ISSN: 4120 – 5671
Volume 10, Number 3, 2024
Advanced Journal of Physical Science Research

EVALUATION OF NATURAL RADIONUCLIDES IN WATER SAMPLES FROM SOME LOCAL GOVERNMENT AREAS IN EDO STATE, NIGERIA.

Damaris Osiga-Aibangbee, Agbajor, G.K., Ofomola, M.O., Mokobia, C.E
Department of Physics, Delta State University, P.M.B 1, Abraka, Delta State, Nigeria

Corresponding authors email: damarisaibangbee@gmail.com

ABSTRACT

Twelve samples of water were collected from four communities in Edo state using Gamma ray spectroscopy, NaI(TI) in order to detect and calculate the activity concentration, radiation health indices and the daily radionuclide intake of water and age dependent annual effective dose due to the intake of ^{40}K, ^{238}U, *and* ^{232}Th, *In the water samples were also calculated, activity concentrations for* ^{40}K, ^{238}U, *and* ^{232}Th *varied from 205.50±1.15 to 723.92±8.96, 5.23±0.04 to 20.58±0.12, and 0.93±0.04 to 7.17±0.12 Bq/l, respectively. For the radionuclide health indices of water samples all the radiological health parameters in this research work were below the recommended limits, lastly ages 0-1yr and ages 12-17yrs had the highest value for radionuclide intake of water.*

Keywords: Radionuclides, Water, Communities, Health, Risk, activity concentrations

INTRODUCTION

Ecosystems of aquatic origin constitute a range of interactions of physical or biological as well as chemical origin that impact the behavior of radionuclides. These interactions include morphometric, physical qualities, chemical properties, and biological components. Nutrients, metals, radionuclides, and hazardous chemicals are dispersed in aquatic ecosystems via basic processes. These processes are governed by hydrological and morphometrical parameters, which cannot be altered by therapies like liming and potash treatment [1]. Natural radionuclides occur naturally in varied amounts, including ^{238}U, ^{232}Th, ^{40}K, radium-226, Polonium-210, and Lead-210. These naturally occurring radioactive emissions find use in agricultural, industrial, medical exploitations as well as testing of weapons of nuclear origin [1,2]. Nuclides of radioactive origin can be obtained from different sources within the environment, including natural ones like weathered rock and artificial ones arising from various activities of humans like fertilizers, mining, as well as medical facilities. Three naturally abundant radionuclides, ^{238}U, ^{232}Th, and ^{40}K, can enter water bodies, while studies have documented the numerical value of radionuclides concentrated in water around communities within coastal regions in Nigeria [2,3,5,6,7,8], comprehensive data on the distribution, concentration levels, and sources of radionuclides like uranium, thorium, and potassium in Edo State are lacking.

MATERIALS AND METHOD

STUDY AREA: The city of Benin is the largest in the state of Edo, the fourth-largest city in Nigeria and doubles as its capital. It is situated at 6°20′00″N 5°37′20″E and spans an area of 1,204 km² with an estimated population of 4,777,000 as of 2022. Edo State shares boundaries with Kogi, Anambra, Delta and Ondo states to the north, east, south, and west, respectively. The Niger River runs along its eastern boundary. Coastal communities in Edo State play a crucial role in fishing, oil exploration, and other economic activities, yet they encounter distinct challenges due to climate change, energy access, and sustainable development, as shown in Figure 1. The study area is underlain by sedimentary rocks and is found within Benin, Bende-Ameki, Ogwashi-Asaba, Imo and Nsukka formations [9]

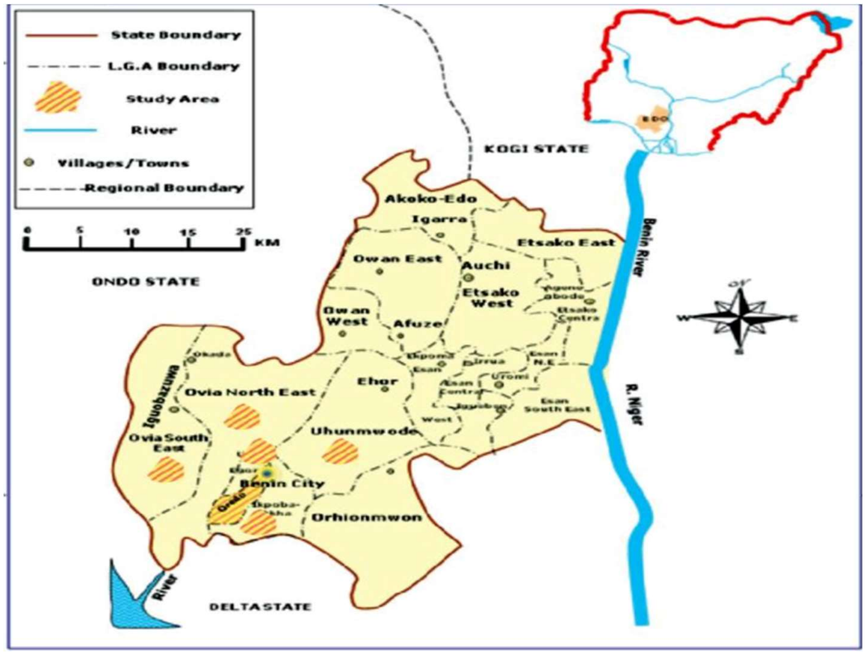

Figure 1: Map of study area [10]

The studied locations in Edo State with their coordinates are shown in Table 1.

SAMPLE PREPARATION: Twelve (12) water samples were randomly collected from four communities within the study area, gathering 200 g of samples at each designated site, spaced 50 m apart. These locations, marked with their geophysical coordinates, were selected based on community access to river water for consumption and other domestic uses, as detailed in Table 1. The samples underwent analysis at the IFE, CERD centre using spctrometric analysis involving ray of gamma origin. This involved a Sodium iodide 16″x16″ [NaI(Tl)] detector activated by thallium and an amplifier 456, ORTEC. Encased in a shield of lead measuring 100 mm in thickness, the detector was connected to a programable computer capable of running program known as SAMPO 90 computer program, which aligns gamma energies with a known isotope library. The spectrometry system's calibration, crucial for accurate quantitative measurements, was conducted using Cs-137 and Co-60 standards from the IAEA in Vienna. Spectra background were collected over 29000 seconds at 900 volts, resulting in pronounced peaks at the gamma emission energy of magnitudes 1460, 609 and 911 in unit of keV for 40K, 214Bi, and 228Ac, respectively. These peaks facilitated the estimation of 238U (226Ra) and 232Th concentrations. The detector's energy resolution, when employing the standards of Co-60 and Cs-137, was respectively 22.2% and 39.5%, with standard activities of 25.37 KBq for Cs-137 and 4.84 KBq for Co-60 at calibration time. Recorded spectra backgr under identical conditions for both standards and samples, were utilized to adjust the sample’s activity concentrations according to [11]. The radionuclides' activity concentration (C) in the samples, expressed in Bq/kg, was determined by applying decay correction with the following expression:

$$C_s = \frac{NE_\gamma}{\varepsilon E_\gamma \times M_v \times t_c \times P_\gamma} \qquad (1)$$

Where Cs=Sample concentration, NE_γ= net peak area of a peak at energy, εE_γ= Efficiency of the detector for a γ-energy of interest, Mv=Sample volume, tc= total counting time, P_γ=Emission probability of radionuclide of interest.

Table 1: Description of water samples collected from Edo State

Locations	Geographical Coordinates	Sample codes	Description of Sample codes
Ogba	Long. 5.5821705 Lat. 6.2849025	OBW1ED	Ogba Water 1 Edo
Ogba	Long. 5.5823069 Lat. 6.2847544	OBW2ED	Ogba Water 2 Edo
Ogba	Long. 5.5824967 Lat. 6.2851333	OBW3ED	Ogba Water 3 Edo
Uvbua	Long. 5.7581783 Lat. 6.2027650	UVW1ED	Evbuarhue Water 1 Edo
Uvbua	Long. 5.7596968 Lat. 6.2021195	UVW2ED	Evbuarhue Water 2 Edo
Uvbua	Long. 5.7599500 Lat. 6.2023653	UVW3ED	Evbuarhue Water 3 Edo
Gelegele	Long. 5.3447443 Lat. 6.1555097	GEW1ED	Gelegele Water 1 Edo
Gelegele	Long. 5.3454862 Lat. 6.1561306	GEW2ED	Gelegele Water 2 Edo
Gelegele	Long. 5.3483275 Lat. 6.1609400	GEW3ED	Gelegele Water 3 Edo
Ologbo	Long. 5.6631734 Lat. 6.0533387	OLW1ED	Ologbo Water 1 Edo
Ologbo	Long. 5.6625925 Lat. 6.0531807	OLW2ED	Ologbo Water 2 Edo
Ologbo	Long. 5.6640505 Lat. 6.0525589	OLW3ED	Ologbo Water 3 Edo

ESTIMATION OF RADIOLOGICAL PARAMETERS

Absorbed Dose Rate (D)

The rate of dose absorbed in air, resulting from the activity concentrations of naturally occurring radionuclides such as K-40, U-238, and Th-232 (Bq/kg-1), in coastal regions, is estimated by the employment of Equation (2).

$$\mathrm{D}\,(\mathrm{nGyh}^{-1}) = 0.462\mathrm{B_U} + 0.604\,\mathrm{B_{Th}} + 0.041\,\mathrm{B_K} \qquad (2)$$

Where $\mathrm{B_K}$,$\mathrm{B_U}$ and $\mathrm{B_{Th}}$ are the respective activities of K-40, U-238, and Th-232 in the samples under consideration [12,13,14,15]

Annual effective dose for external exposures (AED)

The received total annual dose due to external exposure was obtained with the help of Equation (2) as

$$\mathrm{AED_{Outdoor}}\,(\mathrm{mSvy}^{-1}) = \mathrm{D(nGy/h)} \times 8760\mathrm{h} \times 0.7\,(\mathrm{SvG/y}) \times 0.2 \times 10^{-6} \qquad (3)$$

where the standard values of 0.7 SvG/y as conversion factor for dose and 0.2 as factor for occupancy have been used [14].

Radium Equivalent Activity Index ($\mathrm{Ra_{eq}}$)

The Raeq value is obtained from Equation (4) as

$$\mathrm{Ra_{eq}} = \mathrm{B_{Ra}} + 1.43\mathrm{B_{Th}} + 0.077\mathrm{B_K} \qquad (4)$$

where $\mathrm{B_{Ra}}$, $\mathrm{B_{Th}}$ and $\mathrm{B_K}$ represent concentrations of ^{226}Ra, thorium-232, and potassium-40 in unit of Bqkg^{-1}. The average index $\mathrm{Ra_{eq}}$ value is 370 Bqkg^{-1} [13,16].

Excess Lifetime Cancer Risk (ELCR)

Equation (5) gives the parameter of ELCR (Excess Lifetime Cancer Risk)

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

where AED stands for effective dose annual value, DL is mean time one remains on earth (56.05 years as given by [17], while the per Sievert fatal cancer risk value or RF value is given as 0.05and RF is the fatal cancer risk per Sievert assumed to be 0.05 for effect of stochastic origin. The standard ELCR value limit of 0.29×10^{-3} has been employed [14,18].

External Hazard Index (H_{ext})

The external hazard index serves as a valuable metric for regulating safety standards and protecting against radiation of gamma origin emitted by different substance that are radioactive in nature substances. It is calculated using Equation (6), as referenced by [14,19,20].

$$\mathrm{H_{ext}} = \frac{B_K}{4810} + \frac{B_U}{370} + \frac{B_{Th}}{259} \quad (6)$$

where $\mathrm{B_U}$,$\mathrm{B_{Th}}$ and $\mathrm{B_K}$ are the respective activity concentrations of U-238, Th-232 and K-40.

Internal Hazard Index (H_{in})

The internal hazard index, which quantifies exposure to radon and its progeny, is defined by Equation (7), as referenced in [14,19,20].

$$\mathrm{H_{in}} = \frac{B_K}{4810} + \frac{B_U}{184} + \frac{B_{Th}}{259} \quad (7)$$

Where $\mathrm{B_U}$,$\mathrm{B_{Th}}$ and $\mathrm{B_K}$ stand for activity concentrations of U-238, Th-232 and K-40 respectively

Gamma Index (I_γ)

This parameter estimates the gamma radioactivity level of linked to various radionuclide as a result of varying concentrations [21,22].

$$\mathrm{I_\gamma} = \frac{B_K}{3000} + \frac{B_U}{300} + \frac{B_{Th}}{200} \quad (8)$$

where $\mathrm{B_U}$,$\mathrm{B_{Th}}$ and $\mathrm{B_K}$ are the activity concentrations of ^{238}U, ^{232}Th and ^{40}K respectively. It is advised that certain materials capable of producing a dose rate greater than 1 in building construction must be avoided [22].

Annual Gonad Equivalent Dose (AGED)

This parameter concerns itself with quantity of exposure received by vital organs of the body within the area of this study as a result of specified radioactive activities of natural origin within the soil. These organs include the gonads, active bone marrow, as well as bone surface cells. AGED is calculated using Equation (9) [20,23,24].

$$\mathrm{AGED}\ (mSvyr^{-1}) = 3.09\ \mathrm{B_U} + 4.18\ \mathrm{B_{Th}} + 0.314\mathrm{B_K} \quad (9)$$

where $\mathrm{B_U}$,$\mathrm{B_{Th}}$ and $\mathrm{B_K}$ are the activity concentrations of ^{238}U, ^{232}Th and ^{40}K respectively.

Daily Intake of the Radionuclide

The daily nuclide intake of radioactive origin was calculated by means of Equation (10) [23,24].

$$D_{int} = \frac{AC\ X\ CR}{D_y} \quad (10)$$

Where D_{int} = daily intake of Radionuclides; AC = Activity Concentration of given Radionuclides; CR = rate at which the studied food crop consumes annually and D_y = a pure number representing days (D_y = 365).

Life Time Cancer Risk

This was estimated and defined by the Equation (10) [23,24] with respect to US Environmental Protection Agency (USEPA). Risk of cancer coefficient due to radionuclide exposure in the environment as expressed by [25] is given as

$$LCR = AC \times CR \times LS \times \text{AC} \tag{11}$$

where AC is activity concentration of radionuclides; CR is the average rate at which the studied food crop is consumed; LS = average life expectancy (56.05 years given by [18] and RC is the radionuclides cancer mobility risk coefficient.

RESULTS AND DISCUSSIONS

Tables 2, 3 and 4 display the activity concentration of radionuclides in water, Radiation health indices parameters in water and daily amount of radionuclides taken in due to water consumption and effective dose of annual origin obtained because of ingestion of ^{40}k and ^{238}U and ^{232}Th from Edo State.

Activity concentrations in water samples for ^{40}K, ^{238}U, and ^{232}Th ranged from 260.50±5.38 to 723.92±8.96, 5.23±0.04 to 20.58±0.12, and 0.93±0.04 to 7.17±0.12, respectively, as indicated in Table 2. The highest activity concentrations of these natural radionuclides were in samples OBW3ED, UVW3ED and UVW3ED respectively, while the lowest were in OBW2ED, OBW1ED and OBW1ED respectively. These variations may be due to differences in arrangement of geological formation and the presence of thorium minerals like zircon, monazite, as well as thorite, as reported by [21].

For water samples, the absorbed dose rate varied from 18.39 to 39.82 nGy/h, with an estimated average of 23.42 nGy/h. This average is about 41% below the acceptable limit of 59 nGy/h. For the water sample, the H_{in} index fluctuates between 0.11 and 0.20, averaging at 0.14. The mean values for both samples are significantly below the global average value of unity (1), suggesting that the internal index of health hazard is beneath the threshold, corroborating findings by [23]. These results are also less than half the approved safety limit according to [14,25], deeming them safe for the local population.

The H_{out} index for water samples ranged between 0.09 and 0.13, with a mean of 0.11. When compared to the recommended value of ≤ 1 by [14], both mean values from this study were lower. For the water sample, the R_{eq} values range from 188.72 to 568.68 Bqkg^{-1}, with mean of 294.94 Bqkg^{-1}, which also falls below the global average. These values suggest uncertainty in radiological risks to the public.

Regarding the water sample, the gamma activity index was between 0.26 and 0.56, with an average of 0.33. This suggests that the dose rate from the water sample also remains below the global average limit of 1 mSv/year. Similarly, the AGED values for water samples varied from 0.262 to 0.56, associated with samples OBW2ED and OBW3ED, respectively. The mean value of 154.4601 obtained was well below the permissible limit of 370, aligning with findings by [20].

Similarly, the AEDR values for water samples range from 0.11 μSvy^{-1} to 0.24 μSvy^{-1}, with the lowest and highest values found in samples OBW2ED and OBW3ED, respectively. The mean value of 0.14 is below the global permissible limit of $1\mu Svy^{-1}$.

The mean value reported in this study is lower than the global average of 0.29×10^{-3}, suggesting that the lifetime cancer risk for residents in the sampled areas is comparatively lower.

The daily analysis of water samples from Edo state, as depicted in Table 4, shows that D_K-^{40} levels vary between 29.77 and 82.73 with the lowest and highest values recorded in samples OBW2ED and OBW3ED, respectively. The D_U-^{238} levels ranged from 0.87 to 1.58, and D_Th-^{232} levels were between 0.20 and 0.39. The majority of the readings for ^{238}U, and ^{232}Th were below one, which is under the recommended dose limit set by [15]. According to [23], the findings suggest a potential for low dose radiological risk of long-term effects on the health of individuals residing in these coastal communities.

Table 2: Activity Concentration of Radionuclide in water from Edo States

Sample codes	^{40}K (Bq/L)	^{238} U (Bq/L)	^{232} Th (Bq/L)
OLW1ED	276.70±5.54	9.16±0.07	2.40±0.07
OLW2ED	405.06±6.70	13.84±0.06	1.94±0.06
OLW3ED	269.93±5.47	8.70±0.07	2.41±0.07
UVW1ED	421.82±6.84	5.73±0.06	2.11±0.06
UVW2ED	372.00±6.42	9.21±0.06	1.90±0.06
UVW3ED	205.05±1.15	20.58±0.12	7.17±0.12
GEW1ED	362.13±6.34	7.70±0.06	1.96±0.06
GEW2ED	328.62±6.04	7.63±0.06	1.79±0.06
GEW3ED	380.99±6.5	8.15±0.06	2.16±0.06
OBW1ED	387.64±6.56	5.23±0.04	0.93±0.04
OBW2ED	260.50±5.38	8.12±0.08	3.42±0.08
OBW3ED	723.92±8.96	8.49±0.06	1.94±0.06
Mean	**366.20±5.99**	**9.37±0.06**	**2.51±0.06**
RL	**10.0**	**1.0**	**0.1**

Table 3. Radiation health indices parameters in water from Edo state

Samples	ADR (nGyhr^{-1})	AEDE (mSvyr^{-1})	ELCR X 10^{-3}	H_{in}	H_{ex}	R_{eq}	AGED	Iγ
OLW1ED	18.96	0.12	0.07	0.12	0.09	225.65	125.22	0.27
OLW2ED	26.90	0.16	0.09	0.17	0.13	328.51	178.06	0.38
OLW3ED	18.43	0.11	0.06	0.11	0.09	219.99	121.71	0.26
UVW1ED	24.20	0.15	0.08	0.13	0.11	333.55	158.98	0.34
UVW2ED	23.22	0.14	0.08	0.13	0.11	298.37	153.21	0.33
UVW3ED	23.77	0.15	0.08	0.18	0.13	188.72	157.95	0.35
GEW1ED	22.11	0.14	0.08	0.12	0.10	289.34	145.69	0.31
GEW2ED	20.36	0.12	0.07	0.12	0.10	263.23	134.25	0.29
GEW3ED	23.35	0.14	0.08	0.13	0.11	304.60	153.84	0.33
OBW1ED	21.55	0.13	0.08	0.11	0.10	305.04	141.77	0.30
OBW2ED	18.39	0.11	0.06	0.11	0.09	213.60	121.18	0.26
OBW3ED	39.82	0.24	0.14	0.20	0.18	568.68	261.65	0.56
Mean	23.42	0.14	0.08	0.14	0.11	294.94	154.46	0.33
Standard value	59	1	0.29	1	1	370	370	1

Table 4 Daily intake of Radionuclides in water and age dependent annual effective dose due to the Intake of ^{40}k and ^{238}U and ^{232}Th from Edo state

Sample codes	Din(^{40}K)	D_{in}(^{238}U)	D_{in}(^{232}Th)	0-1 yr	1-2yrs	2-7yrs	7-12yrs	12-17yrs	>17yrs
OLW1ED	6.823	0.2259	0.0592	1.4249	0.5589	0.3699	0.4067	0.9866	0.2859
OLW2ED	9.988	0.3413	0.0478	1.9817	0.8105	0.533	0.5915	1.4594	0.3978
OLW3ED	6.656	0.2145	0.0594	1.3742	0.5401	0.3572	0.3909	0.9424	0.2770
UVW1ED	10.40	0.1413	0.0520	1.2558	0.6283	0.3945	0.3739	0.7397	0.3016
UVW2ED	9.173	0.2271	0.0468	1.5018	0.6583	0.4256	0.4464	1.027	0.3213
UVW3ED	5.056	0.5075	0.1768	1.2818	0.8214	0.5873	0.7423	2.053	0.4836
GEW1ED	8.929	0.1899	0.0483	1.3532	0.6106	0.3919	0.4002	0.8875	0.2980
GEW2ED	8.103	0.1881	0.0441	1.2894	0.5702	0.3677	0.3813	0.8634	0.2790
GEW3ED	9.394	0.2010	0.0532	1.4372	0.6447	0.4143	0.4235	0.9396	0.3158
OBW1ED	9.558	0.129	0.0229	1.0576	0.5647	0.3513	0.3322	0.6614	0.2597
OBW2ED	6.423	0.2002	0.0843	1.4009	0.5272	0.3511	0.3806	0.9009	0.2820
OBW3ED	17.85	0.2093	0.0478	1.87	1.0251	0.6343	0.5868	1.123	0.4718
Mean	9.03	0.2312	0.0619	1.436	0.6633	0.4315	0.4547	1.049	0.3313

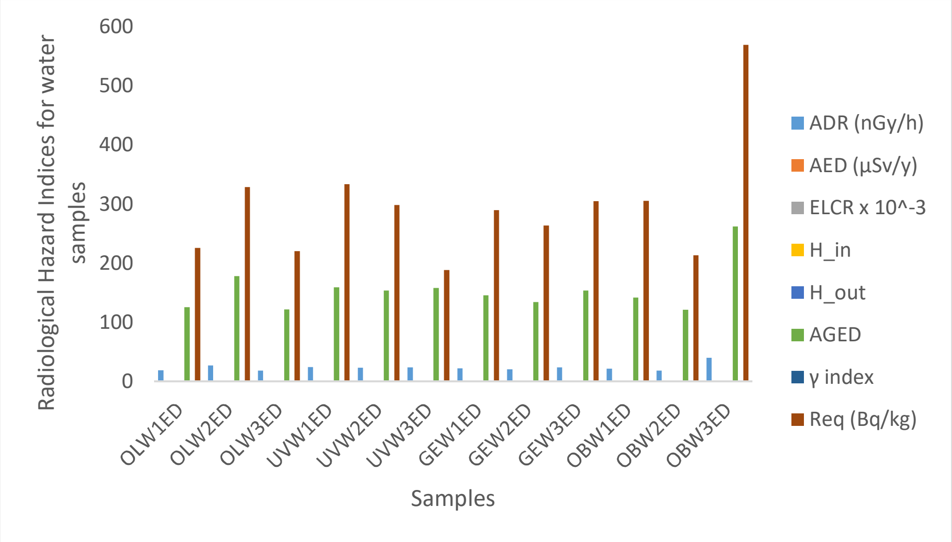

Figure 2: Variation of the Radiological Hazards for water samples for the studied locations

CONCLUSION

In the research of water samples carried out in some communities of Edo State along with their radiological risk parameters. The evaluated parameters were below globally recommended limits, suggesting a radiation-safe environment. While the current levels of radionuclide hazard indices do not present an immediate health risk, the cumulative effects of low-dose radiation exposure could lead to health issues over time. Consequently, it is advised that regular monitoring programs be established to track radionuclide levels in various environments, within these communities in Edo State.

REFERENCES

[1] Erenturk, S., Yusan, S., Turkozu, D. A., Camtakan, Z., Olgen, M. K., Aslani, M. A., ... & Isik, M. A. (2014). Spatial distribution and risk assessment of radioactivity and heavy metal levels of sediment, surface water and fish samples from Lake Van, Turkey. *Journal of Radioanalytical and Nuclear Chemistry*, *300*, 919-931.

[2] Garba, N. N., Ramli, A. T., Saleh, M. A., Sanusi, S. M., & Gabdo, H. T. (2016). Radiological mapping of Kelantan, Malaysia, using terrestrial radiation dose rate. *Isotopes in environmental and health studies*, *52*(3), 214-218.

[3] Ademola, J. A., & Ehiedu, S. I. (2010). Radiological analysis of 40K, 226Ra and 232Th in fish, crustacean and sediment samples from fresh and marine water in oil exploration area of Ondo State, Nigeria. *African Journal of Biomedical Research*, *13*(2), 99-106.

[4] Ononugbo, C., & Anyalebechi, C. (2017). Natural radioactivity levels and radiological risk assessment of surface water from coastal communities of Ndokwa East, Delta State, Nigeria. *Physical Science International Journal*, *14*(1), 1-14.

[5] Ayeku, P. O., Ogundele, L. T., & Adeniyi, I. F. (2019). A study of heavy metals pollution in the coastal marine sediment of Ondo State, Nigeria. *Current Journal of Applied Science and Technology*, *34*(1), 1-10.

[6] Aliyu, A. O., Yakubu, A., & Ajagbe, O. O. (2018). Determination of radionuclide concentrations, hazard indices and physiochemical parameters of water, fishes and sediments in River Kaduna, Nigeria. *IOSR J. Appl. Chem*, *11*(1), 28-34.

[7] Adeleye, M. O., Musa, B., Oyebanjo, O., Gbenu, S. T., & Alayande, S. O. (2020). Activity concentration of natural radionuclides and assessment of the associated radiological hazards in the marine croaker (Pseudotolitus typus) fish from two coastal areas of Nigeria. *Science World Journal*, *15*(2), 90-95.

[8] Omeje, M., Orosun, M. M., Aimua, G. U., Adewoyin, O. O., Sabri, S., Louis, H.,& Targema, T. V. (2024). Radioactivity distributions and biohazard assessment of coastal marine environments of niger-delta, Nigeria. *All Earth*, *36*(1), 1-19.

[9] Davies, O., Amachree, D., & Teere, M. (2019). Effects of radionuclides in aquatic lives of Nigerian coastal rivers: A review. *Int. J. Res. Stud. Sci. Eng. Technol*, *692*, 25-33.

[10] Adebiyi, S. K., Emoresele, E., & Ogbonnaya, M. J. (2021). Antimicrobial Efficacy of Solar Disinfection of Selected Drinking Well Water in Benin City, Nigeria. *Open Journal of Bioscience Research (ISSN: 2734-2069)*, *2*(1), 16-25.

[11] Omeje M., O., Joel, E. S., Ijeh I.B., Mary, A. T. T., Emeka, E. O., Uchechukwu, O. A., & Saeed, M. A. (2021). Measurements Of Seasonal Variations Of Radioactivity Distributions In Riverine Soil Sediment Of Ado-Odo Ota, South-West Nigeria:

Probabilistic Approach Using Monte Carlo.Radiation Protection Dosimetry. 00(00), 1–14.

[12] Omeje, M., Usiaka Aimua, G., Oladotun Adewoyin, O., Michael Orosun, M., Sunday Joel, E., Usikalu, M. R., & Anne, O. U. (2023). Dispersion of gamma dose rates and natural radionuclides in the coastal environments of the Unumherin community in Niger Delta. *Cogent Engineering*, *10*(1), 2204546.

[13] Sugandhi, S., Joshi, V. M., & Ravi, P. M. (2014). Studies on natural and anthropogenic radionuclides in sediment and biota of Mumbai Harbour Bay. *Journal of Radioanalytical and Nuclear Chemistry*, *300*, 67-70.

[14] United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR, (2000). Exposures from natural radiation sources. Report to the General Assembly, with Annexes, Annex-B, United Nations, New York.

[15] Mokobia, C.E, Oduah, C. and Edomi, O. (2019). Estimation of Background Ionization Dose Equivalent in Some Radio-Diagnostic Centres Delta State, Nigeria Journal of science and Environment Vol.17:44-50

[16] Omeje, M., Wagiran, H., Ibrahim, N., Lee, S. K., & Sabris, S. (2013). Comparison of activity concentration of 238U, 232Th and 40K in different layers of subsurface structures in Dei-Dei and Kubwa, Abuja Northcentral Nigeria. *Radiation Physics and Chemistry*, *91*, 70-80.

[17] World Health Organisation, WHO (2008). Meeting the MDG (Millennium Development Goals) drinking water and sanitation target: the urban and rural challenges of the decade. WHO Library Catalogue-in-Publication Data; 2008.

[18] Mokobia, C.E and Oyibo,B (2017) Determination of Background Ionization Radiation (BIR) Level in Some Selected Farms in Delta state Nigeria, Nigeria Journal of Science Environment. Vol.15:27-31.

[19] Ononugbo, C. P. and Mgbemere, C. J. (2016). Dose rate and annual effective dose Assessment of terrestrial gamma radiation in Notre fertilizer plant, Onne, Rivers State, Nigeria. International Journal of Emerging Research in Management and Technology, 5(9): 30-35.

[20] Ononugbo, C., & Anyalebechi, C. (2017). Natural radioactivity levels and radiological risk assessment of surface water from coastal communities of Ndokwa East, Delta State, Nigeria. *Physical Science International Journal*, *14*(1), 1-14.

[21] Sirelkhatim, D. A., Sam, A. K., & Hassona, R. K. (2008). Distribution of 226Ra–210Pb–210Po in marine biota and surface sediments of the Red Sea, Sudan. *Journal of Environmental Radioactivity*, *99*(12), 1825-1828.

[22] Innocent, A. J., Onimisi, M. Y., & Jonah, S. A. (2013). Evaluation of naturally occurring radionuclide materials in soil samples collected from some mining sites in Zamfara State, Nigeria. *British Journal of Applied Science & Technology*, *3*(4), 684-692.

[23] Akpolile, F. A., & Ugbede, F. O. (2019). Natural radioactivity study and radiological risk assessment in surface water and sediments from Tuomo River in Burutu, Delta State Nigeria. *Journal of Nigerian Association of Mathematical Physics (J. NAMP)*, *50*, 267-274.

[24] Damaris Osiga-Aibangbee, A.F. Akpolile, M.O. Ofomola, Omamoke O.E. Enaroseha, Godwin K. Agbajor and C.E, Mokobia (2024). Radionuclide Evaluation in Sediment Samples in some Communities in Edo State, Nigeria. Journal of Physical Sciences and Engineering, Volume 10(2), 67-73.

[25] ICRP (1991). Recommendations of the International Commission on Radiological Protection 1990 (ICRP) Publication No. 60. Annals of the ICRP 21: 1-201