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# Evaluation and Risk Assessment of Selected Heavy Metals and Essential Elementsin Crude Palm Oils from Oil Mills in South-West and South-South Nigeria

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***Abstract***
*Crude palm oil (product of Elaeis guineensis Jacq Arecaceae) is a staple food in Nigeria and the whole world, being consumed for its nutritive values. This study aims to evaluate the levels of some heavy metals and essential elements in crude palm oil from fifty (50) sampling sites located along the roads in South-West and South-South Nigeria, cutting across five States (Oyo, Osun, Ondo, Bayelsa and Rivers States). The samples were digested using mixture of acids ($HNO_3$: $HClO_4$: $H_2$ $SO_4$ in ratio1:1:1) and analyzed usingFlame Atomic Absorption Spectrometer (GBC Avanta PM A6600. The mean concentrations obtained in mg/L were in the ranges: Ca (23.19-47.41), Mg (5.15-8.28), Na (6.39-13.72), K (15.65-34.96), Fe (34.49-56.14), Mn (0.47-1.98), Ni (0.33-0.65), Cr (0.16-0.31), Pb (<0.001-0.02), Cd (<0.001-0.03), Cu (0.33-1.28), As (<0.001), Zn (3.53-10.09) and Al (1.18-3.12). The estimated dietary intake (EDI) in (µg/kg bw/day) ranges were: Ca (2.443-4.996) Mg (0.543-0.770), Na (0.674-1.446), K (1.648-3.664), Fe (3.635-5.916), Mn ($4.10E^{-2}$-0.209), Ni ($3.30E^{-2}$ - $6.80E^{-2}$), Cr ($1.60E^{-2}$-$6.70E^{-2}$), Pb ($1.10E^{-4}$-$3.99\ E^{-4}$), Cd ($1.10E^{-4}$ - $8.88\ E^{-4}$), Cu ($3.41E^{-2}$ -0.134), As ($9.02E^{-5}$ - $1.10E^{-4}$), Zn ($3.63E^{-1}$-1.062) and Al ($3.00E^{-4}$-0.329).The estimated target hazard quotient (THQ) and the total health risk index (HRI) values indicated no lifelonghealth concern of metals associated with the consumptionof these locally produced crude palm oil samples since the THQ and HRI are less than one (<1).The results revealed differences between the South-Western States (Oyo, Osun and Ondo) and the South-South States (Rivers and Bayelsa) in the levels of Ca, K and Pb,while there was no significant difference in Fe, Cr, Cu, Cd, As for all the States. This can be ascribed to the different methods of palm oil production in the various States. The levels of the parameters determined show that the crude palm oil would contribute to dietary intakes of macro(Ca, Mg, Na, K,) and micro (Fe, Mn, Ni, Cr, Cu, Zn) essential elements, while the levels of heavy metals(Pb, Cd, Al and As) were low in comparison with WHO limits, and therefore safe for consumption.*

***Keywords:*** *Crude Palm Oil, Essential Elements, EstimatedDaily Intake,Target HazardQuotient, Health Risk Index,*

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## I. Introduction

Palm oil is produced from the oil palm fruit (*Elaesis guineensis* Jacq Arecaceae). It requires climatic conditions of between 1800 to 5000 mm of rainfall per year, temperature range of 17-28 °C and relative humidity above 75% to flourish (Poku, 2002). The oil palm is propagated by seedling and requires nursery period of 9-12 months before it is planted. Its fruiting begins from between 3-5 years and reaches optimal yield at 10 years after cultivation. It is an economic tree that has a life span of about 200 years, but its economic life is usually between 20 to 30 years (Matthew, 2009). It forms a vital crop in Southeast Asia, West Africa and South America especially due to its nutritional and healing properties (Edem,2002).

Major players in palm oil production in the world are Indonesia, Malaysia, Colombia, Thailand and Nigeria. Meanwhile, Nigerian oil palm belt covers twenty-four States of South-western, South-South, South-Eastern States, where palm trees are found both in the wild and in plantations and about 80% of the oil palm industry dominated by small holders who are in major agro-based enterprise, using rudimentary and semi-mechanized equipment for processing (Nwaugo *et al.*, 2008, Ohimain and Izah., 2013).

Palm oil processing is carried out using large quantities of water in mills where crude or virgin oil is extracted from the palm fruits and is widely used in African cooking. The refined edible palm oil is utilized in food, pharmaceutical, cosmetics and other industrial processing activities (Adepoju Bello *et al.*, 2012) which brought the domestic consumption of palm oil in Nigeria in 2016/2017 and 2017/2018 to about 1.34 and 1.40 million metric tons respectively (Statista, 2018).

Crude palm oil or Vegetable oils may be contaminated by heavy metals through migration from arable soil (use of fertilizer, location of plantation and processing palm oil mills along highways), technological/ production processes, packaging and storage (Adepoju-Bello *et al.*, 2012; Szyczewski, 2016; Izah and Ohimain, 2016). These metals can equally enter the human body via food. Living organisms however, require varying amounts of these metals. Iron, cobalt, copper, manganese, molybdenum, manganese, chromium, and zinc, but in small amounts to perform some biological activities. Humans are also responsible for altering the chemical forms of heavy metals released to the environment and such alterations often affect a heavy metal's toxicity by allowing it to bio-accumulate in plants and animals, bio-concentrate in the food chain, or attack specific organs of the body. Some heavy metals such as mercury and lead are toxic metals that have no known vital or beneficial effect on organisms, and their accumulation over time in the bodies of animals can cause serious illnesses (Strömgren, 1998) hence the necessity to evaluate the concentration of the heavy metals and other essential elements, estimate dietary intake and risk assessment of some selected elements in crude palm oil obtained from local mills located along the traffic route in the southern Nigeria.

## II. Materials And Methods

### 2.1 Sampling and Sampling Locations

Crude palm oil samples were collected in amber glass bottles neatly washed and oven dried from local palm oil mills located along the roads from Ogbomosho-Ilajue (Oyo State), Ifon-Orolu-Osogbo- Sekona-Ile-Ife-Ondo road (Osun State), Oke Ogbomosho-Ondo-Ore junction-Akinjagunla on East-West road (Ondo State), Amassoma-Yenagoa- Azikoro- Otuokpoti- Onuebum-Otuoke-Emeyal- Elebele road (Bayelsa State) and Okubie-Ahoada-Elele-Alimini on East-West road (Rivers State) South-West and South-South, Nigeria.The samples were collected from November 2018 to January 2019. Ten (10) samples were collected from each Statemaking a total of 50 samples in all.The sampling sites in the various States are as illustrated in Figure 1.

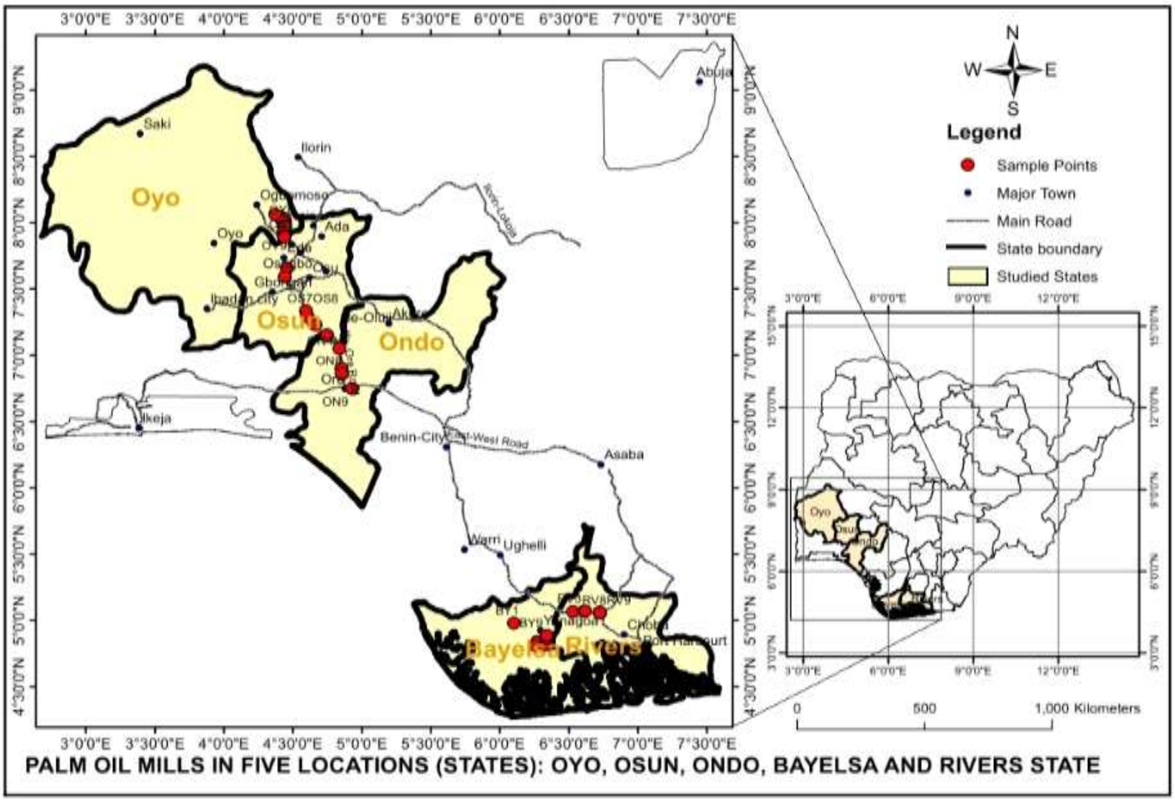


**Figure1: Map of Study Area showing Sampling Sites**

### 2.2Elemental Analysisof Crude Palm OilSamples

Samples were carefully handled to avoid contamination.Glassware and samplecontainers used were soaked in1 M $HNO_3$ for 48 h and rinsed with distilled water.Allreagents used were of analytical grade:70%perchloric acid ($HClO_4$),98% sulphuric acid($H_2SO_4$); 69%nitric acid ($HNO_3$) supplied by BDH Laboratory Supplies, Poole, England.Working standards of Cd, Pb, Ni, Cr, Cu, Al, Fe, Mn, As, Zn, Ca, Mg, K,and Na were prepared by diluting concentrated stocksolution (BDH Laboratory Supplies, Poole, England) of

1000 mg/Lwith 0.25 mol/L nitric acid.

All crude palm oil samples were analyzed for metal after digestion with mixed acid as described in AOAC (2005) and Nnorom *et al.*(2014). A 5.0 g portion of each sample was carefully weighed into a 250ml conical flask and 10 ml of the mixed acid (0.5N nitric acid, 1N perchloric acid and 1M sulphuric acid in volume ratio 2:1:2) respectively. The digestion was carried outin a fume hood on electrically operated hot plate at a temperature of 250ºC for two and half hoursto obtain a completely digested clear solution. The mixturewas cooled to room temperature, made up to 50 ml with distilled water, agitated in a shaker and transferred to a set of centrifuge tubes, then centrifuged for five minutes at 5000 rev/min using a centrifuge (TDL-4 B. Bran Scientific and instrument company, England). The digested sample was then decanted and subjected to elemental analysis. The procedure of acid digestion was repeated but without the palm oilto serve as blank. The elements determined were: Ca, Mg, Na, K, Fe, Mn, Ni, Cr, Pb, Cd, Cu, As, Zn, and Al using flame atomic absorptionspectrophotometer (FAAS: GBC Avanta PM A6600) following standard procedures.

## III. Results And Discussion

The results obtained from the elemental analysis are as presented in Figure 3.1

Table 3.1: Concentration of metals in (mg/L)analyzed in Crude Palm Oil from South-West and South-South State, Nigeria

| Element | | Oyo | Osun | Ondo | Bayelsa | Rivers |
|---|---|---|---|---|---|---|
| Ca | Mean±SD | 44.10±12.55 | 41.03± 13.70 | 47.41± 20.34 | 23.19± 7.78 | 25.75±11.09 |
| | Ranges | 28.36 to63.36 | 20.19to60.41 | 23.74to81.12 | 12.6to34.36 | 11.46 to 46.93 |
| Mg | Mean±SD | 5.48±3.66 | 7.08±11.70 | 8.28±5.35 | 5.145± 2.37 | 7.31±14.45 |
| | Ranges | 1.89 to12.32 | 2.15 to12.32 | 2.80 to 21.38 | 2.26to10.12 | 2.35 to12.6 |
| Na | Mean±SD | 8.20±4.85 | 8.137±3.21 | 13.72±8.36 | 6.39±4.73 | 7.65± 3.29 |
| | Ranges | 2.36 to 19.09 | 4.24to12.88 | 4.58 to 32.80 | 0.88 to 13.83 | 4.32 to13.21 |
| K | Mean±SD | 34.75± 10.49 | 34.96± 10.54 | 28.32±11.30 | 17.55± 8.56 | 15.65±5.87 |
| | Ranges | 18.53to53.88 | 20.53to50.42 | 10.36to50.21 | 5.29 to 35.83 | 6.86 to24.95 |
| Fe | Mean±SD | 53.19± 16.81 | 56.14± 22.28 | 41.09± 20.04 | 37.05± 18.37 | 34.49±15.69 |
| | Ranges | 27.61to80.00 | 25.57to83.94 | 15.30to72.60 | 18.54to75.33 | 12.48 to 66.71 |
| Mn | Mean±SD | 0.47± 0.32 | 0.80± 0.25 | 1.98 ± 1.33 | 0.38± 0.22 | 0.82±0.72 |
| | Ranges | 0.14 to1.04 | 0.42 to1.13 | 0.13 to 4.18 | 0.09 to 0.77 | 0.09 to2.48 |
| Ni | Mean±SD | 0.35±0.17 | 0.33± 0.18 | 0.65 ±0.42 | 0.41± 0.16 | 0.54±0.22 |
| | Ranges | 0.10 to 0.61 | 0.08 to0.63 | 0.10 to1.36 | 0.21 to 0.72 | 0.25 to1.02 |
| Cr | Mean±SD | 0.31±0.13 | 0.30±0.16 | 0.25± 0.15 | 0.16 ± 0.09 | 0.27±0.15 |
| | Ranges | 0.10 to0.51 | 0.09 to 0.57 | 0.07 to0.54 | 0.07 to 0.35 | 0.05 to0.51 |
| Pb | Mean±SD | 0.001±2.3E-19 | 0.001±2.3E-19 | 0.01±0.020 | 0.02±0.023 | 0.004±0.01 |
| | Ranges | 0.001to0.001 | 0.001to0.001 | 0.001 to 0.06 | 0.001 to 0.06 | 0.001 to 0.03 |
| Cd | Mean±SD | 0.001±2.3E-19 | 0.001±2.3E-19 | 0.009±0.02 | 0.03±0.07 | 0.001±2.3E-19 |
| | Ranges | 0.001to0.001 | 0.001to0.001 | 0.001 to 0.05 | 0.001 to 0.22 | 0.001to0.001 |
| Cu | Mean±SD | 0.79±0.99 | 0.33± 0.23 | 0.61±0.32 | 1.28± 2.18 | 0.77±0.30 |
| | Ranges | 0.12 to 2.93 | 0.01 to0.72 | 0.18 to 1.25 | 0.13 to7.39 | 0.26 to1.42 |
| As | Mean±SD | 0.001±2.3E-19 | 0.001±2.3E-19 | 0.001±2.3E-19 | 0.001±2.3E-19 | 0.001±2.3E-19 |
| | Ranges | 0.00 to0.001 | 0.001to0.001 | 0.001to0.001 | 0.001to0.001 | 0.001 to 0.001 |
| Zn | Mean±SD | 3.53±1.73 | 5.19 ± 3.13 | 6.94±3.08 | 4.99± 2.38 | 10.09±3.50 |
| | Ranges | 0.94 to 6.25 | 0.76 to 10.21 | 2.65 to 11.83 | 2.76 to9.40 | 4.22 to15.81 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Al | Mean±SD | 2.85±1.85 | 3.12± 1.64 | 2.79±2.23 | 1.18±1.33 | 2.02±1.34 |
| | Ranges | 0.49 to6.12 | 1.31 to6.34 | 0.33 to 6.23 | 0.19 to4.45 | 0.45 to4.51 |

Results are presented as Mean ±SD, Sample number (N=10)

The Na concentration rangedfrom 0.88 to 32.80 mg/kg. The highest mean sodium concentration of 13.72±8.36 mg/kg wasfound in Ondo samples, while the lowest concentration of 6.39±4.73 mg/kg wasfound inBayelsa samples.The obtained result was very low compared to (115 to 533 mg/kg)reported by Nnorom *et al.*(2014). Sodium is necessary to maintain balance in physical fluid systemsand is also required for the operation of nerves and muscles, but high-sodium diets arelinked to a number of health problems including damage of the kidneys and increase in blood pressure which mightcause hypertension (Mir-Marqués *et al.*, 2012). There are no dangers of excess intake of Na as theconsumption of 5-10g/day of palm oil will expose a consumer to less than 6 mgNa/day.

Potassium content of crude palm oil samples from the five-state ranged from 5.29 to 53.88mg/kg and the mean values varies from15.65±5.87 mg/kg (Rivers State samples) to 34.96± 10.54 mg/kg (Osun State samples) as the lowest and the highest values respectively(Figure 3.1). Potassium has been known to play an important role for disease prevention and control; it is an essential electrolyte formaintaining normal fluid balance in cells and a delicate balance of this element is reported toprevent an increase in blood pressure and maintain normal cardiac rhythm (Desideri *et al.*, 2012).

The mean magnesium concentration ranged from 5.145± 2.37 mg/kg for Bayelsa samples to 8.28±5.35 mg/kg for Ondo samples as the lowest and the highest values. The overall concentration ranged from1.89-12.32 mg/kg). Magnesium play a vital role in the skeleton formation and its function in muscles and soft tissues, such as a co-factor of many enzymes involved in energymetabolism, protein synthesis, RNA and DNA synthesis, and maintenance of the electricalpotential of nerve tissues and cell membranes (Mir-Marqués *et al.*, 2012). However, it should be noted thatmagnesium dietary deficiency, which is sufficient to induce pathologic changes, is rare (FAO/WHO, 2002).

The results showed that Calcium concentrationrange varies from 11.09-81.12 mg/kg across the five States, but Bayelsa samples had the lowest mean concentration of 23.19± 7.78 mg/kg and Ondo samples had 47.41± 20.34 mg/kg as the highest value. Calcium, amongst the macro elements determined showedthe highest overall mean concentration (47.41± 20.34 mg/kg).It ranged from23.74 to 81.12) mg/Kg followed by Na(13.72±8.36 mg/kg), K (34.96± 10.54 mg/kg) and then Mg (8.28±5.35 mg/kg) (Table 3.1). Calcium plays a vital role in neuromuscular function, many enzyme-mediated processes, blood clotting,and providing rigidity to the skeleton via phosphate salts (Mir-Marqués*et al.*, 2012).

The results of this research have shown that crude palm oil contains lead ranged from (0.001 to 0.06 mg/kg) with the mean concentration of varies from 0.001±2.3E-19 1n both Oyo and Osun sample while Ondo samples, Bayelsa samples and Rivers samples had 0.01±0.02 mg/kg, 0.02±0.023 mg/kg and 0.004±0.01 mg/kg respectively while obtained result for Arsenic was below detection limit (0.001±2.3E-19) for all the fifty samples sites from the five States.Cypriano *et al.* (2008)reported (ND-1.82±0.01 μg/g (mg/kg) and ND-1.90±0.03 mg/kg) for Pb concentrations which were higher than (overall mean, 0.02±0.023; ranged,<0.001 to 0.06 mg/kg) result obtained from this study. Adepoju-Bello *et al.*(2012) and Nnorom *et al.*(2014)reporteda Pbconcentration of (0.0225-0.038mg/kg and 0.024-0.067 mg/kg) respectively, in palm oil bought from several markets in Lagos,Nigeria and in palm oil from South-Eastern, Nigeria, thus, this result compares well with the results of this study. Lead accumulates andsubstitute's calcium inbone tissues and the resultant effect is disruption of mineralization,alteration of compositionalproperties and bone formation mechanisms, as well as thegradual depletion of bone minerals (Medeiros., 2004; Gangoso., 2009). The Codex Standard for Named Vegetable Oils(210-1999) refers to lead and arsenic and the Codex Standard for Contaminants and Toxinsin Food and Feed (193/1995, amended 2010) gives maximum levels of lead and arsenic of0.1 mg/kg in crude and edible oils of palm and palm kernel including palmolein, stearin andsuperolein (FAO., 2002). Similarly, the EU limit for Pb contamination of fats and oils including milk fatis 0.10mg/kg (EU.,2001).

The overall mean Cd concentration in the crude palm oil samples studied was 0.064±0.020 mg/kg(data ranging from (0.001 to 0.06 mg/kg) with mean values for the various sites varying from 0.001±2.3E-19 mg/kg (Oyo,Osun and Rivers) to 0.009±0.02 mg/kg and0.03±0.07mg/kg for (Ondo and Bayelsa). Adepoju-Bello *et al.*(2012) and Nnorom *et al.*(2014) reported a Cd concentration of (0.025-0.065 mg/kg and 0.024 to 0.089) respectively which compares relatively with the results fromthis study. Cd is known to exert adverse effects on brain metabolism and other severeeffects such as prostate cancer, and could also cause kidney, liver, lungs, and bone damage(Desideri *et al.*, 2012). There is no European Standard for Cd in fats and oil, however, the limit for soybean is0.2mg/kg (EU., 2001).

The mean Fe concentration ranged from 34.49±15.69 mg/kg to 56.14± 22.28 mg/kg for Rivers samples and Osun samples respectively with the individual concentrations ranging from 12.48-83.96 mg/kg. It hasbeen recognized that adequate Fe in a diet is very imperative for diminishing the incidenceof anemia (Ashraf and

Mian., 2008). The recommended Fe intake is 18 mg/day.Daily intake from palm oil isestimated at 0.33-1.16 and 0.65-2.32 mg/day on consumption of 5-10 g of palm oil in mealsper day.

Cu in the analyzed crude palm oil samples investigated ranged from 0.01 to 7.38 mg/kg with mean values varyingfrom 0.33±0.23 mg/kg for Osun samples to 1.28±2.18 mg/kg Bayelsa samples. Considering the highest Cucontent of this study, the daily intake of Cu fromconsumption of 10 g of palm oil is about 1%(0.0738 mg/day) of the recommended daily intake of 2 mg/day. The Cu concentration of thisresearch (overall mean 1.28± 2.18 mg/kg; range: 0.01-7.38 mg/kg) considered higher when compared with theCu content obtained by Cypriano *et al.*,2008 (ND - 2.67±0.04 and ND-2.55±0.06) and Nnorom *et al.*,2014 (0.56-2.09 mg/kg).

Trivalent chromium ($Cr^{+3}$) is an essential nutrient for man as it is involved in the glucose tolerance (Mir-Marqués *et al.*, 2012). Adequate chromium nutrition may reduce risk factors associated with cardiovasculardiseases as well as diabetes mellitus, though hexavalent chromium is, in contrast, very toxic (Reilly., 2002). The mean concentration of Cr in samples from all five-states samples investigated was in the ranged0.05-0.57 mg/kg and considered close to results reported by Nnorom *et al.*, (2014)who worked on palm oil samples from South-Eastern Nigeria (0.101-0.298 mg/kg) but higher than the values reported byAdepoju-Bello *et al.* (2012) (0.021-0.033 mg/kg).

The mean Manganese concentrations ranged from 8.09±1.53(0.38±0.22 mg/kg) forBayelsa samples to (1.98 ± 1.33 mg/kg) for Ondo samples (overall mean concentration of 1.98 ± 1.33mg/kg;range: (0.09-4.18 mg/kg) were the obtained result for Mn is considered to be lower than (6.55-12.05 mg/kg) reported byNnorom *et al.* (2014). The deficiency ofmanganese can result in severe skeletal and reproductive abnormalities in mammals whilehigh doses of manganese produceadverse effects primarily on the lungs and on the brain (Zhu *et al.*,2011).

Considering the highest Mn content of this study (4.18 mg/kg) the daily intake from 5-10 g of palm oil will be between 3-6% (8.2 $E^{-4}$-0.0415 mg) of the recommended 2 mg/day.

The obtained result for Zn and Ni concentrations of this study as presented Figure 3.1are range: (0.76-15.81 mg/kg) and (0.08-1.02 mg/kg) respectivelywith CPO samples from Osun havingthe lowest value and CPO samples from Rivers havingthe highest value respectively. Adepoju-Bello *et al.*(2012)reported a Ni concentration of 0.0435-0.068 mg/kg which is lower than the results of thisstudy while Nnorom *et al.*(2014) also reported concentration of Zn and Ni values thatranged between (3.6-14.6mg/kg and 0.15-0.81 mg/kg)which are considered comparable to results from this current study. Zinc plays essential roles as metallo-enzymes and as a cofactor of large number of enzymes. More so,Zhu *et al.* (2011)have confirmed that nickel toxicity at elevated level is more prominent, but trace amounts may be beneficial as an activator of some enzyme systems. The Draft East African Standard for Edible palm oil set the maximum limit of Pb, As and Ni in edible palm oil at 0.1mg/kg.

The Aluminum concentrations in CPO ranged from (0.19-6.34 mg/kg) with samples from Bayelsa and Osun havingthe lowest and highest values respectively.Umar (2004) studied four Nigerian vegetable based oils (palm oil, palm kernel oil, shear butter and groundnut oil) and reported concentration ranges of 19.4–44.0µg/g for Al; 30.0–81.0 µg/g for Ca; 11.9–60.4 µg/g for Cl; 1.43–5.96 µg/g for Cu; 7.3–28.1 µg/g for Mg; 0.47–1.69 µg/g for Mn; 17.5–72.8 µg/g for Na and 0.04–0.07µg/g for V. Though our results for elements in this study were mostly higher thanthe results of Umar (2004), their daily intakes were adequateand pose no toxicological health concern

**3.2 Estimated dietary intake of metals for consumption of 30.4g of crude palm oil samples from South-West and South-South, Nigeria**

The daily intake of metals from CPO is estimated using the standard consumption of 30.4g of CPO per day. The estimates are as stated in Table 3.2.

**Table 3.2.** Estimated Daily Intakes of metals analyzed in crude palm oil samples (µg/kg bw/day)

| Elements in CPO samples | Oyo State | Osun State | Ondo State | Bayelsa State | Rivers State | Ranges |
|---|---|---|---|---|---|---|
| Ca | 4.654 | 4.325 | 4.996 | 2.443 | 2.715 | 2.443 to 4.996 |
| Mg | 0.575 | 0.748 | 0.872 | 0.543 | 0.770 | 0.543 to 0.872 |
| Na | 0.758 | 0.859 | 1.446 | 0.674 | 0.808 | 0.674 to 1.446 |
| K | 3.526 | 3.664 | 2.985 | 1.849 | 1.648 | 1.648 to 3.664 |
| Fe | 5.606 | 5.916 | 4.330 | 3.904 | 3.635 | 3.635 to 5.916 |
| Mn | $4.90E^{-2}$ | $8.60E^{-2}$ | 0.209 | $4.10E^{-2}$ | $8.60E^{-2}$ | $4.10E^{-2}$ to 0.209 |
| Ni | $3.30E^{-2}$ | $3.36E^{-2}$ | $6.80E^{-2}$ | $4.30E^{-2}$ | $5.60E^{-2}$ | $3.30E^{-2}$ to $6.80E^{-2}$ |
| Cr | $6.70E^{-2}$ | $3.10E^{-2}$ | $2.60E^{-2}$ | $1.60E^{-2}$ | $3.30E^{-2}$ | $1.60E^{-2}$ to $6.70E^{-2}$ |
| Pb | $1.10E^{-4}$ | $1.10E^{-4}$ | $1.39 E^{-3}$ | $2.94E^{-3}$ | $3.99 E^{-4}$ | $1.10E^{-4}$ to $3.99 E^{-4}$ |
| Cd | $1.10E^{-4}$ | $1.10E^{-4}$ | $8.88 E^{-4}$ | $1.28E^{-2}$ | $1.10 E^{-4}$ | $1.10E^{-4}$ to $8.88 E^{-4}$ |

| | | | | | | |
|---|---|---|---|---|---|---|
| Cu | $8.30E^{-2}$ | $3.41E^{-2}$ | $6.40E^{-2}$ | 0.134 | $8.20E^{-2}$ | $3.41E^{-2}$ to 0.134 |
| As | $1.00E^{-4}$ | $1.10E^{-4}$ | $1.10E^{-4}$ | $9.02E^{-5}$ | $1.10\ E^{-4}$ | $9.02E^{-5}$ to$1.10\ E^{-4}$ |
| Zn | $3.63E^{-1}$ | 0.549 | 0.732 | 0.526 | 1.062 | $3.63\ E^{-1}$ to 1.062 |
| Al | $3.00E^{-4}$ | 0.329 | 0.292 | 0.123 | 0.212 | $3.00E^{-4}$ to 0.329 |

Results are presented as Mean, Number of Samplesper State, N=10

The estimated dietary intakes for Calcium and Magnesium obtained (Table 3.2) ranged from (2.443 to 4.996µg/kg bw/day) and (0.543 to 0.872 µg/kg bw/day) with the consumption 30.4kg or 11g of crude palm oil and these values were considered moderate compared to what Nnorom *et al.* (2014) reported (0.73-3.43µg/kg bw/day and 1.45-6.86 µg/kg bw/day) considering the consumption of 5g and 10g of fresh palm oil in meals. The recommendeddietary allowance (RDA) for Calcium (Ca) is set at 1000 mg Ca/day while Magnesium(Mg) for male and female healthy adultsare 400–420 and 310–320 mg Mg/day respectively(Institute of Medicine, 2002).

The estimated daily intake of potassium and Sodium in this study ranged from (1.648 to 3.664µg/kg bw/day and 0.674 to 1.446) µg/kg bw/day, which is very low compared to the recommended K intake of 1000 mg/day. Meanwhile, Nnorom *et al.* (2014) reported a very low Daily intake of K fromconsumption of 5g and 10g of fresh palm oil palm oil (0.39 and 1.65 µg/kg bw/day).

Fe and Mn estimated dietary intake from this study at consumption of 30.4g/kgcrude palm oil samples varied from (3.635 to 5.916µg/kg bw/day) and (0.0410to 0.209µg/kg bw/day) for Feand Mn,respectively. The intake values of Fe and Mn was less than the recommended dietary allowance value for Fe andMn. It has been recognized that adequate Fe in a diet is veryimperative for diminishing the incidence of anemia (Ashraf and Mian.,2008). Nnorom *et al.* (2014) reported a very low estimated daily intake of 0.33-1.16 and 0.65-2.32 mg/day on consumption of 5-10 g of palm oil in meals per day whilethe recommended Fe and Mn intake is 10-18 mg/day person and 2–5 mg/day person.

Theestimated daily intake of Ni ranged from$3.30E^{-2}$ to $6.80E^{-2}$µg/kg bw/day. The tolerable daily intake of Ni is 1.0µg/kg bw/day(Institute of Medicine, 2010).

In this study, the highest dietary intake of $Cr^{+3}$ was obtained from the consumption of crude palm oil ($1.60E^{-2}$ to $6.70E^{-2}$µg/kg bw/day) while lower intakes of Cr were obtained from Bayelsa and Oyo samples.These values were lower than the values reported byAdepoju-Bello *et al.* (2012) and Nnorom *et al.* (2014). The recommended dietary allowance of Cr is equivalent to 2.2 mg/kg bw/day(Institute of Medicine, 2010).

The Cadmium estimated daily intake from the consumption of these CPO spanned between 0.00011to 0.000888mg/kg bw/day. The tolerable intake value of Cd isset at 1 mg/kg bw/day(WHO 1993).

The estimated intake values of Lead(Pb) in this study ranged (0.00011to 0.000399 µg/kg bw/day) was found below recommended values of 0.1µg/kg bw/day.

The recommended dietary allowance (RDA) for Curanged from 15–500 µg/kg bw/day (World Health Organization (WHO) 1993). Theestimated daily intake value for Cu in thisstudy ranged from 0.04 to 2.50 µg/kg bw/day. while that of Arsenic ranged from $9.02E^{-5}$ to$1.10\ E^{-4}$µg/kg bw/day(which was below detection limit of the AAS used in this study). Arsenic as no biological function inhumans although animaldata indicate arequirement, no data on the possibleadverse effects of organicarsenic compounds in foodwere found,however, inorganicarsenic is a known toxicsubstance.

The Joint FAO/WHO Export Committee on FoodAdditives (JECFA) provisional maximal tolerable dailyintake of Zn is 1000 µg/kg bw/day (World Health Organization (WHO, 1982) while theExpert Group on Vitamins and Minerals (EVM)safe upper limit (SUL)for Zn is 4.2 mg/day (equivalent to 700 µg/kg bw/day ina 60 kg adult) for total dietary intake (EVM, 2003). Theestimated intakes of Zn from the consumption of these CPO samples from the five states ranged from $3.63\ E^{-1}$ to 1.062µg/kg bw/day. The highest intake value was obtained from consumption of CPO samples from Rivers. The estimated intake values ofZn in this study were less than $9.7e^{-4}$% of the provisionalmaximal tolerable daily intake of Zn at 11µg/kg bw/day60kg adult.

Lastly, the estimated dietary intake for Aluminum in this study ranged from $3.00E^{-4}$ to 0.329µg/kg bw/day. The results of the estimated dietary intakes of the metals analyzed in the crude palm oil were all below recommended values.

### 3.3 Estimation of Target Hazard Quotients

In order to determine the level of concern arising from metal concentration, Target Hazard Quotient (THQ) values were calculated using the measuredmetal concentration in the intact samples for ten potentially toxic metals in the crude palm oil samples. The THQis a ratio between the measured concentrations and theoral reference dose, weighted by the length and frequencyof exposure, amount ingested of samples, andbody weight (Hague*et al.*, 2008).The THQ is calculated by Equation 1, the formula established bythe Environmental Protection Agency (USEPA 1989)using equation (1).

$$THQ = \frac{E_F \times E_D \times SF_R \times MCS_{inorg} \times C_F}{R_F D \times W_{AB} \times T_A} \qquad \text{Equation 1}$$

where THQ is the Estimated Target Quotients

$E_F$- the exposure frequency (365 day/years)
$E_D$-the exposure duration equivalent to life time (54-56 life expectancy for Nigeria, and the mean value of 55.20 years was used)
$SF_R$- the fresh food ingestion rate (g/person) which was considered to be 30.4 g/day for palm oil;
$C_F$- the conversion factor ($10^{-3}$) for fresh weight
MCS inorg- the concentration of inorganic species in dietary components (mg/kg wet weight) for each element determined in food stuff.
$W_{AB}$- the average body weight (bw) (average adult body weight was considered to be 60kg)
$AT_n$- the average exposure time for non-carcinogen ($E_F$*$E_D$)
$R_FD$ = Reference Oral Dose (for Cr = $1.5x10^{-3}$, Cu =$4.0\ x10^{-2}$, Zn =$3.0\ x10^{-1}$, Fe = $7.0\ x10^{-1}$, Ni = $2.0\ x10^{-2}$, Mn = $1.4\ x10^{-1}$, Pb =1.5, Cd =$1.0\ x10^{-3}$, Al= $1.2x10^{-1}$ and As = $3\ x\ 10^{-4}$)

Estimation of dietary intakes of metals,with ingestion rate of 30.4g/day of crude palm oil sample, was used as standard. For this study, the length of exposure wasset to 13789 days for Nigeria based on the average lifeexpectancy of 55.20 years, from 15 yearsof age (WorldHealth Organization (WHO, 2004; Statista, 2018). The average weightof 60 kg adult was adopted in this study.The estimated THQ values (Table 3.3) for individualmetals from consumption of one 30.4g per daywas less than one in all the crude palm oil samples from all the five States.

**Table 3.3** Estimation of target hazard quotients of heavy metals in crude palm oil samples from South-West and South-South, Nigeria.

| Sample site | Fe | Mn | Ni | Cr | Pb | Cd | Cu | As | Zn | Al | Combine THQ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oyo | 2.15E$^{-2}$ | 9.60E$^{-3}$ | 4.88E$^{-3}$ | 5.88E$^{-2}$ | 1.90E$^{-7}$ | 2.80E$^{-4}$ | 5.32E$^{-3}$ | 9.40E$^{-4}$ | 1.90E$^{-3}$ | 6.63E-03 | 9.90E-02 |
| Osun | 2.26E$^{-2}$ | 1.65E$^{-3}$ | 4.62E$^{-3}$ | 5.59E$^{-2}$ | 1.90E$^{-7}$ | 2.80E$^{-4}$ | 2.30E$^{-3}$ | 9.40E$^{-4}$ | 5.55 E$^{-3}$ | 7.34E-03 | 1.01E-01 |
| Ondo | 1.67E$^{-2}$ | 3.93E$^{-3}$ | 9.18 E$^{-3}$ | 4.65E$^{-2}$ | 1.82E$^{-6}$ | 2.72E$^{-3}$ | 4.35E$^{-3}$ | 9.40E$^{-4}$ | 6.55E$^{-3}$ | 6.58E-03 | 9.75E-02 |
| Bayelsa | 1.49E$^{-2}$ | 7.73E$^{-3}$ | 5.35E$^{-3}$ | 3.03E$^{-2}$ | 3.85E$^{-6}$ | 8.65E$^{-3}$ | 9.06E$^{-3}$ | 9.40E$^{-4}$ | 4.70E$^{-3}$ | 4.25E-03 | 7.89E-02 |
| Rivers | 1.48E$^{-2}$ | 1.60E$^{-3}$ | 1.25E$^{-3}$ | 5.10E$^{-2}$ | 7.91E$^{-7}$ | 2.80E$^{-4}$ | 6.06 E$^{-3}$ | 9.40E$^{-4}$ | 9.50E$^{-3}$ | 4.70E-03 | 9.83E-02 |

Results are presented as Means, Number of Samples per State, N=10

The THQ values <1 indicate safe level whileTHQ values >1 indicate levels of concerns. THQ valuesare additives not multiplicative, thus a THQ value of 20is larger but not 10-fold greater than a THQ = 2. The combined THQ values for crude palm oil analyzed were <1. From the estimated THQ values, no lifelonghealth concern of metals is associated with the consumptionof these locally produced crude palm oil samples from the five States studied.

**3.4 Health Risk Index due to intake of metal contaminated crude palm oil**
The Health risk of consumer due to intake of metal contaminated palm oil or food/fish was assessed by using HRI
HRI = (EDI/$R_FD$)× $10^{-3}$
Where EDI= estimated daily intakes
$R_FD$ = Reference Oral Dose (for Cr = $1.5x10^{-3}$, Cu =$4.0\ x10^{-2}$, Zn =$3.0\ x10^{-1}$, Fe = $7.0\ x10^{-1}$, Ni = $2.0\ x10^{-2}$, Mn = $1.4\ x10^{-1}$, Pb =1.5, Cd =$1.0\ x10^{-3,}$ Al= $1.2x10^{-1}$and As = $3\ x\ 10^{-4}$)

The result of health risk assessments (HRI) of the various heavy metals considered in this study are presented in Table 3.4.

Table 3.4. The Health risk index of consumer due to intake of metal contaminated crude palm oil samples from South-West and South-South, Nigeria.

| Sample sites | Fe | Mn | Ni | Cr | Pb | Cd | Cu | As | Zn | Al |
|---|---|---|---|---|---|---|---|---|---|---|
| Oyo | 7.89E$^{-3}$ | 3.22E$^{-3}$ | 1.65E$^{-3}$ | 2.25E$^{-2}$ | 7.30E$^{-8}$ | 1.10E$^{-4}$ | 2.10E$^{-3}$ | 3.70E$^{-5}$ | 1.20E$^{-3}$ | 2.51E$^{-3}$ |
| Osun | 8.17E$^{-3}$ | 1.07E$^{-3}$ | 1.41E$^{-3}$ | 2.06E$^{-2}$ | 7.30E$^{-8}$ | 1.10E$^{-4}$ | 8.38E$^{-4}$ | 3.70E$^{-4}$ | 2.90E$^{-3}$ | 2.75E$^{-3}$ |
| Ondo | 6.16E$^{-3}$ | 1.49E$^{-3}$ | 3.40E$^{-3}$ | 1.70E$^{-2}$ | 9.28E$^{-7}$ | 8.88E$^{-4}$ | 1.62E$^{-3}$ | 3.70E$^{-4}$ | 2.44E$^{-3}$ | 2.44E$^{-3}$ |
| Bayelsa | 5.56E$^{-3}$ | 2.92E$^{-3}$ | 2.15E$^{-3}$ | 1.07E$^{-2}$ | 1.97E$^{-6}$ | 1.21E$^{-2}$ | 3.41E$^{-3}$ | 3.03E$^{-4}$ | 2.76E$^{-3}$ | 1.03E$^{-3}$ |
| Rivers | 5.18E$^{-3}$ | 1.14E$^{-3}$ | 3.05E$^{-3}$ | 2.19E$^{-2}$ | 2.66E$^{-7}$ | 1.10E$^{-4}$ | 2.75E$^{-3}$ | 3.70E$^{-3}$ | 3.54E$^{-3}$ | 5.32E$^{-3}$ |

Results are presented as Means, Number of Samples per State, N=10

The results indicate that there is no HRI value > 1, indicating that humans would not experience any significant health risk if they onlyconsume metals from these crude palm oil samples from South-West and South-South local palm oil mills, in Nigeria. Among the heavy metals examined in this study were Pb, Cd and As with a HRI value ranged between ($7.30E^{-8}$ to$1.97E^{-6}$) for Pb, ($1.10E^{-4}$ to$1.21E^{-2}$) for Cd and As has ($3.70E^{-5}$ to$3.70E^{-3}$) with relatively low potential health risk, whiles Cd (HRI= $1.21E^{-2}$from Bayelsa) has the highest potential health risk.

Reports have it that exposure to more than onecontaminant may produce an adverse effect on theconsumers. In this study, the total HRIs of the individualmetals examined in the crude palm oil samples wascalculated by adding the individual HRIs of the metals.The total HRI through the consumption of CPO wasless than 1, indicating that there is no potentialsignificant health risk associated with the consumptionof CPO from thefive States. The CPO samples from Bayelsa which its Cd was themajor health risk contributors, accounted for23% of the total HRIs in the study.

## IV. Conclusion And Recommendation

Generally, this study has shown that the palm oils from the studied areas do not pose any health risk from toxic heavy metals including Cd, Pb, As and Al as the concentrationswere generally low but would rather act as a source of both macro and micronutrients in diets.The mean concentrationsof the metals were lower than recommendedvalues by the EU, WHO and EVM. The samples vary widely in theirheavy metal contents, but the estimated daily intakeof the various metals in the samples were below theirrespectively recommended limits. From the health pointof view, the THQ and HRI values for theindividual metals showed that there was no healthrisk for humans due to the intake of individual heavymetals in the crude palm oil from the South-West and South-South, Nigeria. Also, the THQ and total HRI onhumans due to the combined effect of all the metalsconsidered in the study was also less than one, which indicate that potential health risk for consumptionof the crude palm oil is insignificant.

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