Original Research Article

Assessment of Radionuclide Concentration Associated With Locally Produced Palm Kernel Oil in Osun State, Nigeria

Abstract

This study assesses the natural radioactivity as well as their derived health implication in locally produced palm kernel oil in Osun State, Nigeria. A total of 16 samples were collected from four major factories in four towns in the study area. Thallium-doped sodium iodide (NaI (Tl)) scintillation detector was used to determine the activity concentration of these radionuclides and the results obtained were used to calculate radiological impact parameters. The results show that the radionuclides detected and quantified in this study came from the naturally-occurring radionuclides ^{238}U and ^{232}Th decay series, as well as non-series ^{40}K. The overall mean concentrations for ^{40}K, ^{232}Th and ^{238}U in all the samples were 14.68 ± 1.55, 6.03± 1.74 and 5.55 ± 2.09 Bq L^{-1}, respectively. The range of measured activities in the palm kernel oil varies within the same factory which may be due to the fact that the production processes and most especially the source of the palm kernel used by the factories and nature of the soil where the palm tree is planted varied. The estimations of all radiological impact parameters were found to be lower than their respective world average values. These low values imply that the probability of suffering serious radiation hazards is low in the areas.

Keywords: *Palm kernel oil; radionuclides; radiological impact parameters; activity concentration.*

1.0 Introduction

Palm kernel oil used for various domestic and industrial purposes contain minute amount of radionuclides as a result of its origin and manufacturing process. The consumption of these radionuclides above the bio-recommended limits poses a potential health hazard. Radionuclides are isotopes with an unstable nucleus in an attempt to become more stable, emits energy in the form of rays or high energy particles. Radionuclides enter the human body through complex mechanism including foodstuffs via the food chain from natural sources and also through inhalation and ingestion (IAEA, 1989). The ingested radionuclides could be concentrated in certain parts of the body. For examples, ^{238}U accumulate in human lungs and kidney, ^{232}Th in lungs, liver and skeleton tissues and ^{40}K in muscles (Samat and Evans 2011). Depositions of large quantities of these radionuclides in particular organs of the human body can lead to reoccurring health conditions such as weakening the immune system, inducing various types of diseases and eventual increase in mortality rate (Adeleye *et al*., 2020).

Radionuclides produce ionizing radiations and when these radiations strike living organism's cells, they may injure the cells. If radiation affects a significant number of cells, it can eventually lead to cancer. At extremely high doses, exposure can cause death. In general, there is no safe level of radiation exposure (EPA, U. S., 2008). Radionuclides generally move through the environment and into the body through many different pathways such as: air, water, consumer products and the food chain. The radionuclides released into the environment can give rise to human exposure to ionizing radiations.

Human exposure to ionizing radiation is one of the scientific subjects that attract public attention, since radiation of natural origin is responsible for most of the total radiation exposure of the human population (UNSCEAR, 2000). It can cause somatic and genetic effects that tend to damage critical or radiosensitive organs in

the body, and can even lead to death (Ajayi, 1995). Hence, this study aim to determine the activity concentrations of natural radionuclides present in the palm kernel oil consumed by the inhabitants and its possible radiological effects on the residents in the study area.

2.0 Materials and Methods

2.1. Study Area

Osun State is an inland state in south-western Nigeria. Its capital is Osogbo. It is located between the Latitude 7°30′0"N and 7°58′76"N, Longitude 4°30′ 0"E and 4° 56' 24"E. Osun State covers an area of approximately 9,251 square kilometres. The dry season lasts from November to March while the wet season starts from April and ends in October. Average daily temperature ranges between 25^{o}C and 35^{o}C almost throughout the year (Adeola *et al*., 2008).

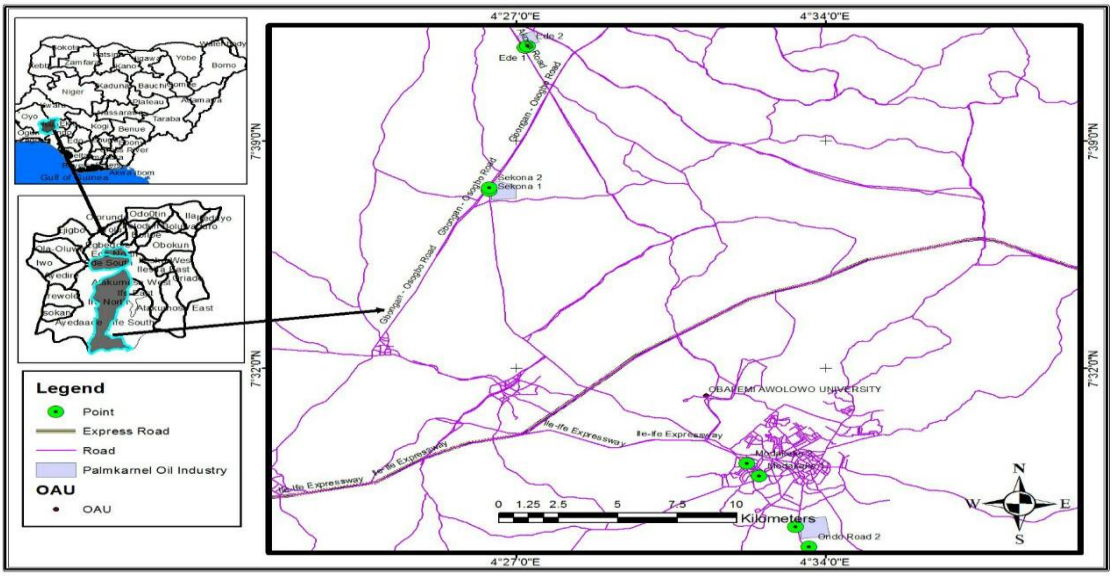

Figure 1: Map of Osun State showing the Study Area

2.2. Sample Collection and Treatment

A total of 16 samples were collected from four major factories in four towns namely; Modakeke, Ife, Sekona and Ede in Osun State, Nigeria. At each location, the sample was poured into clean labeled polyethylene container. All the samples collected were identified and grouped according to their location for radionuclide analysis. The containers were sealed for about 28 days to allow ^{222}Rn and its short-lived progenies to reach secular equilibrium prior to gamma spectroscopy.

2.3. Gamma Spectrometric Analysis

Palm kernel oils collected for gamma spectrometry were weighed and kept, each in well labelled radon-impermeable air tight cylindrical plastic container of 9 cm height by 7 cm diameter previously washed with dilute HNO_3 and rinsed with distilled water. The samples were then sealed and kept for at least twenty eight (28) days in order to attain secular equilibrium between parents and progenies radionuclides. Gamma ray spectrometry counting of the samples was carried out using a well calibrated NaI (Tl) scintillation detector, enclosed in 5 cm thick lead shield to reduce background radiation. The spectra was then analysed and the activity concentration of the radionuclides was computed using a comparative method. The result was then used to determine the radiological health impact of the samples.

2.3.1 Measurement of Radionuclide Concentration

A lead-shielded 76 mm × 76 mm NaI (Tl) detector crystal (Model No. 802 series, Canberra Inc.) coupled to a Canberra Series 10 plus Multichannel Analyzer (MCA) (Model No.1104) through a preamplifier was used for the radioactivity measurements. Each sealed samples was placed on the shielded NaI (Tl) detector and counted for 18,000 s. An empty container of the same geometry and dimension was counted for the same counting time of 18,000 s to determine the

background distribution spectrum. This counting time was used in order to minimize the statistical errors from the full energy peaks.

The choice of radionuclides to be detected was predicated on the fact that the NaI (Tl) would only be sufficiently discriminated if their emission probability and their energy were high enough, and the surrounding background continuum is low enough. Therefore, the activity concentration of ^{214}Bi (determined from its 1.120 MeV γ-ray peaks) was chosen to provide an estimate of ^{226}Ra (^{238}U) in the samples, while that of the daughter radionuclide ^{228}Ac (determined from its 0.911 MeV (911 keV) γ-ray peak) was chosen as an indicator of ^{232}Th. ^{40}K was determined by measuring the 1.460 MeV γ-rays emitted during its decay. The net area under the corresponding peaks in the energy spectrum was computed by subtracting counts due to compton scattering of higher peaks and other background sources from the total area of the peaks. Comparative Method was used in the determination of specific activity concentration. The specific activity of the radioisotope is obtained by direct comparison with the same radionuclide in a given standard. The specific radioactivity "C_x" in the sample and the corresponding specific radioactivity "C_s" in the standard are related by;

$$C_x = C_s \frac{V_s(A_x - A_\circ)}{V_x(A_s - A_\circ)}$$

Where,

C_x is the concentration of specific radioactivity in the sample,

C_s is the specific activity concentration of the standard,

V_s is the volume of the standard,

V_x is the volume of the sample,

$A_\circ$ is the background radiation

A_s is the area of the standard and

A_x is the area of the sample.

2.3.2 Radiological Impact Parameters

2.3.2.1 Annual Effective Dose (AED)

The effective dose is a way of determining the whole body biological damage due to radiation exposure of different types to different organs of the body. It is the tissue-weighted sum of the equivalent doses in all specified tissues and organs of the body and represents the stochastic health risks to the whole body. It takes into account the type of radiation and the nature of each organ or tissue being irradiated, and enables summation of organ doses due to varying levels and types of radiation. The Annual Effective Dose (AED) due to internal exposure is calculated using Equation 1 (UNSCEAR, 2000):

$$AED = A(Bq\ L^{-1}) x\ M\ (L\ y^{-1}) \times DCF \quad 1$$

Where AED is the annual effective dose due to ingestion of the sample; A is the activity concentration of radionuclide; M is the annual consumption rate per person and DCF is the standard dose conversion factor.

The most recent dose conversion coefficients for the case of ingestion for adults are 2.8 $x10^{-7}$, 2.3 $x10^{-7}$ and 6.2 $x10^{-9}$ Sv Bq^{-1} for ^{238}U (^{226}Ra), ^{232}Th and ^{40}K respectively (ICRP, 2012). ^{238}U and ^{232}Th had been assumed to be at secular equilibrium with their respective decay products while M which is the annual

consumption rate of palm kernel oil in Nigeria is 267,000,000 Litre per year (USDA, 2017). With the current population of Nigeria estimated to be 190,000,000 people, therefore, the annual consumption rate of palm kernel oil per individual was estimated to be 1.41 L y^{-1} (USDA, 2017).

2.3.2.2 Radium Equivalent Activity Index (Ra_{eq})

Radium equivalent activity index describes the gamma output from different mixtures of ^{238}U, ^{232}Th and ^{40}K in a geological material. It was calculated using Equation 2 below (UNSCEAR, 2000):

$$Ra_{eq} = A_U + 1.43A_{Th} + 0.077A_K \qquad 2$$

Where A_U (A_{Ra}), A_{Th} and A_K are the radioactivity concentration in Bq L^{-1} of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K, respectively.

2.3.2.3 Radiation Hazard Indices

The external radiation hazard (H_{ext}) and the internal radiation hazard (H_{int}) was calculated as follows (UNSCEAR, 2000):

$$H_{ext} = \left(\frac{A_{Ra}}{370}\right) + \left(\frac{A_{Th}}{259}\right) + \left(\frac{A_K}{4810}\right) \qquad 3$$

$$H_{int} = \left(\frac{A_{Ra}}{185}\right) + \left(\frac{A_{Th}}{259}\right) + \left(\frac{A_K}{4810}\right) \qquad 4$$

Where A_{Ra} is approximately equals to A_u is the activity concentration of ^{238}U; A_{Th} is the activity concentration of ^{232}Th and A_K is the activity concentration of ^{40}K

2.3.2.4 Excess Lifetime Cancer Risk (ELCR)

This was calculated using the following equation (UNSCEAR, 2000)

$$ELCR = AED \times DL \times RF \quad (5)$$

Where AED in μSv yr^{-1} is the annual effective dose; DL is the duration of life (70 years); RF is the risk factor (0.05 Sv^{-1}).

3.0 Results and discussion

3.1 Radioactivity Content

The results of the activity concentration of the radionuclides detected in palm kernel oil collected from eight factories in Osun State are presented in Table 3.1 and illustrated in Figure 3.1. All the radionuclides detected and quantified came from the naturally-occurring headed by ^{238}U (^{226}Ra) and ^{232}Th decay series, as well as non-series ^{40}K. The specific activity concentration of ^{40}K, ^{232}Th and ^{238}U ranged from 16.65 ± 1.78 to 24.17 ± 2.56 Bq L^{-1} (with an average of 20.10 ± 2.22 Bq L^{-1}), 1.43 ± 0.47 to 12.26 ± 4.89 Bq L^{-1} (with an average of 5.04 ± 1.85 Bq L^{-1}) and 0.16 ± 0.06 to 4.72 ± 1.78 Bq L^{-1} (with an average of 2.19 ± 0.82 Bq L^{-1}) in Ife, 1.79 ± 0.18 to 15.30 ± 1.58 Bq L^{-1} (with an average of 11.20 ±1.13 Bq L^{-1}), 0.64 ± 0.21 to 19.53 ± 4.11 Bq L^{-1} (with an average of 7.16 ± 1.77 Bq L^{-1}) and 1.32 ± 0.63 to 6.92 ± 2.35 Bq L^{-1} (with an average of 4.11± 1.55 Bq L^{-1}) in Modakeke, 13.29 ± 1.47 Bq L^{-1} to 22.07 ± 2.27 Bq L^{-1} (with an average of 19.08 ± 2.05 Bq L^{-1}), 1.25± 0.36 to 16.70 ± 4.37 Bq L^{-1} (with an average of 10.08 ± 2.78 Bq L^{-1}) and 6.73 ± 2.62 to 21.52 ± 7.92 Bq L^{-1} (with an average of 14.58 ± 5.47 Bq L^{-1}) in Sekona, 6.79 ± 0.74 to 10.94 ± 1.06 Bq L^{-1} (with an average of 8.33 ± 0.86 Bq L^{-1}), 0.64 ± 0.19 to 3.34 ± 1.00 Bq L^{-1} (with an average of 1.84 ± 0.55 Bq L^{-1}) and 0.10

± 0.05 to 2.17 ± 0.77 Bq L^{-1} (with an average of 1.31 ± 0.53 Bq L^{-1}) in Ede respectively.

Table 3.1: Activity Concentration of Radionuclides (Bq L^{-1}) in Palm Kernel Oil

Locations	^{40}K	^{232}Th	^{238}U
IFE			
PKI1a	16.80±2.14	1.43±0.47	2.71±1.07
PKI1b	24.17±2.56	3.30±1.04	4.72±1.78
PKI2a	22.78±2.39	12.26±4.89	0.16±0.06
PKI2b	16.65±1.78	3.15±1.01	1.17±0.38
IFE MEAN	**20.10 ± 2.22**	**5.04± 1.85**	**2.19 ± 0.82**
MODAKEKE			
PKM1a	12.96±1.34	5.28±1.67	3.59±1.42
PKM1b	15.30±1.58	19.53±4.11	4.62±1.78
PKM2a	1.79±0.18	0.64±0.21	6.92±2.35
PKM2b	14.75±1.43	3.17±1.08	1.32±0.63
MODAKEKE MEAN	**11.20 ± 1.13**	**7.16 ± 1.77**	**4.11± 1.55**
SEKONA			
PKS1a	13.29±1.47	1.25±0.36	16.10±6.17
PKS1b	19.29±2.21	14.95±4.16	13.95±5.16
PKS2a	22.07±2.27	16.70±4.37	21.52±7.92
PKS2b	21.65±2.25	7.42±2.24	6.73±2.62
SEKONA MEAN	**19.08 ± 2.05**	**10.08 ± 2.78**	**14.58 ± 5.47**
EDE			
PKE1a	8.14±0.83	2.25±0.66	2.17±0.77
PKE1b	7.44±0.80	1.14±0.36	1.97±0.83
PKE2a	10.94±1.06	3.34±1.00	0.10±0.05
PKE2b	6.79±0.74	0.64±0.19	0.99±0.46
EDE MEAN	**8.33±0.86**	**1.84±0.55**	**1.31±0.53**

OVERALL MEAN	**14.68±1.55**	**6.03±1.74**	**5.55±2.09**

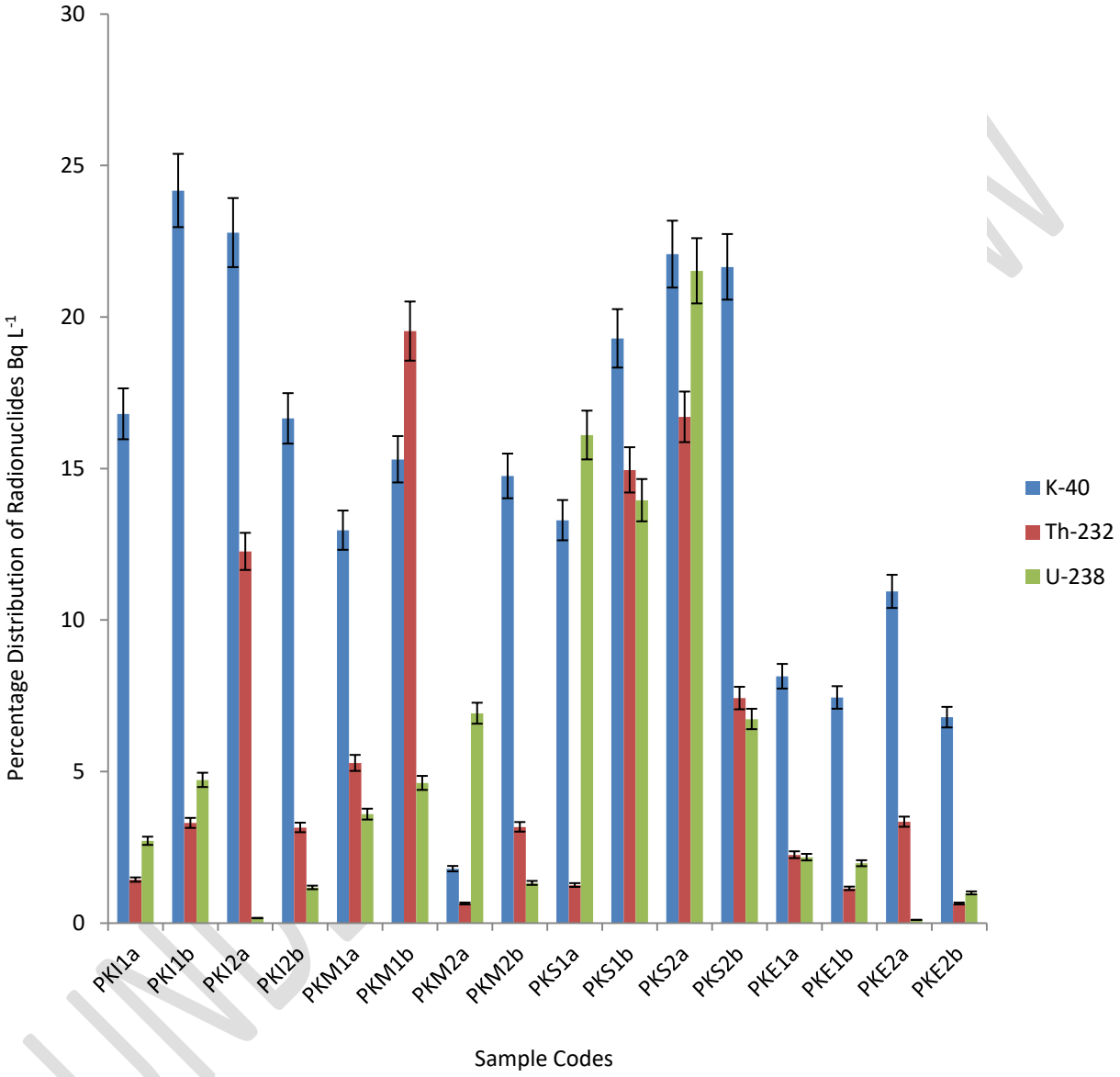

Figure 3.1: Activity Concentration of Radionuclides (Bq L^{-1}) in Palm Kernel Oil

The overall mean of the specific activity concentration due to ^{40}K, ^{232}Th and ^{238}U in the factories were 14.68 ± 1.55 Bq L^{-1}, 6.03 ± 1.74 Bq L^{-1} and 5.55 ± 2.09 Bq L^{-1} respectively.

In Figure 3.1, it is clear that the activity concentration values for ^{40}K were higher than that of both ^{232}Th and ^{238}U. This is because of the natural abundance of ^{40}K in the earth crust. ^{40}K is also present in the body and it is under metabolic regulation when the value is high or low. (UNSCEAR, 2000).

It can be noticed from Table 3.1 that the range of measured activities in the palm kernel oil varies within the same factories and the radioactivity content also varies with other factories this may be as a result of the processing machine, and most especially the source of the palm kernel used by the factories and nature of the soil where the palm tree was planted.

To assess the radiation hazard posed by the detected and quantified radionuclides in the samples, some radiological impacts parameters has to be estimated.

3.2 Radiological Impact Parameters in Palm Kernel Oil

Table 3.2 presents all the radiological impact parameters estimated in order to assess the possible health hazard of palm kernel oil due to its radioactive contamination.

3.2.1 Annual Effective Dose (μSv yr^{-1})

The annual effective dose (μSv yr^{-1}) due to ingestion of palm kernel oil calculated using Equation 1 is presented in Table 3.2 and the results are illustrated in Figure 3.2. The values ranged from 1.62 to 4.21 μSv yr^{-1} (with a mean of 2.66 μSv yr^{-1}) for Ife, 1.67 to 8.23 μSv yr^{-1} (with a mean of 4.02 μSv yr^{-1}) for Modakeke, 5.22 to 10.50 μSv yr^{-1} (with a mean of 8.24 μSv yr^{-1}) for Sekona, 0.65 to 1.65 μSv yr^{-1} (with a mean of 1.18 μSv yr^{-1}) for Ede. The overall averaged annual effective dose was calculated to be 4.03 μSv yr^{-1}. The palm kernel oil from Sekona has the highest value of 10.50 μSv yr^{-1}; nevertheless, the value was less compared to the world average value of 290 μSv yr^{-1} and hence poses no radiation risk (UNSCEAR, 2000).

3.2.2 Radium Equivalent Activity Index (Ra_{eq})

The Radium Equivalent Activity Index, Ra_{eq} (Bq L^{-1}) for palm kernel oil calculated using Equation 2 are given in Table 3.2 and is illustrated in Figure 3.3. The result ranged between 6.05 to 19.45 Bq L^{-1} (with a mean of 10.94 Bq L^{-1}) for Ife, 6.99 to 33.7 Bq L^{-1} (with a mean of 15.20 Bq L^{-1}) for Modakeke, 18.91 to 47.10 Bq L^{-1} (with a mean of 30.46 Bq L^{-1}) for Sekona, 2.43 to 6.01 Bq L^{-1} (with a mean of 4.59 Bq L^{-1}) for Ede with an overall mean of 4.27 Bq L^{-1}. These values were found to be lower than the world average value of 370 Bq L^{-1} (UNSCEAR, 2000), and hence do not pose any serious radiation health risk. This means that the palm kernel oil produced from these selected areas can safely be consumed without much fear of radiological hazards.

3.2.3 Radiation Hazard Indices

The external (H_{ext}) and the internal (H_{int}) radiation hazard indices were calculated using Equations 3 and 4; and the results are shown in Table 3.2 and illustrated in Figures 3.4. The external radiation hazard (H_{ext}) ranged between 0.02 to 0.05 with a mean of 0.04 for Ife, 0.02 to 0.09 with a mean of 0.04 for Modakeke, 0.05 to 0.13 with a mean of 0.09 for Sekona, 0.01 to 0.02 with a mean of 0.02 for Ede while the internal radiation hazard index (H_{int}) ranged between 0.02 to 0.05 with a mean of 0.04 for Ife, 0.02 to 0. 10 with a mean of 0.05 for Modakeke, 0.07 to 0.19 with a mean 0.13 for Sekona, 0.01 to 0.02 with a mean of 0.02 for Ede. The overall mean values estimated for the four factories were 0.10 and 0.12 for the external (H_{ext}) and the internal (H_{int}) radiation hazard indices respectively. These values were both less than world average value of 1 (unity) (UNSCEAR, 2000) and hence poses no radiation risk. H_{ext} and H_{int} equal to unity corresponds to the upper limit of radium equivalent dose (370 Bq L^{-1}) (Avwiri *et al*., 2014; Issa, *et al*., 2013; Avwiri and Ononugbo, 2012; UNSCEAR, 2000).

3.2.4 Excess Lifetime Cancer Risk (ELCR)

The results of the excess lifetime cancer risk (ELCR) for palm kernel oil calculated using Equation 5 are shown in Table 3.2 and illustrated in Figure 3.5. The ELCR in 10^{-3} ranged from 0.01 to 0.01 with a mean 0.01 for Ife, 0.01 to 0.03 with a mean of 0.02 for Modakeke, 0.02 to 0.05 with a mean 0.04 for Sekona, 0.00 to 0.01 with a mean of 0.01 for Ede. The estimated mean value of ELCR for the palm kernel oil in these selected areas was 0.06 which is lower than the world average value of 0.2 (UNSCEAR, 2000). The low value of the ELCR index is due to low annual effective dose in the samples. This low value implies that the probability of developing cancer over a lifetime considering seventy years as the average life span of humans is low.

Table 3.2 Radiological Impact Parameters in Palm Kernel Oil

Locations	AEDE (μSv yr^{-1})	Ra_{eq} (Bq L^{-1})	H_{ex}	H_{in}	ELCR(10^{-3})
IFE					
PKI1A	1.67	6.05	0.02	0.02	0.01
PKI1B	3.12	11.30	0.03	0.04	0.01
PKI2A	4.21	19.45	0.05	0.05	0.01
PKI2B	1.62	6.96	0.02	0.02	0.01
IFE MEAN	**2.66**	**10.94**	**0.04**	**0.04**	**0.01**
MODAKEKE					
PKM1A	3.22	12.14	0.03	0.04	0.01
PKM1B	8.23	33.70	0.09	0.10	0.03
PKM2A	2.93	7.97	0.02	0.04	0.01
PKM2B	1.67	6.99	0.02	0.02	0.01
MODAKEKE MEAN	**4.02**	**15.20**	**0.04**	**0.05**	**0.02**
SEKONA					
PKS1A	6.83	18.91	0.05	0.09	0.05
PKS1B	10.50	36.81	0.10	0.14	0.02
PKS2A	10.40	47.10	0.13	0.19	0.05
PKS2B	5.22	19.01	0.05	0.07	0.02
SEKONA MEAN	**8.24**	**30.46**	**0.09**	**0.13**	**0.04**
EDE					
PKE1A	1.65	6.01	0.02	0.02	0.01
PKE1B	1.20	4.17	0.01	0.02	0.00
PKE2A	1.21	5.72	0.02	0.02	0.00
PKE2B	0.65	2.43	0.01	0.01	0.00
EDE MEAN	**1.18**	**4.59**	**0.02**	**0.02**	**0.00**
OVERALL MEAN	**4.03**	**15.30**	**0.05**	**0.06**	**0.02**

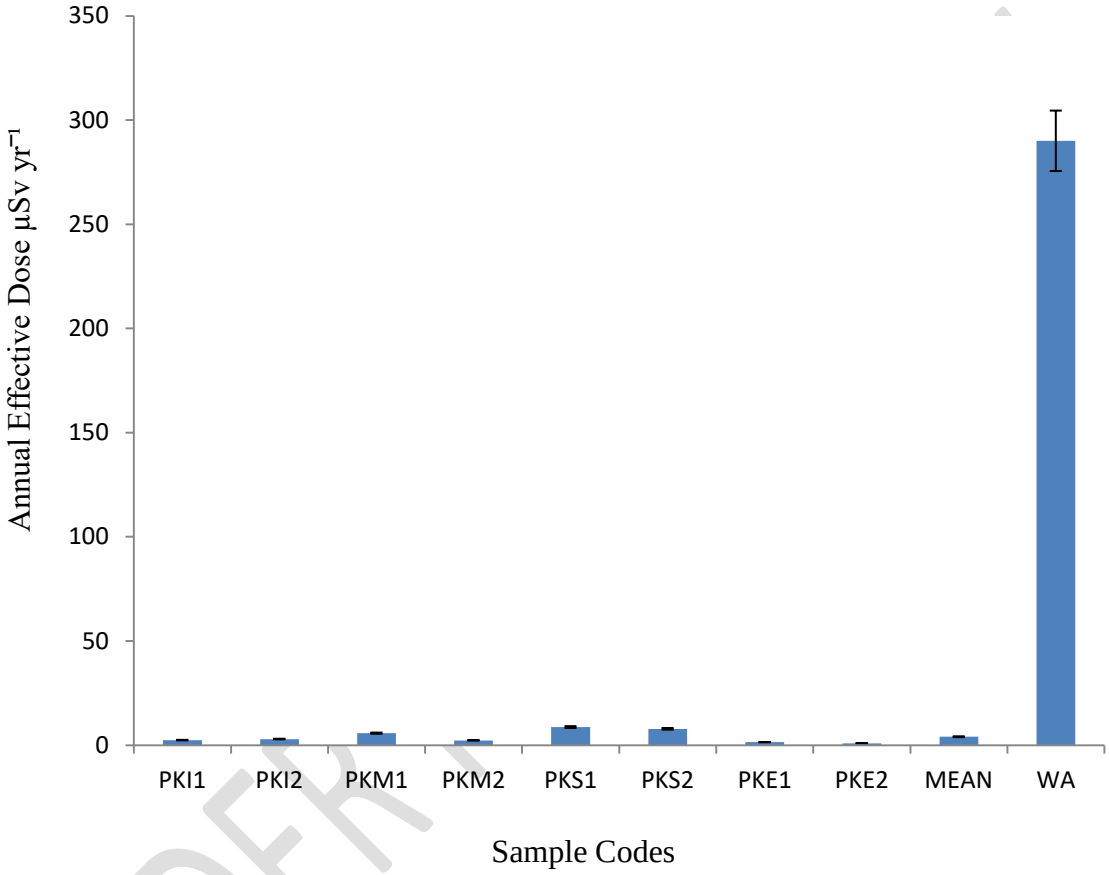

Figure 3.2: Annual Effective Dose (µSv yr^{-1}) of Palm Kernel Oil

WA: World Average Value (UNSCEAR 2000)

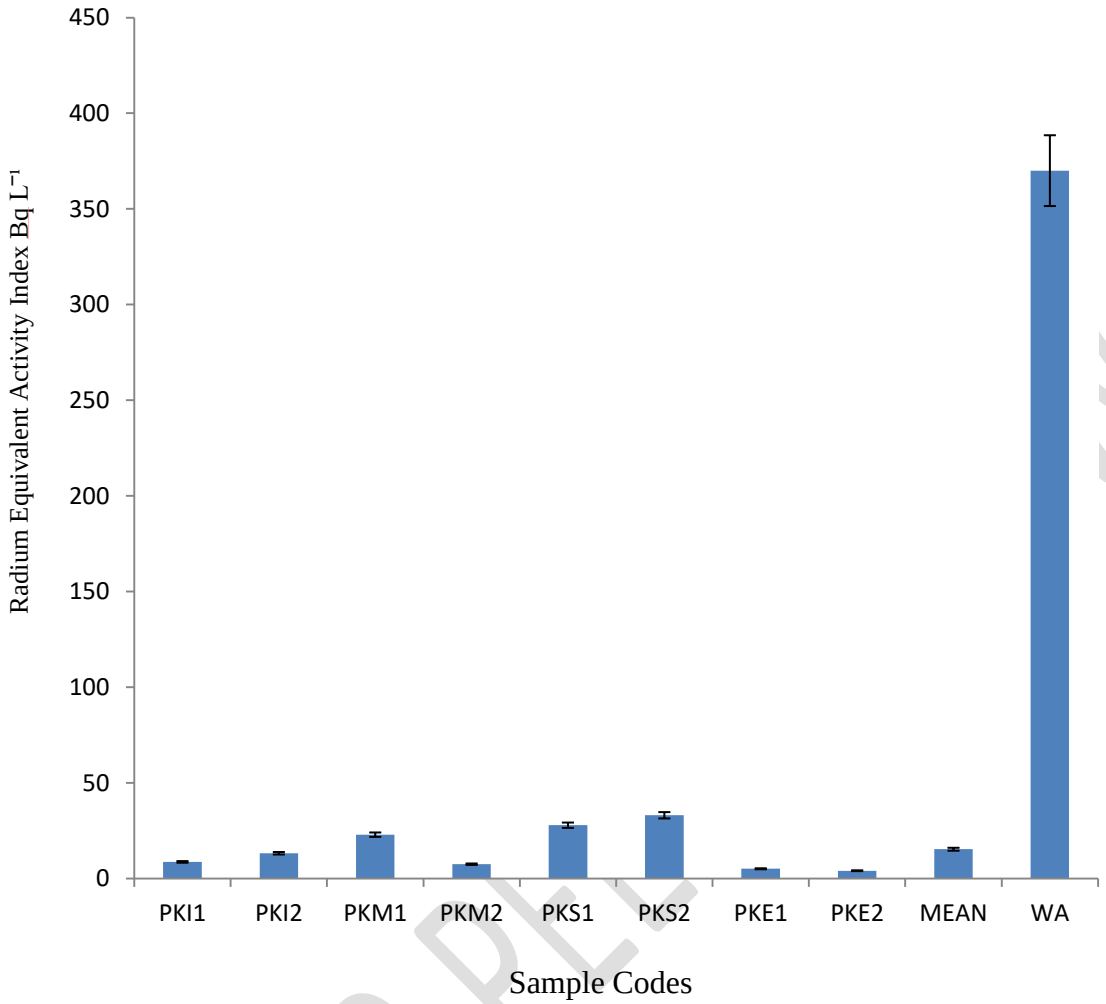

Figure 3.3: Radium Equivalent Activity Index (Bq L^{-1}) in Palm Kernel Oil

WA: World Average Value (UNSCEAR 2000)

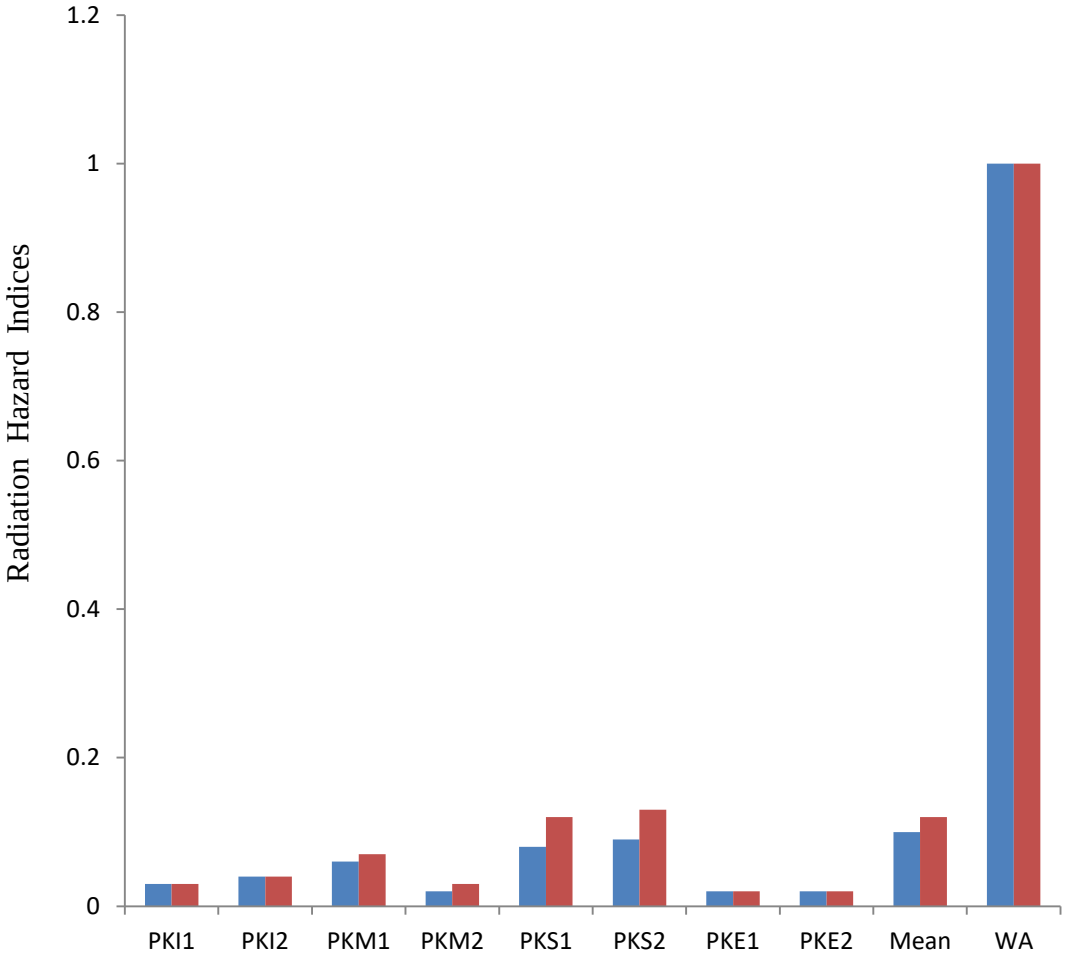

Figure 3.4: Radiation Hazard Indices of Palm Kernel Oil

WA: World Average Value (UNSCEAR, 2000)

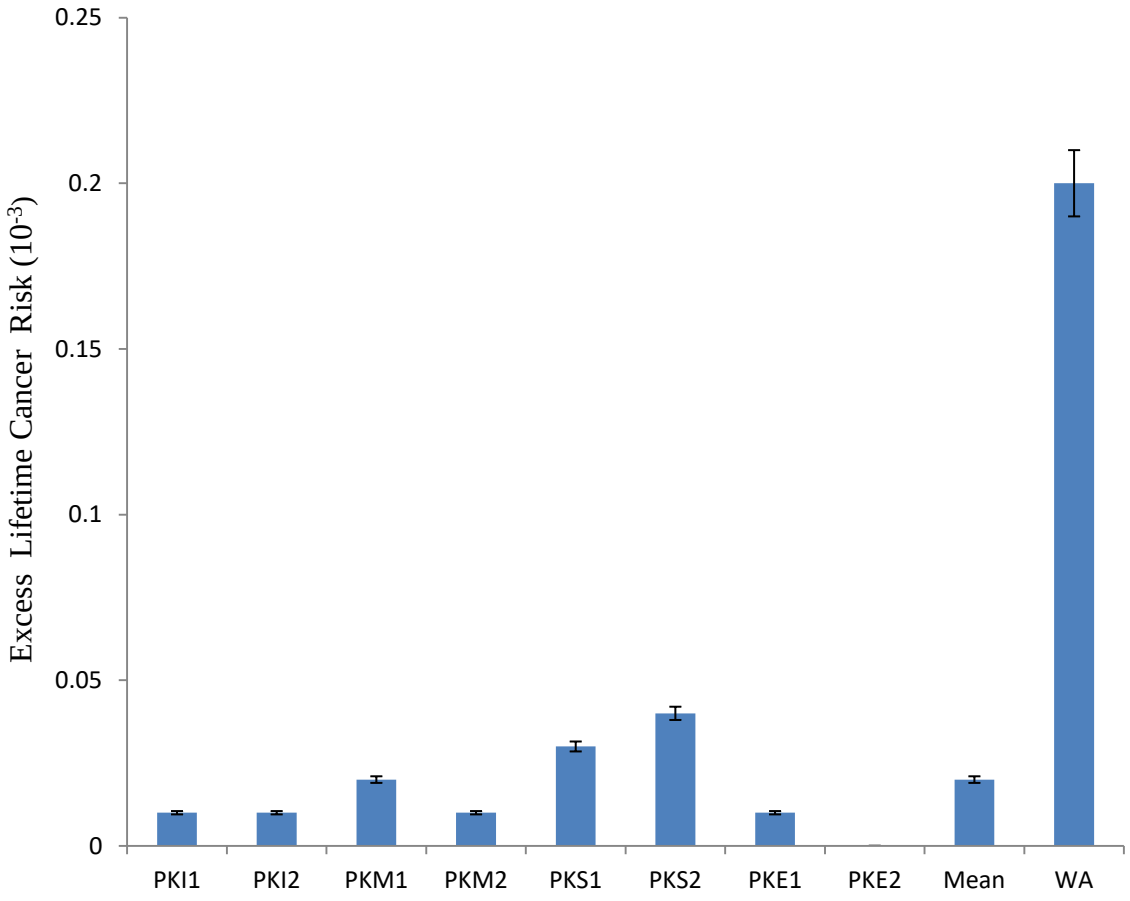

Figure 3.5: Excess Lifetime Cancer Risk (10^{-3}) of Palm Kernel Oil

WA: World Average Value (UNSCEAR 2000)

4.0 Conclusion

The radionuclides detected and quantified in this study came from the naturally-occurring radionuclides ^{238}U and ^{232}Th decay series, as well as non-series ^{40}K. The overall mean concentrations for ^{40}K, ^{232}Th and ^{238}U in all the samples were 14.68 ± 1.55, 6.03± 1.74 and 5.55 ± 2.09 Bq L^{-1}, respectively. The range of measured activities contents in the palm kernel oil varies within the same factory which may be due to the fact that the production processes and most especially the source of the palm kernel used by the factories and nature of the soil where the palm tree is planted varied.

The estimations of all radiological impact parameters were found to be lower than their respective world average values. These low values imply that the probability of suffering serious radiation injury is low. This study has provided information on radionuclides as well as their derived health implication associated with locally produced palm kernel oil collected from various producing factories in specified areas in Osun state, Nigeria.

5.0 References

1. Adeleye, M.O., Musa, B., Oyebanjo, O., Gbenu, S.T., & Alayande, S.O. (2020): Activity Concentration of Natural Radionuclides and Assessment of the Associated Radiological Hazards in the Marine Croaker (*Pseudotolitus Typus*) Fish From Two Coastal Areas of Nigeria. Science World Journal, Faculty of Science, Kaduna State University, 15(2): 90 – 95.

2. Adeola, R. G., Adebayo, O. O. and G. O. Oyelere (2008): Effects of the Federal Government Special Rice Programme on Rice Yields and Farmers' Income in Oyo

State. International Journal of Agricultural Economics & Rural Development, 1(1):1-6.

3. Ajayi, I.R., Ajayi, O.S. and Fusuyi, A.S. (1995): The Natural Radioactivity of Surface Soils in Ijero – Ekiti, Nigeria, Nig. Jour. of Phy. Vol. 7, pp 101 – 103.

4. EPA US (2008): Environmental Protection Agency of U.S: Radiation Protection: Health Effects.

5. IAEA (1989): International Atomic Energy Agency: Measurements of radionuclides in food and the environment, a guidebook, Technical report series No. 295, IAEA, Vienna.

6. ICRP (2012): International Commission on Radiological Protection. Recommendations of the International Commission on Radiological Protection (ICRP) Publication 60, Annals of the ICRP, Vol. 21/1-3.

7. Samat, S. B. and Evans, C. J. (2011): Determination of any Radiation Hazard arising from the 40K content of Bottled Mineral Water in Malaysia Sains Malaysiana 40(12):1355-1358.

8. UNSCEAR (2000): Sources, effects and risks of ionization radiation, United Nations Scientific Committee on the Effects of Atomic Radiation. Report to The General Assembly, with Scientific Annexes B: Exposures from Natural Radiation Sources New York.

9. USDA (2017): Nigeria Palm Kernel Oil Food Use Domestic Consumption by Year. United States Department of Agriculture, Index Mundi, United States. Accessed on April 10, 2021 online at https://www.indexmundi.com/agriculture