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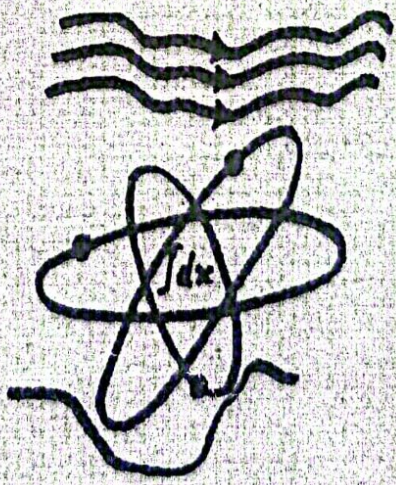
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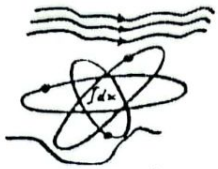
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Natural Radionuclide Concentration and Radiological Impact Assessment of Soil and Water From Dadinkowa Dam, Northeast Nigeria.

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Abstract

Radioactivity measurement of water and sediment samples from Dadinkowa dam, Gombe, Nigeria was carried out using a lead-shielded "76mm×76mm" Sodium iodide [NaI(TI)] detector connected to ORTEC456 amplifier. The obtained gamma results were used to estimate some radiological impact parameters in order to effectively ascertain the level of the radiological health hazard to humankind by the use of such materials in the study area. The mean absorbed dose rates for the sediment and water samples were 66.09 and 39.01 nGy h^{-1}, respectively while the mean Annual Effective Dose AEDfor the ingested radionuclide in water samples from the area for infants, 1 year, 5 years, 10 years, 15 years and adults were 0.00276, 0.00313, 0.00197, 0.00135, 0.00117, and 0.00187 Sv/y, respectively.The mean $AED_{outdoor}$ for the sediments was 0.0809 mSv/y and mean AED_{indoor} was 0.324 mSv/y.Similarly,the mean Radium Equivalent Activity Index (Ra_{eq}) for the sediment and water samples was 139.83 Bq kg^{-1} and 30.84 Bq/L respectively, while the mean estimated internal and external hazard indices for the sediment samples were 0.52 and 0.37, respectively and that of water samples were 0.13 and 0.09, respectively. Furthermore, the estimated mean values for the Annual Gonadal Equivalent Dose(AGED) in the sediment and water were 458.49 and 104.60 μSv/y respectively while the estimated mean Gamma Index(I_γ) for the sediment and water samples were 1.030 and 0.229 mSv/y, respectively. Conclusively, the estimated mean the Excess Lifetime Cancer Risk (ELCR) for the sediment sample was 0.280 x 10^{-3} while that of water samples were 9.66, 10.96, 6.90, 4.73, 4.10 and 6.58 10^{-3} for 1 year, 5 years, 10 years, 15 years and adults, respectively. The results showed trends that were generally low for most of the radiological impact parameters calculated except for few indices whose values were above the UNSCEAR recommended thresholds. Therefore, there may be no serious immediate radiological effects to the populace and the environment in this area.

Keywords: Radioactivity, Soil, Water, Radiological Impact and Dadinkowa dam

1.0 Introduction

The exposure of human beings to ionizing radiation from natural sources is a continuing and inescapable feature of life on earth. There are two main contributors to radiation exposures: Natural and Artificial (man-made) sources. Both external and internal exposures to humans arise from these sources [1]. Exposure to excess level of background ionizing radiation can cause somatic and genetic effects that tend to damage critical and/or radiosensitive organs of the body, and can even lead to death [2-4].

Natural radioactivity is widespread in the earth's environment and it exists in various geological formations like soils, rocks, plants, sand, water, and air [3,4].

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Hence, humans should be aware of their natural environment with regard to the radiation effects due to the naturally occurring and induced radioactive elements. Knowledge about the distribution of these radionuclides present in natural materials enables one to assess any possible radiological hazard to humankind by the use of such materials [5]. That is, the knowledge of radionuclide distribution levels in the environment is important in assessing the effects of radiation exposure due to natural and human-made sources. Hence the objective of this study is to use the activity concentrations of the radionuclides from Gamma spectrometry of the sediment and water samples from the area to estimate the radiological impact parameters in order to effectively ascertain the level of the radiological health hazard to humankind by the use of such materials in the study area.

2.0 Material and Methods

2.1 The Study Area

The DadinKowa Dam is in Yamaltu local government area of Gombe State in the north east of Nigeria. The dam is located about 35 kilometers to the east of Gombe town, and provides drinking water for the town. The dam was completed by the federal government in 1984.The reservoir has a capacity of 800 million cubic meters of water and a surface area of 300 square kilometers, and has potential as a source of fish.

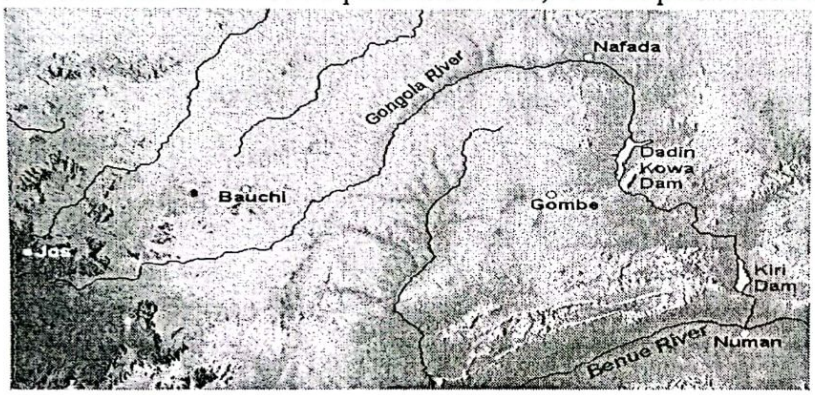


Figure 1: Google map of the study area (DadinKowa Dam).

2.2 Sample Collection and Preparation

Before samples were collected, a collection protocol was established which was strictly followed. This involves establishing a collection procedure, obtaining appropriate containers, and utilizing the appropriate methods of preservation in order to reduce the effect of adsorption or biodegradation. Nine (9) water samples were randomly collected from DadinKowa Dam Gombe state using 1 liter plastic bottles, acidified with 11 M HCl at a rate of 10 ml per liter to minimize the precipitation of the radionuclide present in the water samples. Also nine (9) samples of bottom sediment were also collected from each sample point of the water samples mentioned above in a period of low water levels from the middle of the water bodies. Each sediment sample of 2 kg wet weight were placed in polythene bag, air dried, sieved and then labeled. The water and sediments samples were then sealed in a radon impermeable container for 28 days for secular equilibrium to be attained between radon and its progenies and the samples were then transferred to the laboratory at the National Institute of Radiation Protection and Research (NIRPR) where a well calibrated Sodium Iodide NaI(Tl) detector enclosed in 5 cm thick lead shield to reduce background radiation was used. The spectra were analyzed and activity concentration of the detected radionuclide was computed directly and checked using a comparative method.

2.3 Measurement and Analysis

2.3.1 Measurement of Radionuclide Concentration

The detector used for the radioactivity measurements is a lead-shielded 76 mm × 76 mm NaI(TI) detector crystal (Model No. 802 series, Canberra Inc.) coupled to a Canberra Series 10 plus Multichannel Analyzer (MCA) (Model No.1104)through a preamplifier. It has a resolution (FWHM) of about 8% at energy of 0.662 MeV (^{137}Cs) which is considered adequate to distinguish the gamma ray energies of interest in the present study.

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Each sealed samples was placed on the shielded NaI(Tl) detector and counted for 18,000s. Hence the photons emitted by them would only be sufficiently discriminated if their emission probability and their energy were high enough, and the surrounding background continuum low enough. Therefore, the activity concentration of ^{214}Bi (determined from its 1.120 MeV and 0.609 MeV γ-ray peaks) were chosen to provide an estimate of ^{226}Ra (^{238}U) in the samples, while that of the daughter radionuclide ^{228}Ac (determined from its 0.911 MeV γ-ray peak) was chosen as an indicator of ^{232}Th. ^{40}K was determined by measuring the 1.460 MeV γ-rays emitted during its decay. The samples were placed symmetrically on top of the detector before measurement commenced. The activity concentration (C) of the radionuclide was calculated after subtracting decay correction using the following expression [4, 6-9].

$$C_s = \frac{C_a}{P_\gamma(\frac{M_s}{V_s})\varepsilon_\gamma t_c} \text{ (Bq/kg or Bq/l)} \quad (1)$$

Where C_s = Sample concentration, Ca = net peak area of a peak at energy, ε_γ= Efficiency of the detector for a γ-energy of interest, M_s/V_s = Sample mass/volume for soil/water, t_c = total counting time, P_γ= is the abundance of the γ-line in a radionuclide.

2.4 Radiological Impacts Parameters

These are parameters used to determining the radiation hazards that could be incurred from the exposure to the samples. These include the absorbed dose rate, annual effective dose, radium equivalent activity index, annual gonadal equivalent dose, external and internal hazard indices, gamma index and excess lifetime cancer risk.

2.4.1 Absorbed Dose Rate

Calculating the absorbed dose rate is the first major step for evaluating the health risk. With regard to biological effects, the radiological and clinical effects are directly related to the absorbed dose rate [4, 6-9]. Absorbed dose is a measure of the quantity of energy deposited in a medium per unit mass. It is measured as joules per kilogram and represented by the equivalent S.I. unit Gray (Gy) or Rad. The absorbed dose rate D (nGy h^{-1}) due to activity concentration of ^{238}U, ^{232}Th and ^{40}K was calculated from equation (2) given in [10] as

$$D = C_U F_U + C_{Th} F_{Th} + C_K F_K \quad (2)$$

Where, C_U, C_{Th}, C_K the radioactivity concentration in Bq/L and F_U, F_{Th}, and F_k are dose conversion factors which are 0.462, 0.604 and 0.0417 for ^{238}U, ^{232}Th and ^{40}K respectively. Average value is given as 57nGy h^{-1} [10].

2.4.2 Annual Effective Dose($AED_{ingested}$)Ingested Radionuclides of Water Samples

The annual effective dose rate for all the ingested radionuclides from water was calculated using equation (3)

$$AED_{iingested} = \sum_i I_i \times 365 \times D_i \quad (3)$$

Where I_i is the daily intakes of radionuclide (Bqd^{-1}) = (concentration of radionuclide in water in Bq L^{-1}) × (consumption rate of water or food in L day^{-1}) and the ingestion dose coefficient (dose conversion factor) D_i for ingestion of radionuclides for members of the public for all agesis shown in Table 1[11]. The annual effective dose resulting from the ingestion of water was estimated based on the assumption that a daily intake of water per person is 2 L/d for adults and 1 L/d for lower ages and 0.5 L/d for infants [12].

TABLE 1: Dose Conversion Factors for Ingestion of Radionuclides of Different Age Groups for Members of the Public [11].

Radionuclides	$T_{1/2}$ (years)	DCF (Sv/Bq) for various age groups					
		Infants	1year	5years	10years	15years	Adults
^{40}K	1.2×10^{9}	5.2×10^{-8}	4.2×10^{-8}	2.2×10^{-8}	1.3×10^{-8}	7.6×10^{-9}	6.2×10^{-9}
^{232}Th	1.405×10^{1}	1.6×10^{-6}	4.5×10^{-7}	3.5×10^{-7}	2.9×10^{-7}	2.5×10^{-7}	2.3×10^{-7}
^{238}U	4.468×10^{9}	1.4×10^{-7}	1.2×10^{-7}	8.0×10^{-8}	6.8×10^{-8}	6.7×10^{-8}	4.5×10^{-8}

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2.4.3 Annual Effective Dose Equivalent(AED)due to exposures to radionuclides from sediment samples

The annual effective dose received outdoor and indoor by a member of the public is calculated from the absorbed dose rate by applying dose conversion factor of 0.7Sv/Gy and occupancy factor for outdoor and indoor was 0.2 and 0.8 respectively [4, 6-9]. AED is determined using the following equations [4, 6-9];

$AED_{outdoor}(mSv/y) = D\ (nGy/h) \times 8760\ h \times 0.7\ (Sv/Gy) \times 0.2 \times 10^{-3}$ (4)

$AED_{indoor}(mSv/y) = D\ (nGy/h) \times 8760\ h \times 0.7\ (Sv/Gy) \times 0.8 \times 10^{-3}$ (5)

2.4.3 Radium Equivalent Activity Index (Ra_{eq})

The radium equivalent (Ra_{eq}) activity represents single index used to describe the gamma output from different mixtures of ^{238}U, ^{232}Th and ^{40}K in the samples. It was calculated using equation (6) [4, 6-10].

$$Ra_{eq} = C_U + 1.43C_{Th} + 0.077C_K \quad (6)$$

Where C_U, C_{Th}, $C_K$are the radioactivity concentration in Bq L^{-1} of ^{238}U, ^{232}Th and ^{40}K. Average value is 370 Bq L^{-1}or 370 Bqkg^{-1}

2.4.4 Radiation Hazard Indices

These indices were used to estimate the level of gamma radiation hazard associated with the natural radionuclide in the samples. The external radiation hazard (H_{ext}) and the internal radiation hazard (H_{int}) was calculated using equations (7) and (8) respectively as given in [4, 6-10].

$$H_{ext} = \left(\frac{C_{Ra}}{370}\right) + \left(\frac{C_{Th}}{259}\right) + \left(\frac{C_K}{4810}\right) \quad (7)$$

$$H_{int} = \left(\frac{C_{Ra}}{185}\right) + \left(\frac{C_{Th}}{259}\right) + \left(\frac{C_K}{4810}\right) \quad (8)$$

The values of the indices should be less than unity for the radiation hazard to be negligible [10]. Internal exposure to radon is very hazardous which can lead to respiratory diseases like asthma [4, 6-9]. Natural radionuclide in soil, sediment and rocks produce an external radiation field to which all humans are exposed.

2.4.5 Annual Gonadal Equivalent Dose (AGED)

The gonads, the bone marrow and the bone surface cells are considered as organs of interest [10] because of their sensitivity to radiation. An increase in AGED has been known to affect the bone marrow, causing destruction of the red blood cells that are then replaced by white blood cells. This situation results in a blood cancer called leukemia which is fatal [4, 6-9]. The AGED for the samples was evaluated using equation 10 below

AGED (μSv/y) $C = 3.09C_U + 4.18C_{Th} + 0.314C_K$ (9)

Where, C_U, C_{Th}, and C_K are the radioactivity concentration of ^{238}U, ^{232}Th and ^{40}K in soil and water samples.

2.4.6Representative Gamma Index (I_γ)

This is used to estimate the gamma radiation hazard associated with the natural radionuclide in specific investigated samples. The representative gamma index was estimated as follows [4, 6-10]:

$$I_\gamma = C_U/150 + C_{Th}/100 + C_K/1500) \leq 1 \quad (10)$$

Where, C_U, C_{Th}, and C_K are the radioactivity concentration of ^{238}U, ^{232}Th and ^{40}K in sediment and water samples. The I_γ is correlated with the annual dose rate due to the excess external gamma radiation caused by superficial material. An increase in the representative gamma index greater than the universal standard of unity may result in radiation risk leading to the deformation of human cells thereby causing cancer. Values of $I_\gamma = 1$ corresponds to an annual effective dose of less than or equal to 1 mSv, while $I_\gamma = 0.5$ corresponds to annual effective dose less or equal to 0.3 mSv/y [6].

2.4.7 Excess Lifetime Cancer Risk (ELCR)

The Excess Lifetime cancer risk was calculated using equation (9) [6]:

$ELCR = AED \times DL \times RF$ (11)

Where, AED is the Annual Equivalent Dose, DL is the average duration of life (estimated to be 70 years), and RF is the Risk Factor (Sv^{-1}), i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for public [6]. Average value of ELCR is given as 0.2×10^{-3} [13].

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3.0 Results and Discussion

The result of the gamma ray spectrometry of the sediment and water samples calculated using equation (1) is presented in Table 2 and Table 3 and illustrated in Figures 2 and 3 respectively. The K-40 activity concentration dominated that of U-238 and Th-232 as expected. The activity of concentration rangedfrom248.20±31.8 to 701.0 ± 92.1Bqkg^{-1} with mean activity of 469.33±63.33Bq kg^{-1},18.60±8.00to 62.40±12.00Bq kg^{-1} with a mean activity of 38.95±9.45 Bq kg^{-1} and 20.80±1.10 to 76.10±14.0 Bq kg^{-1} with a mean activity of 49.76±9.05 Bq kg^{-1} for ^{40}K, ^{232}Th and ^{238}U, respectively while that of the water samples ranged from86.23±8.20to109.42±12.10BqL^{-1} with mean activity of 99.14 ±9.40 BqL^{-1},2.71±0.91 to 8.42±3.81 BqL^{-1} with a mean activity of 5.43±1.35 BqL^{-1} and4.58±2.15 to 19.65±4.5 BqL^{-1} with a mean activity of 16.42BqL^{-1}for ^{40}K, ^{232}Th and ^{238}U, respectively. All the mean activity concentrations of the radionuclides detected in the water and sediment samples were above their corresponding world average values except for that of ^{40}K in sediments. The world average values for ^{40}K, ^{238}U and ^{232}Thare 500, 35.0 and 30.0 Bqkg^{-1}, respectively for sediments while that of water sampleare10, 10 and 1 Bq L^{-1},respectively [14].

Table 2: Activity concentration of ^{40}K, ^{238}U and ^{232}Th (Bq kg^{-1}) in the sediment samples

SEDIMENTS	K-40	Th-232	U-238
DS1	445.30 ±88.20	36.30 ±9.50	42.90 ±12.00
DS2	426.50 ±32.60	34.40 ±8.00	62.20 ±1.10
DS3	248.20 ±33.30	18.60 ±8.10	20.80 ±8.60
DS4	386.50 ±42.20	30.00 ±8.60	32.10 ±9.00
DS5	530.30 ±76.50	42.30 ±12.00	61.50 ±8.20
DS6	627.90 ±92.10	56.60 ±9.00	67.10 ±12.00
DS7	701.00 ±87.20	62.40 ±12.00	76.10 ±14.00
DS8	372.20 ±31.80	32.00 ±9.00	36.80 ±8.40
DS9	486.10 ±86.10	38.00 ±9.00	48.40 ±8.20
MIN	248.20 ±31.80	18.60 ±8.00	20.80 ±1.10
MAX	701.00 ±92.10	62.40 ±12.00	76.10 ±14.00
MEAN	469.33±63.33	38.95±9.45	49.76±9.05
MEDIAN	445.30 ±76.50	36.3±9.0	48.40 ±9.00
STDDEV	137.12±27.37	13.43±1.51	18.21±3.66

Table 3: Activity concentration of ^{40}K, ^{238}U and ^{232}Th (Bq L^{-1}) in the water samples

Water	K-40	Th-232	U-238
DW1	109.42 ± 8.21	8.42 ± 3.81	19.65 ± 4.50
DW2	102.41 ± 9.41	6.46 ± 0.96	18.48 ± 2.28
DW3	104.46 ± 8.20	6.61 ± 0.92	18.16 ± 2.45
DW4	86.23 ± 9.20	2.71 ± 1.02	4.58 ± 2.15
DW5	92.16 ± 8.51	4.12 ± 0.91	17.65 ± 3.62
DW6	98.21 ± 10.02	4.14 ± 1.20	17.20 ± 3.15
DW7	104.61 ± 12.1	6.60 ± 1.20	18.81 ± 3.12
DW8	98.24 ± 10.50	4.18 ± 0.92	16.12 ± 2.41
DW9	96.51 ± 8.46	5.67 ± 1.20	17.18 ± 2.65
MIN	86.23 ± 8.20	2.71 ± 0.91	4.58 ± 2.15
MAX	109.42 ± 12.10	8.42 ± 3.81	19.65 ± 4.50
MEAN	99.14 ± 9.40	5.43 ± 1.35	16.42555556
MEDIAN	98.24 ± 9.20	5.70 ± 1.02	17.65 ± 2.65
STDDEV	7.06 ± 1.30	1.77 ± 0.93	4.56 ± 0.76

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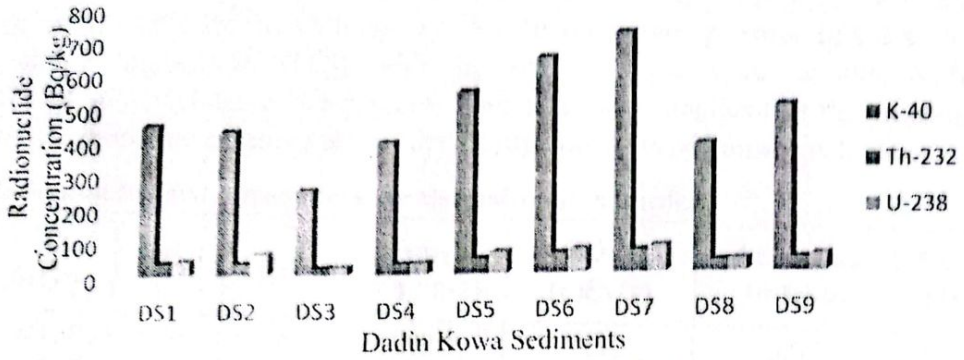


Figure 2: Activity Concentration of ^{40}K, ^{238}U and ^{232}Th in sediment samples

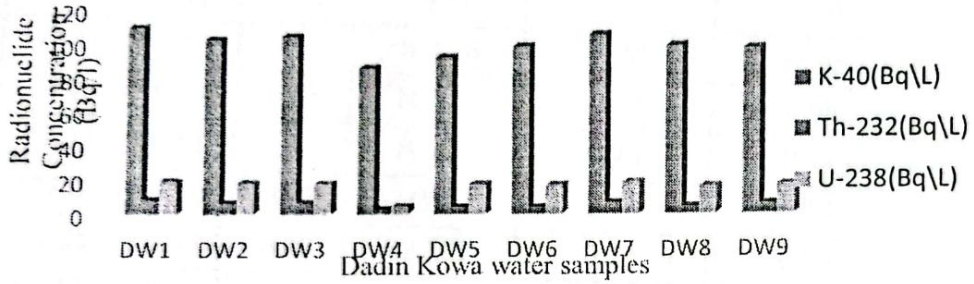


Figure 3: Activity Concentration of ^{40}K, ^{238}U and ^{232}Th in the water samples

The mean absorbed dose rates for the sediment and water samples were66.09 and 39.01nGyh^{-1}, respectively (as shown in Tables 4 and 5, respectively). The mean Absorbed Dose Rate for the soil is slightly above the general average value of 57nGyh^{-1} [13] while the mean AED for the ingested radionuclide in drinking water from the area for infants, 1year, 5years, 10years, 15years and adults are 0.00276, 0.00313, 0.00197, 0.00135, 0.00117, and 0.00187 Sv/y respectively(as shown in Table 6 and figure 3). These average values for the AED for the different age groups are higher than the acceptable limits of 0.001 Sv/y for the general public except for 10years and 15years which were approximately within the safe limits. From Figure 3, it is clear that children within 1year (□ 5years) are surprisingly more susceptible to ionizing radiation hazards in the area followed by the infants (□ 1year) then 5years (□ 10years), adults, 10years (□ 15years) and 15years (□ adult age) respectively. However, 15years and 10years are within the world average value of 1 mSv/y [13].The mean $AED_{outdoor}$ for the sediments was 0.0809 mSv/y and mean $AED_{indoor}$was 0.324 mSv/y. Expectedly, these mean values were within the world average value of 1mSv/y for the general public.

Similarly, the mean Ra_{eq} for the sediment and water samples was 139.83Bq kg^{-1} and 30.84 Bq/L respectively (as shown in Tables 4 and 5, respectively). The estimated average values were lower than the world average value of 370 Bq kg^{-1} for the safe use of materials in the construction of buildings [4, 6-9]. This means that soil from this area can safely be used as building materials without much fear of radiological hazards. While the estimated internal and external hazard indices for the sediment samples were 0.52 and 0.37, respectively and that of water samples were 0.13 and 0.09, respectively (as shown in Tables 4 and 5, respectively). These values of H_{int} and H_{ext} in sediment and water are less than unity which follows that hazardous effects of these radionuclides and their short-lived progenies are negligible.

Furthermore, the estimated mean values for the AGED in the sediment and water were 458.49 and 104.60 μSv/y respectively while the estimated mean I_γ for the sediment and water samples were 1.030 and 0.229 mSv/y, respectively(as shown in Tables 4 and 5, respectively). These values were within their corresponding world average values.

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Conclusively, the estimated mean ELCR for the sediment sample was 0.280 x 10^{-3}while that of water samples were 9.66, 10.96, 6.90, 4.73, 4.10 and 6.58 $10^{-3}$for 1year, 5years, 10years, 15years and adults, respectively. The estimated value of ELCR for the sediment was less than the average value of 0.2 x 10^{-3} while that of water was high. The high values of the ELCR index for water samples is due to high AED caused by the activity concentration of radionuclides in the samples. This high value implies that the probability of developing cancer over a lifetime considering seventy years as the average life span of humans is high.

Table 4: Radiation hazard parameters for the sediment samples

Sediment Samples	D (nG/y)	H_{ext}	H_{int}	Ra_{eq} (Bq kg-1)	AED_{indoor} (mSv/y)	$AED_{outdoor}$ (mSv/y)	ELRC (10^{-3})	AGED (μSv/y)	I (mSv/y)
DS1	60.30	0.35	0.46	129.09	0.30	0.07	0.245	424.12	0.95
DS2	67.30	0.39	0.57	144.23	0.33	0.08	0.280	469.91	1.04
DS3	31.19	0.18	0.24	66.51	0.15	0.04	0.140	219.95	0.49
DS4	49.07	0.28	0.37	104.76	0.24	0.06	0.210	345.95	0.77
DS5	76.08	0.44	0.61	162.83	0.37	0.09	0.315	533.36	1.19
DS6	91.37	0.53	0.71	196.38	0.45	0.11	0.385	641.09	1.43
DS7	102.07	0.59	0.80	219.31	0.50	0.13	0.455	716.10	1.60
DS8	51.85	0.33	0.40	122.82	0.25	0.06	0.210	400.19	0.81
DS9	65.58	0.30	0.51	112.56	0.32	0.08	0.280	375.75	1.03
MIN	31.19	0.180	0.235	66.510	0.153	0.038	0.280	219.954	0.490
MAX	102.07	0.592	0.798	219.31	0.501	0.125	0.455	716.095	1.599
MEAN	66.09	0.370	0.517	139.83	0.324	0.0809	0.280	458.490	1.033
STDEV	21.73	0.127	0.175	47.19	0.106	0.0266	0.096	152.655	0.338

Table 5: Radiation hazard parameters for the water samples

Water Samples	D (nSv/y)	H_{int}	H_{ext}	Ra_{eq} (Bq/L)	AGED (μSv/y)	I (mSv/y)
DW1	18.7200	0.1610	0.1080	40.1150	130.2710	0.2880
DW2	16.7100	0.1460	0.0961	35.5430	116.2620	0.2560
DW3	16.7400	0.1450	0.0963	35.6550	116.5450	0.2570
DW4	39.7100	0.0531	0.0403	15.0950	52.5560	0.1150
DW5	49.0600	0.1310	0.0827	30.6370	100.6980	0.2200
DW6	51.3900	0.1290	0.0828	30.6820	101.2910	0.2220
DW7	56.2800	0.1490	0.0980	34.8950	118.5580	0.2610
DW8	50.9300	0.1240	0.0801	29.6610	98.1310	0.2150
DW9	51.5900	0.1350	0.0884	25.2890	107.0910	0.2350
MIN	16.7100	0.0531	0.0403	15.0950	52.55600	0.1150
MAX	56.2800	0.1610	0.1080	40.1150	130.2710	0.2880
MEAN	39.01000	0.13000	0.08580	30.84100	104.6000	0.22900
MEDIAN	49.06000	0.13500	0.08840	30.6820	107.0910	0.23500
STDEV	16.80000	0.03110	0.01930	7.31300	22.12300	0.04920

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Table 6: AEDand ELCR of water samples for different age category/group for members of the public in the study area

Water Samples	Infant	1YR	5YRS	10YRS	15YRS	ADULT
AED (Sv y^{-1})						
DW1	0.0040	0.0039	0.0025	0.0019	0.0016	0.0026
DW2	0.0033	0.0034	0.0022	0.0016	0.0013	0.0022
DW3	0.0039	0.0035	0.0022	0.0016	0.0013	0.0022
DW4	0.0017	0.0020	0.0012	0.0008	0.0006	0.0001
DW5	0.0025	0.0029	0.0018	0.0013	0.0011	0.0017
DW6	0.0026	0.0029	0.0018	0.0005	0.0011	0.0019
DW7	0.0034	0.0035	0.0022	0.0017	0.0014	0.0019
DW8	0.0026	0.0029	0.0018	0.0013	0.0010	0.0017
DW9	0.0009	0.0032	0.0020	0.0015	0.0012	0.0019
MIN	0.00091	0.00200	0.00117	0.00047	0.00060	0.00010
MAX	0.00399	0.00392	0.00252	0.00189	0.00155	0.00255
MEAN	0.00276	0.00313	0.00197	0.00135	0.00117	0.00188
STDEV	0.00108	0.00063	0.00044	0.00050	0.00031	0.00050
ELCR (10^{-3})						
DW1	14.00	13.65	8.75	6.65	5.60	9.10
DW2	11.55	11.90	7.70	5.60	4.55	7.70
DW3	13.65	12.25	7.70	5.60	4.55	7.70
DW4	5.95	7.00	4.20	2.80	2.10	0.35
DW5	8.75	10.15	6.30	4.55	3.85	5.95
DW6	9.10	10.15	6.30	1.75	3.85	6.65
DW7	11.90	12.25	7.70	5.95	4.90	6.65
DW8	9.10	10.15	6.30	4.55	3.50	5.95
DW9	3.15	11.20	7.00	5.25	4.20	6.65
MIN	3.19	7.00	4.10	1.65	2.10	0.35
MAX	13.97	13.72	8.82	6.62	5.43	8.93
MEAN	9.66	10.96	6.90	4.73	4.10	6.58
STDEV	3.78	2.21	1.54	1.75	1.09	1.75

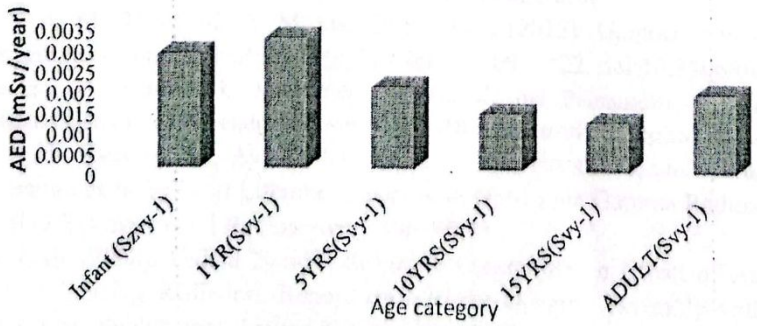


Figure 4: AED of water samples for different age category/group for members of the public in the study area

4.0 Conclusion

The aim of this work was to measure the natural radionuclides (^{40}K, ^{238}U and ^{232}Th) and estimate some major radiological impact parameters in sediments and water samples in order to effectively ascertain the level of the radiological health hazard to humankind by the use of such materials in Dadinkowa dam, Gombe, Nigeria. The results the radionuclides concentrations in all the analyzed samples were found to be higher than the world average values in the study area. More also, the results showed trends that are generally low for most radiation hazard indices calculated except for few indices whose values are above the UNSCEAR recommended thresholds. Therefore, there may be no serious immediate radiological effects to the populace and the environment in the area except for the disturbing fact that beside 10years and 15years which are within the safe limits, the average values for the AED for the other age groups are higher than the acceptable limits of 1mSv/y for the general public. Although it should be noted that daily intake of water per person of 2 L/d for adults was used as against the 1 liter per day for adults. This study can be used as a baseline for future investigations and the data obtained in this study may be useful for natural radioactivity mapping. The results may also be used as reference data for monitoring possible radioactivity pollution in future.

Further investigation is recommended using the High Purity Germanium (HPGe) and other sophisticated detectors with very high detection ability.

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