Faculty of Natural and Applied Sciences Journal of Applied and Physical Sciences
Print ISSN: 3026-9857
www.fnasjournals.com
Volume 2; Issue 2; March 2025; Page No. 12-27.

Radiological Risk Assessment of Adult Exposure to Radionuclides from the New Calabar River, Nigeria

***Igbudu, O., & Ogan, A. C.**
Department of Science Laboratory Technology, School of Applied Sciences, Kenule Beeson Saro-Wiwa Polytechnic, P.M.B 20, Bori, Rivers State, Nigeria

***Corresponding author email**: igbudumege@yahoo.com

Abstract

A natural radioactivity study was carried out to determine the annual effective dose (AED) of radiation in adults (12-17 yr and > 17 yr) due to intake of radioelements in river water from some randomly selected points along the stretch of the New Calabar River, Rivers State, Nigeria. Twenty-eight river water samples. collected into a 50 cl sterile sample container were analyzed in Environmental Laboratory, National Institute of Radiation Protection and Research (NIRPR), Nigerian Nuclear Regulatory Authority (NNRA), University of Ibadan, Nigeria, with the aid of NaI gamma ray detector. The detector helped to determine the activity concentration of the radionuclides (^{40}K, ^{232}Th and ^{232}U) in the water. The AED in adults were evaluated from the results of activity concentration as well as appropriate ingested dose conversion factor. Results showed that the mean AED of ^{40}K in adult (12-17 yr and >17 yr) as a result of consuming the river water are 0.346±0.018 and 0.282±0.015 mSv y^{-1} respectively. The mean AED of ^{232}Th in adult (12-17 yr and >17 yr) are 0.763±0.044 and 0.702±0.039 mSv y^{-1} respectively while the mean AED of ^{232}U in the river water are: 4.270±0.557 mSv y^{-1} for adult (12-17) yr and 2.252±0.252 mSvy^{-1} for (>17) yr. Results further indicated that the mean total annual effective dose (TAED) of radiation in adult (12-17 yr and >17 yr) as a result of intake of (^{40}K, ^{232}Th and ^{232}U) in river water are 5.347±0.619 and 3.207±0.334 mSvy^{-1} respectively. This mean TAED was observed to be above the internationally recommended safe limit of 0.10 mSvy^{-1} for adult 12-17 yr and >17 yr). The study can be concluded that the water supplies from the study area are radiologically polluted and harmful for consumption by inhabitants of the study area. Provision of clean, safe, and alternative water supplies by relevant agencies of government, Non-Governmental Organizations are highly recommended for the inhabitants. Further radiological research studies on other areas of the New Calabar River not captured in this study are also recommended to be carried out.

Keywords: Environmental laboratory, radioelements, anthropogenic activities, inhabitants, pollution

Introduction

The importance of water cannot be undermined as it is an essential commodity which is very important to human environment, and for survival of all forms of living organisms, plants, animals and humans (Orosun et al., 2022). Water serves as source of food for humans (Ononugbo and Anyalebechi, 2017), and transports nutrients, hormones, enzymes, minerals, wastes and respiratory gases from one point to another within the body system of all living organisms (Akinloye, 2008). Water is also a catalyst that quickens the rate of chemical reaction as well as the overall activity in the human body (Akinloye, 2008). Drinking water supplies such as underground and surface water contain some radioelements that are capable of causing serious health effects to humans (Agbalagba et al., 2013). Though, the health risk is usually low compared to those linked to the presence of microorganisms and chemicals (Alias et al., 2008; Igbudu & Briggs-Kamara, 2023). Natural radionuclides are present in river water because of either natural process such as reactions with aquifer minerals (Abdul-Adziz and Khoo, 2017), absorption from the soil, or technological process that involves naturally occurring radioactive materials (Abojassim et al., 2014) such as mining and dredging or phosphate fertilizer production (WHO, 2017; Ononugbo & Anyalebechi, 2017). On the other hand, artificially occurring radionuclides of anthropogenic or technological origin are present in river water as a result of some sources like radionuclides released from nuclear and medical facilities, and industries (Sowole & Egunjobi, 2019). Other anthropogenic sources of radionuclides in the environment include trans-uranium products, drilling, marine transportation, processing (Ononugbo and Anyalebechi, 2017) and burning of fossil fuel, ^{14}C, ^{3}H, ^{90}Sr and ^{131}I and other gamma emitters released in controlled or authorized quantities from nuclear installations. The aim of this study is to assess annual effective

Cite this article as:
Igbudu, O., & Ogan, A. C. (2025). Radiological risk assessment of adult exposure to radionuclides from the New Calabar River, Nigeria. *FNAS Journal of Applied and Physical Sciences, 2*(2), 12-27.

dose of radiation in adult aged (2-17 yr and > 17 yr) as a result of ingestion of radioelements contained in water samples from the New Calabar River, Rivers State, Nigeria.

Many researches have been conducted on assessment of natural radioactivity due to intake of radionuclides in a given water sample within and outside the Niger Delta region. Some of these include the determination of natural radioactive contents in surface and underground water around oilfields in Ogba, Egbema and Ndoni Local Government Area in Rivers State (Ononugbo et al., 2013); radiological health risks assessment of river water from coastal communities of Ndokwa East, Delta State, Nigeria (Ononugbo & Anyalabechi, 2017); health impact of radionuclides in water samples from underground water around three oil mining lease (OML) fields in Niger Delta, Nigeria (Agbalagba et al., 2013); radiation dose consumed by infants and adults from gross alpha activity in selected communities producing oil in Delta State, Nigeria (Agbalagba et al., 2013); evaluation of radiological risk in underground drinking water from Ogun State (Achuka et al., 2017), AED in infants due as a results of consumption of radioelements in water samples from New Calabar river in Rivers State (Igbudu & Briggs-Kamara, 2023), and AED of radiation in children as a result of consumption of radionuclides in water samples from new Calabar river, Rivers State (Igbudu et al., 2023). Others are determination of level of ^{222}Rn concentration and radiological hazards in underground water supplies in Dutse, Jigawa State (Dankawu et al., 2021); radiological risk as a result consumption of packaged table water commonly consumed in Ogbomoso and Ilorin metropolis, South West, Nigeria (Orosun et al., 2022), natural radioelement contents in water and sediments from Asa-Dam, Ilorin, South West Nigeria (Orosun et al., 2021); radiological health implications of consuming water samples from Oniru beach, Lagos State, Nigeria (Jegede et al., 2017); and radiological impacts and level of radioactivity in well water supplies from some towns in Ondo and Ekiti States (Ayodele et al., 2022).

Materials and Methods

The study was conducted along the banks of New Calabar River, Rivers State, Nigeria. The stretch of the New Calabar river under study traverses across nine communities in three Local Government Areas (Emohua, Ikwerre and Obio/Akpor). Its source is Elele-Alimini (latitude N 5^{o} 04′ 24.30″ and longitude E 6^{o} 44 ′ 10.33″) in Emohua Local Government Area, through the popular Choba bridge (latitude N 4^{o} 53′ 48.24 ″ and longitude E 6^{o} 55′ 12.17″) in Obio/Akpor Local Government Area, to the Atlantic Ocean. The river is one of the major water supplies for domestic (drinking, cooking, and swimming) and agricultural (fishing) purposes within the study area. It also serves as discharge point of domestic wastes from inhabitants, industrial effluent discharges from companies located at its banks, medical wastes from medical facilities and electronic wastes from small scale industries, and run-off water into the river (Igbudu & Briggs-Kamara, 2023). Other anthropogenic activities such as bunkering, sand dredging, marine transportation and lumbering take place along the stretch of New Calabar river. These activities largely contributed in general contamination and pollution of the river.

Cite this article as:
Igbudu, O., & Ogan, A. C. (2025). Radiological risk assessment of adult exposure to radionuclides from the New Calabar River, Nigeria. *FNAS Journal of Applied and Physical Sciences, 2*(2), 12-27.

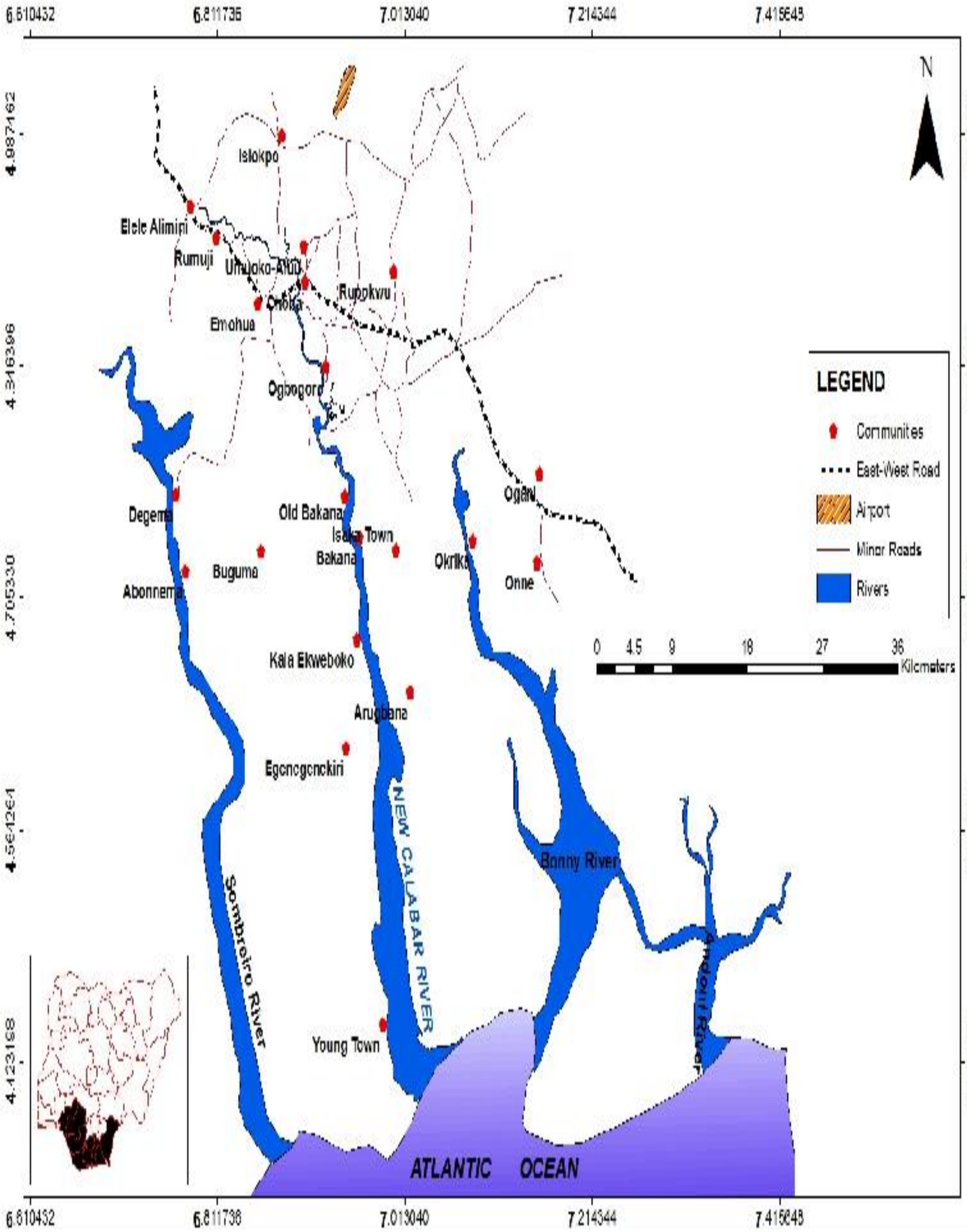


Fig. 1: Map of Rivers State showing communities through which the New Calabar River traverses (Source: Francis & Elewuo, 2012).

Cite this article as:
Igbudu, O., & Ogan, A. C. (2025). Radiological risk assessment of adult exposure to radionuclides from the New Calabar River, Nigeria. *FNAS Journal of Applied and Physical Sciences, 2*(2), 12-27.

Table 1: Geographical Location of Randomly Selected Sample Sites

Location Number	Location Identity	Name of Location	Local Govt. Area	Latitude (N)	Longitude (E)
1	L1	Iwofe Jetty, Rumuolumeni Town	Obio/Akpor	4.810238889	6.92915
2	L2	Ogbogoro Water front, Ogbogoro Town	Obio/Akpor	4.848636111	6.92345
3	L3	Rumuokparali Water front, Rumuokparali Community	Obio/Akpor	4.871322222	6.904297222
4	L4	Choba Market water front, Choba Town.	Obio/Akpor	4.896733333	6.898044444
5	L5	Omuihuechi Aluu water front.	Ikwerre	4.912827778	6.89804444
6	L6	Elele-Alimini Community	Emohua	5.073416667	6.736202778
7	L7	Rumuji/Ibaa Bridge	Emohua	4.945797222	6.795111111
8	L8	Oduoha Emohua Community	Emohua	4.92479722	6.83415
9	L9	Mbuitanwo Emohua Community	Emohua	4.88195	6.893272222

Cite this article as:
Igbudu, O., & Ogan, A. C. (2025). Radiological risk assessment of adult exposure to radionuclides from the New Calabar River, Nigeria. *FNAS Journal of Applied and Physical Sciences, 2*(2), 12-27.

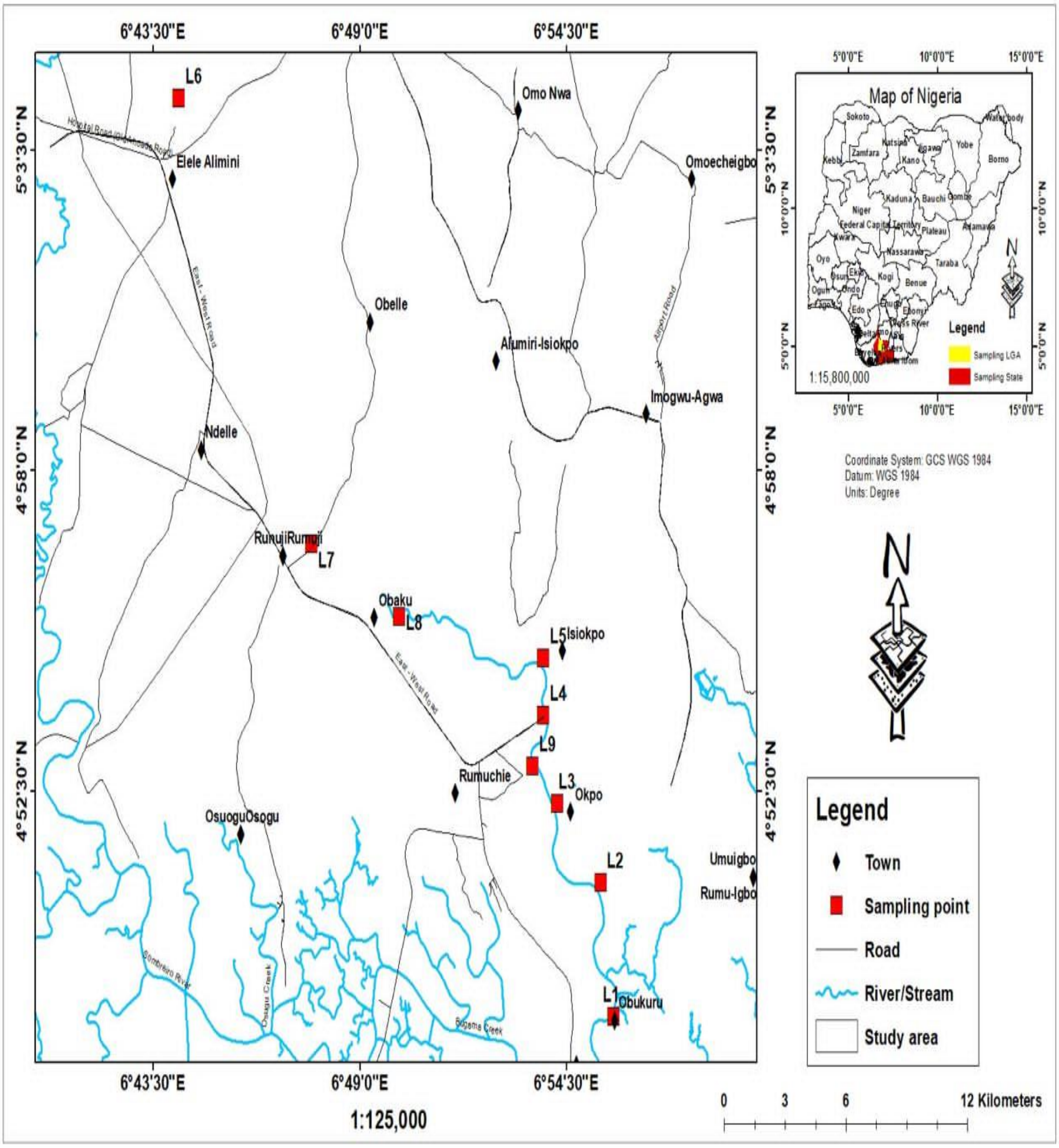


Fig. 2: Map of Nigeria showing co-ordinates of the sampling sites along the river banks of the New Calabar River.

Materials that were used in this study are satellite navigation system or global positioning system (GPS). The device measures the co-ordinates (latitude and longitude) of the sample location and displays the results in degree, minutes and seconds of each sampling point across the sample locations. A digital pH meter (HI8424), manufactured by Hanna company, was used to measure acidity/alkalinity of the water samples. The 50 cl sterile containers were used to collect water samples from randomly selected sampling points. The HNO_3 solution was used to treat the water samples, and Sodium Iodide (NaI) spectrometer was used to analyze the river water which subsequently determines the radioelements in the river water samples. A total of twenty-eight sampling points were selected in this study. Fourteen (14) sample locations and two sample points each, along the banks of the new Calabar River were randomly selected from nine communities across three local government areas of Rivers State, Nigeria. The sampling locations and points were designated ($LiPi$), where L and P represent the sampling locations and sampling points respectively, and i represents the number of sampling location and points respectively. The sterile sample containers were properly washed with the aid of detergent and were later rinsed thrice with distilled water. The river water samples were collected into the twenty-eight sterile containers. The water samples were treated by adding 16 ml, 1 M of HNO_3 acid solution into each water sample container. This helped to increase the acidic content of the river water samples to about less than 2, as well as to reduce precipitation and adsorption on the wall of the sample container (Hankouraou & Shittu, 2016; Orosun et al., 2016; Igbudu & Briggs-Kamara, 2023). The addition of HNO_3 solution helped to establish secular equilibrium before the analysis of river water samples, with the aid of (NaI) gamma ray spectrometer. The sample containers were tightly covered, well packed and ice-cooled for approximately 24 hours before being transported to the laboratory for final analysis.

Estimation of Natural Radioactivity and Radiological Hazard Indices

Activity Concentrations

Activity concentration of the radioelements in the river water samples was estimated using Eq. (1): (Avwiri et al., 2014; Igbudu et al., 2023)**:**

$$A_c(Bql^{-1}) = \frac{C_a}{P_\gamma(V_s)\varepsilon_\gamma\, t_c} \qquad (1)$$

Where A_c is the activity concentration of the radioelements, C_a is the net peak area of a peak at energy,. $\mathcal{E}_\gamma$ is the efficiency of the detector for a γ-energy of interest; V_s is the sample volume; t_c is the total time of counting, and P_γ is the aabundance of the γ-line in a radionuclide

Annual Effective Dose (AED)

The AED as a result of consumption of natural radioelements contained in the river water was obtained with the aid of Eq. (2): (Agbalagba et al., 2013; Ononugbo et al., 2013; Igbudu & Briggs-Kamara, 2023):

$$E = IAC \times 365\ . \qquad (2)$$

Where: I is daily water consumption (Ld^{-1}); A is activity concentration of radionuclide in river water samples (Bql^{-1}); C is dose conversion factors (mSv Bq^{-1}). The values of dose conversion factor vary with the radionuclides present in any given water sample and the age categories of human population. The values of the activity concentration in (Igbudu and Briggs-Kamara, 2023), and dose conversion factor were used in estimating the AED in adults as a result of exposure to natural radioactivity in river water.

Total Annual Effective Dose (TAED)

The TAED of radiation in adults (12-17 yr and > 17yr) as a result of intake of ^{40}K, ^{232}Th and ^{232}U present in river water was obtained using Eq. (3): (Ajayi & Adesida, 2009; Ononugbo & Anyalebechi, 2017):

$$\text{AED (mSv y}^{-1}\text{)} = \sum A_c I_A C_F \qquad (3)$$

where: A_c is activity concentration (Bql^{-1}) of the radioelements; I_A is daily water consumption (Ld^{-1}); C_F is dose conversion factor (mSv Bq^{-1}).

Results

Table 2 represents AED in adults (12-17 yr and >17 yr) as a result of consumption of radioelements in river water samples. Table 3 represents activity concentration and TAED of radiation in adults (12-17) yr due to consumption of radioelements in river water, and Table 4 represents dose conversion factor for ingested radionuclides ^{40}K, ^{232}Th and ^{232}U for the various categories of human population (Infants, Children and Adults). Mean activity concentration and world average value of the radioelements in river water is presented in Fig. 3. The distribution of mean AED of radiation in adults (12-17) yr due to ingestion of radionuclides in river water samples is displayed in Fig. 4 while the distribution of mean annual effective dose of radiation in adult (>17) yr due to consumption of ^{40}K, ^{232}Th and ^{232}U in river water presented in Fig.5. The results in Fig.6 represent the mean TAED of radiation in adult (12-17 yr and >17 yr as a result of radioelements in river water.

Cite this article as:
Igbudu, O., & Ogan, A. C. (2025). Radiological risk assessment of adult exposure to radionuclides from the New Calabar River, Nigeria. *FNAS Journal of Applied and Physical Sciences, 2*(2), 12-27.

Table 2: Annual Effective Dose of radiation in Adult 12-17 yr and >17 yr) Due to consumption of ^{40}K, ^{232}Th and ^{232}U in River Water.

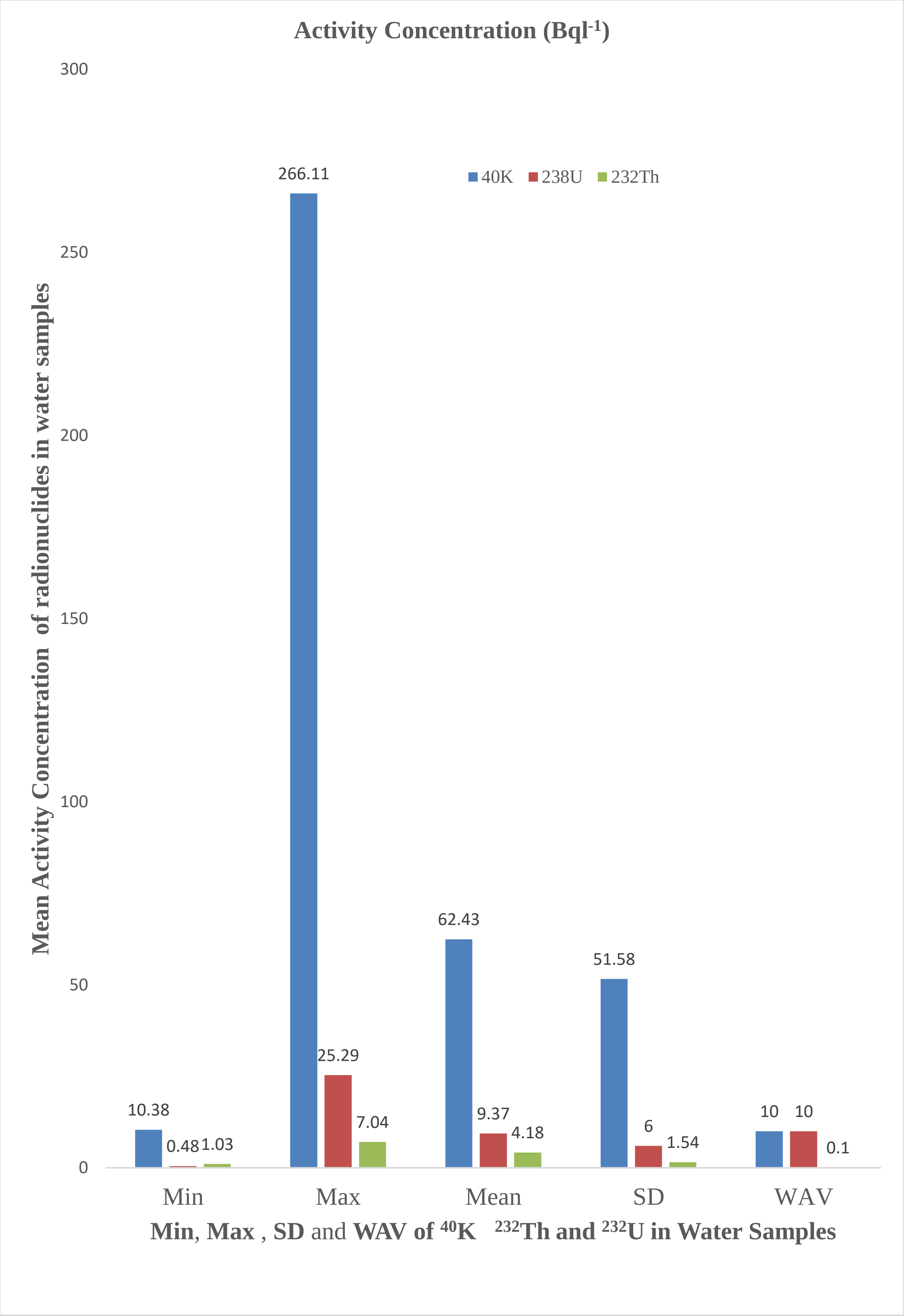
Sample Code	**^{40}K Adults**		**^{232}Th Adults**		**^{232}U Adults**	
	12-17)yr	**> 17 yr**	**12-17)yr**	**> 17 yrs**	**12-17)yr**	**> 17 yrs**
L1P1	0.222±0.012	0.181±0.010	0.829±0.049	0.762±0.045	2.663±0.392	1.373±0.202
L1P2	0.200±0.011	0.163±0.009	0.712±0.042	0.655±0.039	5.158±0.729	2.659±0.376
L2P1	0.083±0.004	0.067±0.003	0.378±0.022	0.348±0.020	2.112±0.280	1.089±0.144
L2P2	0.157±0.008	0.128±0.007	0.513±0.031	0.472±0.028	5.630±0.757	2.903±0.390
L3P1	0.551±0.029	0.450±0.024	0.984±0.058	0.905±0.054	3.172±0.453	1.636±0.234
L3P2	0.369±0.019	0.301±0.015	0.318±0.018	0.292±0.017	3.051±0.299	1.573±0.154
L4P1	0.176±0.009	0.143±0.007	0.768±0.044	0.707±0.040	2.962±0.299	1.527±0.154
L4P2	0.311±0.016	0.253±0.013	0.504±0.031	0.463±0.028	4.742±0.649	2.445±0.353
L5P1	0.224±0.012	0.183±0.010	0.578±0.035	0.532±0.032	5.027±0.701	2.592±0.361
L5P2	0.760±0.040	0.620±0.033	0.648±0.038	0.596±0.035	4.457±0.640	2.298±0.330
L6P1	0.352±0.019	0.287±0.015	1.173±0.069	1.080±0.064	2.948±0.411	1.520±0.212
L6P2	0.529±0.028	0.431±0.023	0.188±0.011	0.173±0.010	11.815±1.416	6.092±0.730
L7P1	0.137±0.007	0.111±0.006	0.865±0.049	0.796±0.045	3.831±0.383	1.975±0.197
L7P2	0.516±0.027	0.421±0.022	0.911±0.055	0.838±0.050	7.050±0,953	3.635±0.491
L8P1	0.074±0.004	0.061±0.003	1.069±0.062	0.982±0.057	5.854±0.584	3.018±0.301
L8P2	0.393±0.021	0.320±0.017	1.097±0.066	1.009±0.060	2.570±0.360	1.325±0.185
L9P1	1.476±0.078	1.204±0.063	0.889±0.053	0.818±0.049	6.405±0.953	3.303±0.491
L9P2	0.425±0.022	0.347±0.018	0.903±0.053	0.831±0.049	0.224±0.033	0.098±0.017
L10P1	0.403±0.020	0.329±0.020	0.703±0.040	0.646±0.037	6.573±0.645	3.389±0.332
L10P2	0.058±0.003	0.047±0.002	1.075±0.064	0.989±0.059	2.154±0.294	1.110±0.152
L11P1	0.224±0.012	0.183±0.010	0.830±0.049	0.764±0.045	4.308±0.561	2.221±0.289
L11P2	0.527±0.028	0.430±0.022	0.726±0.044	0.668±0.050	11.059±1.453	5.702±0.749
L12P1	0.110±0.006	0.090±0.005	1.285±0.077	1.182±0.047	0.336±0.051	0.173±0.026
L12P2	0.333±0.017	0.271±0.014	0.903±0.051	0.831±0.047	0.561±0.056	0.289±0.029
L13P1	0.123±0.006	0.100±0.005	0.458±0.027	0.421±0.025	0.850±0.084	0.438±0.043
L13P2	0.443±0.022	0.361±0.018	0.279±0.016	0.257±0.015	4.611±0.453	2.378±0.234
L14P1	0.061±0.003	0.050±0.003	0.796±0.016	0.732±0.015	5.859±0.813	3.021±0.178
L14P2	0.460±0.024	0.377±0.020	0.990±0.060	0.918±0.055	6.653±0.902	3.430±0.465
Min.	**0.058±0.003**	**0.047 ±0.002**	**0.188 ±0.011**	**0.173 ±0.010**	**0.224±0.033**	**0.098±0.017**
Max.	**1.476±0.07**	**1.204 ±0.063**	**1.285 ±0.011**	**1.182 ±0.070**	**11.815±1.416**	**6.092±0.730**
Mean	**0.346±0.018**	**0.282 ±0.015**	**0.763 ±0.044**	**0.702 ±0.039**	**4.270±0.557**	**2.258±0.279**
WAV	**0.12**		**0.17**		**0.17**	

Table 3: Activity Concentration and TAED of Radiation in Adults 12-17 yr and >17 yr) Due to Consumption of ^{40}K, ^{232}Th and ^{232}U in River Water.

Sample Location and Code		Activity Concentration			TAED of Adults	
Location	**Code**	**^{40} K**	**^{232}Th**	**^{232}U**	**(12-17) yr**	**>17 yr**
Iwofe Jetty Water Front	L1P1	40.05±2.12	4.54±0.27	5.70±0.84	3.714±0.453	2.316±0.257
	L1P2	36.07±1.91	3.90±0.23	11.04±1.56	6.070±0.782	3.477±0.424
Ogbogoro Water Front	L2P1	14.89±0.78	2.07±0.12	4.52±0.60	2.573±0.306	1.504±0.167
	L2P2	28.31±1.49	2.81±0.17	12.05±1.62	3.300±0.796	3.503±0.425
Rumuokparali Water Front	L3P1	99.40±5.23	5.39±0.32	6.79±0.97	4.707±0.540	2.991±0.312
	L3P2	66.52±3.37	1.74±0.10	6.53±0.64	3.738±0.336	2.166±0.186
Choba Market Water Front	L4P1	31.69±1.60	4.21±0.24	6.34±0.64	3.906±0.352	2.377±0.201
	L4P2	55.99±2.96	2.76±0.17	10.15±1.39	5.557±0.696	3.171±0.394
Omuihuechi Aluu Water Front 1	L5P1	40.37±2.13	3.17±0.19	10.76±1.50	5.829±0.748	3.307±0.403
	L5P2	137.04±7.20	3.55±0.21	9.54±1.37	5.865±0.718	3.514±0.398
Omuihuechi Aluu Water Front 2	L6P1	63.43±3.35	6.43±0.38	6.31±0.88	3.473±0.499	2.887±0.291
	L6P2	95.31±5.00	1.03±0.06	25.29±3.03	12.532±1.455	6.696±0.763
Choba Bridge Water Front	L7P1	24.62±1.25	4.74±0.27	8.20±0.82	4.833±0.439	2.882±0.248
	L7P2	93.00±4.89	4.99±0.30	15.09±2.04	8.477±1.035	4.894±0.563
Mini Onuah Stream, Elele Alimini	L8P1	13.38±0.68	5.85±0.34	12.53±1.25	6.997±0.650	4.061±0.361
	L8P2	70.77±3.73	6.01±0.36	5.50±0.77	4.060±0.447	1.654±0.262
Mini Ezi Stream, Elele Alimini	L9P1	266.11±13.99	4.87±0.29	13.71±2.04	8.770±1.084	5.325±0.603
	L9P2	76.65±4.06	4.95±0.29	0.48±0.07	1.552±0.108	1.276±0.084
Rumuji/Ibaa Bridge Water Front	L10P1	72.64±3.68	3.83±0.22	14.07±1.38	7.679±0.705	4.364±0.389
	L10P2	10.38±0.54	5.89±0.35	4.61±0.63	3.287±0.361	2.146±0.213
Alimini Water Front, Oduoha Emohua	L11P1	40.37±2.13	4.55±0.27	9.22±1.20	5.362±0.622	3.168±0.344
	L11P2	94.99±4.99	3.98±0.24	23.67±3.11	12.312±1.525	6.800±0.821
Ogbodo Water Front Oduoha Emohua	L12P1	19.92±1.05	7.04±0.42	0.72±0.11	1.731±0.134	1.445±0.078
	L12P2	59.95±3.04	4.95±0.28	1.20±0.12	1.797±0.124	1.391±0.090
Ogbodo,Water Front 2 Oduoha Emohua	L13P1	22.12±1.12	2.51±0.15	1.82±0.18	1.431±0.117	0.959±0.073
	L13P2	79.83±4.04	1.53±0.09	9.87±0.97	5.333±0.491	2.996±0.267
Mgbuitanwo Emohua Water Front	L14P1	11.01±0.58	4.36±0.09	12.54±1.74	6.716±0.832	3.803±0.196
	L14P2	83.36±4.39	5.47±0.33	14.24±1.93	8.103±0.986	4.725±0.540
Min		**10.38±0.54**	**1.03±0.06**	**0.48±0.07**	**1.431±0.117**	**0.959±0.073**
Max		**266.11±13.99**	**7.04±0.42**	**25.29±3.03**	**12.532±1.455**	**6.800±0.821**
Mean		**62.43±3.26**	**4.18±0.24**	**9.37±1.19**	**5.347±0.619**	**3.207±0.334**
SD		**51.580**	**1.540**	**6.008**	**2.887**	**1.514**
WAV		**10.0**	**0.10**	**10.0**	**0.10**	

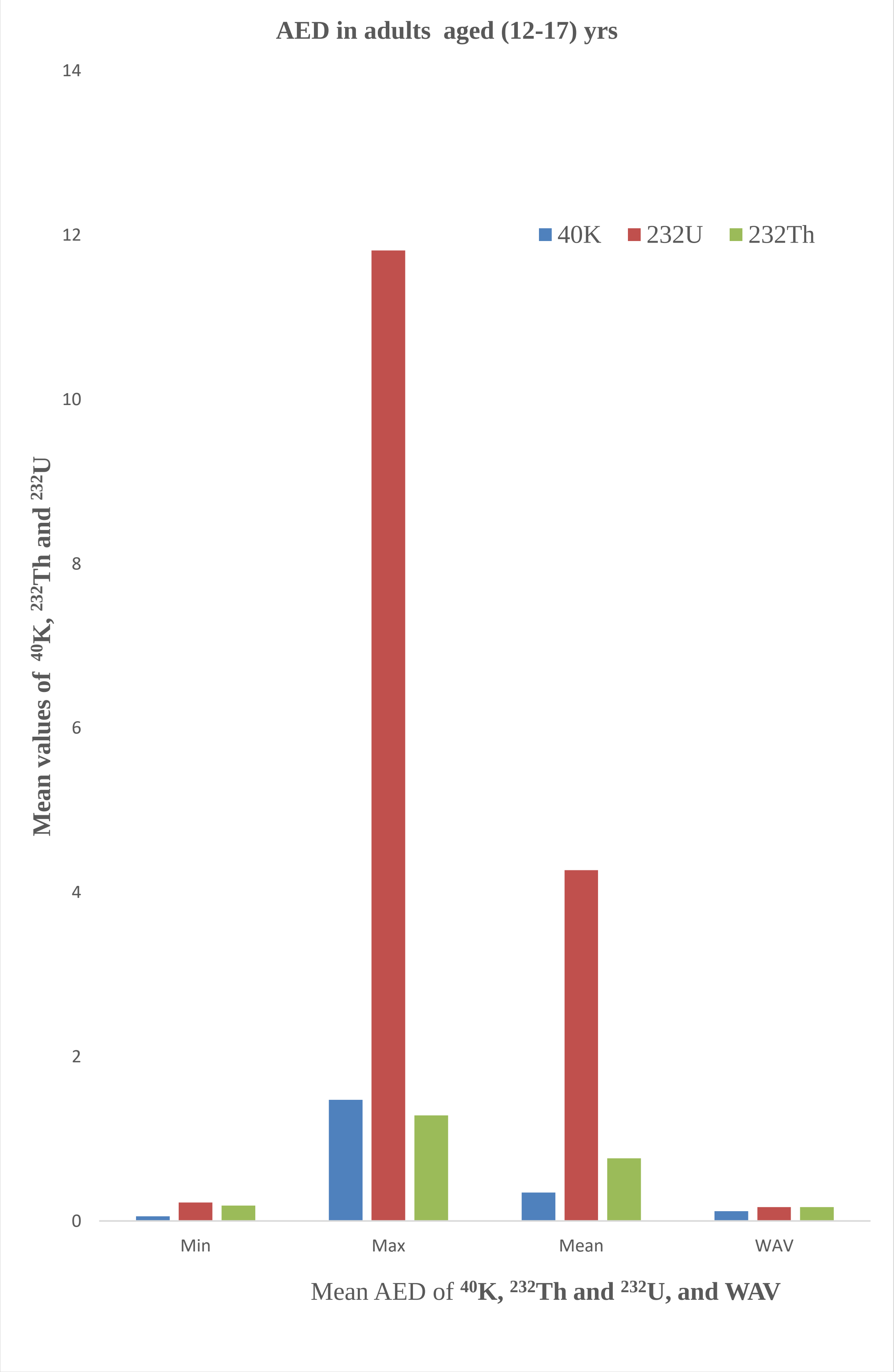
Table 4: Dose Conversion Factor for Ingested Radionuclides: ^{40}K, ^{232}Th and ^{232}U for the various Categories of Human Population (Infants, Children and Adults) (Source: Extracted from STUK, 2014)

S/N	**Radionuclides**	**Infants**		**Children**		**Adults**	
		(0-1)yr	**(1-2) yr**	**(2-7) yr**	**(7-12) yr**	**(12-17) yr**	**(> 17) yr**
1	^{40}K	6.2 E-8	4.2 E-8	2.1 E-8	1.3 E-8	7.6 E-9	6.2 E-9
2	^{232}Th	4.6 E-6	4.5E-7	3.5 E-7	2.9 E-7	2.5 E-7	2.3 E-7
3	^{232}U	2.5 E-6	8.2 E-7	5.8 E-7	5.7 E-7	6.4 E-7	3.3 E-7
	Daily water intake (L/day)	0.5	1.0	1.0	1.0	2.0	2.0
	Annual water intake (L/yr)	182.5	365	365	365	730	730



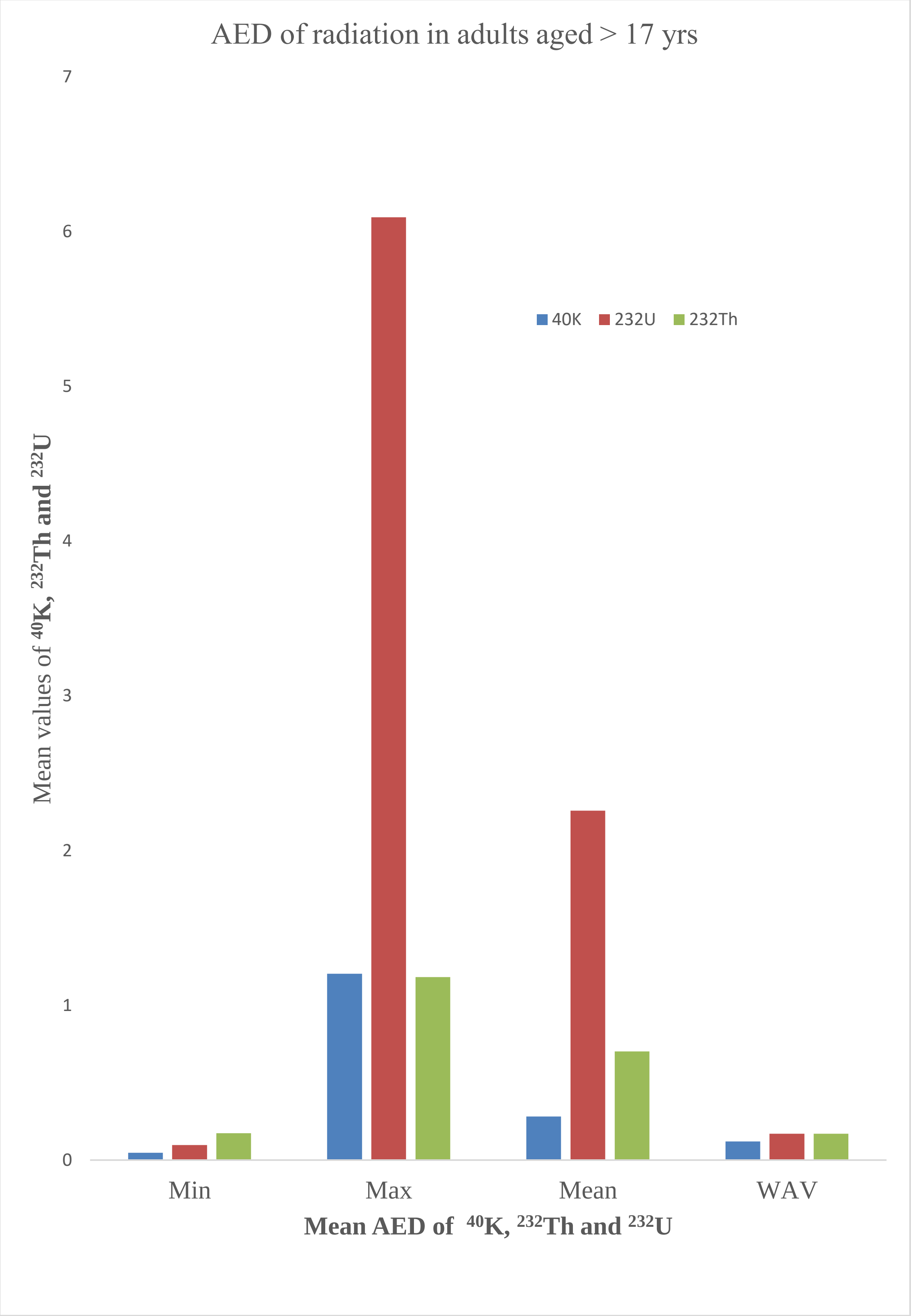
Cite this article as:
Igbudu, O., & Ogan, A. C. (2025). Radiological risk assessment of adult exposure to radionuclides from the New Calabar River, Nigeria. *FNAS Journal of Applied and Physical Sciences, 2*(2), 12-27.

Fig. 3: Mean activity concentration and World Average Value of radionuclides in River water samples



Cite this article as:
Igbudu, O., & Ogan, A. C. (2025). Radiological risk assessment of adult exposure to radionuclides from the New Calabar River, Nigeria. *FNAS Journal of Applied and Physical Sciences, 2*(2), 12-27.

Fig. 4: Distribution of Mean AED of radiation in adults (12-17) yr due to intake of radionuclides in river water samples



Cite this article as:
Igbudu, O., & Ogan, A. C. (2025). Radiological risk assessment of adult exposure to radionuclides from the New Calabar River, Nigeria. *FNAS Journal of Applied and Physical Sciences, 2*(2), 12-27.

Fig. 5: Distribution of Mean AED of radiation in adults (> 17 yr) due to intake of radionuclides in river water samples

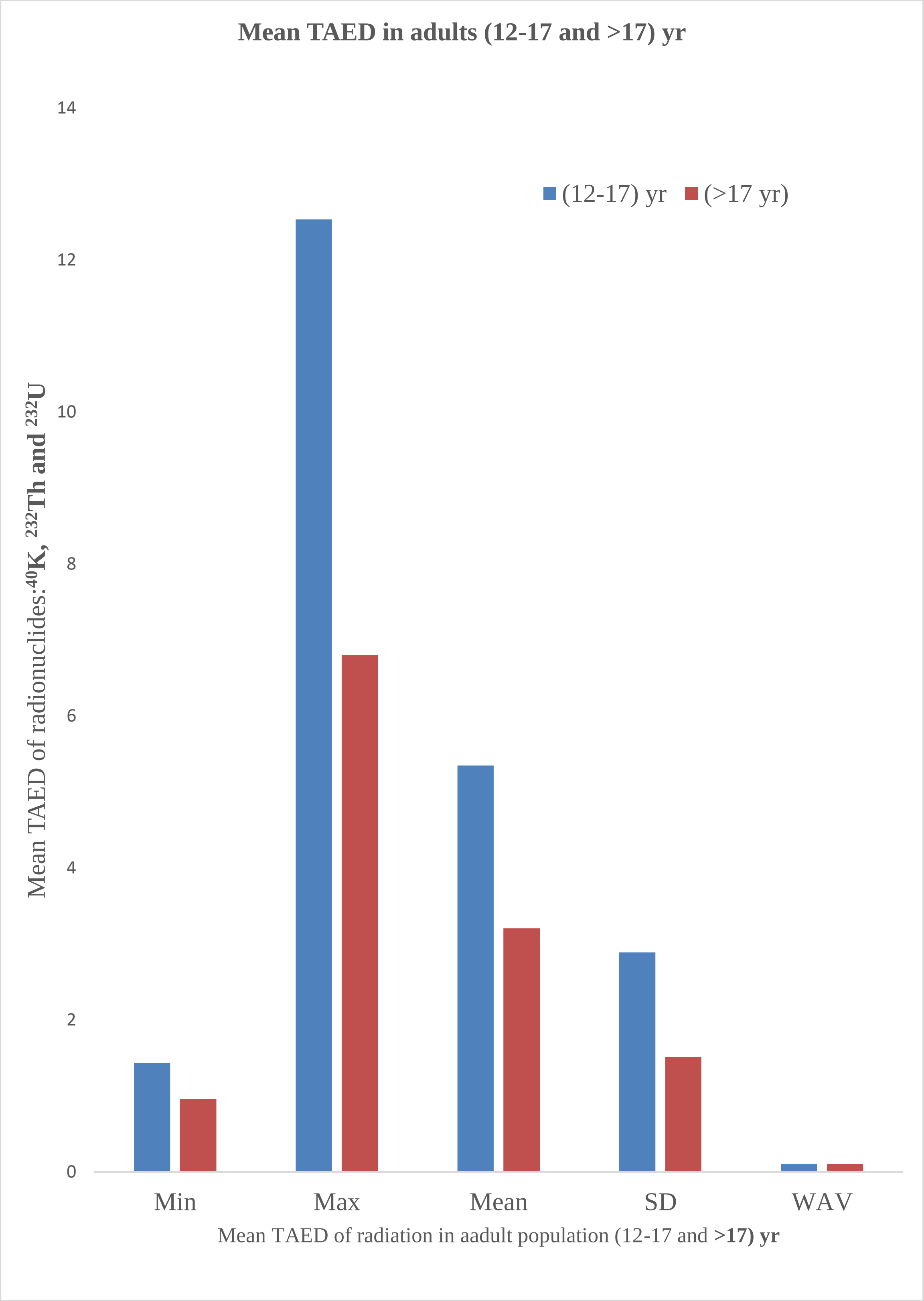


Fig. 6: Mean distribution of TAED of radiation and world average value in adults (12-17 yr and >17) yr due to intake of radionuclides in New Calabar river water.

Discussion

The study on the assessment of AED of radiation in adults (12-17 yr and > 17) yr due to intake of radioelements ^{40}K, ^{232}Th and ^{232}U in river water was conducted. Results of activity concentration in (Igbudu et al., 2023) indicated that ^{40}K had the highest mean activity concentration of 62.43±3.26 Bql^{-1}, followed with ^{232}U (9.37±1.19 Bql^{-1}) and ^{232}Th (4.18±0.24 Bql^{-1}). The results further revealed that ^{40}K is the most dominant radionuclide of all present in the water samples. Comparison of results of activity concentration of the radioelement in the river water samples and internationally recommended reference limit revealed that mean activity concentrations of ^{40}K and ^{232}Th (62.43±3.26 Bql^{-1} and 4.18±0.24 Bql^{-1}) respectively were observed to have exceeded the reference limits of 10.0 and 0.1 Bql^{-1} respectively while the mean activity concentration of ^{232}U (9.37±1.19 Bql^{-1}) was slightly below the recommended limit of 10.0 Bql^{-1}. The results however revealed that the water samples under investigation are radiologically contaminated, polluted and harmful for human consumption.

Annual Effective Dose (AED)

Generally, AED of radiation resulting from intake of radioelements in river water samples was estimated using Eq. (2): (Agbalagba et al., 2013; Ononugbo et al., 2013; Igbudu & Briggs-Kamara, 2023), with activity concentration of the radionuclides (Igbudu and Briggs-Kamara, 2023), as well as dose conversion factor for the six age groups (Igbudu et al., 2023). The AED of the radioelements was estimated for adult (12-17 yr and > 17) yr population of the study area. Results in Table 3 showed that the AED of radiation as a result of ingestion of radionuclide (^{40}K) in river water ranged from 0.058±0.003 mSvy^{-1} to 1.476±0.078 mSvy^{-1} in adult (12-17 yr) and 0.047±0.002 mSvy^{-1} to 1.204±0.063 mSvy^{-1} in adult (>17 yr). The results further revealed that the AED of radiation due to ingestion of ^{40}K in water samples was minimum in samples collected from Rumuji/Ibaa bridge and maximum in samples collected from Mini-Ezi creek. The results also indicated that the mean annual effective dose of radiation in adult (12-17 yr and >17 yr) as a result consumption of (^{40}K) in river water samples are 0.346±0.018 mSv y^{-1} and 0.282±0.015 mSv y^{-1} respectively. Results in Figs. 4 and 5 revealed that distribution of mean AED of radiation in adult 12-17 yr and >17 yr) due to intake of ^{40}K exceeded the internationally recommended safe limit of 0.12 mSvy^{-1} (WHO, 2008; UNSCEAR, 2017). This implies that the river water samples are radiologically harmful, unsafe, and contained substances capable of causing radiological hazards among the adult population of the study area. Results in Table 2 further showed that the AED of radiation due to ingestion of ^{232}Th in river water ranged from 0.188±0.011 to 1.285±0.011, and 0.173±0.010 to 1.182±0.070 mSv y^{-1} in adults (12-17 yr and >17 yr) respectively.

The AED of radiation as a result of ingestion of ^{232}Th was maximum in samples collected from Ogbodo water front 1 (L12P1) and minimum in sample from Omuihuechi Aluu 2 (L6P2). The mean AED of ^{232}Th are 0.763±0.044 mSv y^{-1} and 0.702±0.039 mSv y^{-1} in adult 12-17 yr and >17 yr) respectively. The distribution of mean AED of radiation in adults (12-17 yr and >17 yr) due to intake of ^{232}Th in water sample (Figs. 4 and 5) exceeded the internationally recommended safe limit of 0.17 mSvy^{-1} (WHO, 2008; UNSCEAR, 2000). This also implies that the river water is unsafe, radiologically harmful as well as capable of causing radiological hazards. Furthermore, the results in Table 2 indicated that the AED of radiation as a result of ingestion of ^{232}U in river water samples ranged from 0.224±0.033 mSvy^{-1} to 11.815±1.416 mSvy^{-1} and 0.098±0.017 mSvy^{-1} to 6.092±0.730 mSvy^{-1} in adults (12-17) yr and >17 yr) respectively. These values are maximum in samples collected from Omuihuechi Aluu 2 (L6P2) and minimum in Mini-Ezi stream (L9P2). The mean annual effective dose of radionuclide ^{232}U are 4.270±0.557 mSv y^{-1} for adult (12-17) yr and 2.252±0.252 mSvy^{-1} for (>17) yr. The distribution of mean AED of radiation in adult (12-17 yr and >17 yr) due to intake of ^{232}U in river water sample exceeded the internationally recommended safe limit of 0.17 mSvy^{-1} (WHO, 2008; UNSCEAR, 2000). This also implies that the river water samples are radiologically harmful.

Total Annual Effective Dose (TAED)

The TAED as a result of intake of river water was estimated using Eq. (3): (Ajayi & Adesida, 2009; Ononugbo & Anyalebechi, 2017; Igbudu et al., 2023). This was obtained by addition of the AED of each of the three radioelements: ^{40}K, ^{232}Th and ^{232}U in river water samples for the adult (12-17 yr and > 17 yr) population of the study area. Results in Table 3 indicated that the TAED in adult (12-17 yr and >17 yr) due to intake of radionuclides range from 1.431±0.117 mSvy^{-1} to 12.532±1.455 mSvy^{-1} for (12-17) yr, and 0.959±0.073 mSvy^{-1} to 6.800±0.821 mSvy^{-1} for (>17). The mean TAED in adult (12-17 yr and >17 yr) are 5.347±0.619 mSvy^{-1} and 3.207±0.334 mSvy^{-1} respectively. The mean values are less than 6.243 mSvy^{-1} mean value obtained from surface water in Ndokwa East (Ononugbo and Anyalebechi, 2017); 11.91±3.49 mSvy^{-1} and 5.86±1.72 values obtained from drinking water in Ogun State (Achuka et al., 2017); 34.9 mSvy^{-1} and 5.5 mSvy^{-1} values obtained in water from OML oil fields in Niger Delta (Agbalagba et al., 2013). The distribution of mean TAED of radiation in adult population of the study area due to ingestion of radionuclides in river water was maximum in samples collected from Omuihechi Aluu water front 1(L6P2) and minimum in samples from Ogbodo water front 2 (L13P1). The high mean TAED of radiation recorded might be due to high bunkering, dredging or sand mining and lundering activities taking place along the stretch of the river. These activities had resulted in devastation of the environment and loss of aquatic lives and plants within the study area. Results in Fig. 4 showed that distribution of mean TAED in adult (12-17 yr and > 17) yr due to intake of radionuclides in river water in the study area exceeded internationally recommended safe limit of 0.10 $mSvy^{-1}$ (Ononugbo & Anyalebechi, 2017; WHO, 2008; UNSCEAR, 2000). This implies that the river water samples are not safe for human consumption since it contains radiological hazards capable of damaging the tissues and organs of humans due to its consumption.

Conclusion

A radiological survey of AED of radiation in adults (12-17 yr and > 17) yr as a result of ingestion of radionuclides ^{40}K, ^{232}Th and ^{232}U in river water collected from some selected locations along the New Calabar river, was carried out. The activity concentration of radioelements in river water were determined using (NaI) gamma ray detector. Results in Fig. 3 indicated that mean activity concentration was above internationally recommended safe limit.
Mean AED of radiation in adult population (12-17 yr and > 17 yr) of the study area due to ingestion of ^{40}K in river water are 0.346±0.018 mSv y^{-1} and 0.282±0.015 mSv y^{-1} respectively, the mean AED in adult (12-17 yr and > 17 yr) due to intake of ^{232}Th in river water are 0.763±0.044 mSv y^{-1} and 0.702±0.039 mSv y^{-1} respectively, mean AED in adults (12-17 yr and > 17 yr) due to intake ^{232}U in river water are 4.270±0.557 mSv y^{-1} and 2.258±0.252 $mSvy^{-1}$ respectively. Mean TAED in adult 12-17 yr and >17 yr) as a result of intake of ^{40}K, ^{232}Th and ^{232}U in river water are 5.347±0.619 $mSvy^{-1}$ and 3.207±0.334 $mSvy^{-1}$ respectively. Results further showed that the TAED in adults as a result of ingestion of river water in this present study are above the WHO and UNSCEAR recommended safe limit of 0.10 $mSvyr^{-1}$. The study concludes that the water supplies from some selected locations along the banks of the New Calabar River are radiologically contaminated, polluted and are harmful for human consumption, especially among the adult population of the study area.

Recommendations

1. It is recommended that alternative, safe, reliable and clean source of water supplies be provided by relevant agencies of government for the inhabitants of the study area.
2. Further studies on assessment of radiological hazards on inhabitants due to intake of the river water sample from other locations outside the scope of this present study, as well as on sediments is highly encouraged.

References

Abojassim, A. A., Al-Gazaly, H. H., & Kadhim, S. H. (2014). Estimated the Radiation Hazard Indices and Ingestion Effective Dose in Wheat Flour Samples of Iraq Markets. *International Journal of Food Contamination, a Spring Journal, 1*(6), 1-5.

Abdul-Adziz, M. I. A., & Khoo, K. S. (2017). An Assessment of Absorbed Dose and Radiation Hazard Index from Soil around Repository Facility at Bukit Kledang, Perak, Malaysia. *IOP Conference Series: Materials Science and Engineering, 298* (012001), 1-9.

Achuka, J. A., Usikalu, M. R., & Oyeyemi, K. D. (2017). Radiological Risks Assessment of Ogun State Drinking Water. *American Journal of Applied Sciences*, *14*(5), 540-550.

Agbalagba, E. O., Avwiri, G. O., & Ononugbo, C. P. (2013). Activity Concentration and Radiological Impact Assessment of ^{226}Ra, ^{232}Th and ^{40}K in Drinking Water from (OML) 30, 58 and 61 Oil Fields and Host Communities in Niger Delta Region of Nigeria. *Journal of Environmental Radioactivity 116*(2013), 197-200.

Agbalagba, E. O., Avwiri, G. O., & Ononugbo, C. P. (2013). Evaluation of Naturally Occurring Radioactive Materials (NORM) of Soil and Sediments in Oil and Gas Wells in Western Niger Delta Region of Nigeria. *Environmental Earth Science, 70,* 2613-2622.

Agbalagba, E.O., Enaibe, E. A., Osakwe, R. O., & Obi, J. (2013). Estimation of Radiation Dose Intake for Infants and Adults from Gross Alpha Activity in Selected Oil Producing Area in Delta State, Nigeria. *Journal of Research in Environmental Science and Toxicology, 2*(6), 23-31.

Agbalagba, E. O., Avwiri, G. O., & Chad-Umoren, Y. E. (2013). Gross α and β Activity Concentration and Estimation of Adults and Infants Dose Intake in Surface and Ground Water of Ten Oil Fields Environment in Western Niger Delta of Nigeria. *Journal of Applied Science and Environmental Management, 17*(2), 267-277.

Ajayi, O.S., & Adesida, G. (2009). Radioactivity in Some Sachet Drinking Water Samples Produced in Nigeria. *Iranian Journal Radiation Resources 7*(3), 151-158

Akinloye, M. K. (2008). Radioactivity in LAUTECH Water Supplies, Nigeria. *Nigerian Journal of Physics, 20(1),* 29-37.

Alias, M., Hamzah, Z., Saat, A., Omar, M., & Wood, A. K. (2008). An Assessment of Absorbed

Dose and Radiation Hazard Index from Natural Radioactivity. *The Malaysia Journal of Analytical Sciences, 12*(1), 195-204.

Anekwe, U. L., Uzoekwe, S. A., & Ibe, S. O. (2023). Estimation of Health Risks in Borehole Water Supply, Case Study in Ogbia, Nigeria. *OSP Journal of Health Care and Medicine, 4*(1), 1-8.

Avwiri, G. O. (2005). Determination of Radionuclide Levels in Soil and Water around Cement Companies in Port Harcourt. *Journal of Applied Science. Environment and Management, 9*(3), 27-29.

Avwiri, G. O., & Agbalagba, E. O. (2007). Survey of Gross Alpha and Gross Beta Radionuclide Activity in Okpare Creek, Delta State, Nigeria. *Journal of Applied Sciences*, *7*(22), 3542-3546.

Avwiri, G. O., Egieya, J. M., & Ononugbo, C. P. (2013). Radiometric Assay of Hazard Indices and Excess Lifetime Cancer Risk Due to Natural Radioactivity in Soil Profile in Ogba/Egbema/Ndoni Local Government Area of Rivers State. *Academic Research International, 4*(5), 54-65.

Avwiri, G. O., Esi, E., & Agbalagba, E. O. (2013). Gamma Spectroscopy Analysis of Produced Water from Selected Flow Stations in Delta State, Nigeria. *International Journal Environmental Monitoring and Analysis, 1*(5), 167-174.

Avwiri, G. O., Ononugbo, C. P., & Nwokeoji, I. E. (2014). Radiation Hazard Indices and Excess Lifetime Cancer Risk in Soil, Sediment and Water around Mini-Okoro/Oginigba Stream, Port Harcourt, Rivers State, Nigeria. *Journal of Environmental and Earth Sciences, 3*(1), 38-50.

Ayodele, A. E., Arogunjo, A. M., Ajisafe, J. I., & Arije, O. T. (2020). Radioactivity Level of Drilled Well Water Accross Selected Cities in Ondo and Ekiti States, Southwestern Nigeria and its Radiological Implications. *International Journal of Radiation Research, 18*(2), 1-7.

Dankawu, U. M., Shuaibu, H. Y., Maharaz, M. N., Zangina, T., Lariski, F. M., Ahmadu, M., Zarma, S. S., Benedict, J. N., Uzair, M., Adamu, G. D., & Yakubu, A. (2021). Estimation of Excess Lifetime Cancer Risk and Annual Effective Dose for Boreholes and Well Water in Dutse, Jigawa State, Nigeria. *Dutse Journal of Pure and Applied Sciences (DUJOPAS) 2*(4a*)*, 208-218.

Elenwo, M. (2021). Showing Blacksmithing as an Alternative Income Earner to Unemployed Nigerians and Other Parts of the World for Sustainable Development: Elele-Alimini Blacksmithing in focus. *Saphientia Foundation of Education, Sciences and Gender Studies (SFJESGS), 3*(3), 2514-2522.

El-Gamal, H; Negm, H., & Hasabelnaby, M. (2019). Detection Efficiency of NaI (TI) Detector Based on the Fabricated Calibration of HPGe. *Journal of Radiation Research and Applied Sciences 12*(1*)*, 360-366.

El-Mageed, A. I. A., El-Hadi, A., El-Kammel, A., El-Bast, A., Harb, S., & Saleh, I. I. (2011). Natural Radioactivity of Groundwater and Hot Spring in Some Areas in Yemen. *Desalination. The International Journal of the Science and Technology of Desalting and Water Purification, 321,* 28-31.

Francis, A., & Elewuo, U. (2012). Aspect of the Biology of Trap Caught Chrysichthysnigrodigitatus (Lacepede: 1803) From the New Calabar River, Nigeria. *International Journal of Fisheries and Aquaculture, 4,* 99-104.

Igbudu, O. & Briggs-Kamara, M. A. (2023). Determination of Effective Dose of Radionuclides in Water Samples on Infants from Communities Along the Banks of New Calabar River, Rivers State, Nigeria. *International Journal of Microbiology and Applied Science, 1*(1), 85-93.

Igbudu, O., Briggs-Kamara, M. A., & Amakiri, A. R. C. (2023). Assessment of Annual Effective Dose in Children Due to Intake of Water Samples from New Calabar River, Rivers State, Nigeria. *International Journal of Scientific Development and Research (IJSDR), 8*(10), 849-860.

Jegede, O., Suraju, K., & Kolo, T. M. (2017). Evaluation of Natural Radioactivity and Radiological Health Implication of Oniru Beach, Lagos, South-Western Nigeria. *Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) 11*(10*)*, 65-74.

Kabir, K. A., Islam, S. A. N., & Rahman, M. M. (2009). Distribution of Radionuclides in Surface Soil and Bottom Sediments in District of Jessore, Bangladesh and Evaluation of Radiation Hazard. *Journal of Bangladesh Academy of Science, 33*(1), 117-130.

Meindinyo, R. K., & Agbalagba, E. O. (2012). Radioactivity Concentration and Heavy Metals Assessment of Soil and Water, in and around Imirigin Oil Field, Bayelsa State, Nigeria. *Journal of Environmental Chemistry and Ecotoxicology, 4*(2), 29-34.

Miebaka, M., Wosu, B. H., & Miebaka, C. A. (2022). Comparative Studies of Physico-chemical Parameters and Total Hydrocarbon Content (THC) of Choba and Iwofe axis of the New Calabar River in the Niger Delta, Nigeria. *Open Access Research Journal of Multidisciplary Studies, 3*(2), 43-49.

Nwochigoziri, E. C., Ekpete, O. A., & Kpee, F. (2023). Assessment of Physico-Chemical Parameters of New Calabar and Orashi Rivers Exposed to Open Waste Discharge in Nigeria. *Journal of Applied Sciences and Environmental management, 37*(7), 1541-1549.

Ononugbo, C. P., & Anyalebechi, C. D. (2017). Natural Radioactivity Level and Radiological

Risk Assessment of Surface Water from Coastal Communities of Ndokwa East, Delta State, Nigeria. *Physical Science International Journal*, *14*(1), 1-14.

Ononugbo, C. P., Avwiri, G. O., & Egieya, J. M. (2013). Evaluation of Natural Radionuclide Content in Surface and Ground Water and Excess Lifetime Cancer Risk Due to Gamma Radioactivity. *Academic Research International*, *4*(6), 636-647.

Orosun, M. M., Ajibola, T. B., Ehinlafa, O. E., Sharafuden, F. A., Salawu, B. N., Ige, S. O., & Akoshile, C. O. (2022). Radiological Hazards Associated With ^{238}U, ^{232}Th and ^{40}K in Some Selected Packaged Drinking Water in Ilorin and Ogbomoso, Nigeria. *Journal of Environmental Pollution*, *8*(1), 117-131.

Orosun, M. M., Usikalu, M. R., Onwumejor, C. A., Akinnagbe, D. M., Orosun, O. R., Salawu, N. B., Olasunkanmi, N. K., Akinpelu, A., Adagunodo, T. A., & Achuka, J. A. (2021). Assessment of Natural Radionuclide Contents in Water and Sediments from Asa-Dam, Ilorin, Nigeria. *Earth and Environmental Science, 655*, 1-7.

Onyegeme-Okerenta, B. M., Obia, C., & Wegwu, M. O. (2016). Physicochemical Properties of Water Quality of Ime, Edegelem and Chokocho Communities Located along Otamiri-Oche River, in Etche Ethnic Nationality of Rivers State. *Journal of Applied Science and Environmental Management, 20*(1), 113-119.

Samaila, B., & Tampul, H. M. (2021). Determination of Soil Radioactivity and Radiological Hazard Indices in Nigeria: A Review. *Savanna Journal of Basic and Applied Sciences*, *3*(1), 71-80.

Sowole, O., & Egunjobi, K. A. (2019). Radioactive Assessment of the ^{40}K, ^{235}U and ^{232}Thorium on Surface Soil Samples of Igbokoda, Southwest, Nigeria. *Tanzania Journal of Science, 45*(3), 307-314.

UNSCEAR, (2010). United Nations Scientific Committee on Effects of Atomic Radiation. Report to the General Assembly Annex B: Exposure from Natural Radiation Source.
United States Environmental Protection Agency (US, EPA 2000). Office of Water Setting Standards for Safe Drinking Water, Revised June 9 (US-EPA, Washington

WHO (2017). (World Health Organization) Guidelines for Drinking-Water Quality. Fourth Edition Incorporating the First Addendum. *WHO Geneva*, 1-137.

Cite this article as:
Igbudu, O., & Ogan, A. C. (2025). Radiological risk assessment of adult exposure to radionuclides from the New Calabar River, Nigeria. *FNAS Journal of Applied and Physical Sciences, 2*(2), 12-27.