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Determination of Annual Dose Rate of Natural Radionuclides in Man from Fishes in Victoria Island Lagoon, Southwest of Nigeria

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Abstract

Radioactivity concentrations and dose rates of ^{40}K, ^{226}Ra and ^{228}Ra in fishes from Victoria Island Lagoon, Lagos State Southwest of Nigeria had been determined by gamma spectrometry using NaI (TI) detector coupled with a pre-amplifier base to a multiple channel analyzer (MCA). 15 samples of fishes were collected from the river having six (6) species. *Papyrocranus afer* had the highest mean concentration and dose rate of ^{40}K of values 83.28±5.21Bqkg^{-1} and 0.00748mGyhr^{-1} respectively. Also, *Tilapia zilli* had the highest mean concentration and dose rate of ^{226}Ra with values 4.82 ± 0.38Bqkg^{-1} and 8.44 x 10^{-7}mGyhr^{-1} respectively. The highest mean concentration and dose rate of ^{228}Ra was found in *Hepsetusodoe* with values 9.54±1.84Bqkg^{-1} and 1.14 x 10^{-12} mGyhr^{-1}respectively. The average dose rates of ^{40}K in the fishes was calculated to be 0.0049mGyhr^{-1}, 5.32 x 10^{-7} mGyhr^{-1} for ^{226}Ra and that of ^{228}Ra was 9.93x10^{-13}mGyhr^{-1} which are below the 0.4mGyhr^{-1} limit recommended. The annual dose rate in man consuming the aquatic animal species was estimated to be 0.216mSvyr^{-1} which was below the recommended limit of 1.0mSvyr^{-1}. All the values obtained show that there is no significant radiological health implication to the aquatic animals and man that consumes them.

Keywords: Radionuclides, Fishes, Radionuclide concentration, Dose rate, Gamma spectrometry.

INTRODUCTION

Sources of radioactivity in the aquatic environment like rivers include naturally occurring radionuclides, fallout from the atmosphere, runoff from watersheds that have received atmospheric deposition, and radioactive effluents from medical, industrial, and nuclear facilities released either accidentally or routinely. Radionuclides are a special class of environmental substances. They are the unstable configurations of chemical elements which undergo radioactive decay, emitting radiation in the form of alpha or beta particles, or gamma rays. The interaction of radiation with biological materials causes energy to be released to these materials which may result in a variety of harmful effects if beyond limit. Radiation is thus a potential hazard to man, although it may also be used in many beneficial ways, as in medical diagnosis and treatment, in industrial and consumer products and in the generation of electricity with nuclear reactors. Three types of radiation can be released: alpha particles, beta particles and gamma rays (photons). Most naturally occurring radionuclides are alpha particle emitters (uranium and radium-226), but some beta particle emitters also occur naturally (radium-228 and potassium-40). Manmade radionuclides are mainly beta and photon (gamma) emitters. Tritium is a beta particle emitter that may be formed naturally in the atmosphere or by human activities (OEPA, 2005). 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 the radionuclides: ^{40}K, ^{226}Ra and ^{228}Ra concentration levels were carried out by Sowole (2011) along with their dose rates in species of fish from major rivers at Sagamu where the mining of limestone along with the production of cement are taking place, in Ogun State Southwest of Nigeria. The average dose rate of all the radionuclides in the fishes was calculated to be 1.74 x 10^{-3}mGyhr^{-1} which was below the limit of 0.4mGy hr^{-1}recommended by NCRP (1991) as reported by Blaylock *et al* (1993) and therefore does not pose radiological health problem to the aquatic animals. Also, Khan et al. (2007) assessed the ingestion dose for natural radionuclides of 25.0 μSvyr^{-1} through the consumption of fish by man around the Kudankulam Nuclear Power Project site. Ingestion doses via fish had estimates of 18.0 μSvyr^{-1} from natural radionuclides for the critical population in Chitrapuzha River, near Cochin (Haridasan et al. 2001).

This research work is to determine the radioactivity concentrations and dose rates of ^{40}K, ^{226}Ra and ^{228}Ra in fishes from Victoria Island Lagoon of Lagos State Nigeria, also to determine the annual dose rate of the radionuclides in man that consumes them.

MATERIALS AND METHODS

The method of gamma spectrometry was adopted for the analysis of the samples collected in order to obtain data on ^{40}K, ^{226}Ra and ^{228}Ra. 15 samples of fishes from the Lagoon in the study area were collected and six (6) species were obtained. They were preserved in 40% formaldehyde in labelled containers. They were identified and grouped into their species putting into consideration their locations. The groups were then oven dried at 80^0C (Akinloye *et al*, 1999). The dried animal samples were later pulverized, weighed, packed 110.0g by mass in plastic containers and carefully sealed for 4 weeks in order to establish secular radioactive equilibrium between the natural radionuclides and their respective progenies.

The method of gamma spectrometry was adopted for the analysis of the samples collected in order to obtain data on ^{40}K, ^{226}Ra and ^{228}Ra. The spectrometer used 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 0.662MeV of ^{137}Cs. According to Jibiri and Farai (1998) the value is good enough for NaI detector to distinguish the gamma ray energies of most radionuclides in samples. 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 put to sit on the high geometry 7.6cm x 7.6cm 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 10hrs because of suspected low activities of the radionuclides in the samples. The areas under the photo-peaks of ^{40}K, ^{226}Ra and ^{228}Ra were computed using the Multichannel Analyzer system.

Table 1: Name of river, samples collected and species.

RIVER	SAMPLES	SPECIES
LAGOS ISLAND LAGOON	SF_1	*Tilapia mariae*
	SF_2	*Sarotherodon melanotheron*
	SF_3	*Tilapia mariae*
	SF_4	*Tilapia zilli*
	SF_5	*Sarotherodon melanotheron*
	SF_6	*Sarotherodon melanotheron*
	SF_7	*Papyrocranus afer*
	SF_8	*Tilapia mariae*
	SF_9	*Hepsetus odoe*
	SF_{10}	*Papyrocranus afer*
	SF_{11}	*Sarotherodon melanotheron*
	SF_{12}	*Hepsetus odoe*
	SF_{13}	*Sarotherodon melanotheron*
	SF_{14}	*Sarotherodon galilaeus*
	SF_{15}	*Sarotherodon galilaeus*

The concentrations of the radionuclides were calculated based on the measured efficiency of the detector and the net count rate under each photopeak over a period of 10 hours using equation 1.0

$$A = \frac{N(E_\gamma)}{\varepsilon(E_\gamma) I_\gamma M t_c} \qquad 1.0$$

Where:

$N(E_\gamma)$ = Net peak area of the radionuclide of interest, $\varepsilon(E_\gamma)$ = Efficiency of the detector for the γ- energy of interest, I_γ = Intensity per decay for the γ- energy of interest, M = Mass of the sample and t_c = Total counting time in seconds (36000s).

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

$$D = 5.76 \times 10^{-4}\ E\ n\ \Phi C \qquad 2.0$$

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, C is the concentration of the radionuclide of consideration and D is the dose rate of the radionuclide of consideration.

The annual dose rate of the radionuclides in man consuming the aquatic animal species was estimated using the expression:

$$\text{Annual Dose Rate (Sv yr}^{-1}) = \text{Radionuclide intake x Dose Conversion Factor} \qquad 3.0$$

Where:

Radionuclide intake = Radionuclide conc. (Bq kg^{-1}) x Consumption rate (kg yr^{-1})

RESULTS AND DISCUSSION

Radioactivity concentrations of radionuclides in the fishes from the study area are shown in table 2. Ranges, mean values of radioactivity concentrations of ^{40}K, ^{226}Ra and ^{228}Ra, and their dose rates in aquatic species are shown in tables 3,4 and 5 respectively. For ^{40}K, *Papyrocranus afer* had the highest mean concentration and dose rate of values 83.28±5.21Bqkg^{-1} and 0.00748mGyhr^{-1} respectively.

Table 2: Radioactivity concentrations of radionuclides in fishes

RIVER	SAMPLE	SPECIE	RADIOACTIVITY CONCENTRATIONSOF RADIONUCLIDES IN FISHES ($Bqkg^{-1}$)		
			^{40}K	^{226}Ra	^{228}Ra
VICTORIA ISLAND LAGOON	SF_1	*Tilapia mariae*	27.58 ± 2.13	2.04 ± 0.31	4.37 ± 0.43
	SF_2	*Sarotherodon melanotheron*	32.87 ± 2.76	1.87 ± 0.63	5.28 ± 1.24
	SF_3	*Tilapia mariae*	42.62 ± 3,24	2.54 ± 0.41	7.63 ± 1.35
	SF_4	*Tilapia zilli*	67.85 ± 5.12	4.27 ± 0.36	6.24 ± 0.95
	SF_5	*Sarotherodon melanotheron*	45.91 ± 4.89	2.53 ± 0.46	3.01 ± 0.62
	SF_6	*Sarotherodon melanotheron*	52.94 ± 4.67	3.27 ± 0.76	11.75 ± 3.78
	SF_7	*Papyrocranus afer*	76.83 ± 4.58	2.68 ± 0.37	3.65 ± 0.67
	SF_8	*Tilapia mariae*	31.82 ± 2.64	4.27 ± 0.36	9.04 ± 2.05
	SF_9	*Hepsetus odoe*	56.12 ± 4.65	2.48 ± 0.49	13.24 ± 2.86
	SF_{10}	*Papyrocranus afer*	89.73 ± 5.84	3.37 ± 0.86	12.93 ± 3.38
	SF_{11}	*Sarotherodon melanotheron*	57.04 ± 5.39	2,04 ± 0.42	8.62 ± 1.17
	SF_{12}	*Hepsetus odoe*	75.83 ± 5.35	3.04 ± 0.47	5.84 ± 0.82
	SF_{13}	*Tilapia zilli*	43.17 ± 4.29	5.37 ± 0.39	7.25 ± 1.26
	SF_{14}	*Sarotherodon galilaeus*	36.87 ± 3.87	3.46 ± 0.79	4.67 ± 0.94
	SF_{15}	*Sarotherodon galilaeus*	42.15 ± 3.72	1.02 ± 0.31	8.07 ± 1.36

Table 3: Ranges, mean values of radioactivity concentrations of ^{40}K and dose rates in fishes

SPECIE	RANGE ($Bqkg^{-1}$)	MEAN ($Bqkg^{-1}$)	DOSE RATE ($mGyhr^{-1}$)
Tilapia mariae	27.58 – 42.62	34.01± 2.67	0.00306
Sarotherodon melanotheron	32.87 – 57.04	47.19± 4.43	0.00424
Tilapia zilli	43.17 – 67.85	55.51 ± 4.82	0.00499
Papyrocranus afer	76.83 – 89.73	83.28 ± 5.21	0.00748
Hepsetus odoe	56.12 – 4.65	65.98 ± 5.00	0.00593
Sarotherodon galilaeus	36.87 – 42.15	39.51 ± 3.80	0.00355

Table 4: Ranges, mean values of radioactivity concentrations of ^{226}Ra and dose rates in fishes

SPECIE	RANGE ($Bqkg^{-1}$)	MEAN ($Bqkg^{-1}$)	DOSE RATE ($mGyhr^{-1}$)
Tilapia mariae	2.04 – 4.27	2.95 ± 0.36	5.17×10^{-7}
Sarotherodon melanotheron	1.87– 3.27	2.43 ± 0.57	4.26×10^{-7}
Tilapia zilli	4.27 – 5.37	4.82 ± 0.38	8.44×10^{-7}
Papyrocranus afer	2.68 – 3.37	3.03 ± 0.62	5.31×10^{-7}
Hepsetus odoe	2.48 – 3.04	2.76 ± 0.48	4.83×10^{-7}
Sarotherodon galilaeus	1.02 – 3.46	2.24 ± 0.55	3.92×10^{-7}

Table 5: Ranges, mean values of radioactivity concentrations of ^{228}Ra and dose rates in fishes

SPECIE	RANGE ($Bqkg^{-1}$)	MEAN ($Bqkg^{-1}$)	DOSE RATE ($mGyhr^{-1}$)
Tilapia mariae	4.37 – 9.04	7.01± 1.28	8.36×10^{-13}
Sarotherodon melanotheron	3.01– 11.75	7.17± 1.70	8.55×10^{-13}
Tilapia zilli	6.24 – 7.25	6.75 ± 1.11	8.05×10^{-13}
Papyrocranus afer	3.65 – 12.93	8.29 ± 2.03	9.88×10^{-13}
Hepsetus odoe	5.84 – 13.24	9.54 ± 1.84	1.14×10^{-12}
Sarotherodon galilaeus	4.67 – 8.07	6.37 ± 1.15	7.60×10^{-13}

Also, *Tilapia zilli* had the highest mean concentration value of ^{226}Ra and dose rate of 4.82± 0.38$Bqkg^{-1}$ and 8.44 x $10^{-7}$$mGyhr^{-1}$respectively. *Hepsetusodoe* had the highest mean concentration value and dose rate of ^{228}Ra with values 9.54± 1.84$Bqkg^{-1}$ and 1.14 x 10^{-12} $mGyhr^{-1}$. The average dose rates of ^{40}K in the fishes was calculated to be 0.0049$mGyhr^{-1}$, 5.32 x 10^{-7} $mGyhr^{-1}$ for ^{226}Ra, and that of ^{228}Ra was 8.96x $10^{-13}$$mGyhr^{-1}$ which are below the 0.4$mGyhr^{-1}$ limit recommended by NCRP (1991) as reported by Blaylock *et a*l (1993). The annual dose rate of the radionuclides in man consuming the aquatic animal species was estimated to be 0.216mSv yr^{-1} which was below the recommended limit of 1 $mSvyr^{-1}$.

CONCLUSION

The study had revealed that the average dose rates of ^{40}K in the fishes was calculated to be 0.0049$mGyhr^{-1}$,5.32 x 10^{-7} $mGyhr^{-1}$ for ^{226}Ra and that of ^{228}Ra was 8.96x$10^{-13}$$mGyhr^{-1}$ which are below the 0.4$mGyhr^{-1}$ limit recommended by NCRP (1991) as reported by Blaylock *et al* (1993). The annual dose rate in man consuming the aquatic animal species was estimated to be 0.216$mSvyr^{-1}$ which was below the recommended limit by ICRP (2007) of 1 $mSvyr^{-1}$. All the values obtained show that there is no significant radiological health implication to the aquatic animals and man that consumes them.

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