ACTIVITY CONCENTRATION OF NATURAL RADIONUCLIDES AND ITS ASSOCIATED RADIOLOGICAL HAZARDS IN FISH (*BONGA SHAD*) SAMPLES OF THE COASTAL COMMUNITIES OF OKRIKA, RIVERS STATE, NIGERIA

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Abstract

A study was conducted of radionuclides concentration and radiological hazards in Fish (Bonga Shad) samples between latitude: 4^0.43'44" N and 4^0.45'57" N and longitude range of of 7^0.3'20" E to 7^0.6'42" E of the Coastal communities of Okrika, in Rivers State, Nigeria using gamma spectroscopy method with NaI (TI) detector. The average activity concentration of radionuclides of ranged from 104.88 to 1271.04 with a mean value of 551.47±336.50 Bq/Kg, varied from 1.04 to 49.35 with a mean value of 13.67±14.47 Bq/Kg and ranged from 4.47 to 16.62 with a mean value of 8.81±3.32 Bq/Kg in terms of ^{40}K, ^{238}U, and ^{232}Th respectively. The Radium equivalent (Raeq) ranged from 30.05 to 170.99 with a mean value of 68.73Bq/Kg which is lesser than the recommended limit of 370 Bq/Kg. The Total effective dose ranged from 22.49 to 106.49 with a mean value of 38.58±27.54 $\mu Sv/y$, which is below the safe limit of 70$\mu Sv/y$ (UNSCEAR) and far lesser than the recommended limit of 1mSv/y(ICRP). The Internal Hazard index (H_{in}) ranged from 0.11 to 0.60 with a mean value of 0.22±0.16 which is below the safe limit of 1.0 (UNSCEAR). These values implies that the exposure or ingestion of Fish (Bonga Shad) samples of coastal communities of Okrika pose no radiological risks.

Keywords: Coastal Communities, Natural Radionuclides, Total Effective Dose, Internal Hazard.

Introduction

Radiation is everywhere and man is constantly exposed to both natural and anthropogenic sources, radionuclides in form of radiation can be eaten swallowed inhaled or ingested. Naturally abundant radionuclides (^{238}U,

^{232}Th and ^{40}K) in the environment could be originate by the use of fertilizers on farmlands, research and medical facilities, nuclear weapon testing, pharmaceutical products and large quantities release into the environment from major sources like soil, water and sediment (Samavat *et al.,* 2006; Khan *et al.,* 2007; Adamu *et al.,* 2013; Orosun 2018).

The presence of radionuclides in contaminate environment has the potential to affects the quality of fresh water, crops and vegetables grown on soil, as well as the fish obtained in rivers and other dietary products consumed by man. Within riverine or coastal communities, it has been a well-known fact that fish consumption has been a major source of protein to man in diet and a main source of livelihood for many fishermen living within coastal borders especially to the inhabitants of the coastal communities of Okrika. In addition, the consumption of these fish products could pose radiological health threat to the populace, especially when these fish products are contaminated with radioactive substances or toxic chemical compounds. This also refers that the consumption of these radionuclides from contaminated fish could leads to stochastic effect on human health. The presence of radioactivity in contaminated environment can be attributed to naturally occurring radionuclides in the environment and artificially sources induced by human activities (IAEA, 1996; Goddard, 2003; Jibiri, *et al.*,2007; UNSCEAR,2000; FAO, 2010).

The disintegration of these unstable nucleus into another nucleus to become more stable is always associated with the release of an α or β particle, and sometimes electromagnetic radiations (γ or x-ray photons). If the transition is spontaneous, the process is called natural radioactivity but if the transition is induced by humans by the bombardment of particles or radiation, then it is called artificial radioactivity commonly used in nuclear warfare, medical facilities, mining activities research centers. The emitted particles from these radionuclides ionizing in nature. Ionizing radiations have the potentials to destroy cells in tissues and upset the natural chromosome balance of the body. The severity of the damages depends solely on the absorbing tissue or organ, source and nature of radiation and the dose intake (Orosun *et al.*, 2018). These dispersed radionuclides mostly find their way into water bodies, affecting the ecosystem directly into the food chain and affect humans by the consumption of fish products (Tahir *et al.,* 2010; Bolaji *et al.,* 2015; Khandaker *et al.,* 2015; Fasae, 2018). In addition, unregulated disposal of radioactive sources, nuclear reactor spent fuel elements and the indiscriminate discharge of untreated industrial effluents and oil-spills into water bodies pose significant health risks to human existence. The effluents sometimes contain radioactive nuclides and toxic contaminants which can accumulate to dangerous levels in the environment especially the receiving water bodies on the coast communities of Okrika. These radionuclides degrade water quality and accumulate in fish tissue. Consequently, the consumption on fish from a polluted water body poses long-term health risks to the public. In severe cases, it might lead to failure of vital organs such as liver, kidneys or causing cancer of the lungs

(Adeleye, 2013; Agbalaba *et al.,* 2011; Ademola and Ehiedu 2010; Erenturk *et al.,* 2014; Khandaker *et al.*, 2015 Babatunde, *et al.,* 2015; Khandaker *et al.,* 2016;).

Fish plays an active role in coastal communities, based on this fact, the exposure to radionuclides as a result of consumption is of great concern, as it may give rooms to radiological health threat especially in areas where detail assessment has not been carried out. Various research has been reviewed in fish samples in different location as Tabulated in Table 1. Therefore, this research is focus at assessing the radiological hazard resulting from the consumption of fish sample (Bonga Shad) of the coastal communities of Okrika.

Materials and Methods

Study Area

Okrika town is a renown coastal community in River State. It lies between latitude: 4^0.43'44" N and 4^0.45'57" N and range from longitude of 7^0.3'20" E to 7^0.6'42" E (Sokari, 2018). Fishing is one one the major occupation within the study area as fish consumption account for the major intake of proteins to the populace. The coastal town is a host to few multinational companies, and other operations such as sea-vessels maintenance are carried out within the study area. The sampled locations are indicated in Figure 1.

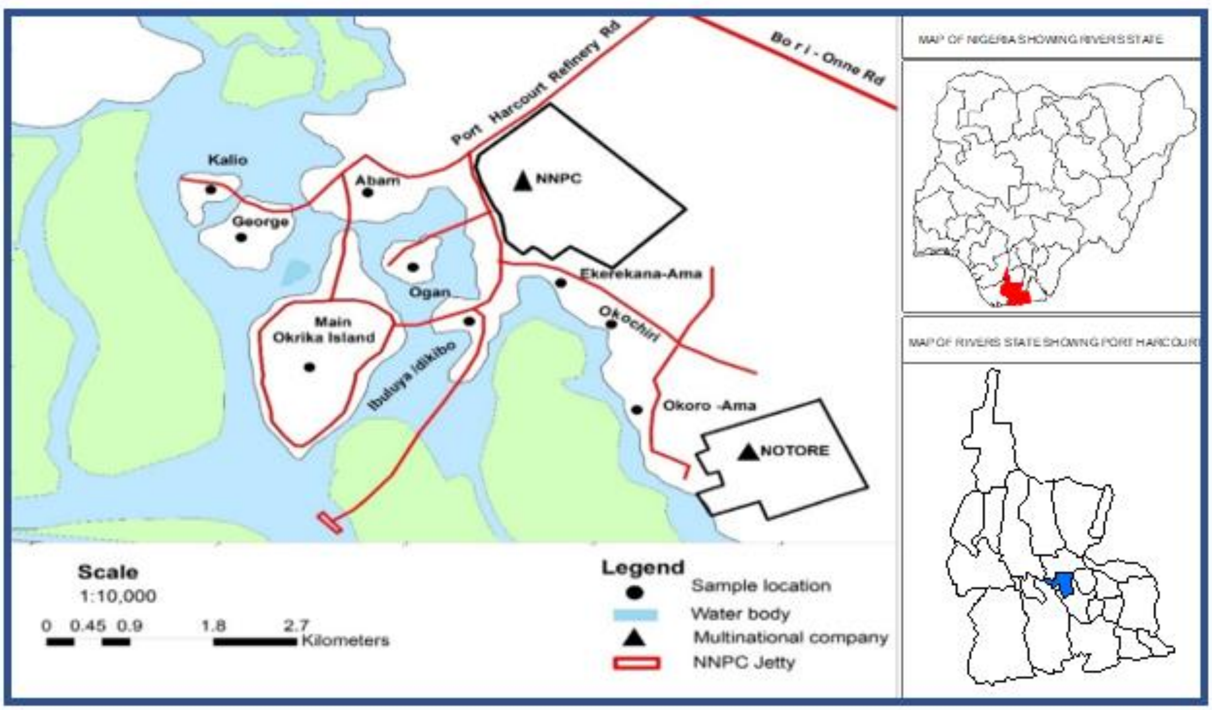

Figure 1: Modified Google Map of Okrika LGA Showing the Study Area

Sample Collection and Preparation

Nine (9) communities of Okrika were accessed, in each of the communities Two (2) Fish samples were caught with the help of the local Fishers men with the use of their boats and fishing nets. These Fish samples were oven-dried at a controlled temperature of 70^0 until there was no detectable change in the mass of the samples (Ogundele et al., 2020), and then pulverised to fine grains to ensure homogeneity and weighted to 300 grams per sample (dry weight). Each sample was well package and labelled and taken to Nigeria Nuclear Regulatory Authority (NNRA) in University of Ibadan. In Total Eighteen (18) samples were obtained from the nine (9) coastal communities, it was kept for several days for its radon its daughter progenies to reach secular equilibrium, prior to NaI (Ti) Gamma-Ray Spectroscopy analysis.

Gamma-Ray Spectroscopy

The activity concentration measurement was determined using a thallium activated Canberra vertical high purity 2″×2″ Sodium iodide NaI(TI) detector connected to ORTEC 456 Digi base amplifier. The detector was connected to a computer program MAESTRO window that matched gamma energies to a library of possible isotopes according to IAEA standard. The detector was shielded by 15cm thick lead on all four sides and 10 cm thick on top. The energy resolution of 2.0 keV and relative efficiency of 33% at 1.33Mev was achieved in the system with the counting time of 10800 seconds, Sodium iodide detector were used.

Parameters for Fish Samples

Radium equivalent activity ($Raeq$)

The Raeq measures the hazard associated with the presence of ^{238}U, ^{232}Th and ^{40}K radionuclides in a material. It is based on the assumption, that 10 Bq /kg of ^{238}U, 7 Bq /kg of ^{232}Th 130 Bq/kg of ^{40}K produce the same gamma (γ) dose rate. (Omowumi, 2020). The radium equivalent concept allows a single index or number to describe the gamma output from different mixture of the aforementioned radioisotopes distributed in most of environmental materials throughout the world. So that, for uniformity with respect to the exposure to gamma. radiation UNSCEAR (2000), has defined the radium equivalent activity as expressed in equation 1.

$$Raeq\ (Bq/kg) = A_U + 1.43\ A_{Th} + 0.077\ A_K \qquad (1)$$

Where AU, ATh and AK are the activity concentration of U-238, Th-232 and K-40 in (Bq/kg). 1, 1.43 and 0.077 are the activity conversion rates of uranium, thorium, and potassium respectively.

External and Internal Hazard Indices

Internal Hazard Index (H_{in})

The internal radiation exposure is quantified by the Internal Hazard Index (Hin) given by UNSCEAR (2000)

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (2)$$

The internal exposure to radon Rn-222 and its decay products is controlled by internal hazard index (Hin) and for safe use UNSCEAR (2000) provided that the value of the above indexes must be less than unity for the radiation hazard to be negligible.

Effective Dose (D)

The effective Dose (ingested) D value in fish food was calculated using equation 3 (Samavat *et al.*, 2006; Jibiri *et al.*, 2007).

$$D\ (\mu Sv\ y\text{-}1) = Df \times U \times (Cd \times h) \qquad (3)$$

where, Df is the dose coefficient (Sv/Bq) which are 2.8×10^{-7}, 2.2×10^{-7}, and 6.2×10^{-9} Sv /Bq for ^{238}U, ^{232}Th, and ^{40}K respectively (IAEA, 1996), U is the annual per capita fish consumption in Nigeria taken as 9.8 kg y-1 (USAID, 2010), Cd is the activity concentration of the radionuclide in dried fish sample (Bq/kg), h is the ratio of dried to fresh fish consumption in Nigeria estimated at 30:70 (Adamu *et al.,* 2013).

Results and Discussions

The results of the activity concentration of fish samples are presented in Table 2. The average activity concentration of radionuclides ranges from 104.88 to 1271.04 with a mean value of 551.47±336.50 Bq/Kg, varied from 1.04 to 49.35 with a mean value of 13.67±14.47 Bq/Kg and range from 4.47 to 16.62 with a mean value of 8.81±3.32 Bq/Kg in terms of ^{40}K, ^{238}U, and ^{232}Th respectively as tabulated in Table 3. The radionuclides are of the order ^{40}K> ^{238}U> ^{232}Th. This order is similar to the work previously reported by (Alam *et al.,* 1995; Ogundele *et al.,* 2020; Adeleye *et al.,* 2020). Figures 2-4 show the contours of the spatial distribution of ^{238}U, ^{232}Th and ^{40}K in Fish samples obtained within the study location. North-East direction has a peak concentration of the aforementioned radionuclides, but there is general decrease over other parts of the study area, but the least minimal concentration is highly significant towards the South-East region of the study location.

Figures 5-7 show positive correlation of ^{238}U and Ra_{eq}, ^{232}Th and Ra_{eq}, and ^{40}K and Ra_{eq} activity in Fish samples respectively. ^{238}U and Ra_{eq} has the strongest correlation of R^2 = 0.9722, followed by ^{238}U and Ra_{eq} having correlation coefficient of R^2 = 0.7923 and lastly, ^{232}Th and Ra_{eq} with correlation coefficient of R^2 = 0.7604. This strong correlation suggests that the origin from the radionuclides in Fish samples suggest the radionuclides might originate from the same origin. Fig. 8 shows the percentage contribution of ^{238} U, ^{232} Th and ^{40} K activity in Fish samples. The distribution of the percentage contribution is of the order ^{232} Th < ^{238} U < ^{40} K.

Table 4 shows the total effective dose rate and Internal Hazard index in fish sample. The effective dose rate in ^{238}U ranged from 1.22 $\mu Sv/y$ in Okoro-Ama to 58.04 $\mu Sv/y$ in George-Ama with a mean value of 16.08±17.03 $\mu Sv/y$. Also, the effective dose rate in ^{232}Th varied from 4.13 $\mu Sv/y$ in Abam/Igbiri-Ama to 15.36 $\mu Sv/y$ in George-Ama with a mean value of 8.14±3.07 $\mu Sv/y$. While the effective dose date in ^{40}K ranged from 2.73 $\mu Sv/y$ in Ibuluya/Dikibo to 33.10 $\mu Sv/y$ in George-Ama with a mean value of 14.36±8.76 $\mu Sv/y$. The total effective dose from the ingestion of Fish from the coastal communities range from 22.51 to 106.49 with a mean value of 38.58±27.54 $\mu Sv/y$ which is lesser than the acceptable limit of 70 $\mu Sv/y$ (UNSCEAR) and much lower than the standard value of 1 mSv/y as recommended by ICRP for the general public as indicated in Fig.10.

The Internal hazard (H_{in}) ranged from 0.17 to 0.60 with a mean value of 0.22±0.16 which is lower than the acceptable limit of 1.0 (UNSCEAR, 2000) as display in Fig.11 This implies that the internal exposure to radon and its progenies in indoor environment pose no radiological health threat.

Table 5 gives the Spearman rank correlation of of radionuclides and radiological hazard in Fish samples of the Coastal communities of Okrika using two tail analysis and significant level of 0.5.

Table 1: Comparison of Activity Concentration in Fish with other Authors

Location	Sample	Activity Concentration Bq/Kg			Reference
		^{40}K	^{238}U	^{232}Th	
Marine Fish Bay, (Bengal)	20 Marine species	41.015	1.025	1.26	Alam *et al.,* 1995
Eko-Ende Dam, (Nigeria)	*Oreochromis niloticus*	162.45±11.36	34.04± 5.26	26.55±4.77	
	Chrysichthys auratus	136.87±10.64	28.77± 4.80	21.52±3.37	Ogundele *et al.* ,2020
Borikiri, Lagos (Nigeria)	Marine Croaker (Borikiri) PH	1767.19 - 2305.84	54.42 – 74.75	10.43 – 299.33	Adeleye *et al,* 2020
Okrika, Nigeria	***Bonga Shad***	**551.47±336.50**	**13.67±14.47**	**8.81±3.32**	**This work**

Table 2: Activity Concentration in Fish samples

S/N	Location	SOIL	ACTIVITY CONCENTRATION (Bq/Kg)			
			K-40	U-238	Th-232	Raeq
1	Main Okika Island-1	MOI/F-1	753.65±52.90	BDL	10.39±1.00	72.89
2	Main Okika Island-2	MOI/F -2	865.68±60.78	20.88±4.26	9.89±0.95	101.68
3	Ogan-Ama-1	OGA/F -1	188.90±13.41	3.93±0.84	6.50±0.63	27.77
4	Ogan-Ama-2	OGA/F -2	595.70±41.81	BDL	10.10±0.97	60.31
5	Kalio-Ama-1	KAL/F -1	642.56±45.12	15.56±3.18	8.17±0.79	76.72
6	Kalio-Ama-2	KAL/F -2	344.42±24.17	6.57±1.34	9.25±0.89	46.32
7	Okochiri-1	OKC/F -1	251.36±17.96	10.74±2.38	9.01±0.88	42.98
8	Okochiri-2	OKC/F -2	545.63±38.31	BDL	8.54±0.82	54.23
9	Ibuluya/Dikibo-1	IBU/F -1	BDL	BDL	7.53±0.73	10.77
10	Ibuluya/Dikibo-2	IBU/F -2	104.88±7.53	10.50±2.30	8.52±0.83	30.76
11	Abam/Igbiri-1	ABM/F -1	168.32±11.82	1.63±0.33	5.73±0.60	22.78
12	Abam/Igbiri-2	ABM/F -2	490.93±34.50	16.10±3.30	3.20±0.31	58.48
13	George-Ama-1	GEG/F -1	1842.73±129.40	49.35±10.10	23.32±2.24	224.59
14	George-Ama-2	GEG/F -2	699.34±49.10	BDL	9.92±0.95	68.03
15	Okoro-Ama-1	OKR/F -1	725.63±50.94	BDL	8.02±0.77	67.34
16	Okoro-Ama-2	OKR/F -2	509.19±36.32	1.04±0.24	5.22±0.51	47.71
17	Ekerekana-1	EKE/F -1	540.70±37.96	BDL	5.81±0.60	49.94
18	Ekerekana-2	EKE/F -2	495.94±34.83	6.70±1.40	9.6±0.92	58.62
19	Control-1	MOI/F-1	753.65±52.90	BDL	10.39±1.00	72.89
20	Control-2	MOI/F -2	865.68±60.78	20.88±4.26	9.89±0.95	101.68

BDL= below detectable limit

Table 3: Mean activity concentration in Fish samples

S/N	Location	K-40	U-238	Th-232	Reaq
		MEAN ACTIVITY CONCENTRATION (Bq/Kg)			
1	Main Okika Island	837.67	20.88	10.02	99.70
2	Ogan-Ama	392.30	3.93	8.30	46.01
3	Kalio-Ama	493.49	11.07	8.71	61.52
4	Okochiri	398.50	10.74	8.78	53.97
5	Ibuluya/Dikibo	104.88	10.50	8.03	30.05
6	Abam/Igbiri	329.63	8.87	4.47	40.63
7	George-Ama	1271.04	49.35	16.62	170.99
8	Okoro-Ama	617.41	1.04	6.62	58.05
9	Ekerekana-Ama	518.32	6.70	7.71	57.63
	Mean	**551.47±336.50**	**13.67±14.47**	**8.81±3.32**	**68.73±42.90**
	UNSCEAR (2000)				**370**
	BDL = below detectable limit				

Table 4: Effective Dose Rate and Internal Hazard Index in Fish samples

S/N	Location	Effective Dose Rate in $\mu Sv/y$ U-238	Effective Dose Rate in $\mu Sv/y$ Th-232	Effective Dose Rate in $\mu Sv/y$ K-238	Total Effective Dose Rate in $\mu Sv/y$	H_{in}
1	Main Okika Island	24.55	9.25	21.81	55.62	0.33
2	Ogan-Ama	4.62	7.67	10.22	22.51	0.13
3	Kalio-Ama	13.01	8.05	12.85	33.91	0.20
4	Okochiri	12.63	8.11	10.38	31.12	0.17
5	Ibuluya/Dikibo	12.35	7.42	2.73	22.49	0.11
6	Abam/Igbiri	10.43	4.13	8.58	23.13	0.13
7	George-Ama	58.04	15.36	33.10	106.49	0.60
8	Okoro-Ama	1.22	6.12	16.08	23.42	0.16
9	Ekerekana-Ama	7.88	7.12	13.50	28.50	0.17
	Mean				**38.58±27.54**	**0.22±0.16**
	UNSCEAR ($\mu Sv/y$)				**70**	**1**
	ICRP (mSv/y)				**1**	

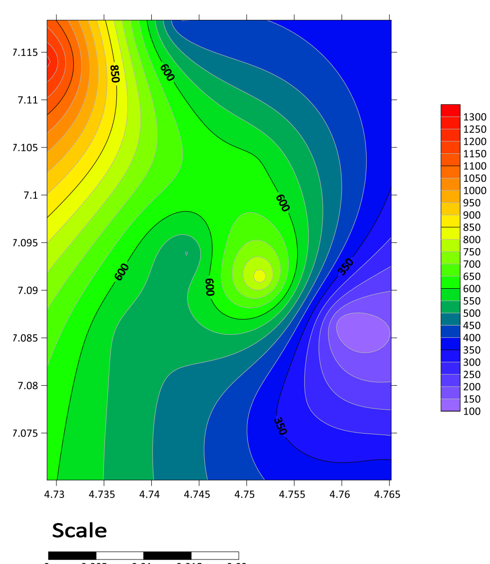

Fig 2: Contour map of the spatial distribution of ^{238}U in Fish samples of study area

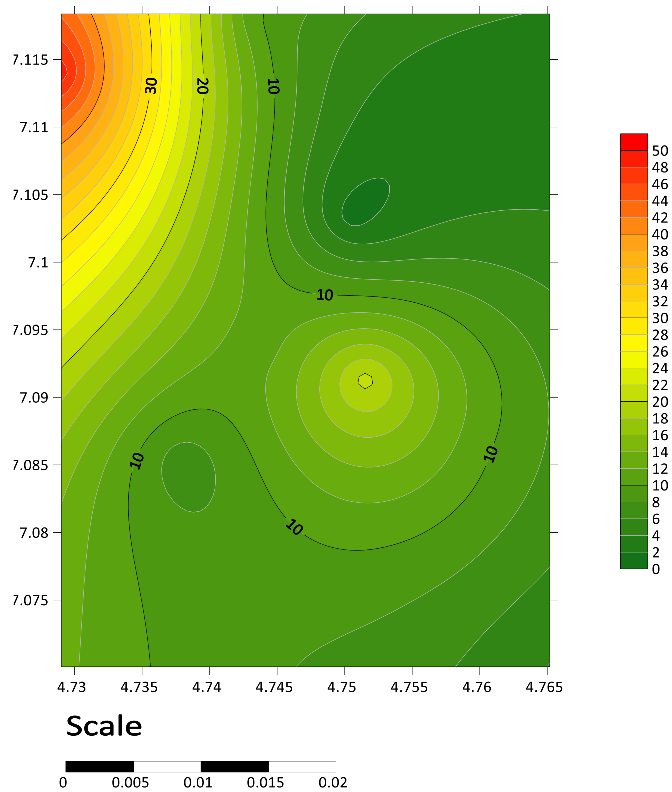

Fig 3: Contour map of the spatial distribution of ^{232}Th in Fish samples of study area

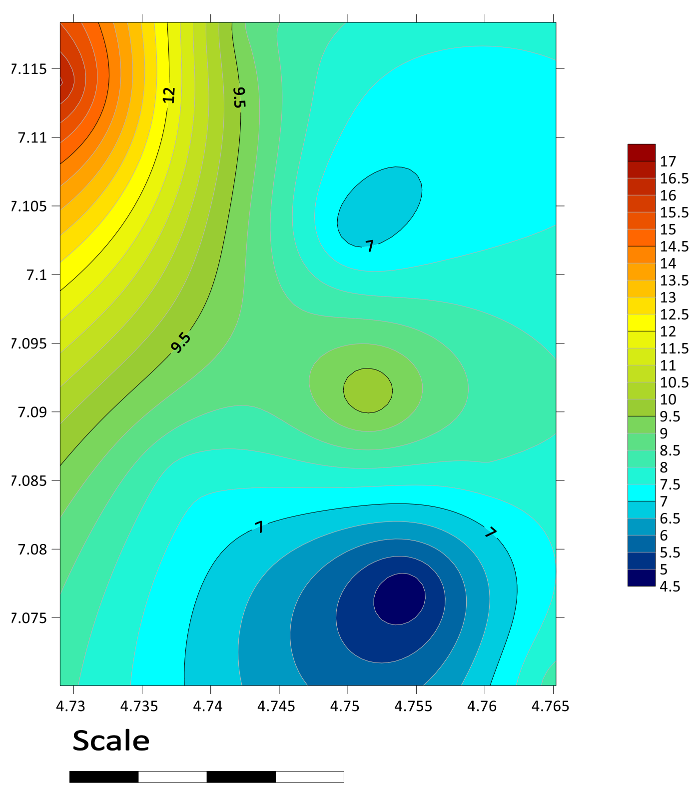

Fig 4: Contour map of the spatial distribution of ^{40} K in Fish samples of study area

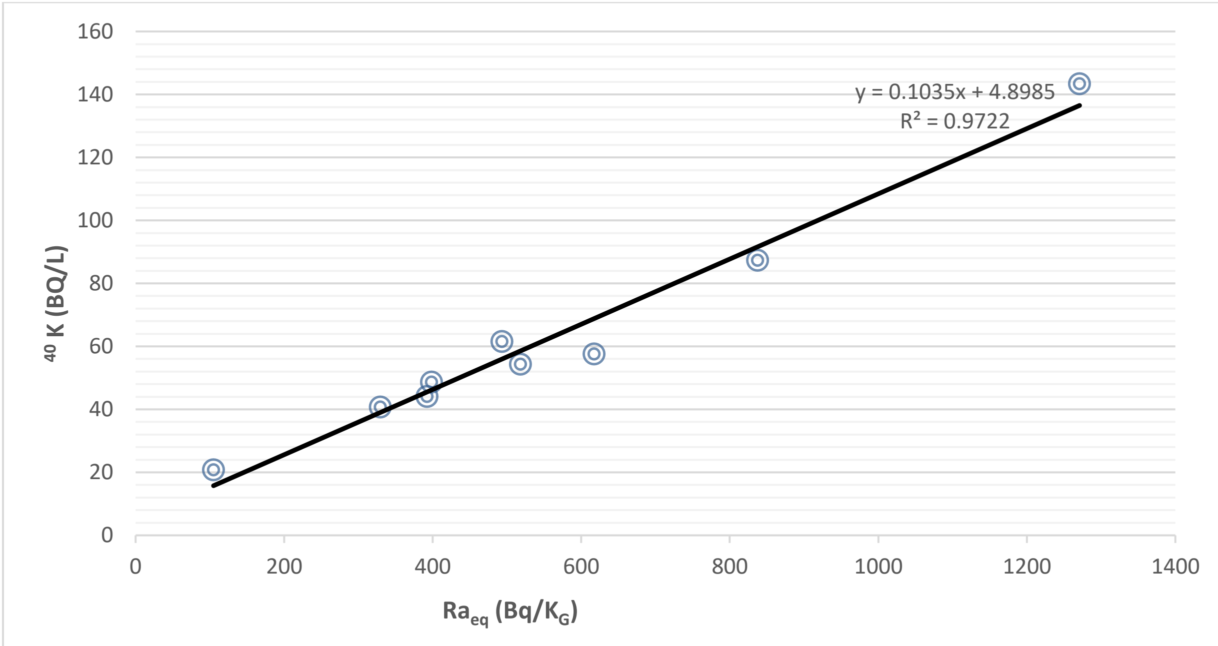

Fig 5: Correlation of ^{40}K and Ra_{eq} activity in Fish samples

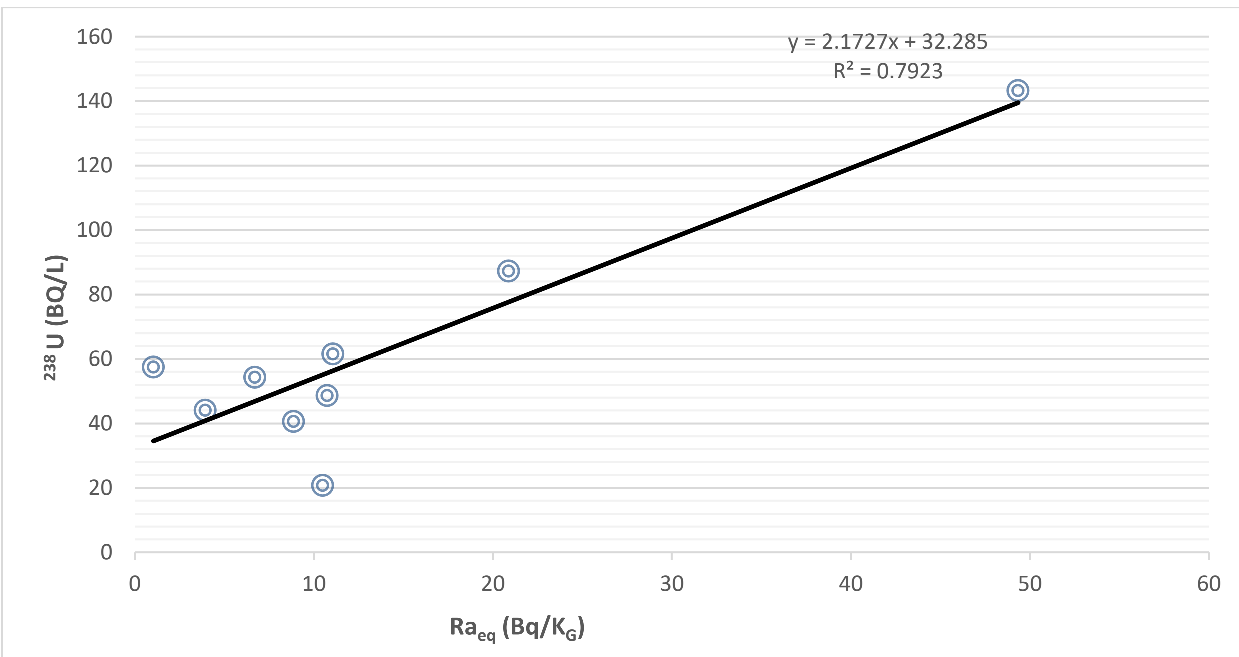

Fig 6: Correlation of ^{238}U and Ra_{eq} activity in Fish samples

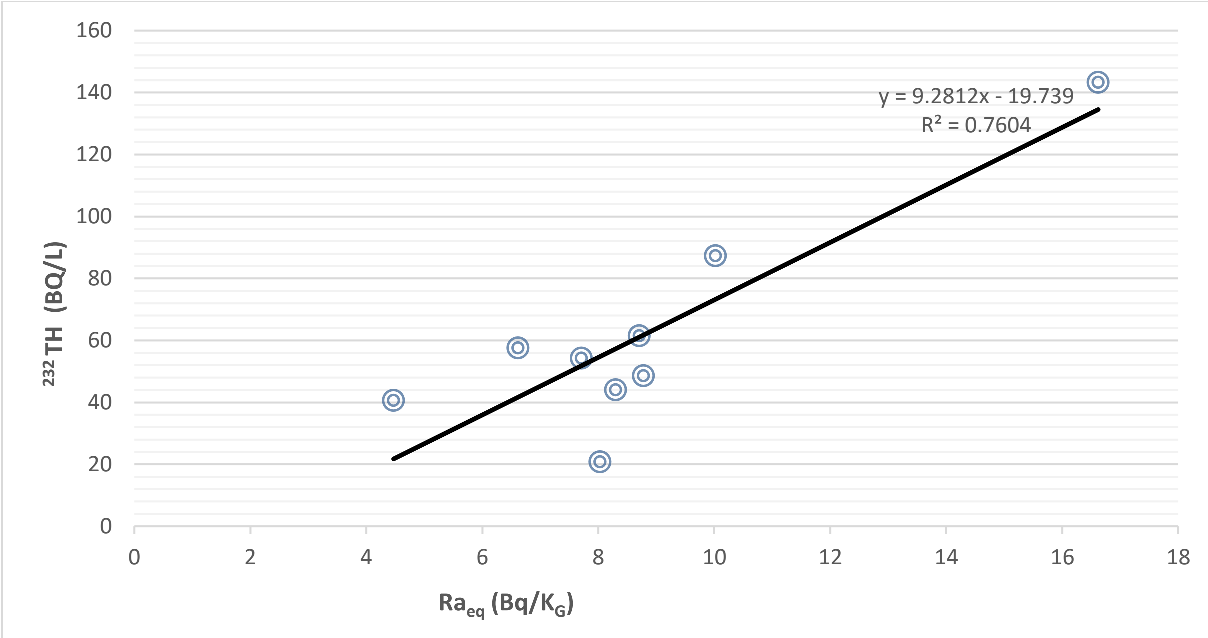

Fig 7: Correlation of ^{232}Th and Ra_{eq} activity in Fish samples

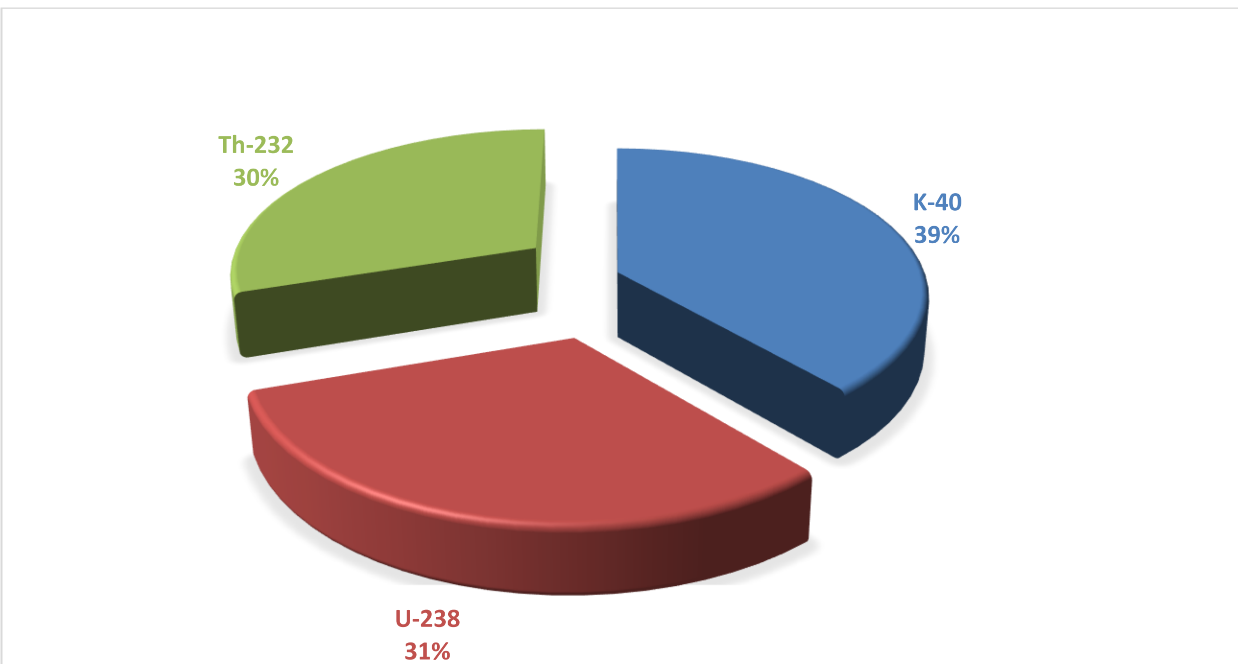

Fig 8: Percentage Contribution of ^{238} U, ^{232} Th and ^{40} K activity in Fish samples

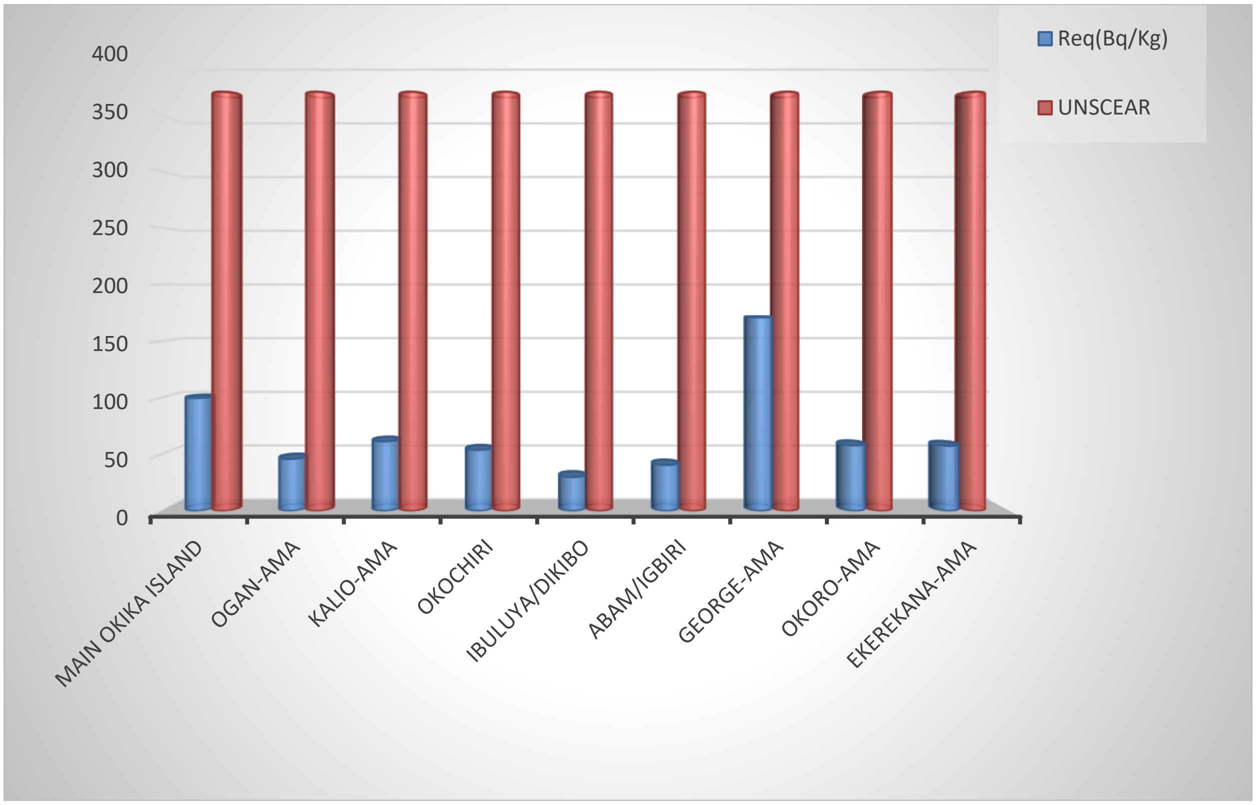

Fig 9: Comparison of Req (Bq/Kg) in Fish samples with with world average., UNSCEAR, 2000

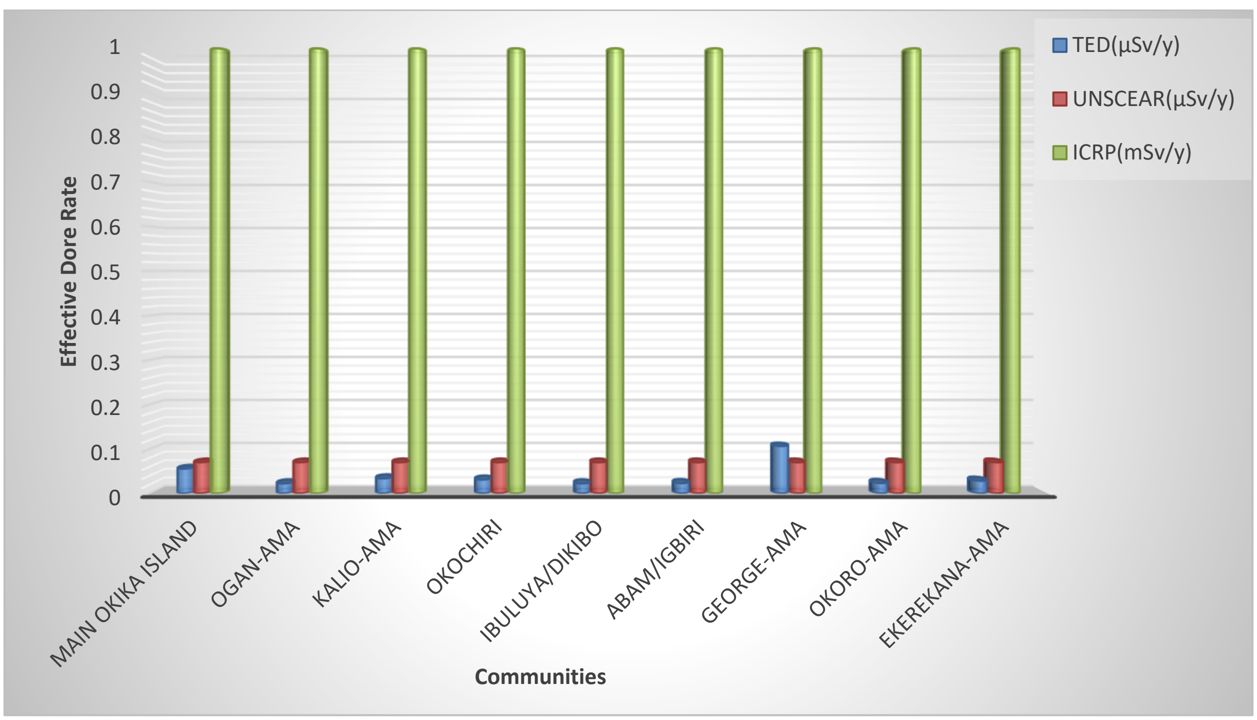

Fig 10: Comparison of Total Effective Dose in Fish samples with world average., UNSCEAR, 2000

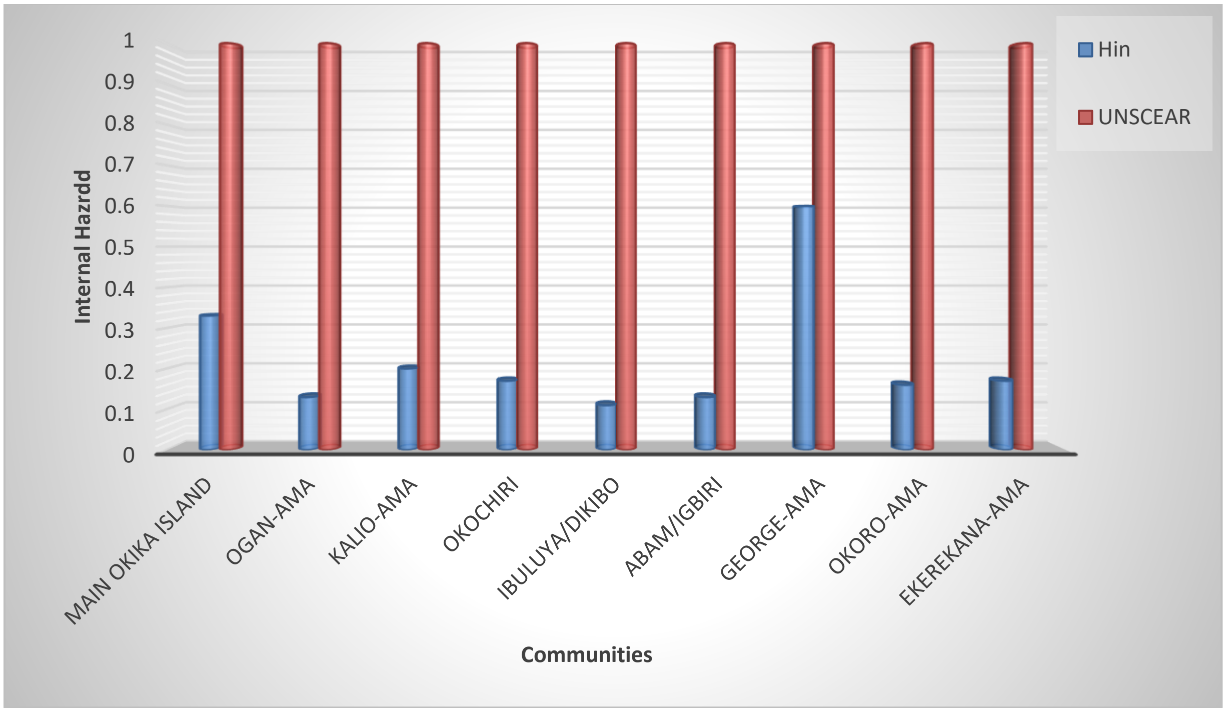

Fig 11: Comparison of Total Effective Dose in Fish samples with world average., UNSCEAR, 2000

Table 5: Spearman rank correlation of Radionuclides and Radiological hazard in Fish samples

S/N	^{40}K	^{238}U	^{232}Th	Raeq	TED (μSvy)	H_{in}
^{40}K	1					
^{238}U	0.383	1				
^{232}Th	0.517	0.817	1			
Raeq	0.950	0.550	0.633	1		
TED (μSvy)	0.833	0.750	0.733	0.917	1	
H_{in}	0.866	0.714	0.740	0.941	0.992	1

Conclusion

The radionuclides and computed radiological hazard in Fish (*Bonga Shad*) samples of the Coastal communities of Okrika are within the range of the recommended limits. This implies that the exposure or ingestion of Fish (*Bonga Shad*) samples from the coastal communities of Okrika is radiologically free.

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