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Radiological Assessment of Primordial Radionuclides in Crab Species from Igbokoda River in Southwest of Nigeria

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Abstract: *Primordial radionuclides are natural radionuclides of specific half-lives that are capable of disintegrating with the release of ionizing radiations along with huge amount of energy which can be so harmful to living organisms. Activity concentrations and radiological indices of ^{40}K, ^{226}Ra and ^{228}Ra in crab species from Igbokoda River in the coastal area of South Western Nigeria, have been determined using gamma spectrometry method. Twenty (20) samples of three different species (Callinectes latimanus, Callinectes amnicola and Cadiosoma armatum) of crabs were collected from the River. The results obtained indicated that the highest dose rates of ^{40}K, ^{226}Ra and ^{228}Ra were associated with Callinectes latimanus while the highest annual committed effective dose of ^{40}K to man was 0.0026mSvyr^{-1} and was associated with Callinectes latimanus for ^{226}Ra (0.0068mSvyr^{-1}) and ^{228}Ra (0.0208mSvyr^{-1}). The highest excess lifetime cancer risk associated with ^{40}K, ^{226}Ra and ^{228}Ra 0.0237 x 10^{-3} 0.0728 x 10^{-3}. All the values obtained were within the limits recommended globally; indicating that there was no significant radiological health implication to the aquatic animals and man the consumer.*

Key Words: *Radionuclides, gamma spectrometry, crab, dose rate, cancer risk, health*

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1.0 Introduction

Seafood is widely consumed globally, due to their nutritional content. They are rich sources of several nutrients, fat soluble and vitamins. According to Adeyeye (2002), seafoods are also recognised for their dietary and minerals sources. Crab constitutes one of the main sources of animal protein most especially among coastal dwellers in some parts of Nigeria. They have high ash, mineral and crude fibre content (Oduro *et al.*, 2001). Akin-Oriola *et al*. (2005) have reported crabs to be one of the richest sources of mineral nutrition and that they are mostly consumed by several classes of population. Based on their nutritional significant, Adeyeye and Kenni (2008) recommended crabs as a food of preference for pregnant women. They are generally found in oceans across the globe. Sowole and Olaniyi (2018) natural radionuclides are very active chemical elements that exist in soil and water as primordial type and those that are released from the sun due to its activities as cosmogenic form of radionuclide. In the aquatic environment, radionuclides may accumulate in bottom sediment or remain in the water column in the dissolved state (Blaylock *et al.*, 1993). With this, they can subsequently accumulate in biota and be transferred through the aquatic food chain.

The study of natural radionuclides: ^{40}K, ^{226}Ra and ^{228}Ra concentration levels has been reported by Sowole (2011) for major Rivers at Sagamu where the mining of limestone along with the production of cement were taking place, in Ogun State Southwest of Nigeria. The average dose rate of all the radionuclides in the fish samples were below the recommended limit of 0.4mGy hr^{-1}. Farai and Oni (2002) investigated the presence of radionuclides in some aquatic animals across coastal area of Nigeria and found that *Cardiosoma armatum* had the highest concentration of ^{40}K, and the annual effective dose to man consuming the aquatic animals was obtained to be 0.099mSvyr^{-1}. Khan *et al*. (2007) reported radionuclides ingestion dose of 25.0µSvyr^{-1} achieved through the consumption of fish by man around the Kudankulam Nuclear Power Project site. Ingestion dose via fish consumption was also observed to exhibit mean value of 18.0μSvyr^{-1} for natural radionuclides in Chitrapuzha River, near Cochin (Haridasan *et al*., 2001). Studies conducted by Sowole *et al*. (2019) on the assessment of the level of ^{40}K, ^{226}Ra and ^{228}Ra concentrations in fish from Victoria Island lagoon in Lagos State (Southwest of Nigeria) was found to exhibit an average dose rates of 0.0049 mGy hr^{-1}, 5.32 x 10^{-7} mGy hr^{-1} and 8.96 x 10^{-13}mGy hr^{-1} for ^{40}K, ^{226}Ra and ^{228}Ra respectively. Arising from the fact that substantial evidences exit on radiological risk of consuming some seafoods, the present study is aimed at determining the activity concentrations, radiological indices, dose rates and cancer risk indices of ^{40}K, ^{226}Ra and ^{228}Ra in crab species from Igbokoda River in South West Nigeria.

2.0 Materials and Methods

The samples were analysed for ^{40}K, ^{226}Ra and ^{228}Ra using gamma spectro-photometer. 20 samples of crab samples were obtained from Igbokoda River at various locations ranging from 20 – 40m. The collected samples were sorted out into three different species, namely: *Callinectes latimanus*, *Callinectes amnicola* and *Cadiosoma armatum*. They were preserved in 40% formaldehyde in labelled containers. They were identified and grouped into their species. The samples were oven dried at 80^{0}C, pulverized, weighed and preserved in sealed plastic containers for four weeks (in order to establish secular radioactive equilibrium between the natural radionuclides and their respective progenies) (Akinloye *et al.*, 1999; Sowole, 2011).

The spectro-photometer used for radioactive analysis was a Canberra lead shielded 7.6cm x 7.6cm NaI (Tl) detector coupled to a multichannel analyzer (MCA) through a preamplifier base. The resolution of the detector is about 10% at and operates at 0.662MeV of ^{137}Cs. For the analysis of ^{40}K, ^{226}Ra and ^{228}Ra, the photo peak regions of ^{40}K (1.46 MeV), ^{214}Bi (1.76 MeV) and ^{208}TI (2.615 MeV) were respectively used.

The cylindrical plastic containers holding the samples were positioned on the high geometry 7.6 cm × 7.6 cm NaI (TI) detector. High level shielding against the environmental background radiation was achieved by counting in a Canberra 10cm thick lead castle. The counting of each sample was done for 8 hours. The areas under the photo-peaks of ^{40}K, ^{226}Ra and ^{228}Ra were calculated using the Multichannel Analyzer system.

The concentrations of the radionuclides were determined based on the measured efficiency of the detector and the net count rate under each photopeak over a period of 8 hours using equation1 (Jibiri and Ajao, 2005).

$$A = \frac{N(E_\gamma)}{\varepsilon(E_\gamma) I_\gamma M t_c} \qquad (1)$$

where N(E$_\gamma$) is the net peak area of the radionuclide of interest, ε(E$_\gamma$) is the efficiency of the detector for the γ- energy of interest, I_γ is the intensity per decay for the γ- energy of interest and M is the mass of the sample and t_c = Total counting time in seconds (28800s).

3.1 Dose rate of natural radionuclides in Crab species

The dose rates of the radionuclides in the aquatic species were determined using equation 2 of Blaylock *et al.* (1993):

$$D = 5.76 \times 10^{-4} E\, n\, \Phi C \qquad (2)$$

where E is the average emitted energy for gamma radiations (MeV), n is the proportion of transitions producing an emission of energy E, Φ is the fraction of the emitted energy absorbed, which are constants obtained from Blaylock *et al*. (1993), C is the concentration of the radionuclide of consideration and D is the dose rate of the radionuclide of consideration.

3.2 Annual committed effective dose to consumer

The annual committed effective dose (ACED) for ingestion of NORMs in crab species to man was determined using equation 3. (Tettey-Larbi *et al.*, 2013):

$$ACED = C \times DCF \times CR \qquad (3)$$

where C is the concentration of radionuclides, DCF is the dose conversion factor for ingestion (UNSCEAR, 2000) and CR is the consumption rate of intake of NORMs from crab species.

3.3 Excess Lifetime Cancer Risk to the consumers

Excess lifetime cancer risk (ELCR) to man (i.e., the consumer) was determined based on the values of the annual committed effective dose according to equation 4 (Qureshi *et al*., 2014):

$$ELCR = ACED \times LE \times RF \qquad (4)$$

where LE is life expectancy taken to be 70 years and RF is fatal risk factor per sievert which was 0.05 (ICRP, 2007)

3.0 Results and Discussion

Activity concentrations of radionuclides in crab species from the study area are shown in Table 1 while the range and mean concentrations (of activity concentrations of ^{40}K, ^{226}Ra and ^{228}Ra) and estimated dose rates in aquatic species are recorded in Tables 3 to 5 respectively. The lowest concentration of ^{40}K (64.92 ± 4.75 Bqkg^{-1}) was found in *Callinectes latimanus* while the highest concentration (124.35 ± 9.37 Bqkg^{-1}) was also from *Callinectes latimanus*, which are less than the value obtained by Farai and Oni (2002). It was also observed that *Callinectes latimanus* had the lowest and highest concentrations of ^{226}Ra; which were 2.54 ± 0.12 Bqkg^{-1} and 7.19 ± 1.03 Bqkg^{-1} respectively. However, lowest concentration of ^{228}Ra, was observed to be 4.17 ± 0.65Bqkg^{-1} in *Cadiosoma armatum* while the highest concentration of 9.24 ± 1.78Bqkg^{-1} was recorded from *Callinectes latimanus*. The highest dose rate of ^{40}K (Table 2.) was obtained in *Callinectes latimanus* (i.e., 1.12 x 10^{-2}mGyhr^{-1}) while the lowest was observed in *Callinectes latimanus* to be 5.83 x 10^{-3}mGyhr^{-1}. Also for ^{226}Ra, *Callinectes latimanus* had the highest dose rate of value 1.26 x 10^{-6}mGyhr^{-1} and the lowest was from *Callinectes latimanus* of value 4.45 x 10^{-7}mGyhr^{-1}. Concerning ^{228}Ra, the highest dose rate was obtained in *Callinectes latimanus* of value 1.10 x 10^{-12}mGyhr^{-1} and the lowest was from *Cadiosoma armatum* of value 4.97 x 10^{-13}mGyhr^{-1}.

Table 1: Activity concentrations of radionuclides in crabs

River	Sample	Specie	Activity concentrations of radionuclides in crabs (Bqkg^{-1})		
			^{40}K	^{226}Ra	^{228}Ra
ONDO	CCS_1	*Cardiosoma armatum*	113.48 ± 8.6	4.18 ± 0.65	6.29 ± 1.03
	CCS_2	*Callinectes latimanus*	97.75 ± 7.25	6.24 ± 0.98	8.78 ± 1.82
	CCS_3	*Callinectes amnicola*	105.19 ± 10.65	2.99 ± 0.03	5.22 ± 0.89
	CCS_4	*Callinectes amnicola*	87.42 ± 6.78	3.62 ± 0.41	5.95 ± 1.08
	CCS_5	*Callinectes latimanus*	124.35 ± 9.37	5.11 ± 0.45	7.31 ± 1.46
	CCS_6	*Callinectes latimanus*	103.84 ± 7.89	4.68 ± 0.72	6.01 ± 0.75
	CCS_7	*Cardiosoma armatum*	75.44 ± 8.36	3.26 ± 0.31	5.28 ± 1.11
	CCS_8	*Cardiosoma armatum*	95.05 ± 8.09	5.08 ± 0.82	4.17 ± 0.65
	CCS_9	*Callinectes latimanus*	112.97 ± 10.01	7.19 ± 1.03	9.24 ± 1.78
	CCS_{10}	*Callinectes latimanus*	84.35 ± 7.26	3.22 ± 0.61	4.26 ± 0.84
	CCS_{11}	*Cardiosoma armatum*	117.21 ±9.06	4.49 ± 0.94	5.34 ± 1.25
	CCS_{12}	*Callinectes latimanus*	76.85 ± 6.39	6.01 ± 1.24	7.62 ± 0.79
	CCS_{13}	*Callinectes amnicola*	99.46 ± 8.17	3.75 ± 0.55	6.02 ± 1.83
	CCS_{14}	*Callinectes amnicola*	120.63 ± 11.48	4.25 ± 1.13	5.62 ± 0.58
	CCS_{15}	*Callinectes latimanus*	87.19 ± 7.23	5.62 ± 0.99	4.86 ± 1.04
	CCS_{16}	*Callinectes latimanus*	92.41 ± 7.34	4.18 ± 0.61	5.72 ± 0.85
	CCS_{17}	*Cardiosoma armatum*	84.39 ± 5.26	6.35 ± 1.62	8.60 ± 1.32
	CCS_{18}	*Cardiosoma armatum*	115.06 ± 8.35	3.89 ± 0.25	5.37 ± 0.42
	CCS_{19}	*Callinectes latimanus*	64.92 ± 4.75	2.54 ± 0.12	6.09 ± 0.82
	CCS_{20}	*Callinectes latimanus*	111.25 ± 11.04	4.72 ± 0.93	7.43 ± 1.47

Table 2: Determined values of dose rates of radionuclides in crab samples

Sample	Specie	$^{40}K \times 10^{-3}$ (mGyhr^{-1})	$^{226}Ra \times 10^{-7}$ (mGyhr^{-1})	$^{228}Ra \times 10^{-13}$ (mGyhr^{-1})
CCS_1	*Cardiosoma armatum*	10.2	7.32	7.50
CCS_2	*Callinectes latimanus*	8.78	10.9	10.5
CCS_3	*Callinectes amnicola*	9.45	5.24	6.22
CCS_4	*Callinectes amnicola*	7.86	6.34	7.09
CCS_5	*Callinectes latimanus*	11.2	8.95	8.72
CCS_6	*Callinectes latimanus*	9.33	8.20	7.17
CCS_7	*Cardiosoma armatum*	6.78	5.71	6.30
CCS_8	*Cardiosoma armatum*	8.54	8.90	4.97
CCS_9	*Callinectes latimanus*	10.2	12.6	11.0
CCS_{10}	*Callinectes latimanus*	7.58	5.64	5.08
CCS_{11}	*Cardiosoma armatum*	10.5	7.87	6.37
CCS_{12}	*Callinectes latimanus*	6.91	10.5	9.09
CCS_{13}	*Callinectes amnicola*	8.94	6.57	7.18
CCS_{14}	*Callinectes amnicola*	10.8	7.44	6.70
CCS_{15}	*Callinectes latimanus*	7.84	9.84	5.80
CCS_{16}	*Callinectes latimanus*	8.30	7.32	6.82
CCS_{17}	*Cardiosoma armatum*	7.58	11.1	10.3
CCS_{18}	*Cardiosoma armatum*	10.3	6.81	6.40
CCS_{19}	*Callinectes latimanus*	5.83	4.45	7.26
CCS_{20}	*Callinectes latimanus*	9.99	8.27	8.86

Table 3: Range, mean value of activity concentration and mean dose rate of ^{40}K in crab species

Specie	Range (Bqkg^{-1})	Mean (Bqkg^{-1}) (Bqkg^{-1})	Mean dose rate x 10^{-3} (mGyhr^{-1})
Cardiosoma armatum	75.44 – 117.21	100.11 ± 7.96	8.98
Callinectes latimanus	64.92 – 124.35	95.59 ± 7.85	8.59
Callinectes amnicola	87.92 – 120.63	103.17 ± 9.27	9.28

Table 4: Range, mean value of activity concentration and mean dose rate of ^{226}Ra in crab species

Specie	Range (Bqkg^{-1})	Mean (Bqkg^{-1})	Mean dose rate x 10^{-4} (mGyhr^{-1})
Cardiosoma armatum	3.26 – 6.35	4.54 ± 0.77	0.155
Callinectes latimanus	3.22 – 7.19	4.95 ± 0.77	1.030
Callinectes amnicola	4.25 – 2.99	3.65 ± 0.53	0.033

Table 5: Range, mean value of activity concentration and mean dose rate of ^{228}Ra in crab species

Specie	Range ($Bqkg^{-1}$)	Mean ($Bqkg^{-1}$)	Mean dose rate x 10^{-12} ($mGyhr^{-1}$)
Cardiosoma armatum	4.17– 8.60	5.84 ± 0.96	3.73
Callinectes latimanus	4.26 – 9.24	6.73 ± 1.16	2.32
Callinectes amnicola	5.22 – 6.02	5.70 ± 1.10	8.75

Table 6: Determined values of annual committed effective doses (ACED) to the consumers

Sample	Specie	^{40}K ACED ($mSvyr^{-1}$)	^{226}Ra ACED ($mSvyr^{-1}$)	^{228}Ra ACED ($mSvyr^{-1}$)
CCS_1	*Cardiosoma armatum*	0.0024	0.0039	0.0141
CCS_2	*Callinectes latimanus*	0.0020	0.0059	0.0198
CCS_3	*Callinectes amnicola*	0.0022	0.0028	0.0118
CCS_4	*Callinectes amnicola*	0.0018	0.0034	0.0134
CCS_5	*Callinectes latimanus*	0.0026	0.0048	0.0165
CCS_6	*Callinectes latimanus*	0.0022	0.0044	0.0135
CCS_7	*Cardiosoma armatum*	0.0016	0.0031	0.0119
CCS_8	*Cardiosoma armatum*	0.0020	0.0048	0.0094
CCS_9	*Callinectes latimanus*	0.0024	0.0068	0.0208
CCS_{10}	*Callinectes latimanus*	0.0018	0.0030	0.0096
CCS_{11}	*Cardiosoma armatum*	0.0024	0.0042	0.0120
CCS_{12}	*Callinectes latimanus*	0.0016	0.0057	0.0172
CCS_{13}	*Callinectes amnicola*	0.0021	0.0035	0.0136
CCS_{14}	*Callinectes amnicola*	0.0025	0.0040	0.0127
CCS_{15}	*Callinectes latimanus*	0.0018	0.0053	0.0109
CCS_{16}	*Callinectes latimanus*	0.0019	0.0039	0.0129
CCS_{17}	*Cardiosoma armatum*	0.0018	0.0060	0.0194
CCS_{18}	*Cardiosoma armatum*	0.0024	0.0037	0.0121
CCS_{19}	*Callinectes latimanus*	0.0014	0.0024	0.0137
CCS_{20}	*Callinectes latimanus*	0.0023	0.0044	0.0167

Table 7: Determined values of excess lifetime cancer risk (ELCR) to the consumers

Sample	Specie	^{40}K ELCR x 10^{-3}	^{226}Ra ELCR x 10^{-3}	^{228}Ra ELCR x 10^{-3}
CCS_1	*Cardiosoma armatum*	0.0083	0.0138	0.0496
CCS_2	*Callinectes latimanus*	0.0071	0.0206	0.0692
CCS_3	*Callinectes amnicola*	0.0077	0.0099	0.0411
CCS_4	*Callinectes amnicola*	0.0064	0.0119	0.0469
CCS_5	*Callinectes latimanus*	0.0091	0.0168	0.0576
CCS_6	*Callinectes latimanus*	0.0076	0.0154	0.0474
CCS_7	*Cardiosoma armatum*	0.0055	0.0107	0.0416

CCS_{8}	*Cardiosoma armatum*	0.0069	0.0167	0.0329
CCS_{9}	*Callinectes latimanus*	0.0082	0.0237	0.0728
CCS_{10}	*Callinectes latimanus*	0.0062	0.0106	0.0336
CCS_{11}	*Cardiosoma armatum*	0.0086	0.0148	0.0421
CCS_{12}	*Callinectes latimanus*	0.0056	0.0198	0.0600
CCS_{13}	*Callinectes amnicola*	0.0073	0.0124	0.0474
CCS_{14}	*Callinectes amnicola*	0.0088	0.0139	0.0443
CCS_{15}	*Callinectes latimanus*	0.0064	0.0185	0.0383
CCS_{16}	*Callinectes latimanus*	0.0067	0.0138	0.0451
CCS_{17}	*Cardiosoma armatum*	0.0062	0.0209	0.0678
CCS_{18}	*Cardiosoma armatum*	0.0084	0.0128	0.0423
CCS_{19}	*Callinectes latimanus*	0.0047	0.0084	0.0479
CCS_{20}	*Callinectes latimanus*	0.0081	0.0155	0.0585

The highest mean dose rate of ^{40}K was recorded for *Callinectes amnicola* (9.28 x 10^{-3} $mGyhr^{-1)}$ as recorded in Table 3. On the other hand, ^{226}Ra (Table 4) exhibited highest and lowest concentrations of 1.03 x 10^{-4} $mGyhr^{-1}$ and 8.75 x 10^{-12} $mGyhr^{-1}$ in *Callinectes latimanus* and *Callinectes amnicola* respectively. The observed concentrations are below the recommended 0.4 $mGyhr^{-1}$ limit (Blaylock *et* al., 1993; NCRP, 1991). From the results obtained in this work, the highest annual committed effective dose of ^{40}K (Table 6) to man was 0.0026 $mSvyr^{-1}$ and was recorded in *Callinectes latimanus* which was less than the result obtained by Farai and Oni (2002). Similar data for ^{226}Ra was 0.0068 $mSvyr^{-1}$ while that of ^{228}Ra was 0.0208 $mSvyr^{-1}$.These values are also below the recommended limit of 1.0 $mSvyr^{-1}$ (ICRP, 2007). The highest ELCR of ^{40}K to the consumers was 0.0091 x 10^{-3} as shown in Table 7. The results for other radionuclides were ^{226}Ra which had 0.0237 x 10^{-3} and ^{228}Ra which recorded 0.0728 x 10^{-3}. All the calculated values were below the recommended limit of 0.29 x 10^{-3} (UNSCEAR, 2000). Therefore, there is no current radionuclides threat in the study area.

4.0 Conclusion

Radiological assessment of natural radionuclides in crab species from Igbokoda River had shown that the dose rates of the primordial radionuclides in the aquatic species were within the dose rate limit of 0.4 $mGyhr^{-1}$ recommended by NCRP (1991) as reported by Blaylock et al. (1993). Similarly, the values of annual committed effective doses were below 1.0$mSvyr^{-1}$ limit recommended by ICRP (2007). Excess lifetime cancer risk values to the consumers were below the recommended limit of 0.29 x 10^{-3} (UNSCEAR, 2000). All the values of radiological parameters obtained showed that there was no significant radiological health implication to the aquatic animals and man that consumes them. In addition, all the results in this research work could serve as baseline for further research work in the study area.

5.0 References

Adeyeye, E. I. (2002). Determination of the chemical composition of the nutritionally valuable parts of male and female common west-African fresh water crab Sudananautes africanus africanus. *International Journal of Food Science Nutrition, 53*, pp.189-196.

Adeyeye, E. I., & Kenni, A. M. (2008). The relationship in the amino acid of the whole body, flesh and exoskeleton of common West African fresh water male Crab Sudananautes africanus africanus. *Pakistan Journal of Nutrition*, *7*, pp.748-752.

Akinloye, M. K., Olomo, J. B., & Olubunmi, P. A. (1999). Meat and poultry consumption contribution to the natural radionuclide intake of the inhabitants of the Obafemi Awolowo University, Ile-Ife, Nigeria, *Nuclear*

Instruments and Methods in Physics Research, A422, 795-800.

Akin-Oriola, A., Anetekhai, M. A., & Olowonirejuaro, K. (2005). Morphometric and meristic studies in two crabs: Cardiosoma armatum and Callinectes pallidus. *Turkish Journal of Fisheries and Aquatic Sciences, 5*, pp. 85-89.

Blaylock, B. G., Frank, M. L., & O'Neal B. R. (1993). *Methodology for Estimating Radiation Dose Rates to Freshwater Biota Exposed to Radionuclides in the Environment*, ES/ER/TM-78, Oak Ridge Natl. Lab., Oak Ridge, Tenn.

Farai, I. P., & Oni, O. M. (2002). Natural radionuclide concentrations in aquatic species and absorbed dose equivalent to the dwellers of the coastal areas of Nigeria. *Nigerian Journal of Physics, 14, 2*, pp. 94-98.

Haridasan, P. P., Paul, A. C., & Desai, M. V. M. (2001). Natural radionuclides in the aquatic environment of a phosphogypsum disposal area. *Journal of Environmental Radioactivity*, *53*, pp. 155–165.

ICRP (International Commission on Radiological Protection) (2007). Recommendations of the ICRP Publication, 103; Annuals ICRP, *37*, pp. 2–4.

Jibiri, N. N., & Ajao, A. O. (2005). Natural activities of ^{40}K ^{238}U and ^{232}Th in elephant grass (Pennisetum purpureum) in Ibadan metropolis, Nigeria. *Journal of Environmental Radioactivity*, 78, pp. 105-111

Khan, M. F., Raj, Y. L., Ross, E. M., & Wesley, S. G. **(**2007)**.** Concentration of natural radionuclides (^{40}K ^{228}Ra and ^{226}Ra) in seafood and their dose. *International Journal of Low Radiation*, *4*, pp. 217–231.

NCRP (National Council on Radiation Protection and Measurements) (1991). *Effects of Ionizing radiation on aquatic organisms,* NCRP Report No. 109, Bethesda, Maryland.

Oduro, W., Ellis, W. O., Oduro, I., & Tetteh, D. (2001). Nutritional quality of selected Ghanaian crab species. *Journal of the Ghana Science Association*, *3*, 3, pp. 37-40.

Qureshi, A. A., Tariq, S., Din, K. U., Manzoor, S., Calligaris, C., & Waheed, A. (2014). Evaluation of excessive lifetime cancer risk due to natural radioactivity in the rivers sediments of Northern Pakistan. *Journal of radiation research and applied sciences*, 7, 4, pp. 438-447

Sowole, O. **(**2011). Dose rates of natural radionuclides in fishes from Rivers in Sagamu Ogun State Nigeria. *Canadian Journal of Pure and Applied Sciences*, 5, 3, pp.1729 – 1732.

Sowole, O., & Olaniyi, O. E. **(**2018). Assessment of radioactivity concentrations and effective of radionuclides in selected fruits from major markets at Ijebu-Ode in Ogun State, Southwest of Nigeria. *Journal of Applied Science and Environmental Management*, 22, 1, pp. 95-98.

Sowole, O., Egunjobi, K. A., & Amodu, F. R. (2019). Determination of annual dose rate of natural radionuclides in Man from fishes in Victoria Island Lagoon, Southwest of Nigeria**.** *International Journal of Oceans and Oceanography,* 13, 1, pp. 57 – 64

Tettey-Larbi, L., Darko, E. O., Schandorf, C., & Appiah, A. A. (2013). Natural radioactivity levels of some medicinal plants commonly used in Ghana. *Springer Plus*, 2, 1, pp. 1-9

UNSCEAR (United Nations Scientific Committee on Effects of Atomic Radiation) (2000). Sources and Effects of ionizing radiation, Annex B, New York.

Conflict of Interest

The authors declared no conflict of interest.