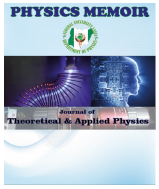

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Original

Evaluation of Radiological Hazard Indices and Environmental Safety in Soil Samples from Different Source Term Within the Tributaries of Awba Dam in the University of Ibadan

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Abstract

Artificial and Natural radionuclides exist in environmental materials such as water, soil, rocks, and plant as well as in animals and human body tissues. Therefore, human being and environment are at constant radiation exposure. Regarding this, the present study aimed to determine the specific activities of radionuclides and perform the risk assessment study to establish if there was a potential threat posed by radionuclides to humans and aquatic life in Awba dam, the University of Ibadan, due to untreated effluents discharge from the hall of residences. In this study, natural and artificial radioactivity concentrations were determined in soil samples from different source terms located along the banks of the input water discharge points into Awba dam, University of Ibadan, were collected and analyzed for natural radioactivity level using gamma-ray spectroscopy. A total of Twenty-eight sediment samples were collected for the measurement. Samples were collected one after the other along the banks of the source point. Prior to the collection of all the samples from each source point, both analogue and digital survey meter were used to ascertain the level of radiation in their immediate environment. The prepared sample was sealed and stored for a minimum of thirty-days to allow for radium equilibration with daughters nuclide. The range of the activity concentration due to ^{40}K was 2.023 to 1194.1 $BqKg^{-1}$ while those for ^{238}U and ^{232}Th were respectively 2.12 to 21.82 and 0.91 to 31.10 $BqKg^{-1}$. The total absorbed dose rate of the three radionuclides are 0.08 – 8.54, 1.0 – 10.01, 0.26 – 10.56 nGy^{-1} respectively, for the result shows that the total concentration of ^{232}Th is much higher than that of ^{238}U while ^{40}K leads the table of radioactivity concentration. The entire soil sample from different source term does not pose any significant radiological threat to the general public, and the activity concentration of the radionuclides in the sediments are equally low. No artificial sources of radionuclides were detected in any of the soil and sediment samples of the Dam.

Keywords: In Situ Measurement, Assessment Dose, Radioactivity Concentrations, Ionize Radiation.

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1. Introduction

Radioactivity can be present in our environment by two different forms as naturally occurring and anthropogenic (man-made) sources [1-11]. The human population is exposed to a background radiation level that is contributed by three components, namely cosmic rays, artificial and natural radioactivity. The contribution from these components varies with location and altitudes [5].

In soil, the natural radioactivity concentrations determine both the natural and man-made sources which are important in radiological monitoring and radiation dose assessment for the public. There have been many environmental impact assessment conducted to determine the background levels of radionuclides in soil sediments, which can, in turn, be related to the absorbed dose rates in air. The risk associated with radiation commands considerable public attention, and for that reason, regulatory systems of radiation protection are developed to improve the understanding of the effects of radiation [10].

Awba reservoir in University of Ibadan is a man-made lake that serves as a source of water supply to the water treatment plant for domestic uses. It serves as a sink for the disposal of untreated effluents from the student residential halls, zoological garden, agricultural farms, Radiation Protection Institute, laboratories, and its environment. It is an earthen dam which was constructed in 1964 by damming the stream and impounding the water at a point where it flows through a natural valley. It receives effluent from university community in the form of domestic waste water from the hall of residences, sewage discharge, experimental waste water from science laboratories of several departments and non-point sources such as erosion, flooding and leaching of chemicals from surrounding farm lands. It has a capacity of two-hundred and twenty-seven million litres of water with a treatment rate of about 68000 litres per day.

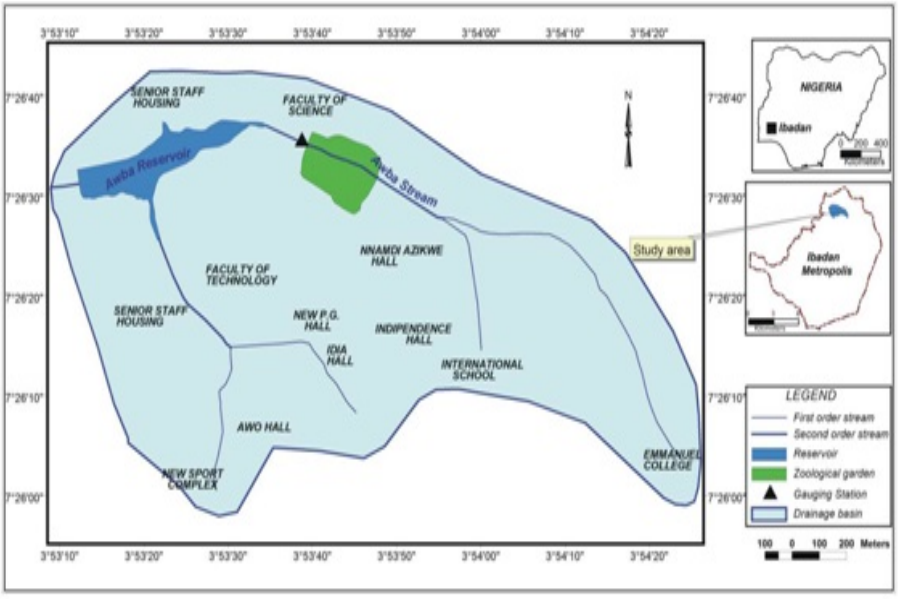

Figure 1. Sample collection at hall of residence along the discharge source

2. Materials and Methods

2.1. Sample Collection and Preparation

The study area, Awba dam, and the reservoir is located at the south-west part of the University of Ibadan, Ibadan. It lies between latitudes 7°26' - 7°28'N and longitudes 3°53' - 3°54'E at an altitude of 209 m above sea level and is a tributary of Ona river.

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Table 1. Table 1: Source Point for Sample Identification

Sample Identification	Source Point	Sample Type
Sample A	Awba Dam	Banks of the Source Point
Sample B	Awba Dam (Opposite R.H.S)	Banks of the Source Point
Sample C	Emmanuel College	Banks of the Source Point
Sample D	Zik Hall	Banks of the Source Point
Sample E	Awo Hall	Banks of the Source Point
Sample F	Idia Hall	Banks of the Source Point
Sample G	Science Laboratories	Banks of the Source Point
Sample H	Indy Hall and Black Market	Banks of the Source Point
Sample I	Tafabalewa Hall	Banks of the Source Point

Table 2. Table 2: Radiation Readings Obtained at Each Sample Point

Radiation Level of Each Sample Point	Analogue ($\mu S\, vy^{-1}$)	Digital ($\mu S\, vy^{-1}$)
Emmanuel College	0.11	0.12
Staff Quarters	0.09	0.13
Fish Farm	0.06	0.09
Black Market And Independent Hall	0.10	0.10
Tafabalewa Hall	0.12	0.13
Sultan Bello Hall	0.11	0.13
Zik and PG Hall	0.11	0.13
Car Wash and Baptist School	0.15	0.13
Idia Hall	0.11	0.13
Awo Hall	0.10	0.10
Faculty of Science	0.13	0.12

Table 3. Table 3: Activity Concentrations of Soil Sample ($Bqkg^{-1}$)

Sample ID	^{40}K	^{238}U	^{232}Th
1A	2.03 ± 5.35	16.39 ± 1.68	11.38 ± 1.53
3A	68.33 ± 7.01	4.91 ± 1.07	14.12 ± 1.63
4A	48.98 ± 5.16	2.70 ± 0.94	5.47 ± 1.33
5A	65.31 ± 6.91	7.65 ± 1.22	1.89 ± 1.24
8A	28.53 ± 4.47	2.22 ± 0.90	0.43 ± 1.24
9A	97.31 ± 8.07	21.82 ± 1.95	31.11 ± 2.38
11A	20.26 ± 4.23	13.80 ± 1.55	1.06 ± 1.22
12A	72.98 ± 7.17	16.60 ± 1.69	13.99 ± 1.63
2B	81.97 ± 6.47	7.65 ± 1.22	4.86 ± 1.32
3B	67.28 ± 6.97	4.76 ± 1.06	10.15 ± 1.48
4B	23.47 ± 4.32	2.12 ± 0.90	0.91 ± 1.22
5B	87.67 ± 6.71	7.24 ± 1.20	8.79 ± 1.44
6B	31.73 ± 4.57	7.34 ± 1.20	1.17 ± 1.23
7B	54.09 ± 5.35	2.844 ± 0.94	1.41 ± 1.23
1C	53.90 ± 6.54	6.62 ± 1.16	14.49 ± 1.64
3C	63.48 ± 6.85	9.10 ± 1.30	8.96 ± 1.44
4C	98.76 ± 8.12	8.74 ± 1.28	10.15 ± 1.48
1D	66.43 ± 6.94	8.53 ± 1.27	4.40 ± 1.30
2D	82.76 ± 7.52	14.43 ± 1.58	2.23 ± 1.25
4D	112.13 ± 8.65	17.79 ± 1.75	17.48 ± 1.77
3E	119.87 ± 8.96	20.07 ± 1.83	6.70 ± 1.37
4E	105.38 ± 8.38	17.22 ± 1.72	1.08 ± 1.23
2F	118.76 ± 8.92	13.45 ± 1.53	14.14 ± 1.63
1G	203.41 ± 12.63	16.14 ± 1.67	8.79 ± 1.44
2G	155.28 ± 10.47	3.05 ± 0.96	12.78 ± 1.58
3H	194.17 ± 12.21	16.08 ± 1.66	17.05 ± 1.75
4H	188.79 ± 11.96	21.67 ± 1.94	15.75 ± 1.70
Range	20.26 – 194.1	4.76 – 21.82	6.70 – 31.11
Mean ± Stddev	85.67 ± 7.44	10.77 ± 1.38	8.92 ± 1.47

Table 1 shows the selected sampling area within the university of Ibadan campus. Before the collection of all the samples from each source point, both analog and digital survey meter were used to ascertain the level of radiation in their immediate environment. A total of Twenty-eight samples were collected for the assessment. Samples were carefully handled to avoid contamination. The sample collected at Emmanuel College was used as the control source point because is at the point of entry into the university.

2.2. In Situ Measurement Using A Calibrated Survey Meter

In situ measurements were made using a calibrated MODEL 3A survey meter (Analogue) and RADOS Synodys GR (Digital), RDS 30 with serial number 293092 manufactured by the Ludlum measurement Inc. Sweet Water, Texas. Measurement was taken at about 1 m above ground level. At each sampling point, a minimum of two survey meter readings were taken, and the average was calculated and recorded. A total of 12 survey meter readings were obtained from each source point. Table 2 shows the values of the survey meter reading obtained at each source point.

2.3. Sample Preparation

The sediment was air dried in the laboratory before grinding. It was grounded into the powdery form using mortar and pestle after which it was passed through a 2 mm sieve and packed to fill a cylindrical plastic containers with an inner dimension of 6.5 cm diameter and 6 cm height, which could conveniently take soil mass of 200 g for spectrometric analysis. The prepared samples were stored in air-tight containers to avoid absorption. It was

Table 4. Table 4: (^{40}K) Radium Equivalent Conc. Absorbed Dose Rate, Internal and External Hazard Indices and Effective Dose Rates for Soil Sample from Different Source Term in Awba Dam

Sample ID	Raeqv($Bqkg^{-1}$)	Hex($Bqkg^{-1}$)	Hint($Bqkg^{-1}$)	D($nGyh^{-1}$)	$E_d(mSvy^{-1})$
1A	0.156	0.000	0.004	0.085	0.000
3A	5.261	0.016	0.014	2.869	0.003
4A	3.771	0.015	0.010	2.057	0.002
5A	5.029	0.015	0.013	2.743	0.003
8A	2.196	0.006	0.005	1.198	0.001
9A	7.493	0.023	0.020	4.087	0.005
11A	1.560	0.004	0.004	0.851	0.001
12A	5.619	0.017	0.015	3.065	0.003
2B	6.311	0.019	0.017	3.442	0.004
3B	5.180	0.016	0.013	2.825	0.003
4B	1.807	0.005	0.004	0.985	0.001
5B	6.750	0.020	0.018	3.682	0.004
6B	2.443	0.007	0.006	1.333	0.001
7B	4.165	0.012	0.011	2.272	0.002
1C	4.150	0.012	0.011	2.263	0.002
2C	3.948	0.012	0.010	2.153	0.002
3C	4.887	0.015	0.013	2.666	0.003
4C	7.604	0.023	0.020	4.147	0.005
1D	5.114	0.015	0.013	2.789	0.003
2D	6.372	0.019	0.017	3.475	0.004
4D	8.634	0.026	0.023	4.709	0.005
3E	9.230	0.028	0.024	5.034	0.006
4E	8.114	0.025	0.021	4.425	0.005
2F	9.144	0.028	0.024	4.987	0.006
1G	15.66	0.048	0.042	8.543	0.010
2G	11.95	0.037	0.032	6.521	0.007
3H	14.95	0.046	0.040	8.155	0.010
4H	14.53	0.045	0.039	7.929	0.009
Range	0.15-15.66	0.000-0.049	0.005-0.0403	0.085-8.543	0.001-0.01
Mean	6.50	0.020	0.017	3.54	0.0043

sealed and stored for a minimum of thirty-days to allow for radium equilibration with daughters. The samples were preserved properly to maintain the original condition, properties, and the identities of the sample at all stages of sample preparation.

2.4. Sample Analysis

The prepared samples were counted to determine the activity concentration of the three radionuclides using the value of each gamma photo peaks, respectively. A library of radionuclide, which contained the energy of the characteristics gamma peaks for each nuclide are analysed, and the corresponding emission probabilities were built from the data supplied in the software. Gamma-ray spectrometry was employed for the activity concentration measurements. The samples were analysed at radiation and health physics laboratory at physics department of University of Ibadan, using a thallium activated 7.62×7.62 cm, NaI (TI) detector maintained in a vertical position in a Canberra lead cylindrical shield of 10 cm thickness and 52 cm height. Each sealed sample was placed on the sodium iodide detector and counted for 25200 secs. The gamma-ray counting of the samples was done on a lower gamma ray spectrometer consisting of a detector with a coupled amplifier which amplifies the incoming signals and integrate them to volts (0-12 volts).Its Analog to digital converter (A.D.C) and S100 Multi-digital Analyser card were hosted in a desktop computer. The raw data for each sample was displayed as a spectrum on the computer screen while the gamma emitting radionuclide are identified with their characteristics pulse heights..

Table 5. Table 5: (^{238}U) Radium Equivalent Conc. Absorbed Dose Rate, Internal and External Hazard Indices and Effective Dose Rates for Soil Sample from Different Source Term in Awba Dam

Sample ID	Raeqv($Bqkg^{-1}$)	Hex($Bqkg^{-1}$)	Hint($Bqkg^{-1}$)	D($nGyh^{-1}$)	$E_d(mSvy^{-1})$
1A	26.29	0.044	0.088	7.573	0.009
3A	4.912	0.013	0.026	2.269	0.002
4A	4.484	0.007	0.014	1.246	0.001
5A	7.653	0.020	0.041	3.536	0.004
8A	3.744	0.006	0.012	1.027	0.001
9A	21.82	0.058	0.117	10.08	0.012
11A	22.17	0.037	0.074	6.379	0.007
12A	16.60	0.044	0.089	7.669	0.009
2B	12.38	0.033	0.066	5.721	0.007
3B	4.757	0.012	0.025	2.198	0.002
4B	3.579	0.005	0.011	0.979	0.001
5B	11.72	0.079	0.039	3.344	0.004
6B	11.89	0.019	0.039	3.392	0.004
7B	4.731	0.007	0.015	1.314	0.001
1C	4.150	0.017	0.035	3.058	0.003
2C	3.948	0.011	0.022	1.935	0.002
3C	4.887	0.024	0.049	4.205	0.005
4C	8.739	0.023	0.047	4.037	0.004
1D	8.532	0.023	0.046	3.942	0.004
2D	14.42	0.038	0.077	6.665	0.008
4D	17.78	0.048	0.096	8.218	0.010
3E	20.06	0.054	0.108	9.270	0.011
4E	17.22	0.046	0.093	7.956	0.009
2F	13.44	0.036	0.072	6.211	0.007
1G	16.13	0.043	0.087	7.454	0.009
2G	3.051	0.008	0.016	1.409	0.001
3H	16.08	0.043	0.086	7.430	0.009
4H	21.66	0.058	0.117	10.01	0.012
Range	3.051-26.29	0.005-0.079	0.012-0.117	0.979-10.01	0.001-0.012
Mean	11.92	0.031	0.057	4.95	0.006

2.5. Dose Assessment

The external absorbed dose rate D (nGy^{-1}) in air at 1 m above the ground level due to activity concentrations of ^{40}K, ^{238}U and ^{232}Th for the twenty-eight samples were calculated using the equation below [6].

- Activity Concentration

$$C_A = \frac{N}{E_A \times \gamma \times M \times t} \tag{1}$$

E_A = Efficiency of the activity of the three radionuclide, γ = gamma yield, M_S = Mass of sample

t = Time of counting, N = Net count, C_A = Activity concentration

- Absorbed Dose Rate In Air (D)

The outdoor air-absorbed dose rate D, due to terrestrial gamma rays at 1 meter above the ground level can be calculated from the activity concentration values of ^{226}Ra, ^{232}Th and ^{40}K in a soil sample. Its unit is nGy/h and can be determined from the following [2,8].

$$D(nGy^{-1}) = (0.462C_u + 0.604C_{Th} + 0.0417C_k)nGy^{-1} \tag{2}$$

Table 6. Table 6: (^{232}Th) Radium Equivalent Conc. Absorbed Dose Rate, Internal and External Hazard Indices and Effective Dose Rates for Soil Sample from Different Source Term in Awba Dam

Sample ID	Raeqv($Bqkg^{-1}$)	Hex($Bqkg^{-1}$)	Hint($Bqkg^{-1}$)	D($nGyh^{-1}$)	$E_d(mSvy^{-1})$
1A	16.28	0.043	0.043	6.878	0.008
3A	20.19	0.054	0.054	8.529	0.010
4A	7.816	0.021	0.021	3.301	0.004
5A	2.698	0.007	0.007	1.139	0.001
8A	0.620	0.001	0.001	0.262	0.000
9A	44.48	0.120	0.120	18.78	0.023
11A	1.519	0.004	0.004	0.641	0.000
12A	20.00	0.054	0.054	8.450	0.010
2B	6.948	0.018	0.018	2.934	0.003
3B	14.51	0.039	0.039	6.131	0.007
4B	1.302	0.003	0.003	0.550	0.000
5B	12.56	0.006	0.006	5.306	0.006
6B	1.675	0.004	0.004	0.707	0.008
7B	2.016	0.005	0.005	0.851	0.001
1C	20.72	0.055	0.055	8.752	0.010
2C	10.45	0.028	0.028	4.415	0.005
3C	12.81	0.034	0.034	5.411	0.006
4C	14.51	0.039	0.039	6.131	0.007
1D	6.296	0.017	0.017	2.659	0.003
2D	3.194	0.008	0.008	1.349	0.001
4D	25.00	0.067	0.067	10.56	0.012
3E	9.584	0.025	0.025	4.048	0.004
4E	1.550	0.004	0.004	0.655	0.000
2F	20.22	0.054	0.054	8.542	0.010
1G	12.56	0.033	0.033	5.306	0.006
2G	18.27	0.049	0.049	7.716	0.009
3H	24.38	0.065	0.065	10.29	0.012
4H	22.51	0.060	0.060	9.511	0.011
Range	0.620-25.00	0.003-0.067	0.001-0.065	0.550-18.78	0-0.023
Mean	12.66	0.033	0.033	5.35	0.066

- Annual Effective Dose Equivalent (AEDE/E_d)
  The *AEDE* is the dose received by an adult given an average worldwide outdoor occupancy factor of 20% (UNSCEAR, 2000). The world average annual effective dose equivalent (AEDE) from outdoor terrestrial gamma radiation is 460 μ Sv/year [8,6].

$$AEDE(mSvy^{-1}) = D(nGyh^{-1}) \times 8760h \times 0.2 \times 0.7 \times 10^{-6} \tag{3}$$

- Equivalent Activity (Ra_{eq})
  Radium equivalent, Raeq is used to assess hazards associated with materials containing ^{226}Ra, ^{232}Th and ^{40}K nuclides. The values were calculated on the assumption that 370 Bq/kg of ^{226}Ra or 260 Bq/kg of ^{232}Th or 4810 Bq/kg of ^{40}K produce the same gamma dose rate [5] and can be represented by

$$Raeq(Bq.kg^{-1}) = Cu + 1.43C_{Th} + 0.077C_K \tag{4}$$

- Internal and External Hazard Index
  The external hazard index *Hex* is used to evaluate the danger of natural gamma radiation and its purpose is to

restrict the radiation dose to permissible dose equivalent limit of 1 mSv/y [3].

$$H_{int} = \frac{C_k}{4810} + \frac{C_u}{185} + \frac{C_{Th}}{259} \tag{5}$$

$$H_{ext} = \frac{C_k}{4810} + \frac{C_u}{370} + \frac{C_{Th}}{259} \tag{6}$$

$H_{int} \rightarrow$ Internal Hazard, $H_{ext} \rightarrow$ External Hazard, $C_K \rightarrow$ Concentration of Potassium, $C_U \rightarrow$ Concentration of Uranium, $C_{Th} \rightarrow$ Concentration of Thorium

3. Results

The activity concentrations evaluate the intensity of each line taking into account the mass of the sample, branching ratios of gamma decay, counting time and efficiency of the detector were found. According to table 3, the activity concentrations for the soil samples ranges from 2.03 ± 5.35 to 203.41 ± 12.63 for ^{40}K, 2.12 ± 0.90 to 21.67 ± 1.94 for ^{238}U and 0.43 ± 1.24 to 31.11 ± 2.38 for ^{232}Th respectively.

4. Discussion

By using a gamma-ray spectrometer, activity concentrations of the natural radionuclides were investigated in the soil samples. The three most important primordial radionuclides investigated in the area of interest were ^{226}Ra, ^{232}Th, and ^{40}K. The results of activity concentrations (in $Bqkg^{-1}$) of ^{228}U, ^{232}Th and ^{40}K in the samples are shown in Table 4. It can be seen from the table that the concentration of ^{238}U, ^{232}Th and ^{40}K in the dam sediment ranged from 20.26 to 1194.1 $Bqkg^{-1}$, 4.76 to 21.82 $Bqkg^{-1}$ and 6.70 to 31.106 $Bqkg^{-1}$ with an average of 85.67 ± 7.44 $Bqkg^{-1}$, 10.77 ± 1.38 $Bqkg^{-1}$, and 8.92 ± 1.47 $Bqkg^{-1}$ respectively. In all sampled areas the activity concentration of potassium was higher than that of uranium and thorium, clearly shown in Table 3.

5. Conclusion

The method of gamma spectrometry was used to measure the radioactivity concentration of 28 soil samples collected along the Awba reservoir channels and 8 soil samples from farm site along the dam in the University of Ibadan, Oyo State, Nigeria. The extent of the presence of natural radionuclides in the soil sample from the discharge unit of all the hall of residences, and science laboratories along the channels connecting to Awba Dam has been established. Statistical analysis of the results showed that Sample (1G) from science laboratories have the highest activity concentration (C_k), Absorbed Dose (D) and Annual effective dose (E_d) for potassium (^{40}K) while Sample (9A) from Awba Dam has the highest activity concentration, Absorbed Dose concentration (D) and Annual effective dose (E_d) concentration for both Uranium (^{238}U) and Thorium (^{232}Th) respectively. There is no much significant difference between the radionuclide concentrations of the sediment samples from different source points. The exposure level for the members of the general public is within the recommended value of 1 $mSv.y^{-1}$ [4,6]. Therefore, this is an indication that the effluents discharge from the hall of residence (source point) in the study areas do not appear to have any impact on the radiation burden of the environment. The radiation exposure level for members of the public in the study areas is within the safety limit since all the observe dose assessment are below permissible value, and the Awba reservoir water is considered to be radiologically safe for consumption.

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