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Radiological Assessment of Sediment of Zobe Dam Dutsinma, Katsina State, Northern Nigerian.

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ABSTRACT: *A radioactivity measurement was carried out in sediments of Zobe Dam. Samples of sediments from Zobe Dam were collected, prepared and analyzed using NaI(Tl) gamma ray spectrometer for the activity concentrations of the primordial ^{226}Ra, ^{232}Th and ^{40}K. The results obtained show average activity concentrations of 49.67±3.07 (35.89-75.75), 127.29±4.42 (47.21-112.91) and 443.43±9.51 (338.88-638.40) in Bq/kg for ^{226}Ra, ^{232}Th and ^{40}K respectively. To assess the radiological hazard of Dam sediments, the radiological hazard indices such as absorbed dose rate, annual effective dose equivalent (AEDE), hazard indices (H_{ex} and H_{in}) were calculated and found to be comparable with the world average values. The mean absorbed dose rate obtained is124.52 nGy/ h, and is higher than the world average of 55 nGy/h. The measured average annual effective dose rate 0.152mSv/y is lower than the world average value of 1 mSv/y [7]. The measured average values of external and internal hazard index is 0.717 and 0.851 and are lower than unity set by [6], which indicate that the sediments in all the sampling sites can be used for safety construction of buildings.*

Key words*: sediments, hazard index, dose rate and annual effective dose rate.*

I. INTRODUCTION

All life on earth is exposed to radiation from natural sources including cosmic radiation; external radiation from natural radionuclides present in soils, rocks and building materials; and internal radiation due to potassium-40 and inhaled radionuclides, particular radon decay products. Natural radiation exposure varies regionally as the compositions of soils and rocks change, and increases with altitude as cosmic radiation intensity increases.

When rocks are disintegrated through natural processes, radionuclides are seep to the soil and are carried to the rivers by rain and flows [15]. Soil radionuclide activity concentration is one of the main determinants of the natural background radiation. The knowledge of the distribution of these radionuclides in soil, water, sediment, rock and building materials plays an important role in the protection, measurement, geoscientific research and guidelines for the use and management of these materials [14].

Due to gravitational settling and other depositional phenomena, the highest proportion of the radioactive materials is mainly found in the sediment compartment of the aquatic ecosystem [12]. Thus river sediment is considered as a durable and reliable register of the river pollution by radionuclides [1]. Knowledge of natural radioactivity present in aquatic sediments enables one to assess any possible radiological hazard to mankind, by the uses of such materials especially in building and construction material [13].

II. MATERIALS AND METHODS

2.1 The Study Area

The Zobe Dam is located between latitude 12^0 20' 34.62'' N to 12^0 23' 27.48'' N and between longitude 7^0 27' 57.12'' E to $7^0$34' 47.68'' E, in Dutsinma Local Government Area of Katsina State.

The reservoir formed by the Dam cover 4500 hectares of rocky land and during the rainy season stores 177 million cubic metres of water which is released downstream for irrigation and town water supplies.

The Zobe Dam has only two tributaries; these include river Karaduwa and river Gada in which river Gada drains to river Karaduwa.

The Dam is constructed in river Karaduwa and the Dam over Karaduwa is about 2.7 kilometres long and flowing north westward to the Sokoto river Basin. Along the river course, there are no large cities, no mining cites, no nuclear enterprises such as chemical and phosphate industries. Farmers' lives in the area generally rear animals, raise crops and some vegetables. Therefore, agrochemical such as fertilizers and pesticides, herbicides are the main contaminant of the Dam reservoir. Fishing is another major activity in the area.

2.2 Sample Collection Procedures

Sediments were collected from Garhi A, Garhi B, Makera and Tabobi. Garhi A, Garhi B, Makera are the areas where farming, domestic/live stocks activities and fishing are very high. While Tabobi is the control area in which the activities mentioned are very less. The sample collection method was achieved as described below.

2.3 Sample Collection and Preparation

Bottom sediments were collected from the 15 different locations. Four (4) samples each were collected in an area where farming, domestic/livestock activities and fishing is very high and three (3) from the control area where farming, domestic/livestock activities and fishing is very less. The sediment samples were collected in period of low water levels during the dry season so that undisturbed sediments could be taken [9]. The sediment were put into different polyethylene labeled bags and transported to the laboratory. The point of collection of each sample were given a unique code and noted with its GPS coordinate taken with a handheld GPS device.
Sample preparation and analysis was done at the Center for Energy Research and Training (CERT) Ahmadu Bello University, Zaria, Kaduna State. The collected samples were kept opened to dry at an ambient temperature in the laboratory in a clean environment in order to avoid contaminations. The dried samples were grounded into a fine powder with the use of a table ceramic mortar and pestle and then a pulverizer. The process was followed by packaging into radon impermeable cylindrical plastic containers of height 7cm by 6cm in diameter. This satisfied the selected optimal sample container height [5] i.e the detector geometry. Each container would accommodate approximately 300g of sample. A 3-stage sealing system was made for each of the packaging to prevent Ra-222 from escape. This include, smearing of the inner rims of each container lid with Vaseline, filling the lid assembly gap with candle wax to block the gaps between lid and container and tight-seal lid container with a masking adhesive tape. The prepared samples were then stored for period of 30 days to allow radon and its short-lived progenies to reach secular radioactive equilibrium prior to gamma spectroscopy measurements.

III. Gamma Ray Spectroscopy Instrumentation and Analysis

The gamma-ray spectrometry set-up is made up of a 7.62 cm by 7.62 cm NaI (Tl) detector housed in a 6 cm thick lead shield (to assist in the reduction of the background radiation) and lined with cadmium and copper sheets [3]. The samples were placed on the detector surface and each counted for about 29,000 seconds in reproducible sample detector geometry. The configuration and geometry was maintained throughout the analysis, as previously characterized based on well established protocol of the laboratory (at the Centre for Energy Research and Training, Zaria).
With reference to Ibeanu [5], there are two renowned ways of achieving spectra analysis for the energy discrimination needed for qualitative and quantitative analysis of the radionuclides; the integral and the differential spectrometry. The integral spectrometry approach involves the recording of whole spectrum from a predetermined low position that covers the energy peak of interest. The differential spectrometry involves acquisition of information on the energy peaks with an energy window set at about the peak.

In this particular work, differential spectrometry is employed in three channels and this was achieved by using a computer based Multichannel Analyser (MCA) MAESTRO Programme from ORTEC for data acquisition and analysis of gamma spectra. The 1764 keV Gamma-line of ^{214}Bi for ^{238}U was used in the assessment of the activity concentration of ^{226}Ra, while 2614.5 keV Gamma-line of ^{208}Tl was used for ^{232}Th. The single 1460 keV Gamma-line of ^{40}K was used in its content evaluation.
All the obtained raw data were converted to conventional units using calibration factors to determine the activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th respectively. In order to determine the specific activity concentrations in the samples, the IAEA mixed standard consisting of ^{40}K, ^{226}Ra and ^{232}Th of the same dimension as the samples were subjected to the same experimental procedures. After the subtraction of background counts, conversion of the count per second to activity concentration in Bq/kg was performed using the conversion factors which are different for each nuclide such that for ^{40}K, ^{226}Ra and ^{232}Th as 6.431, 8.632 and 8.768, respectively.

3.1 Activity Concentration of the Sediments

The activity concentrations in the sediment samples were obtained using the equation (1.0) [8].

$$C(Bqkg^{-1}) = kC_n \quad \text{……………………………………………..} \quad (1.0)$$

where $k = \frac{1}{\varepsilon P_\gamma M_s}$, C is the activity concentration of the radionuclide in the sample given in Bq/kg, C_n is the count rate under the corresponding peak, ε is the detector efficiency at the specific γ- ray energy, P_γ is the absolute transition probability of the specific γ-ray, and M_s is the mass of the sample (kg). The below detection limit (BDL) of a measuring system describes its operating capability without the influence of the samples. The BDL given in $Bqkg^{-1}$ which is required to estimate the minimum detectable activity in samples was obtained using equation (2.0), [8]

$$DL(Bqkg^{-1}) = 4.65\frac{\sqrt{C_b}}{t_b}\, k \quad \ldots\ldots\ldots\ldots (2.0)$$

where C_b is the net background count in the corresponding peak, t_b is the background counting time (s) and k is the factor that converts count per second (cps) to activity concentration ($Bqkg^{-1}$) as given in equation (1.0).

All the obtained raw data were converted to convectional units using conversion factors of $8.632x10^{-4}$, $8.768x10^{-4}$ and $6.431x10^{-4}$ for ^{40}K, ^{226}Ra and ^{232}Th respectively to determine their activity concentrations [3]. With the counting time of 29,000 seconds for each sample, the environment γ-ray background of the laboratory site was determined using an empty container under identical measured conditions. This then gave the below detectable limit (BDL) limits to be $310.99Bqkg^{-1}$ for ^{40}K, $16.21Bqkg^{-1}$ for ^{226}Ra and $123.16Bqkg^{-1}$ for ^{238}Th respectively. This was subtracted from the measured γ-ray spectrum of each sample.

3.2 Absorbed dose rate from measured activity concentration for sediments

Radiation emitted by a radioactive substance is absorbed by any material it encounters. [16] has given the dose conversion factors for converting the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K into dose ($nGyh^{-1}$ per $Bqkg^{-1}$) as 0.427, 0.662 and 0.043, respectively. Using these factors, the total absorbed dose rate in air is calculated as given in the Equation (3.0) [16].

$$D = (0.427C_{Ra} + 0.662C_{Th} + 0.043C_K)\ nGyh^{-1} \quad \ldots\ldots\ldots (3.0)$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations ($Bqkg^{-1}$) of radium, thorium and potassium, respectively in the samples.

3.3 Annual effective dose from sediment

The estimation of the annual effective dose rates, depended on conversion coefficient from absorbed dose to effective dose as $0.7SvGy^{-1}$ and outdoor occupancy factor of 0.2 as proposed by [16]. The effective dose rate in units of $mSvGy^{-1}$ was calculated by the following formula in equation (4.0)

$$\text{Effective dose rate } (mSvGy^{-1}) = D\ (nGyh^{-1}) \times 870h \times 0.2 \times 0.7SvGy^{-1} \times 10^{-6} \quad \ldots.. (4.0)$$

3.4 External hazard index (H_{ex})

Radiation exposure due to ^{226}Ra, ^{232}Th and ^{40}K may be external. This hazard, defined in terms of external hazard index or indoor radiation hazard index and denoted by H_{ex}, can be calculated using the equation (5.0) [2]:

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad \ldots\ldots\ldots (5.0)$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations ($Bqkg^{-1}$) of radium, thorium and potassium, respectively as obtained in the analyzed samples. The value of this index should be less than $1mSvy^{-1}$ in order for the radiation to be considered acceptable to the public.

3.5 Internal hazard index (H_{in})

The internal hazard index (H_{in}) gives the internal exposure to carcinogenic radon and is given by equation (6.0), [2]:

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad \ldots\ldots\ldots (6.0)$$

The value of this index should be less than $1mSvy^{-1}$ in order for the radiation hazard to have negligible hazardous effects to the respiratory organs of the public [2].

IV. RESULTS AND DISCUSSION

4.1 Activity Concentration in Sediments

The activity concentrations of the three primordial radionuclides ^{226}Ra, ^{232}Th and ^{40}K were measured and an average of 49.67±3.07 $Bqkg^{-1}$, 127.29±4.42 $Bqkg^{-1}$ and 443.43±9.51 $Bqkg^{-1}$ respectively were obtained. The minimum activities for ^{226}Ra, ^{232}Th and ^{40}K were found to be 41.51 $Bqkg^{-1}$, 62.49 $Bqkg^{-1}$ and 316.18 $Bqkg^{-1}$ while the maximum values were 57.91 $Bqkg^{-1}$, 291.9 $Bqkg^{-1}$ and 516.29 $Bqkg^{-1}$ respectively. Table1.0 shows the

activity concentrations of the natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K and their coordinates in all the sampling sites and Table2.0 shows the mean activity concentrations and the range for the three natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in all the sampling sites.

Table1.0 Activity Concentration of the natural radionuclides ^{226}Ra,^{232}Th and ^{40}K and their coordinates.

Sample Location	Sample code	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	Coordinates
GARHI A	SA_1	44.84±2.20	42.07±0.57	272.78±11.04	N12^0 22.784' E007^0 27.987'
	SA_2	57.70±3.82	96.00±2.85	800.77±12.59	N12^0 22.787' E007^0 27.905'
	SA_3	39.62±4.51	163.28±3.30	704.66±14.61	N12^0 22.642' E007^0 27.926'
	SA_4	23.87±1.04	41.73±2.16	286.93±	N12^0 22.613 E007^0 27.925
	MEAN	41.51±2.89	85.77±2.22	516.29±12.48	
GARHI B	SB_1	52.95±6.95	51.31±6.61	458.79±3.11	N12^0 21.173' E007^0 30.250'
	SB_2	84.59±5.33	68.87±1.82	496.27±12.59	N12^0 21.210' E007^0 30.256'
	SB_3	32.91±2.20	99.20±2.74	562.90±12.47	N12^0 21.216' E007^0 30.289'
	SB_4	51.56±3.13	72.52±2.96	320.22±7.6	N12^0 21.261' E007^0 30.139'
	MEAN	55.50±4.40	291.9±3.53	459.56±8.5	
MAKERA	SC_1	52.26±2.89	105.93±3.53	556.45±11.66	N12^0 22.480' E007^0 27.885'
	SC_2	55.85±1.74	66.48±1.37	487.09±8.86	N12^0 22.496' E007^0 22.896'
	SC_3	65.01±4.06	57.81±2.28	436.08±9.07	N12^0 22.517' E007^0 27.904'
	SC_4	58.52±3.24	45.84±1.03	447.12±9.95	N12^0 22.433' E007^0 27.873'
	MEAN	57.91±2.98	69.02±2.05	481.69±10.07	
TABOBI	SD_1	95.71±1.29	54.28±8.44	483.20±3.11	N12^0 23.121' E007^0 30.715'
	SD_2	44.73±1.74	83.24±1.59	223.34±5.13	N12^0 23.51' E007^0 30.737'
	SD_3	34.53±3.01	49.94±4.56	241.99±11.35	N12^0 23.299' E007^0 30.656'
	MEAN	43.74±2.01	62.49±4.86	316.18±6.53	

Table2.0 Mean Activity Concentrations for the three natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K.

Activity Concentrations (Bq/kg)

	^{226}Ra		^{232}Th		^{40}K	
SITE	MEAN	RANGE	MEAN	RANGE	MEAN	RANGE
SA	41.51±2.89	23.87-57.70	85.77±2.22	41.73-163.28	516.29±12.48	272.78-800.77
SB	55.50±4.40	32.91-84.59	291.9±3.53	51.31-99.20	459.56±8.95	320.22-562.99
SC	57.91±2.98	52.26-65.01	69.02±2.05	45.84-105.93	481.69±10.07	436.08-556.45
SD	43.74±2.01	34.53-95.71	62.49±9.86	49.94-83.24	316.18±6.53	326.46-633.19
AVERAGE	49.67±3.07	35.89-75.75	127.29±4.42	47.21-112.91	443.43±9.51	338.88-638.40

Activity concentrations for ^{40}K are generally high than those of ^{226}Ra and ^{232}Th in all the sampling sites. The highest values of ^{226}Ra were found at site SC, It could be due to the presence of the loamy sediments [4]. While the highest value of ^{232}Th is found at site SB, this may be due to the high content of monazite [11].
There is generally higher activity concentration of ^{40}K at SA. These can be attributed to Dam from the intensive use of agrochemical such as NPK fertilizer for agricultural practice.

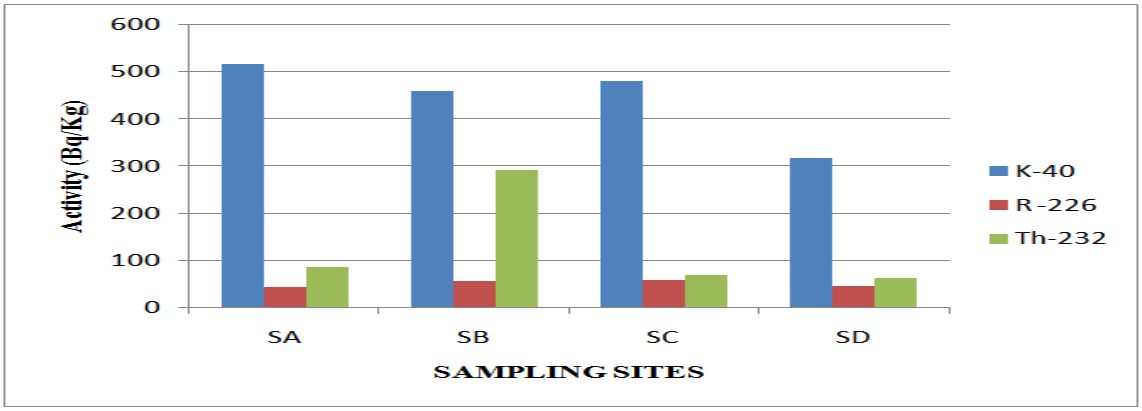

Figure 1.0: Activity concentrations of the natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in sediments samples.

4.2 Dose rate

The total dose rates from the sediments of Zobe Dam were calculated for all the sampling sites. The total dose rate was found to be 124.52±4.62 $nGyh^{-1}$ with the minimum value being 73.62 $nGyh^{-1}$ and the maximum 236.68 $nGyh^{-1}$. Table 3.0 shows the average dose rates of the natural radionuclides in all the sampling sites and the total dose in Zobe Dam. The total dose rates were estimated using equation (3.0).

Table 3.0: Average dose rates of the natural radionuclides and the total dose rates measured in this work for all sampling sites.

Dose Rates (nG/h)				
SITES	^{226}Ra	^{232}Th	^{40}K	TOTAL
SA	17.72±1.23	56.77±1.46	22.20±0.53	96.69
SB	23.69±1.87	193.23±2.33	19.76±0.36	236.68
SC	24.72±1.27	45.69±1.35	20.71±0.43	91.12
SD	18.67±0.85	41.36±6.52	13.59±0.28	73.62
AVERAGE	21.20±1.30	84.26±2.91	19.06±0.40	124.52

Contribution of each radionuclide to the gamma dose rate varied with the sampling sites. Figure 2.0 shows dose rates in which the sampling site SB has the value above the average for the whole Dam. The sampling site is on the southern region of Dam. The sampling sites SD and SC are within the worldwide value range which is from 18 $nGyh^{-1}$ to 93 $nGyh^{-1}$. While the sampling sites SA and SB are higher than the worldwide value.

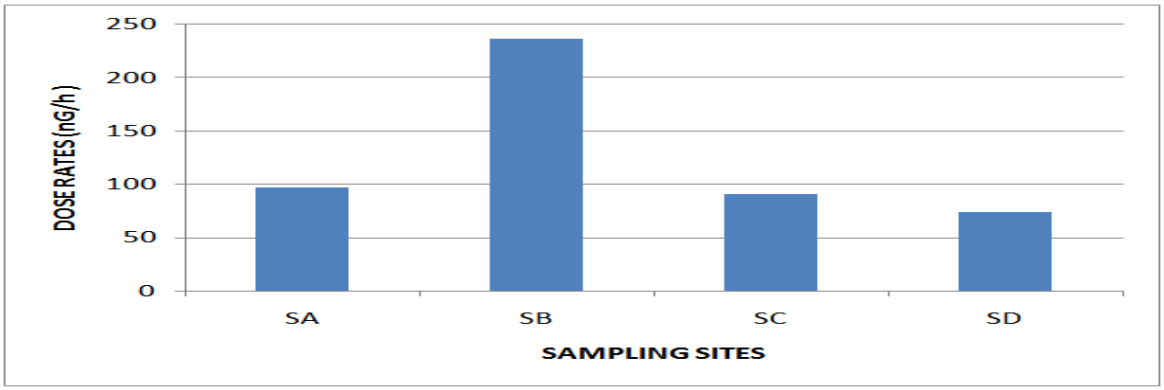

Figure 2.0: Dose rates for sediment samples measured in this work.

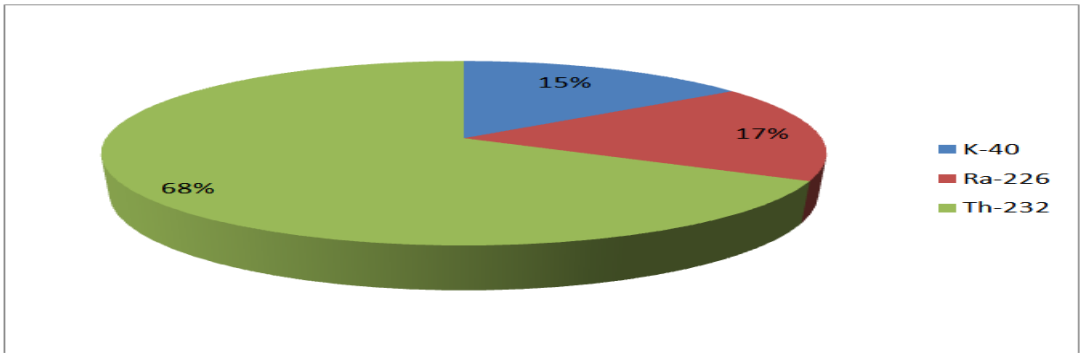

Figure 3.0: Estimate of the average dose rates contribution by the three radionuclides in sediment samples measured in this work.

4.3 Annual Effective Dose Rate (AEDR), External Hazard and Internal Hazard index.

The annual effective dose rates (AEDR), external hazard index (H_{ex}) and internal hazard index (Hi_n) were calculated for the sediments of Zobe Dam. The mean annual effective dose rate was found to be 0.152±0.014 $mSvy^{-1}$ with a minimum value of 0.090±0.009 $mSvy^{-1}$ at the sampling site SD at the northern side of the Dam and maximum value of 0.2901±0.0056 $mSvy^{-1}$ at the sampling site SB on the western side of the Dam. Table 4.0 shows the values of AEDR, H_{ex} and H_{in} values for all the sampling sites. The AEDR is below the maximum allowed limit of 1 $mSvy^{-1}$ of radiation exposure to the public [7].

The external (H_{ex}) and internal (Hi_n) hazard indices represent the risk associated from exposure of the radionuclides in the sediment samples. The external hazard index was found to be 0.717±0.126 with a minimum value of 0.425±0.445 at sampling site SD and maximum value of 1.372±0.027 at sampling site SB while the internal hazard index was found to be 0.851±0.035 with a minimum value of 0.543±0.050 at sampling site SD and maximum value of 1.522±0.039 at sampling site SB. This indicated that the risk associated with sediments sample is quite below the limit set by [6] for radiological exposure protection to the public which is unity. Since the value of the external hazard index is less than unity we can therefore say that the radiation hazard due the sediments of the Dam is low. However at the sampling site SB there are elevated values of external and internal hazard index which are above the unity and this indicate that the sediments sample at the site can pose a health risk to the public when use as building material. Figures 4.0, 5.0 and 6.0 shows the AEDR, external hazard and the internal hazard index for all the sampling sites.

Table 4.0: The annual effective dose rate (AEDR), external hazard index (H_{ex}) and internal hazard index (H_{in}) for sediment samples.

SITE	AEDR ($mSvy^{-1}$)	H_{ex}	H_{in}
SA	0.119±0.039	0.550±0.018	0.662±0.026
SB	0.290±0.005	1.372±0.027	1.522±0..039
SC	0.112±0.003	0.523±0.017	0.679±0.026
SD	0.090±0.009	0.425±0.0445	0.543±0.050
AVERAGE	0.152±0.14	0.717±0.126	0.851±0.035

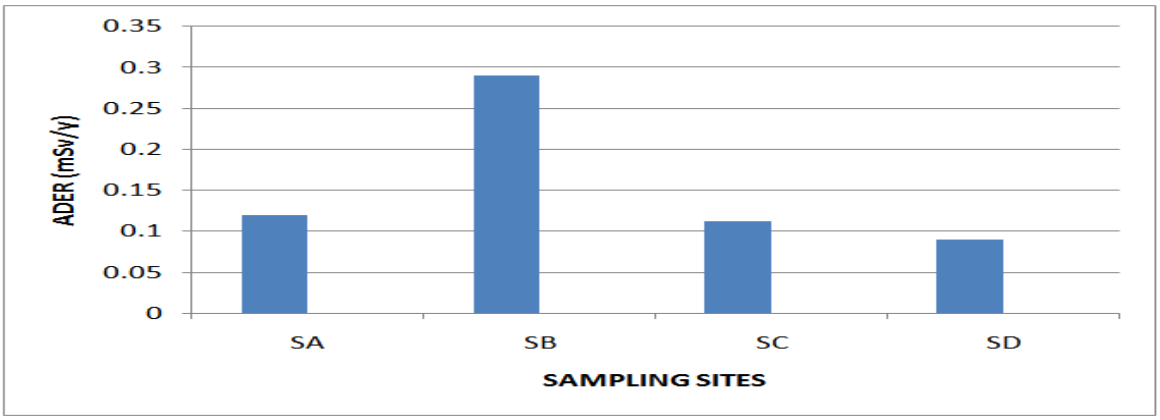

Figure 4.0: Annual Effective Dose Rate (AEDR) for sediment samples analysed in this work.

Figure 5.0: Estimate of the external hazard index for the sediment samples analysed in this work.

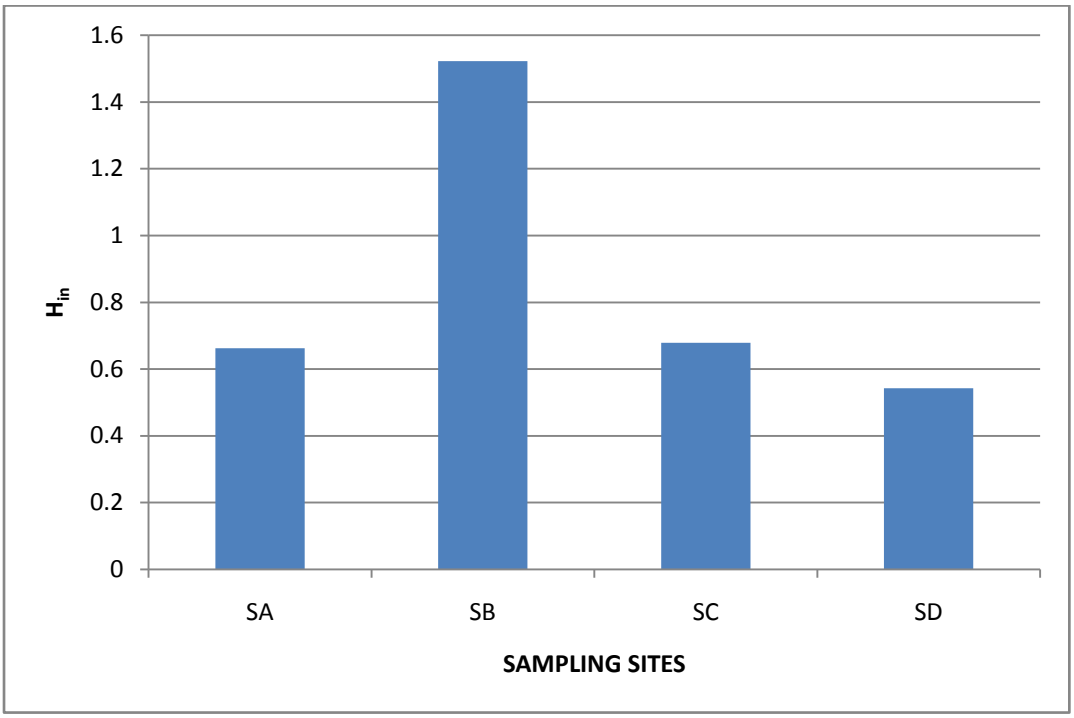

Figure 6.0: Estimate of the internal hazard index for the sediment samples analysed in this work.

V. Conclusion

The study showed that the radioactivity levels of ^{226}Ra, ^{232}Th and ^{40}K were 49.67±3.07 Bq/kg,127.29±4.42 Bq/kg and 434.43±9.51 Bq/kg respectively and were comparable with the world average values. However, slight variation in the radioactivity content in soil observed with different locations worldwide mainly due to soil type, formation and transport process involved. This may be the reason for the variation. The mean absorbed dose rate obtained in the present study (124.52±4.61 nGy/h) is comparable to the world average (55 nGy/h). The measured average annual effective dose rate in this study is 0.152 mSv/y, and is lower than the world average value 1 mSv/y [16]. The measured average values of external and internal hazard index found in this study are 0.717 and 0.851 (all are lower than unity), which indicate that the sediments in all the sampling sites can be used for safety construction of buildings. This information is important for the local people to utilize the Zobe Dam sediments.

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