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Assessment of Natural Radionuclide Contents in Water and Sediments from Asa-Dam, Ilorin, Nigeria

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Abstract. Natural radionuclides content of ^{238}U, ^{232}Th and $^{40}K$for water and sediment samples collected from Asa-dam Ilorin, Nigeria weremeasured using NaI(*TI*) detector.The mean activity concentration in the water samples were 6.05, 3.23 and 9.65 $Bql^{-1}$for ^{238}U, ^{232}Th and ^{40}Krespectively. The mean activity concentration of ^{238}U, ^{232}Th and ^{40}Kmeasured in the sediment samples were 7.57, 8.19 and 73.48 $Bqkg^{-1}$respectively. Theactivity concentration of $^{40}K$was higher than that of ^{238}U and $^{232}Th$for the water and sediment samples. All measured activity concentration and estimated radiological parameters were below world permissible limit values. Therefore, there may be no serious immediate radiological health burden on the environment and the people using the dam.
Keywords: Radioactivity, Water, Sediment, Radiological Parameters, Asa-dam

1. Introduction

Radionuclides are elements with unstable nucleus. The unstable nucleus breaks down to release radiation. The disintegration or spontaneous breakdown processes are described by radioactivity. Primordial radionuclides are those classified as naturally occurring and have been in existence since the formation of the Earth [1]. All naturally-occurring isotopes belong to primordial nuclides, example of such isotopes are the decay series chain heads; ^{238}U and ^{232}Th and the non- series ^{40}K. The isotopes or radioactive materials that exist naturally in the earth-crust are termed natural occurring radioactive materials (NORM). The radiation released into the environment at constant intervals by NORMs adds up with the artificial sources to form the background radiation of any particular environment. The radiation comes in form of alpha particles, beta particles and/or gamma rays (photons)[1]. Exposure of human to high concentration of background radiation can pose adverse health risk. Human can be exposed to radiation from radioactive materials through various media such as ingestion, inhalation and absorption, during daily interaction with the environment. The intake of naturally occurring radionuclide in the environment via ground and surface water, sediments or foods above allowable limit can cause cancer and other stochastic effects of exposure to excess radiation dose [1]. Therefore, assessing the NORM levels in the surrounding sediments and water is needful to ensuring safe environment. In the current study area, scarcity of water has been reported and the dependency of dwellers on available water supply with no guaranteed safety [2, 3]. A lot of research studies have been done on measurement of NORM and radioactivity levels of water, foods and sediments all over the world with Nigeria inclusive [4 - 9].Low activity was reported in groundwater at samples collected from Tanke-Ilorin, KwaraState suggesting no immediate adverse health effect due to exposure [5]. However, until NORM in environment such as water and sediments are assessed, the radiological risk impact and dwellers safety cannot be known. Therefore, this study aimed at assessing the radiological impact and deduced possible risk levelof the measured NORMlevel of water and sediments from Asa-Dam in Ilorin, South-western Nigeria.

1.1 The study area

The study area is Asa Dam, and it is shown in Figure 1. It is located in Asa local government of Kwara State, in Western Nigeria. The Dam position coordinate is 8.5276°N of the latitude and longitude 4.5533°E. The Dam was built to tackle water shortage issues. The foot dimension is 20 x 12 meters of height x width. The pH value ranged between 7.25 to 8.66, which is within consumable water pH of 6.0 to 9.0. The dam serves multiple purposes beside the basic household consumption. It is used agricultural purposes such as irrigation, livestock maintenance, fish farming and recreation [10 - 11].

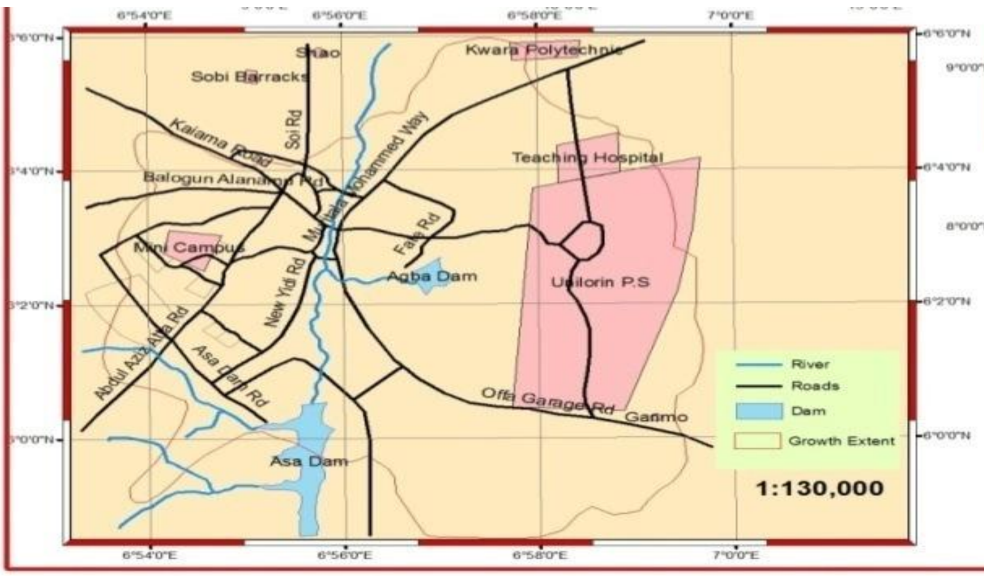

Figure 1: Map of study area

2. Material and methods

2.1 Sample collection and preparation

A total of 6 Samples of water and 6 sediments were collected from upper part and lower part of the dam. The water container was washed with acidified with 0.1 *M* HCl, at a rate of 10 *ml* per litre to avoid contamination and the sediment samples was put directly in transparent cellophane bags. 1 litre of water and about 2 *kg* of sediments were collected, labelled and properly sealed. Sieve of 2mm mesh size was used to shifter the dried sediments to obtained grain uniformity. Ready sediment weighing

200*g* and water samples were sealed in air tight container and left to attain secular equilibrium before gamma counting commenced. Background reading was done first before sample readings were done.

2.2 Gamma Counting

Canberra NaI (TI) detector was used for the gamma counting at the National Institute of radiation Protection and research (NIRPR), University of Ibadan, Nigeria. The detector has 8% resolution (FWHM) using single 137Cs energy (0.662 MeV). Detailed description of the radioactivity counting has been reported by many authors [12 – 14].Each sealed sample was counted for 1800 s. From the net area, the activity concentrations in the samples were obtained using equation 1.

$$C = \frac{A}{P_\gamma (M \text{ or } V)\, T_c \mathcal{E}} \quad (1)$$

M is dried mass of sediment sample in kg, V is the volume of water sample in L, Pγis the gamma emission probability (or branch ratio), Tc is the counting time and ε is the detector efficiency.

2.3 Radiological impact parameters

In order to estimate the radiation risk and hazard rate to dwellers, certain radiological impact parameters were also computed using the measured radioactivity.The absorbed dose rate D (*nGyh*$^{-1}$) due to activity concentration of ^{238}U, ^{232}Th and ^{40}K was assessed using equation 2.

$$D = c_U C_U + c_{Th} C_{Th} + c_K C_K \quad (2)$$

C_U, C_{Th} and C_K are the radioactivity concentration in $Bqkg^{-1}$ and Bql^{-1} for the sediment and water samples, respectively, while c_U, c_{Th} and c_K are their dose conversion factors respectively [15].The radium equivalent (Raeq) activity index was determined using equation 3.

$$Ra_{eq} = C_U + 1.43C_{Th} + 0.077C_K \quad (3)$$

The external radiation hazards (Hext) and the internal radiation hazards (Hint) were calculated using equations 4 and 5.

$$H_{ext} = \left(\frac{C_{Ra}}{370}\right) + \left(\frac{C_{Th}}{259}\right) + \left(\frac{C_K}{4810}\right) \quad (4)$$

$$H_{int} = \left(\frac{C_{Ra}}{185}\right) + \left(\frac{C_{Th}}{259}\right) + \left(\frac{C_K}{4810}\right) \quad (5)$$

Radiation induced leukemia or gonadal damage is a possible occurrence when exposed to excess radiation, hence the need to estimate annual gonadal equivalent dose (AGED). This was done using equation 6.

$$\text{AGED } (\mu Svy^{-1})\ C = 3.09C_U + 4.18C_{Th} + 0.314C_K \quad (6)$$

C_U, C_{Th} and C_K are the radioactivity concentration in $Bqkg^{-1}$for^{238}U, ^{232}Th and ^{40}K in the given samples.

The effective dose *H* is the tissue-weighted sum of the equivalent doses specified tissues and organs of the body and represents the stochastic health risks to the whole body. The H due to the radionuclides detected in the water samples was calculated using equation 7 [15-16].

$$H = R_a A_i C_f \quad (7)$$

R_a is the radioactivity concentration of radionuclide in the water samples (Bql^{-1}), $A_i$is the annual intake (ly^{-1}) and C_f is the ingested dose conversion factor for radionuclides ($mSvy^{-1}$), and varies with radionuclides and the age of individuals ingesting the radionuclides. Adding contributions from all radionuclides present in the study, the total annual effective dose H_E ($mSvy^{-1}$) to an individual was found for the studied samples using equation 8.

$$H_E = \sum R_a A_i C_f \quad (8)$$

The dose conversion factors used in the calculation and the annual effective dose were adopted from International Commission on Radiological Protection [16-17] for six age groups 0 – 1y, 1 – 2y, 2 – 7y, 7 – 12y, 12 – 17y and > 17y old with annual average water intake of 200, 260, 300, 350, 600 and 730 litres respectively.

3. Results and Discussions

The activity concentration of ^{238}U, ^{232}Th and ^{40}K for water and sediment samples are shown in Figures 2 and 3 respectively. The mean activity concentration measured for the water samples in the upper dam was 6.66, 4.28 and 10.52 $Bql^{-1}$for ^{238}U, ^{232}Th and ^{40}Krespectively. The mean concentration measured in the lower side of the dam was5.44, 2.18 and 8.78 $Bql^{-1}$for ^{238}U, ^{232}Th and ^{40}Krespectively.The mean activity concentration measured in the sediments collected at the upper side of the dam was 7.93, 8.66 and 82.1$Bqkg^{-1}$ for ^{238}U, ^{232}Th and ^{40}Krespectively. The mean activity obtained in sediments from the lower side of the dam was 7.21, 7.71 and 64.86 $Bqkg^{-1}$in the same aforementioned isotope order. The measured activity in both sediment and water samples obtained from the upper part of the dam was high compared to those obtained from lower part but the difference is not significant. It was observed that the activity measured in the sediments were higher by a factor range of 1.19, 1.96 and 1.22 for ^{40}K, ^{232}Th and ^{238}U respectively, than what was measured in water samples.This is not surprising since sediments will transfer part of the radionuclide contents to the water. The estimated radiological impact parameters calculated were presented in Table 1. The absorbed dose rate ($nGyh^{-1}$) for sediment samples were below world standard limit value (Table 1). The radiation hazard indices values are < 1 for sediment, hence, it can be said that radiation hazard for the study area is negligible. The estimated annual gonadal equivalent dose (AGED) is also less than the world limit of 1Svy^{-1}. The calculated absorb dose for water was used to further calculate the total annual effective dose H_E ($mSvy^{-1}$) as shown in Table 2. The total annual effective dose obtained for all age groups were below the permissible reference limit [15]. This study suggests that there is no immediate health risk to those making use of the water and sediment from the dam.

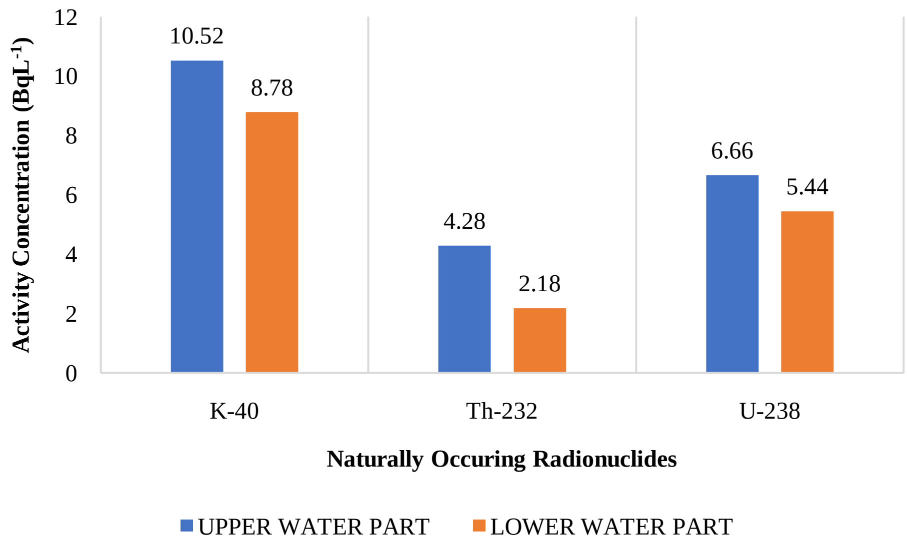

Figure 2: Mean activity concentration of ^{40}K, ^{238}U and ^{232}Th in water samples

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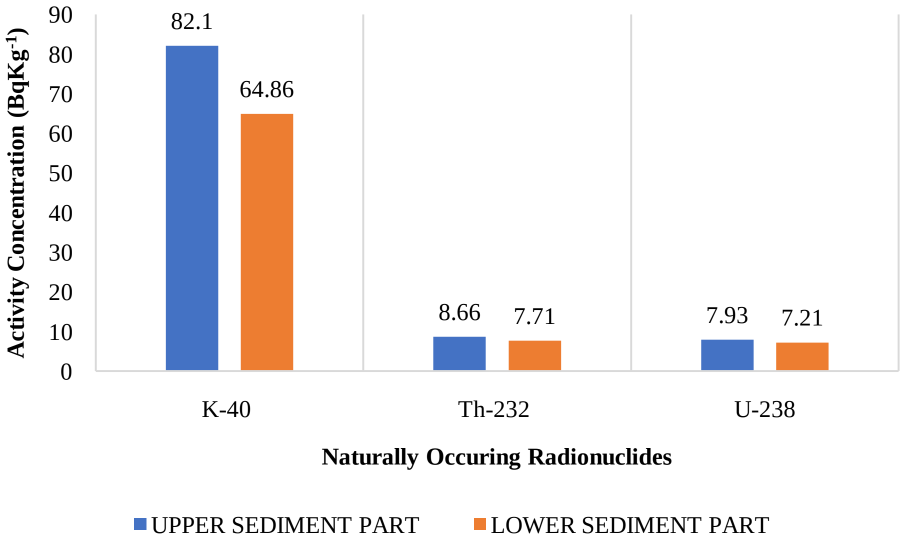

Figure 3: Mean activity concentration of ^{40}K, ^{238}U and ^{232}Th in sediment samples

Table 1: Estimated radiological parameters for the sediments

Samples Code	D ($nGyh^{-1}$)	$Raeq$ ($Bqkg^{-1}$)	H_{ext}	H_{in}	$AGED$ (μSvy^{-1})
Dam Upper Side	12.32	26.64	0.072	0.093	86.48
Dam Lower Side	10.69	23.23	0.063	0.082	74.87
World Standard Value [15]	57.00	370.00	1.00	1.00	1.00 Svy^{-1}

Table 2: Total annual effective dose (H_E) for water samples

Age group (Year)	0-1	1-2	2-7	7-12	12-17	17 above
Upper Side ($mSvy^{-1}$) x 10^{-3}	1.22	1.59	1.83	2.14	3.66	4.45
Lower Side ($mSvy^{-1}$) x 10^{-3}	0.84	1.09	1.26	1.47	2.52	3.06
World Standard Value [15]	0.12 $mSvy^{-1}$					

4. Conclusion

Assessment of NORM from water and sediments from Asa-Dam in Ilorin, Southwestern Nigeria was done and the radiological parameters were also evaluated for sediment samples. The measured activity concentration of ^{40}K, ^{232}Th and ^{238}U are all below the world limit value of 370$Bqkg^{-1}$ for ^{40}K and 40$Bqkg^{-1}$ for ^{232}Th and ^{238}U for sediment. The absorbed dose rate and other radiological parameters estimated were below the world permissible limit[17]. The total annual effective dose obtained for all age groups calculated the water samples were within the world permissible limit of

0.12$mSvy^{-1}$. In conclusion, dwellers that use the water and sediment from Asa dam are not in any serious immediate radiological health burden. The study therefore recommended that anthropogenic activities around Asa dam should be monitored to avoid increase in the radiological impact level.

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