Ogun State, Nigeria. Residents cultivate food crops (vegetables) around open spaces in the cement areas and irrigate their farms with wastewater (discharges) from the industries. Absorption of natural radionuclides and heavy metals from this disposed waste, sludge, and dust is a possible way of contamination of the soil, which may adversely affect the quality and safety of the food produced (Adedokun et al., 2019). When these vegetables are ingested or consumed by humans or animals, they may cause serious health issues. Therefore, research is needed to determine the health risk resulting from consuming these vegetables so that humans and animals will not be adversely affected. This study, therefore, aimed at measurement of the naturally occurring radionuclides and some toxic metals in some vegetable samples cultivated around Dangote Cement factory, Ibese, and Elephant Cement, Ewekoro areas, South-Western Nigeria to estimate the risk from the consumption of the vegetables

## 2. Methodology

### 2.1 Sampling Area

Ibese and Ewekoro are hosts to two big cement factories in Ogun State, Nigeria. Ewekoro hosts Elephant cement, and Ibese hosts Dangote cement plants. The study area lies between 3.02 to 3.33°E and from 6.76°N to 7.02° N. Fig. 1 shows the sampling points in the study area.

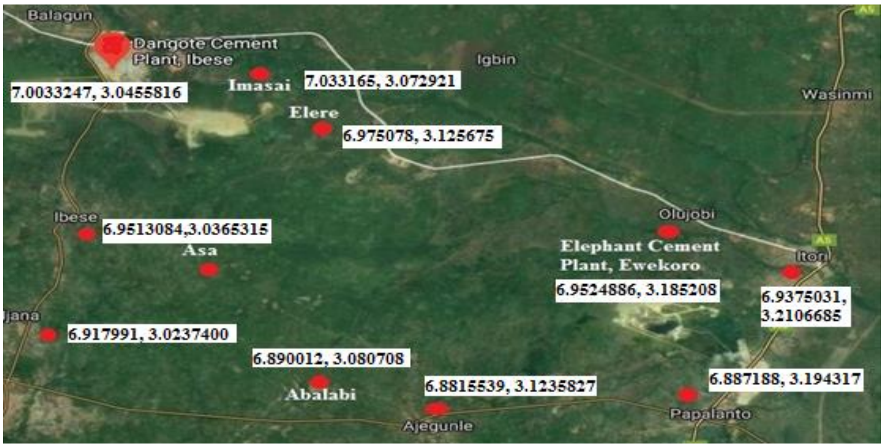


**Fig. 1 - Geological map of Ibese and Ewekoro showing the sampling locations**

### 2.2 Collection of Samples and Preparation

Five types of vegetable (Telfairia occidentalis, Corchorus olitorius, Solanum Lycopersicum, Amaranthus hybridus, and Talinum fruticosum) grown in farmlands around Dangote Cement plants in Ibese and Elephant Cement plants in Ewekoro, Ogun State, were collected. 10 samples of each vegetable were collected from 5 sites in each area. A total of 100 samples were used for this study. At each site, samples were collected at the height of 2 to 5 cm above the ground, packed individually into a polythene bag, labelled to avoid mix-up, and taken to the laboratory.

The samples were cleaned with water to remove any surface deposit, left to dry in the laboratory, dried again at 105°C for 48 hours in an oven to get constant weight. The dried samples were crushed into powder form and sieved. Forty gram of the powdered form of each vegetable was parked into a plastic container, sealed, and left for 4 weeks for the decay rate of the parent nuclides and the production rate of the progenies to be approximately constant (secular equilibrium) (Sathyapriva, Rao and Prabhath 2017).

### 2.3 Measurement of Radionuclides Activity

Determination of activity was performed using the gamma spectrometry method using a highly efficient well-type NaI detector. The detector was connected to a multi-channel analyzer (MCA) manufactured by UNISPEC with the serial number 22060316 and shielded with a cylindrical lead shield of about 10 cm thick. The signal pulse from the MCA was amplified using a pre-amplifier model 2002CSL with serial number 13000742. The detector system was calibrated using the radionuclide specific efficiency method reported by (Kpeglo et al., 2010). The energy calibration was carried out with point sources ($^{60}$Co and $^{137}$Cs) from IAEA. A resolution graph, i.e., the photopeak's energy obtained against the corresponding channel numbers, is drawn and shown in Fig. 2. The energy-channel calibration analysis function was used to fit the graph. With the linear equation stored in the memory of the MCA, it is easy for the MCA to identify the radionuclide in the samples. The resolution of the assembly is ~8% at 0.662 MeV of $^{137}$Cs. The counting time is 36,000 s for better accuracy. The activity in an empty container was counted to obtain background count. The values of the activities (background counts of the three radionuclides) are subtracted from the gross count to obtain the net count used to calculate of the specific activity of the element. The activity of $^{226}Ra$ was determined using $^{214}Bi$ of gamma-ray energy of 1.764 MeV, $^{232}Th$ was determined from the gamma-ray energy of 2.614 MeV from $^{208}Tl$, $^{228}Ra$ was determined from gamma-ray energy of 911.07 keV from $^{228}Ac$, and gamma-ray energy of 1.460 MeV was used to obtain the activity of $^{40}K$. The radionuclide in the sample was identified by using gamma-ray spectrum analysis software, Gene 2K.

The activity concentrations of the radionuclides ($A_{sp}$) in the samples were calculated from the net area using Eq. 1.

$$A_{sp} = \frac{A_{Net}}{\varepsilon P_{\gamma} M_s T_c} \quad (1)$$

where $A_{Net}$ is the net counts under the corresponding peak range, $M$ is the mass of sample (kg), $P_{\gamma}$ is the absolute transition probability of the specific gamma-ray, $T_c$ is the counting time, and $\varepsilon$ is the detector efficiency at the specific ý-ray energy

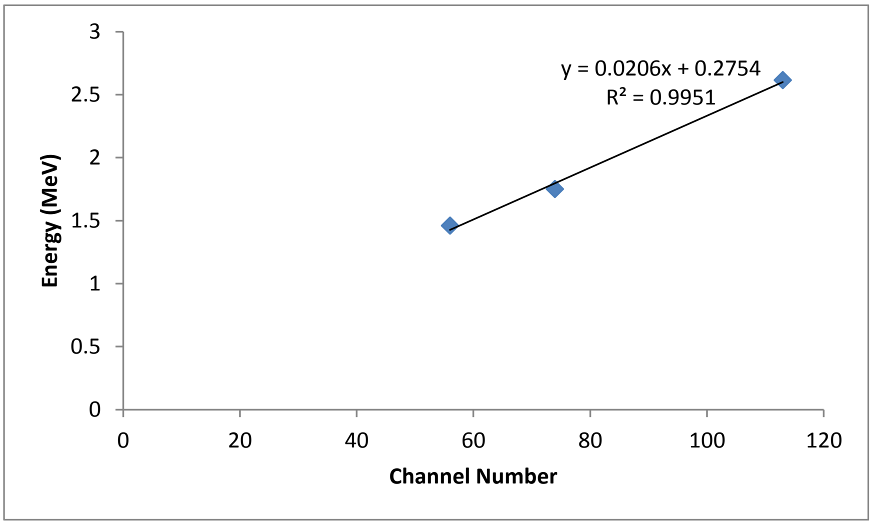


**Fig. 2 - Graph of energy against the channel for the gamma peaks used for calibrating the spectrometer**

## 2.4 Heavy Metal Measurement using Atomic Absorption Spectrometer (AAS)

The method used was the wet digestion method. The Chemicals used for digestion were of higher analytical grades. One gram of each sample was digested in a 100 ml digestion tube and labelled to escape being mix-up. Five (5ml) of Nitric acid ($HNO_3$) and Hydrogen Peroxide ($H_2O_2$) were first added, and sulfuric acid ($H_2SO_4$) added in drops. The mixture was speed stirred and was continued until the solution is clear. The mixture was diluted with deionized water up to 100 ml and filtered. The method was repeated for each sample.

Each element was calibrated using a standard solution. The analyses were performed simultaneously to avoid possible deterioration of standard (Cantle, 1982). The atomic absorption instrument was set up, and flame condition and absorbance were optimized for the analyte. Calibration curves were drawn for concentration against absorbance and fitted in a straight line by the least square method. The lower limit of detection (LLD) for each metal was calculated as triple the standard deviation of measurements for each solution. The least detectable concentration of each metal was 0.001, 0.001, 0.001, 0.001, and 0.002 mg/kg for Pb, Cd, Zn, Cu, and Ni, respectively. The limit of quantification (LOQ) of the element was determined as ten times the standard deviation, and the following were obtained as 0.003, 0.003, 0.003, 0.01, 0.003, and 0.007 mg/kg for Pb, Cd, Zn, Cu, and Ni, respectively. The ranges of concentration for the measurements are 0.05-1.8 mg/kg for Pb, 0.05-0.28 mg/kg for Cd, 2.0-6.0 mg/kg for Cu, 0.25-1.1mg/kg for Ni and 2.40-2.80 mg/kg for Zn. Necessary corrections were made during the calculation of the concentration of the element in part per million (ppm). The concentration of each metal was obtained using Eq. 2.

$$A_S = \frac{S_R \times S_V \times D_F}{S_W} \quad (2)$$

Where As is the sample concentration (ppm), $S_R$ is the AAS reading, $S_V$ is the sample volume, DF is the dissolution factor, and $S_W$ is the sample weight (kg).

# 3. Results and Discussion

## 3.1 Activity Concentration of Radionuclide

The concentration of radionuclides in the vegetables is shown in Table 1. Radium ($^{226}$Ra) ranged 14.8±0.5 to 26.5±4.6, the range of $^{228}$Ra was from 7.00±0.51 to 12.2±1.61 Bqkg$^{-1}$ and from 175.31±8.6 to 240.81±21.62 Bqkg$^{-1}$ for $^{40}$K in Ibese while, in Ewekoro, $^{226}$Ra concentration ranged from 10.21±0.8 to 42.62±3.6, from 5.8±0.8 to 13.10±1.62 Bqkg$^{-1}$ for $^{228}$Ra, and from 80.41±32.61 to 210.66±4.60 Bqkg$^{-1}$ for $^{40}$K. The mean concentrations of the radionuclide were, respectively, 22.37±3.37, 10.31±1.24, and 212.84±42.56 Bqkg$^{-1}$ for $^{226}$Ra, $^{228}$Ra, and $^{40}$K in Ibese and 21.52±4.83, 10.21±2.38, and 169.82±38.67 Bqkg$^{-1}$ in Ewekoro. The values of radionuclide in this study are well below the recommended values and so radiologically safe for consumption.

Comparison of the results with other similar studies showed higher results than results presented in Lagos, Nigeria (Adedokun et al., 2019), where the concentrations recorded were below the world average (UNSCEAR, 2000) but lower than the result from Jos-Plateau, Nigeria (Jibiri, Farai and Alausa 2007a) where a higher result than UNSCEAR recommended limit was recorded.

**Table 1 - Concentration (Bq kg$^{-1}$) of radionuclide in dry weight vegetable samples**

| Study Area | Dangote cement Area, Ibese | | | Ewekoro Cement Area, | | |
|---|---|---|---|---|---|---|
| | $^{226}$Ra | $^{228}$Ra | $^{40}$K | $^{226}$Ra | $^{228}$Ra | $^{40}$K |
| Pumpkin Leaf *(Telfairia occidentalis)* | 21.31±2.40 | 10.62±2.52 | 220.71±14.32 | 38.81±1.51 | 7.00±0.62 | 190.21±2.32 |
| Jute Leaf (*Corchorus olitorius)* | 18.12±0.61 | 8.61±0.83 | 181.52±10.32 | 19.70±2.00 | 10.41±0.83 | 112.00±4.04 |
| Tomatoes *(Solanum Lycopersicum)* | 20.80±4.31 | 10.51±3.21 | 178.20±12.04 | 20.61±1.63 | 12.32±4.11 | 148.12±7.31 |
| African Spinach *(Amaranthus hybridus)* | 25.82±5.12 | 12.00±1.85 | 182.63±15.31 | 17.40±0.81 | 12.61±1.10 | 200.43±2.52 |
| Waterleaf *(Talinum triangulare)* | 25.80±3.83 | 9.81±1.00 | 201.22±18.26 | 11.10±2.22 | 8.74±0.91 | 198.40±6.00 |
| Mean | 22.37±3.37 | 10.31±1.24 | 212.84±42.56 | 21.52±4.83 | 10.21±2.38 | 169.82±38.67 |

## 3.2 Committed Effective dose and Cancer risk

Committed Effective Dose (CED) from the ingestion of vegetables in the study area was calculated to quantify the health risks that may occur from their consumption using Eq. 3 given in (Lawal and Audu, 2011).

$$CED(\mu Sv/y) = \sum (A_i(Bq/kg) \times D_C(mSv/Bq) \times I_p(kgy^{-1})) \quad (3)$$

where $D_C$ is the dose conversion factor for ingestion of radionuclides according to (UNSCAR, 2008), Ip is the consumption rate from the intake of NORMs in vegetables (40kg y$^{-1}$) (Lawal & Audu, 2011). $A_i$ is the concentration of radionuclides in the vegetables. The mean value of CED obtained in the two sites is presented in Table 2. All the values obtained were well below the 0.3mSv recommended by UNSCEAR, (2000).

The probable cancer risk from the consumption of these vegetable samples was estimated using the cancer risk assessment methodology given in Eq. 4 (Adedokun et al., 2019).

$$Cancer\ Risk(CR) = A_{ir}(Bq/kg) \times A_{is} \times MRF \quad (4)$$

where CED (µSvy$^{-1}$) is the committed effective dose, $A_{is}$ is Life Expectancy in Nigeria (WHO, 2020), and MRF is a mortality risk factor for stochastic effects due to the intake of radioactive material according to USEPA (1999). $A_{ir}$ is the annual intake of radionuclide (Bq kg$^{-1}$). The values of the CR obtained are presented in Table 2 (Column 3 and 5). CR ranged from 0.34 to 0.44 ×10$^{-6}$ with a mean of 0.41 × 10$^{-6}$ in Ibese and from 0.20 to 0.56 × 10$^{-6}$ in Ewekoro with a mean of 0.37 ×10$^{-6}$. All the values obtained are within the World Health Organization limit of 1.0 × 10$^{-6}$ (WHO, 2007).

**Table 2 - Committed Effective dose ($\mu Svy^{-1}$) and cancer risk from consumption of the vegetable**

| Study Area | Dangote cement Area | | Ewekoro Cement Area | |
|---|---|---|---|---|
| Samples | Effective dose (μSv) | Cancer risk × $10^{-6}$ | Effective dose (μSv) | Cancer risk × $10^{-6}$ |
| Pumpkin Leaf *(Telfairia occidentalis)* | 0.39 | 0.41 | 0.55 | 0.56 |
| Jute Leaf (*Corchorus olitorius)* | 0.33 | 0.34 | 0.34 | 0.32 |
| Tomatoes *(Solanum Lycopersicum)* | 0.37 | 0.37 | 0.38 | 0.36 |
| African Spinach *(Amaranthus hybridus)* | 0.45 | 0.43 | 0.36 | 0.36 |
| Waterleaf *(Talinum triangulare)* | 0.43 | 0.44 | 0.25 | 0.28 |
| Mean | 0.40 | 0.41 | 0.38 | 0.37 |

## 3.3 Heavy Metal and Risk Calculations

The concentration of heavy metals in the samples is presented in Table 3. The concentration of Pb in Pumpkin was obtained as 0.08 in Ibese and 0.18 mg $kg^{-1}$ in Ewekoro. The level of Pb in the vegetables was found to be lower than the recommended limit of FAO/WHO in pumpkin leaves (FAO/WHO, 2014). The concentration of Cd was also slightly higher than the recommended value in pumpkin leaves. All other metals concentrations fall within the recommended limit (ATSDR, 2004; IARC, 2012). In Jute leaves, Pb and Cd concentrations fall within the recommended limit in all the samples; but Ni was slightly higher than 0.5 $mgkg^{-1}$ limits set by International Agency for Research on Cancer (IARC, 2012). The concentrations of Cu and Zn fall within the recommended limit in all the locations, but higher concentrations of Cd were observed. All other metals were within the recommended limits of ATSDR and IARC (ATSDR, 2004, IARC, 2012).

In African Spinach (*Amaranthus hybridus*), the concentrations of Pb and Cd in vegetables from Ibese and Ewekoro were found to be higher than the recommended limit. The mean concentration of Pb was about 350% higher in Ibese and 300% higher in Ewekoro than the recommended limit of FAO/WHO (FAO/WHO, 2014). The concentration of Cd in African spinach in both areas was about 50% higher. The mean concentration of Ni was also about 50% higher than the permissible limit in both sites. The highest mean concentration of Cu was 3.26 $mgkg^{-1}$ from Ewekoro.

In waterleaf (*Talinum triangulare*), concentrations of Pb and Cd are higher than the limit in all the vegetables in the study area. Nickel concentration was also slightly higher than the limit in all sampling points. Lead (Pb) concentration was higher than the permissible limit in Tomatoes, African Spinach, and Waterleaf samples from the two areas. The level of Zn and Cu obtained in this study is not hazardous and lower than the ATSDR recommendation intake. Nickel is found naturally in food and water but its concentration increases by pollution (ATSDR, 2004). Copper is essential to human life and animals at a low level. Its concentration is higher than the IARC permissible limit of 0.5mg $kg^{-1}$ (IARC, 2012) in all the vegetable samples from the two sites except for Jute leaf samples from Ibese. Nickel concentration obtained in this study is not up to 10mg that may cause lung cancer (ATSDR, 2004). The high values of some metals obtained in this area are due to air and water pollution, sewage sludges, and industrial wastes that may change the soils' background radioactivity and chemical composition. When these wastes are absorbed may damage the ecosystem on which vegetables are planted (IARC, 2012).

**Table 3 - Concentration of heavy metals in the vegetable samples ($mgkg^{-1}$)**

| Study Area | Dangote Cement Ibese | | | | | Elephant Cement Ewekoro | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample | Pb | Cd | Cu | Ni | Zn | Pb | Cd | Cu | Ni | Zn |
| Pumpkin Leaf *(Telfairia occidentalis)* | 0.08± 0.00 | 0.18± 0.00 | 3.21 ±0.24 | 0.45± 0.07 | 2.5± 0.16 | 0.18± 0.00 | 0.21± 0.01 | 3.07± 0.14 | 0.33± 0.04 | 1.41± 0.01 |
| Jute Leaf (*Corchorus olitorius)* | 0.11± 0.16 | 0.07± 0.00 | 4.29 ±0.42 | 0.58± 0.11 | 2.84± 0.17 | 0.16± 0.00 | 0.15± 0.00 | 4.47± 0.37 | 0.74± 0.12 | 3.28± 0.16 |
| Tomatoes *(Solanum lycopersicum)* | 1.00± 0.15 | 0.18± 0.00 | 4.20 ±0.51 | 0.34± 0.10 | 3.6± 0.11 | 0.81± 0.01 | 0.25± 0.12 | 3.28± 0.15 | 0.41± 0.12 | 2.19± 0.11 |
| African Spinach *(Amaranthus hybdridus)* | 1.40± 0.12 | 0.17± 0.00 | 2.41 ±0.18 | 0.71± 0.13 | 2.48± 0.10 | 1.2± 0.12 | 0.15± 0.00 | 3.26± 0.20 | 0.89± 0.18 | 1.13± 0.01 |
| Water leaf *(Talinum triangulare)* | 0.78± 0.09 | 0.15± 0.00 | 2.80 ±0.12 | 0.60± 0.01 | 2.63± 0.10 | 0.41± 0.01 | 0.11± 0.00 | 2.42± 0.11 | 0.52± 0.12 | 2.26± 0.18 |

## 3.5 Risk from Intake of Heavy Metal from the Vegetable Samples

The health risk is given by US EPA (USEPA, 2011) as Hazard Quotient (HQ) and shown in Eq. 5.

$$HQ = \frac{D_I \times C_M}{R_f D \times B_W} \quad (5)$$

where $D_I$ is the average intake of metal in the samples, (Cm) is the concentration of metals, RfD; the oral reference dose for each metal and Bw is the world adult mean weight (kg). The values of RfD are: for Cd (0.001), Ni (0.02) (USEPA, 2011). The value for Pb (0.0035), Zn (0.3) and Cu (0.004) is taken from (USEPA, 2006). The average Bodyweight for adults is taken as 70 kg (WHO, 2019).

The result of HQ for individual metals in the vegetable samples is as shown in Table 4. HQ for Cu is higher than 1 in Pumpkin leaf, Jute leaf, Tomatoes, and waterleaf from Ibese and also higher than 1 in all the vegetable samples from Ewekoro except in waterleaf. All other metals have their HQ lower than 1, as recommended by US EPA (USEPA, 2011). Therefore, all the vegetables from Ibese and Ewekoro were observed to be contaminated with Cu.

The potential risk from all the in the vegetables (HI) was estimated using Eq. 6 given USEPA, (2011)

$$HI = \sum HQ_{Pb} + HQ_{Cd} + HQ_{Cu} + HQ_{Ni} + HQ_{Zn} \quad (6)$$

The Hazard Indices (HI) in this study were found to be higher than 1, meaning that there is a probable hazard from their consumptions. According to USEPA, If HI is <1, it means there is no hazard; if HI is 1.1 – 3, it means there is a probable hazard from consumption of the plants. If HI is 3-10, it is likely to cause fatal risk.

**Table 4 - Hazard Quotient (HQ) and Hazard Index (HI) in the samples**

| Study Area | Ota Industrial Area | | | | | | Agbara Industrial Area | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | Pb | Cd | Cu | Ni | Zn | ∑HQ = HI | Pb | Cd | Cu | Ni | Zn | ∑HQ = HI |
| Pumpkin Leaf *(Telfairia occidentalis)* | 0.03 | 0.25 | 1.14 | 0.03 | 0.01 | 1.47 | 0.07 | 0.30 | 1.10 | 0.02 | 0.01 | 1.50 |
| Jute Leaf (*Corchorus olitorius)* | 0.01 | 0.1 | 1.53 | 0.04 | 0.01 | 1.69 | 0.01 | 0.21 | 1.60 | 0.03 | 0.02 | 1.86 |
| Tomatoes *(Solanum lycopersicum)* | 0.41 | 0.26 | 1.5 | 0.02 | 0.02 | 2.21 | 0.33 | 0.36 | 1.17 | 0.03 | 0.01 | 1.9 |
| African Spinach *(Amaranthus hybdridus)* | 0.57 | 0.24 | 0.86 | 0.02 | 0.01 | 1.71 | 0.49 | 0.21 | 1.16 | 0.03 | 0.01 | 1.9 |
| Water leaf *(Talinum triangulare)* | 0.03 | 0.21 | 1.00 | 0.04 | 0.01 | 1.29 | 0.02 | 0.15 | 0.86 | 0.04 | 0.01 | 1.08 |

## 4. Conclusion

The measurements of $^{226}$Ra, $^{228}$Ra, and $^{40}$K in five vegetable species (Telfairia occidentalis, Corchorus olitorius, Solanum Lycopersicum, Amaranthus hybridus, and Talinum fruticosum) commonly cultivated around cement industries; Ewekoro and Ibese in Ogun State, Nigeria, were carried out using spectrometry analysis consisting of NaI(Tl) detector. The concentration of $^{226}$Ra measured ranged from 14.8±0.5 to 26.5±4.6, with a mean of 22.37±3.37. The range of $^{228}$Ra is from 7.00±0.51 to 12.2±1.61 with a mean of 10.31±1.24, and for $^{40}$K, the range is from 175.31±8.6 to 240.81±21.62 Bqkg$^{-1}$ with a mean of 212.84±42.56 Bqkg$^{-1}$ in the Ibese area, while in Ewekoro, the concentration of $^{226}$Ra ranged from 10.21±0.8 to 42.62±3.6 with a mean of 21.52±4.83; from 5.8±0.8 to 13.10±1.62 Bqkg$^{-1}$ with a mean of 10.21±2.38 for $^{228}$Ra, and from 80.41±32.61 to 210.66±4.60 with a mean of 169.82±38.67 Bqkg$^{-1}$ for $^{40}$K. The committed doses (CED) were 0.4 and 0.38 μSv y$^{-1}$, respectively. The cancer risk estimated was 0.41 × 10$^{-6}$ in Ibese and 0.37 × 10$^{-6}$ in Ewekoro. All these values are lower than the WHO and UNSCEAR recommendation. So radiologically, the vegetables are safe for consumption. Some toxic metals (Pb, Cd, Cu, Ni, and Zn) in the vegetables were undertaken. Their concentrations in the samples were 0.08, 0.18, 3.21, 0.45 and 2.15 mg kg$^{-1}$, in pumpkin leaves; 0.11, 0.07, 4.29, 0.58 and 2.84 mg kg$^{-1}$ in Jute leaf; 1.00, 0.18, 4.20, 0.34 and 3.60 mg kg$^{-1}$ in tomatoes; 1.40, 0.17, 2.41, 0.71 and 2.48 mg kg$^{-1}$ in African spinach and 0.78, 0.25, 2.80, 0.60 and 2.63 mg kg$^{-1}$ in waterleaf samples from Ibese while in Ewekoro, their concentrations were 0.18, 0.20, 3.07, 0.33 and 1.41 mg kg$^{-1}$ in pumpkin leaves; 0.16, 0.15, 4.47, 0.74 and 3.28 mg kg$^{-1}$ in Jute leaf; 0.18, 0.25, 3.28, 0.41 and 2.19 mg kg$^{-1}$ in tomatoes; 1.20, 0.15, 3.26, 0.89 and 1.13 mg kg$^{-1}$ in African spinach and 0.41, 0.11, 2.42, 0.52 and 2.26 mg kg$^{-1}$ in waterleaf samples. The concentrations of Pb and Cd in Tomatoes, African Spinach, and waterleaf are above the WHO permissible limit. The hazard indices (HI) were 1.47, 1.69, 2.21, 1.71, and 1.29 in Ibese and 1.50, 1.86. 1.9, 1.9, and 1.08 in Ewekoro for pumpkin leaves, jute leaf, tomatoes, African spinach, and waterleaf, respectively. These values are higher than unity which means that there is a probable hazard in consuming the vegetables.

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